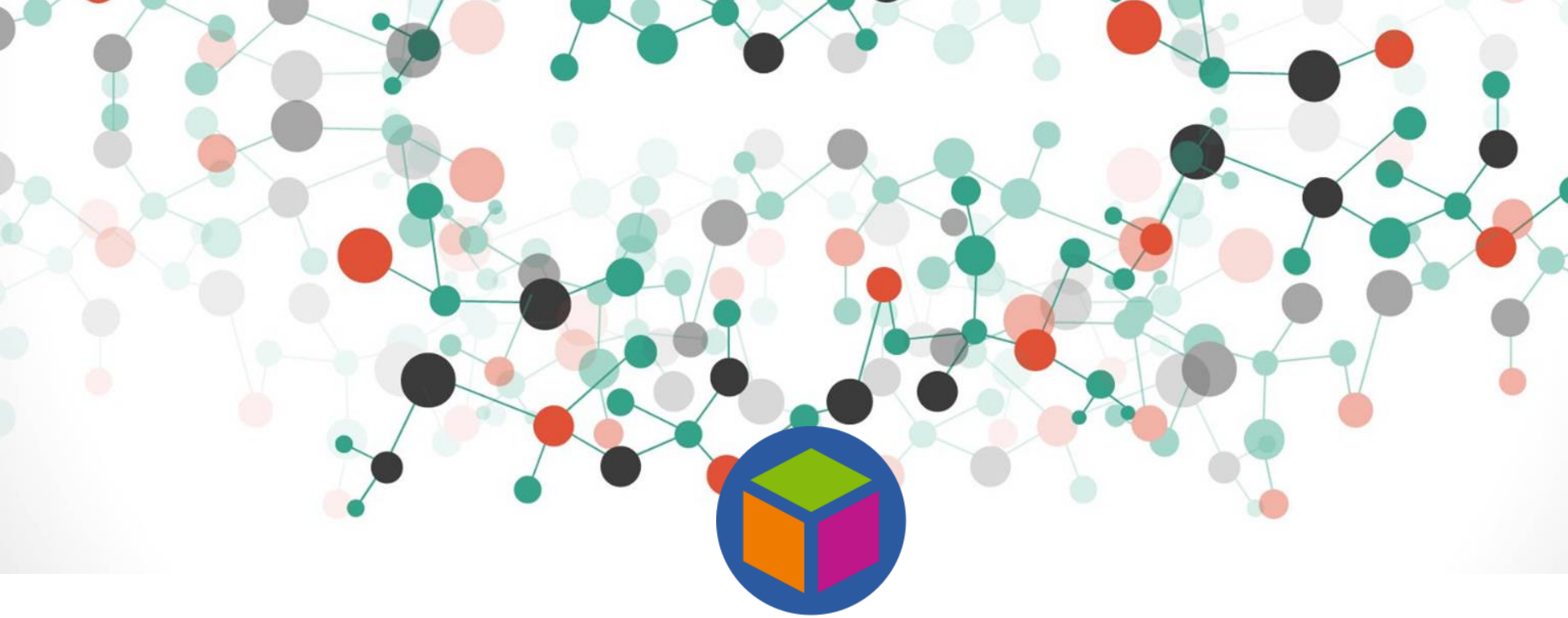


An Introduction to RDF

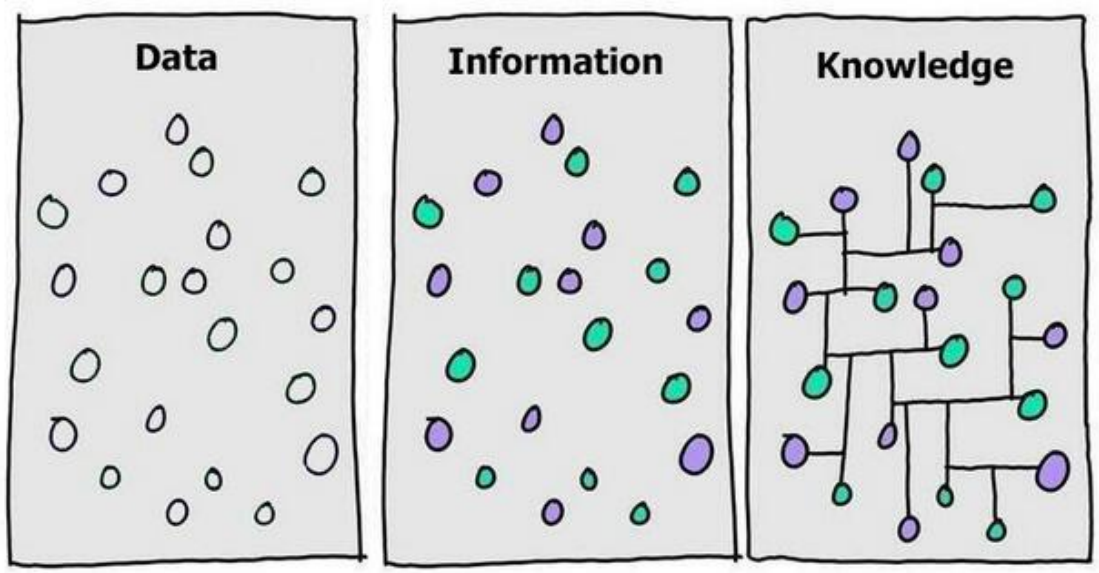
Tutorial

Monday 16:00 - 17:00, ΣΤ’

~~Wednesday 16:00 - 17:00, ΣΤ’~~

~~Thursday 18:00 - 19:00, ΣΤ’~~

Knowledge technologies?



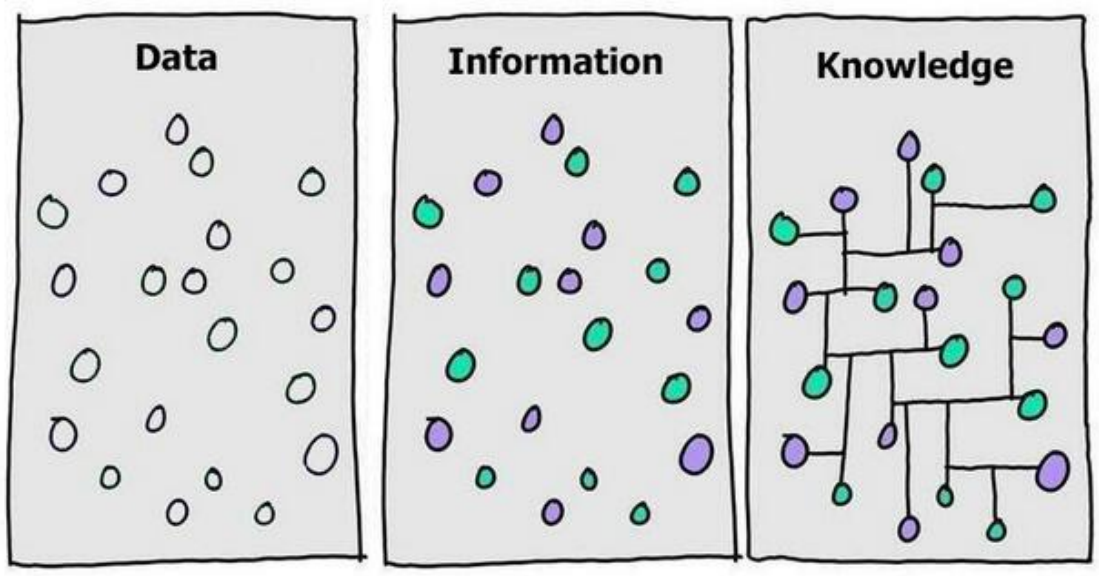
Examples of …

Data?

Information?

Knowledge?

Knowledge technologies?

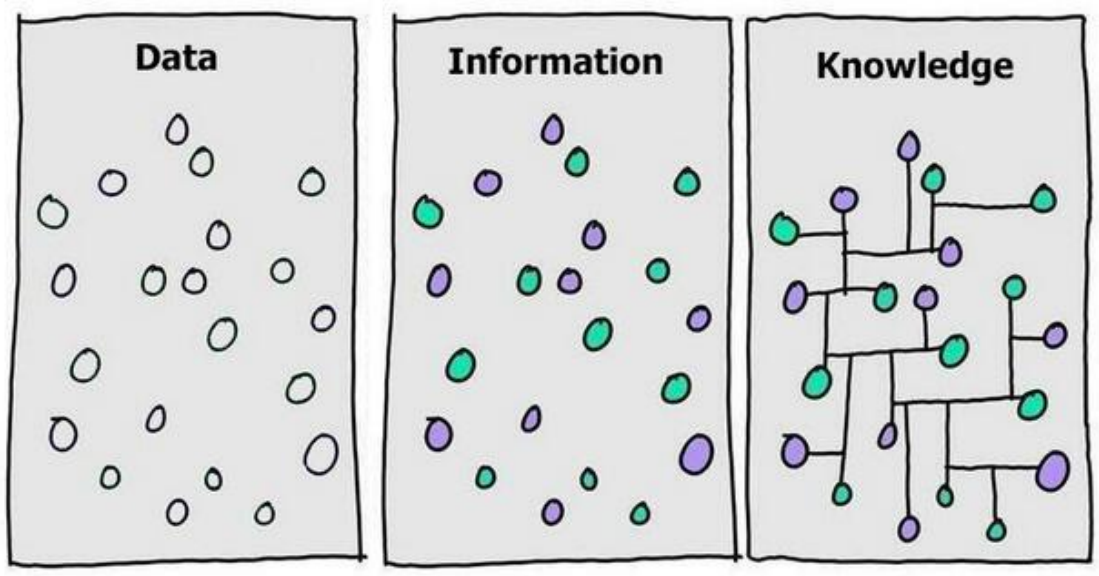


Data: ‘discrete, objective facts or observations, which are unorganized and unprocessed, and do not convey any specific meaning’ (e.g., sensor measurements)

Information ?

Knowledge ?

Knowledge technologies?



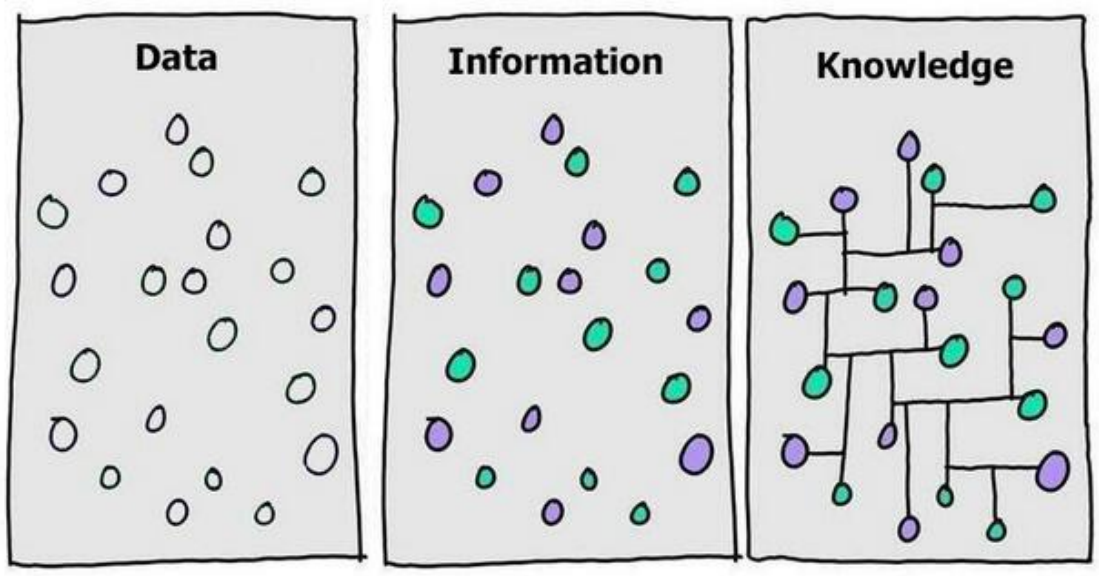
Data: ‘discrete, objective facts or observations, which are unorganized and unprocessed, and do not convey any specific meaning’ (e.g., sensor measurements)

Information: ‘data processed for a purpose’

Knowledge ?

Rowley J. The wisdom hierarchy: representations of the DIKW hierarchy. Journal of Information Science. 2007;33(2):163-180.

Knowledge technologies?



Data: ‘discrete, objective facts or observations, which are unorganized and unprocessed, and do not convey any specific meaning’ (e.g., sensor measurements)

Information: ‘data processed for a purpose’

Knowledge: ‘the combination of data and information, to which is added expert opinion, skills, and experience, to result in a valuable asset which can be used to aid decision making’

Rowley J. The wisdom hierarchy: representations of the DIKW hierarchy. Journal of Information Science. 2007;33(2):163-180.

Some History: The Semantic Web Vision

- Scientific American article by Tim Berners-Lee, James Hendler and Ora Lassila (May 2001)
  - "*The Semantic Web will bring **structure** to the meaningful content of Web pages, creating an environment where **agents roaming** from page to page readily **carry out sophisticated tasks for users**.*"

This practically means, that the data will be published on the web:

- ✓ in a **machine** and **human understandable** way
- ✓ the machines will be able to **collect data** from various **distant resources**
- ✓ and they will be able to make **inferences** from these data

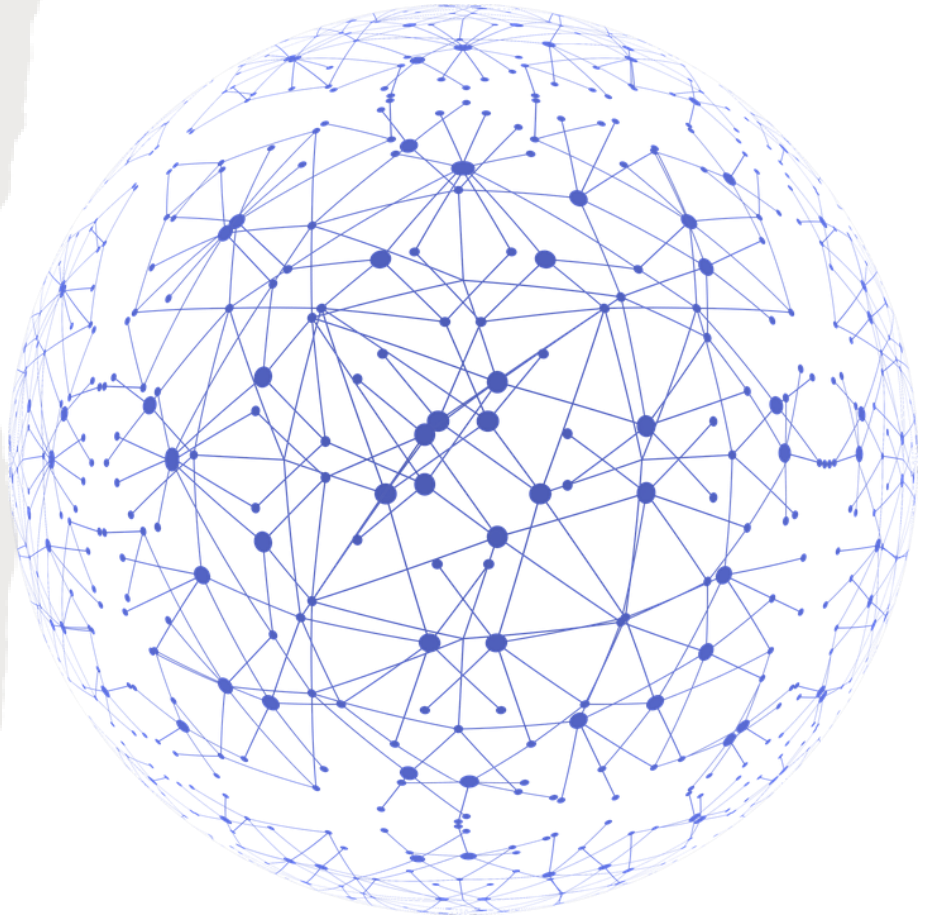
Acknowledgement

- This presentation is based on the excellent RDF primer by the W3C available at http://www.w3.org/TR/rdf-primer/ and http://www.w3.org/2007/02/turtle/primer/ .

- Much of the material in this presentation is verbatim from the above Web site.

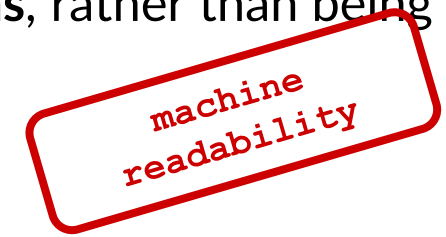
Presentation Outline

- **Basic concepts of RDF:**
  - Basics: resources, properties, values, statements, triples
  - URIs and URIrefs
  - RDF graphs
  - Literals
  - Shorthand notation: QNames
  - URIrefs as vocabularies
  - Other data modeling concepts: structured values and blank nodes
  - Serialization of RDF graphs: XML/RDF and Turtle



What is RDF?

- The **Resource Description Framework (RDF)** is a data model for representing information (especially **metadata**) about **resources** in the Web.
  - What **metadata** means??
  - Now is used to describe data in the web and not only metadata
- RDF can also be used to represent information about things that can be **identified** on the Web, even when they cannot be directly **retrieved** on the Web (e.g., a book or a person).
- RDF is intended for situations in which information about Web resources needs to be **processed by applications**, rather than being only displayed to people.



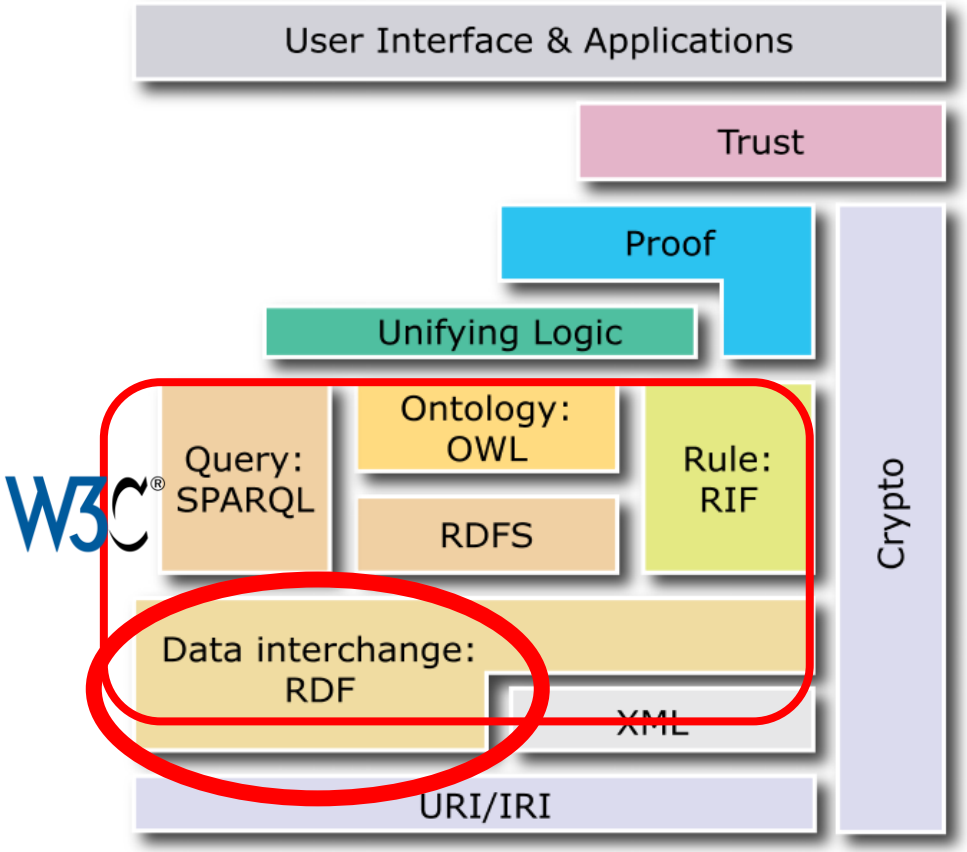
Some History

- RDF draws upon ideas from knowledge representation, artificial intelligence, and data management, including:
  - Semantic networks
  - Frames
  - Conceptual graphs
  - Logic-based knowledge representation
  - Relational databases

- **Shameless self-promotion** 😊 **:** The closest to RDF, pre-Web knowledge representation language is Telos:

  John Mylopoulos, Alexander Borgida, Matthias Jarke, Manolis Koubarakis: Telos: Representing Knowledge About Information Systems. ACM Trans. Inf. Syst. 8(4): 325-362 (1990).

The Semantic Web “Layer Cake”



RDF Basics

- RDF is based on the idea of identifying resources using **Web identifiers** and describing resources in terms of simple **properties** and property **values**.

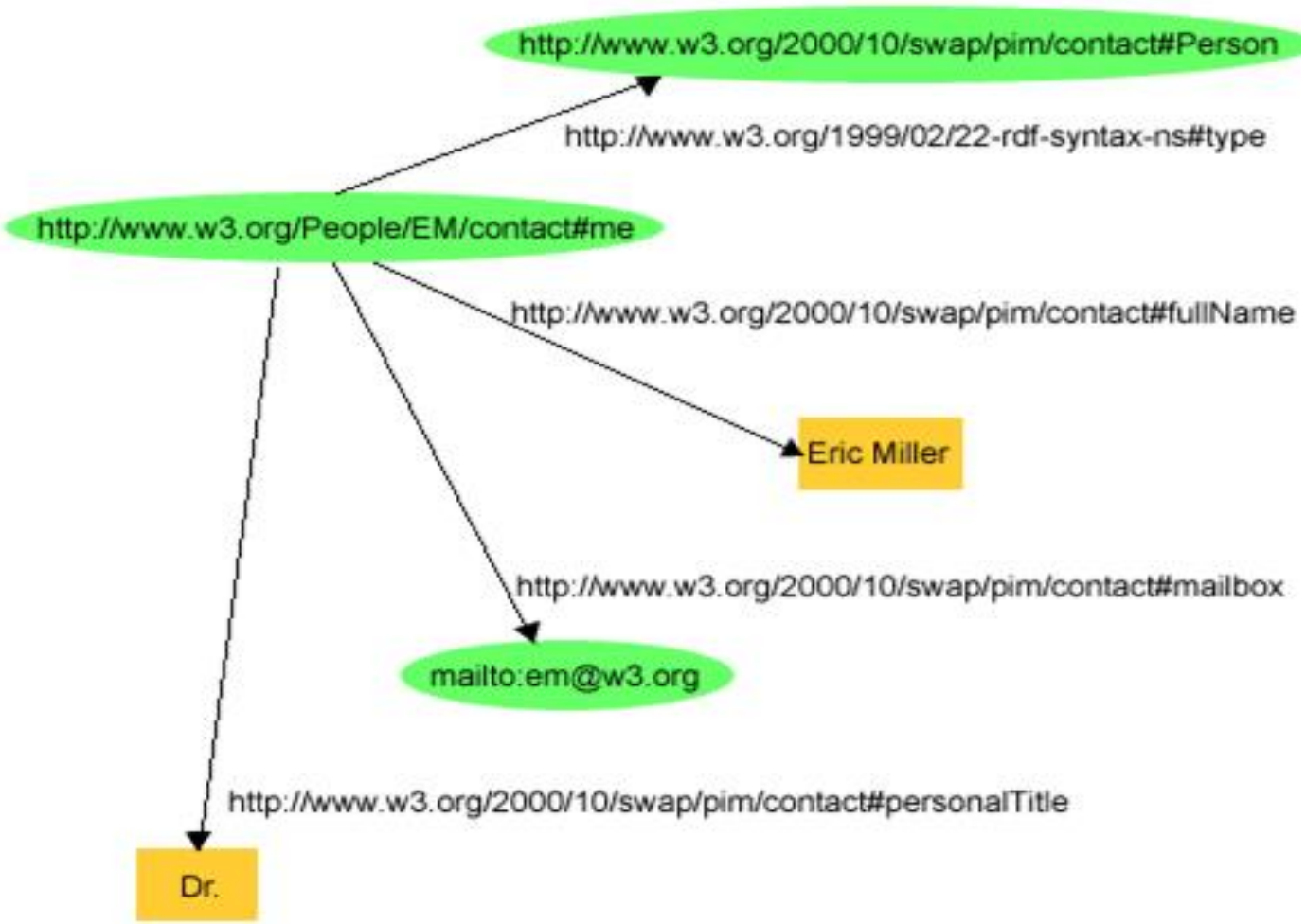
- Consider the following information:

  "there is a **Person** *identified* by

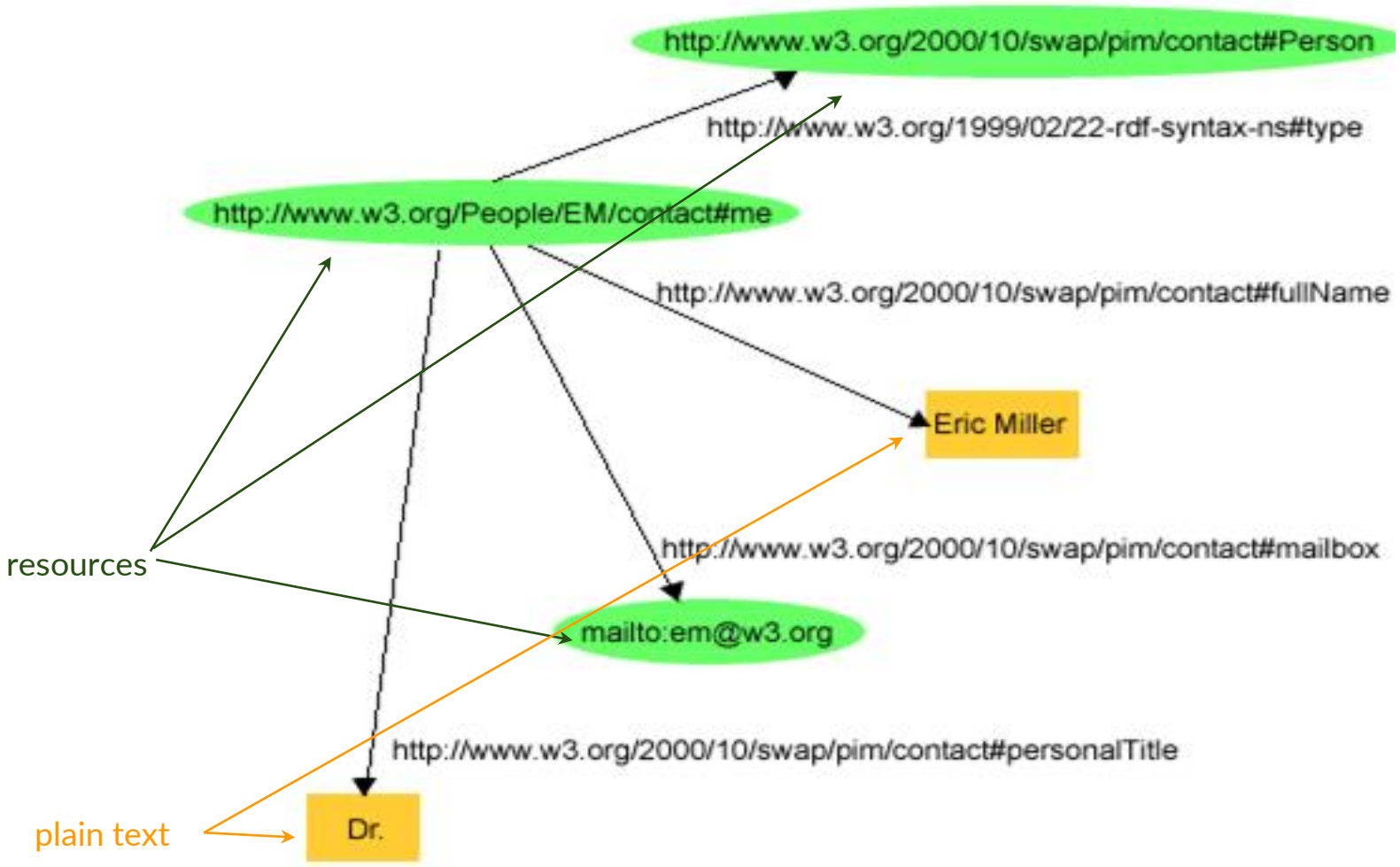
  `http://www.w3.org/People/EM/contact#me`, whose *name* is **Eric Miller**, whose *email address* is **em@w3.org,** and whose *title* is **Dr.**"

- *How would you represent in a graph?*

Example (cont'd)

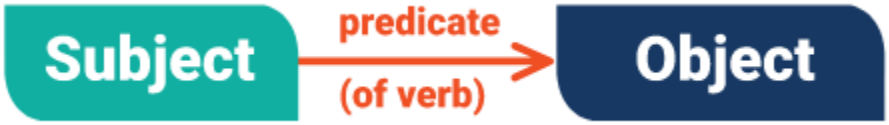


Example (cont'd)



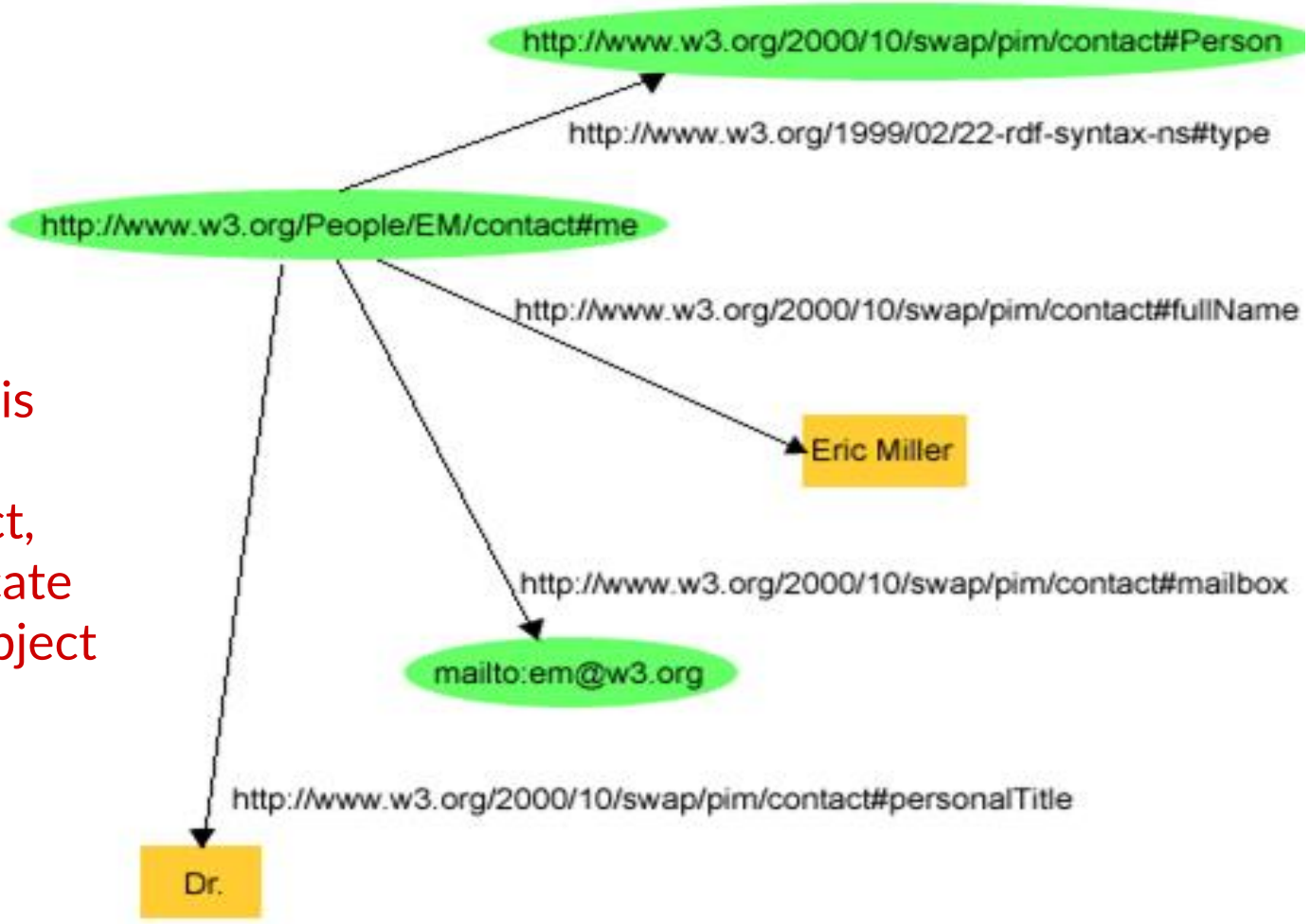
Basics (cont'd)

- RDF is based on the idea that:
  - **the resources have properties which have values**
  - the resources can be described by making **statements** that specify those properties and values.



- **Terminology:**
  - The part that identifies the thing the statement is about is called the **subject**.
  - The part that identifies the property or characteristic of the subject that the statement specifies is called the **predicate**.
  - The part that identifies the value of that property is called the **object**.

Example (cont'd)



What is the subject, predicate and object here?

RDF Triples

- RDF statements can be written down using **triple notation.** In this notation, a statement is written as follows:

  subject predicate object .

- **Example:**

```
<http://www.example.org/index.html>
   <http://purl.org/dc/elements/1.1/creator>
   <http://www.example.org/staffid/85740> .

<http://www.example.org/index.html>
   <http://www.example.org/terms/creation-date> "August 16, 1999" .

<http://www.example.org/index.html>
   <http://purl.org/dc/elements/1.1/language> "en" .
```

- **Note:** In this notation URIs are written out completely, in **angle brackets**.

RDF and Related Data Models

- In terms of the **relational model**, an RDF statement is similar to a **tuple in a relation** called *Triples* or *Graph* with attributes *Subject*, *Predicate* and *Object*.

- In terms of **first-order logic**, an RDF statement is similar to an **atomic formula**

  triple(subj,pred,obj)

  where *triple* is a first-order logic predicate and *subj*, *pred* and *obj* are constants.

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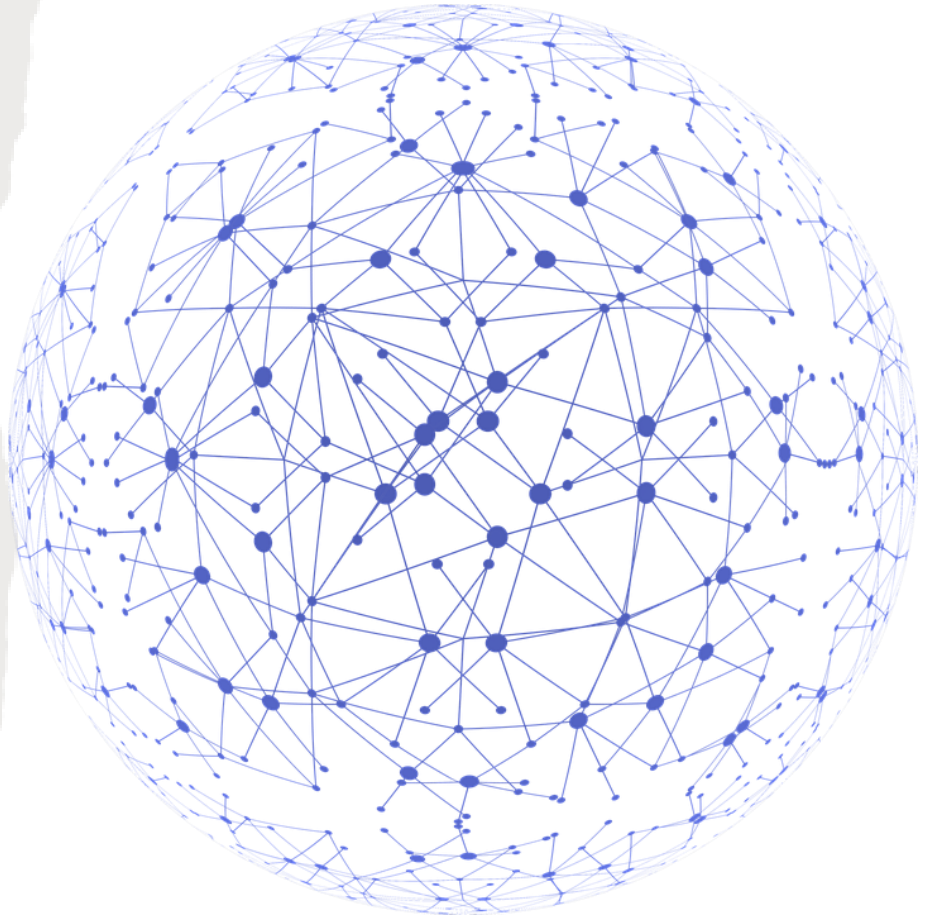

Uniform Resource Identifiers

- RDF is based on the idea of identifying resources using **Web identifiers** and describing resources in terms of simple properties and property values.
- URIs: **identify** (name) resources on the Web.
- URIs are not limited to identifying things that have network locations, or use other computer access mechanisms.
- A number of different **URI schemes** (**URI forms**) have been already been developed, and are being used, for various purposes.
  - **Examples:**
    - **http: (Hypertext Transfer Protocol, for Web pages)**
    - mailto: (email addresses), e.g., mailto:em@w3.org
    - ftp: (File Transfer Protocol)
    - …

Uniform Resource Identifiers

- No one person or organization controls who makes URIs or how they can be used.
- Some URI schemes, such as URL's http:, depend on centralized systems such as DNS, other schemes, such as freenet:, are **completely decentralized.**
- Anyone can create a uri for something

URIs (cont'd)

- A **URI reference** (or **URIref**) is a URI, together with an **optional** fragment identifier at the end.

  Example: the URIref http://www.example.org/index.html#section2 consists of the URI http://www.example.org/index.html and (separated by the "#" or "/" character) the fragment identifier section2.

- RDF defines a resource as *anything* that is identifiable by a URI reference

- Using URIrefs allows RDF to describe practically anything, and to state relationships between such things as well

URIs (cont'd)

- URIrefs may be either **absolute** or **relative**.
  http://www.example.org/index.html#section2

- An **absolute** URIref refers to a resource independently of the context in which the URIref appears, e.g., the URIref http://www.example.org/index.html.

- A **relative** URIref is a shorthand form of an absolute URIref, where some prefix of the URIref is missing, and information from the context in which the URIref appears is required to fill in the missing information.

***Example*:** the relative URIref otherpage.html, when appearing in a resource http://www.example.org/index.html, would be filled out to the absolute URIref http://www.example.org/otherpage.html.

URIs (cont'd)

- A (relative) **URIref consisting of just a fragment identifier** is considered equivalent to the URIref of the document in which it appears, with the fragment identifier appended to it.

  Example: Within the document http://www.example.org/index.html, if #section2 appeared as a URIref, it would be considered equivalent to the absolute URIref http://www.example.org/index.html#section2 .

.

- An **empty URIref** within a document is considered equivalent to the URIref of the document itself.

- See the report from the Joint W3C/IETF URI Planning Interest Group at http://tools.ietf.org/html/rfc3305 for more information.

URIrefs in RDF

- RDF uses URIrefs to identify and name the subjects, predicates, and objects in statements.

- RDF URIrefs can contain **Unicode** characters, allowing many languages to be reflected in URIrefs.

- RDF uses **Internationalized Resource Identifiers (IRIs) and IRIrefs.**
- To have also non-latin languages for the description of resources.

- See http://tools.ietf.org/html/rfc3987 which defines IRIs.

URIrefs in RDF (cont'd)

- RDF and Web browsers use URIrefs to **identify things**.
- They **interpret** URIrefs in slightly **different ways**:
  - RDF uses URIrefs **only** to identify things.
  - Browsers also use URIrefs to **retrieve** things.

- What is the difference?
  - In a **browser**, identifies a resource that can actually be **retrieved**: that something is actually "at" the location identified by the URI.
  - In **RDF**, identifies something, such as a person, that **cannot** be retrieved on the Web.
- But important uses of RDF, like **Linked Data** (http://linkeddata.org/), insist that we use HTTP URIs so data identified by a URI can be retrieved.

URIrefs in RDF (cont'd)

- Another difference is in the way URIrefs with **fragment identifiers** are handled. Consider the following URIrefs:

  http://www.example.org/index.html

  http://www.example.org/index.html#Section2

- In normal HTML usage, these **URIrefs are related** (they both refer to the same document, the second one identifying a location within the first one).

- RDF assumes **no particular relationship** between these two URIrefs. As far as RDF is concerned, they are syntactically different URI references, and hence may refer to **unrelated** things.

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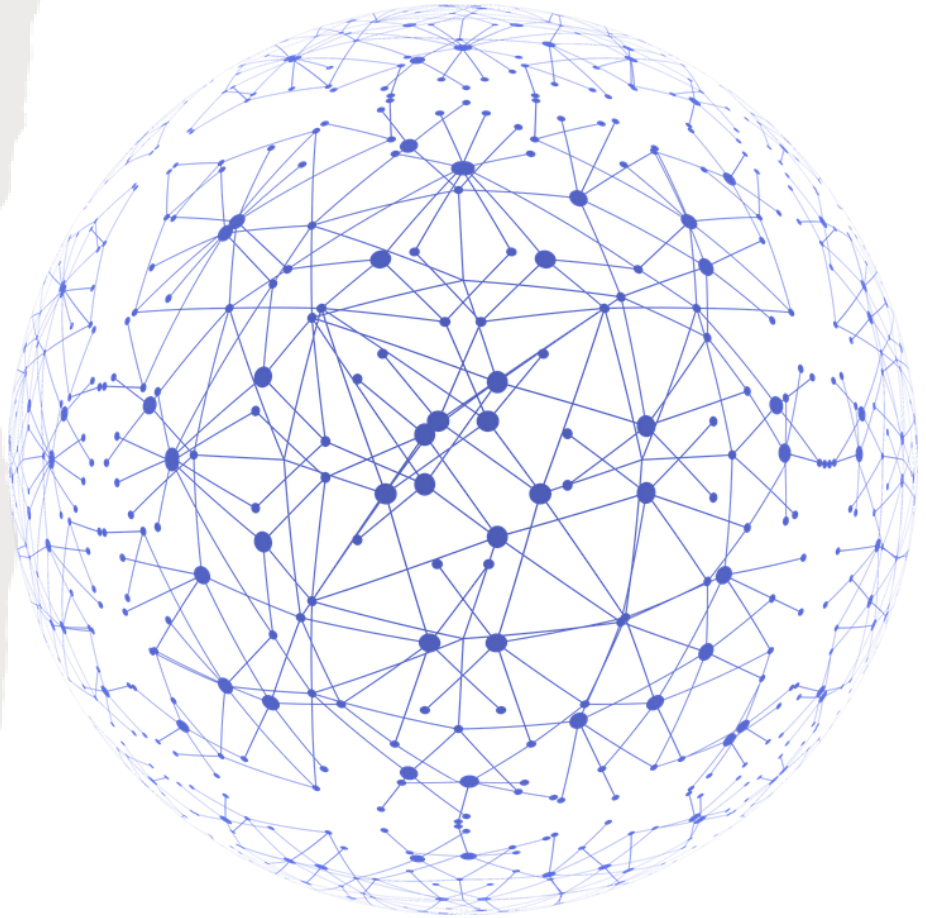


RDF Graphs

- Graphically, RDF models statements by **nodes** and **arcs** in a **graph**.

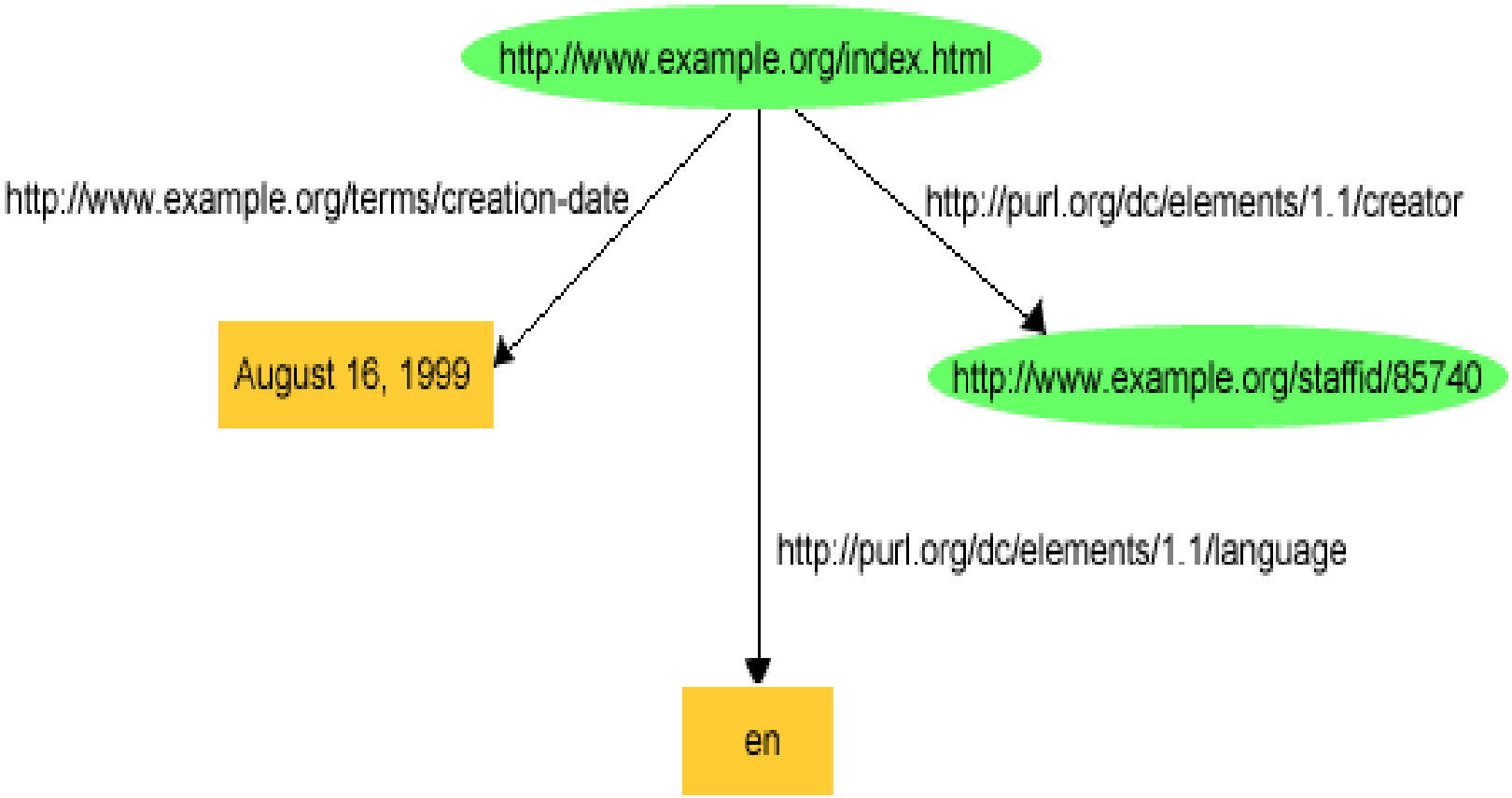
- In the RDF graph notation, a **statement** is represented by:
  - a node for the subject
  - a node for the object
  - an arc for the predicate, **directed** from the subject node to the object node.
- There can be three kinds of nodes in an RDF graph: IRIs, literals, and blank nodes.
- An **arc** is identified by a **URIref**.

- **Note:** We will draw RDF graphs as **directed graphs**. But strictly speaking, directed graphs **are not sufficient** for capturing all of RDF (e.g., directed graphs assume that the sets of nodes and arcs are disjoint but **RDF allows a property as a subject of a statement**).

Example

- Consider the following statements:
  - http://www.example.org/index.html has a creation-date whose value is August 16, 1999.
  - http://www.example.org/index.html has a language whose value is English.

The RDF Graph of the Example



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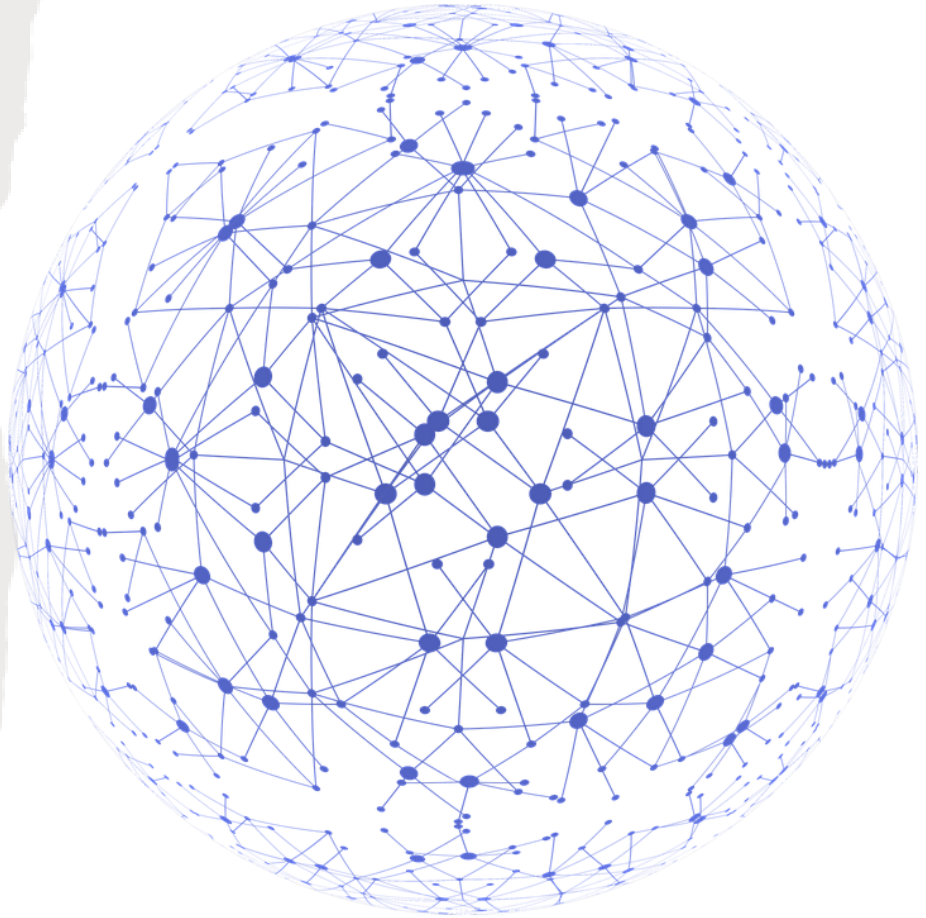
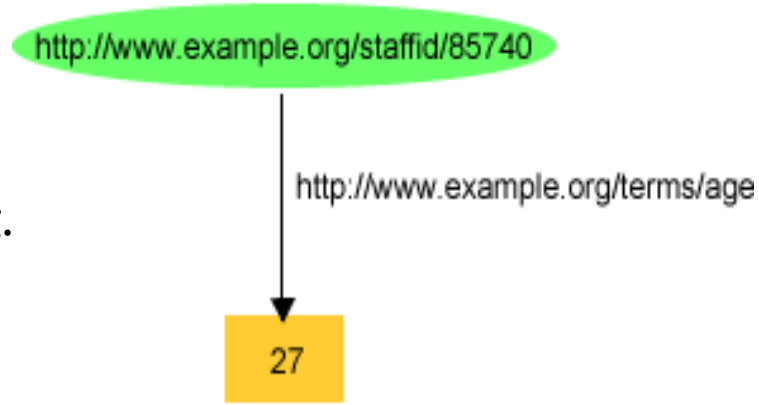


Literals

- Literals are used for values such as strings, numbers, and dates.
- There are two kinds of literals:
  - **Plain (untyped).**
  - **Typed.**



- Plain literals have a **lexical form** (their lexical value) and optionally a **language tag.**

- **Example:** “27” , “Hello world”@en

- Example:
- What is 27? Number or string?

Typed Literals

- RDF typed literals explicitly indicate, for a given literal, **what datatype should be used to interpret it**.

- An **RDF typed literal** is formed by pairing a string with a URIref that identifies a particular **datatype**
  - e.g.,: "27"^^http://www.w3.org/2001/XMLSchema#integer

- RDF defines **one built-in datatype** with the URIref **rdf:XMLLiteral** to represent XML content as a literal value. This is useful when we want to bring into an RDF sentence, content that has already been defined in XML (e.g., in the case of spatial data, a polygon defined in GML).

Typed Literals (cont'd)

- For the rest of the literals we can use datatypes from other formalisms (**identified by their datatype URIs)** or we define own datatypes.

- RDF datatype concepts are based on a conceptual framework from **XML Schema datatypes.** This framework defines the **value space**, the **lexical space** and the **lexical-to-value** mapping for a datatype (see the RDF specifications for more details).

XML Schema Datatypes

- `xsd:integer`
- `xsd:boolean`
- `xsd:string`
- `xsd:date`
- …
- (The XML Schema language is also referred to as XML Schema Definition)

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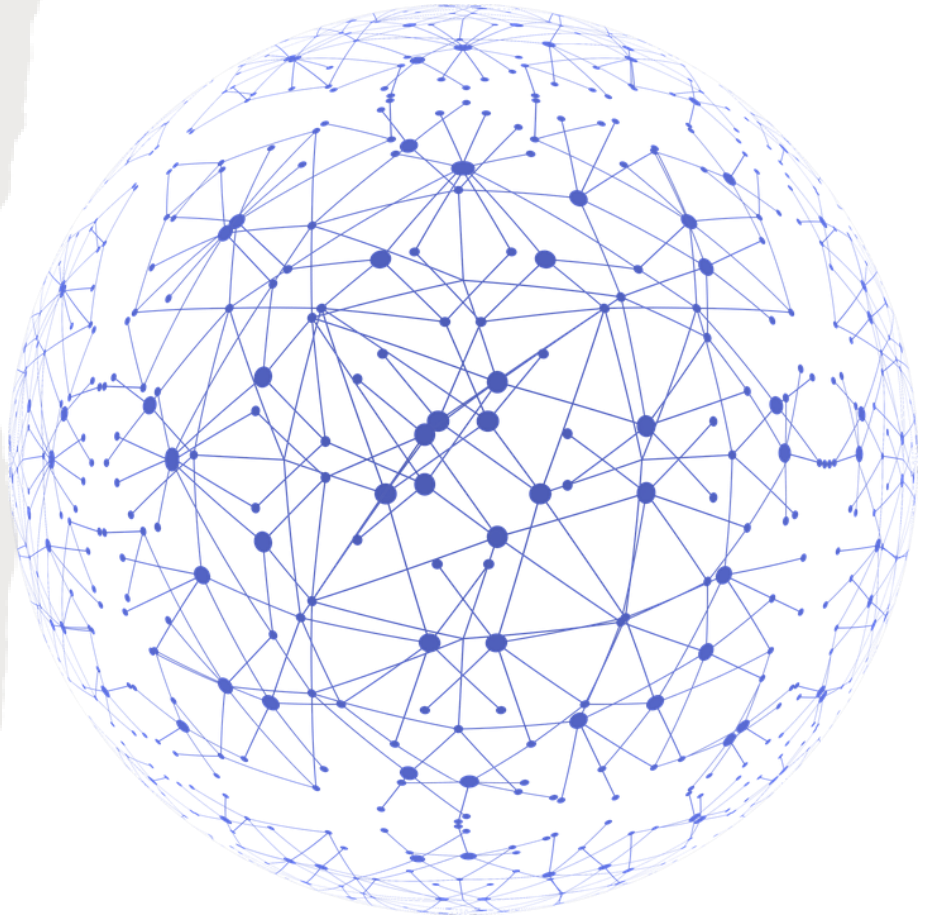
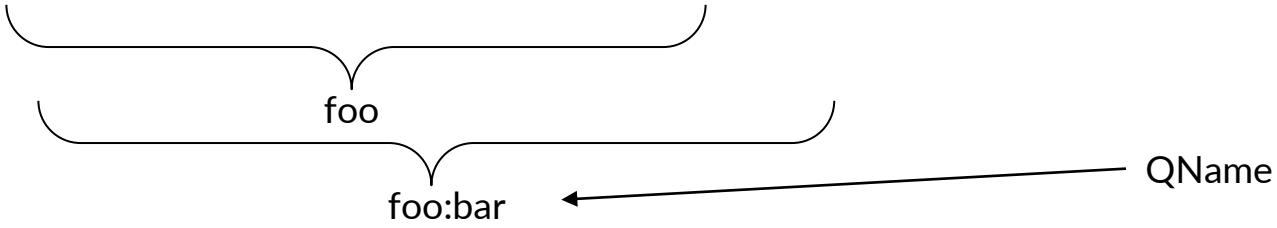


Triple Notation – QNames as Shorthands

- The full triple notation results in very long lines.
- **Shorthand:** We can use an **XML qualified name** (or **QName**) without angle brackets as an abbreviation for a full URI reference.
- http://example.org/somewhere/bar



- A **QName** consists of a **prefix** that has been assigned to a **namespace URI**, followed by a **colon**, and then a **local name**.
- The full URIref is formed from the QName by appending the local name to the namespace URI assigned to the prefix.
- The concepts of **names** and **namespaces** used in RDF originate in XML.

QNames as Shorthands (cont'd)

- **More Examples:**

prefix `rdf:`, namespace URI: `http://www.w3.org/1999/02/22-rdf-syntax-ns#`

prefix `rdfs:`, namespace URI: `http://www.w3.org/2000/01/rdf-schema#`

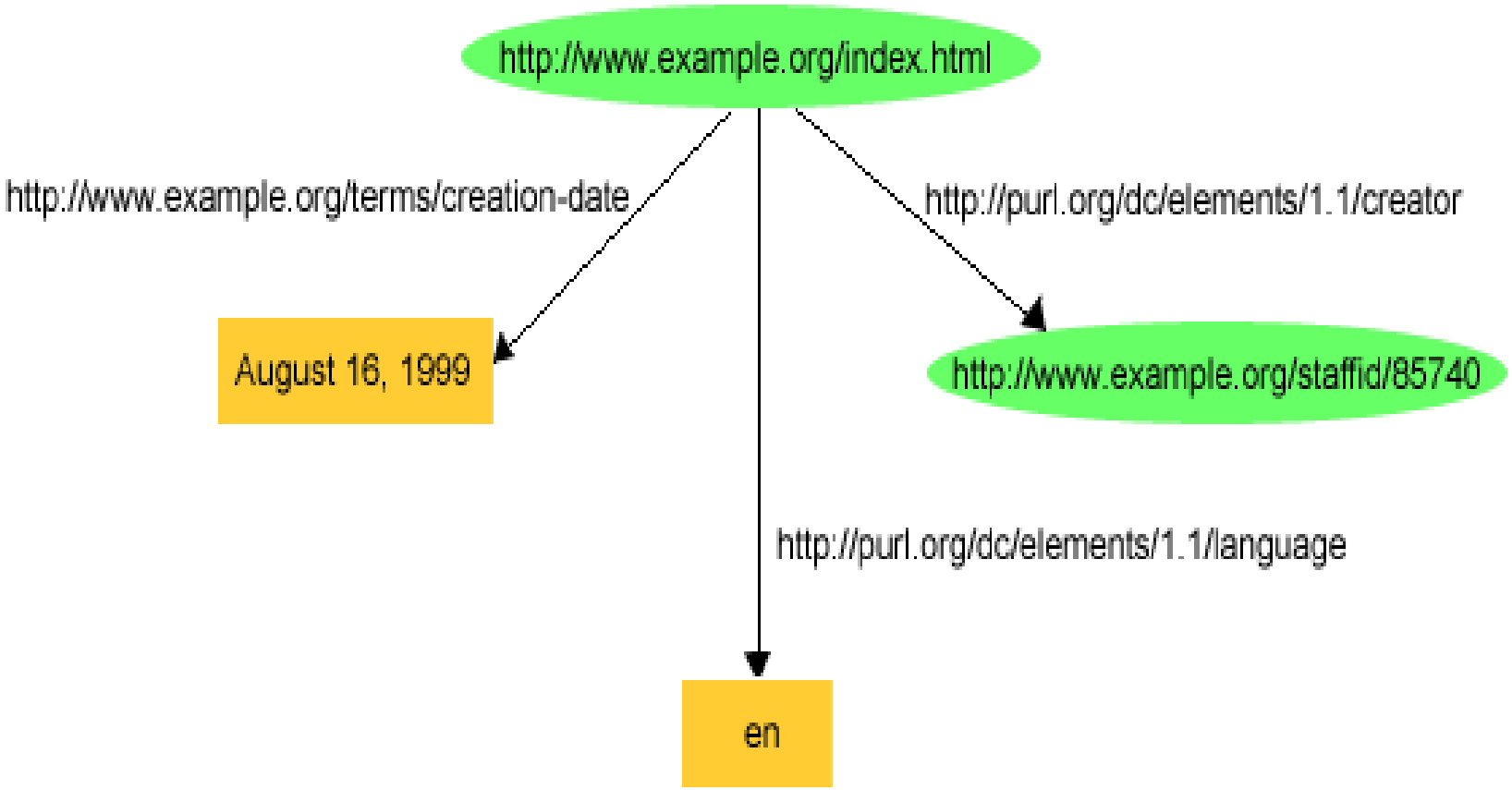
prefix `dc:`, namespace URI: `http://purl.org/dc/elements/1.1/`

prefix `owl:`, namespace URI: `http://www.w3.org/2002/07/owl#`

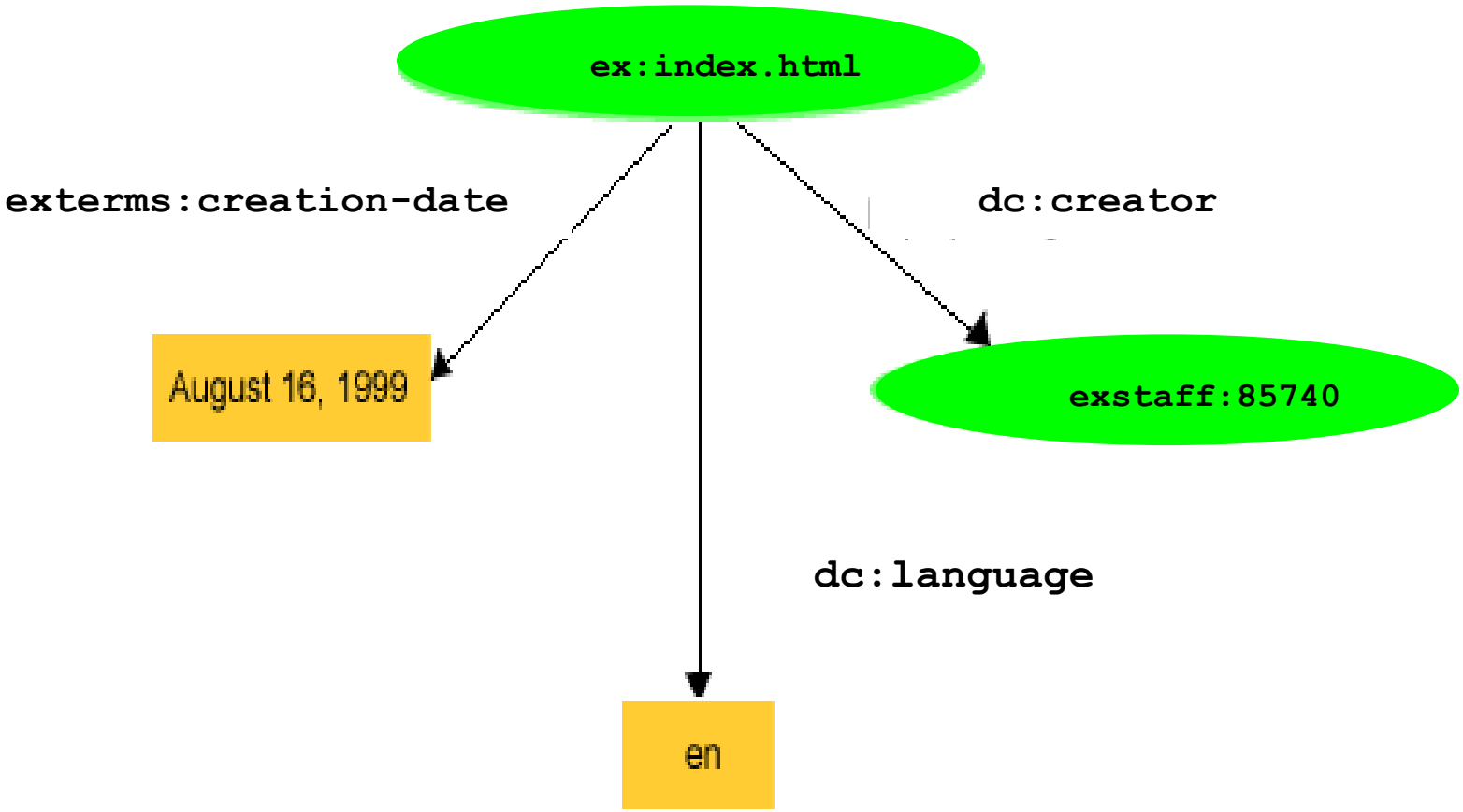
prefix `ex:`, namespace URI: `http://www.example.org/` (or `http://www.example.com/`)

prefix `xsd:`, namespace URI: `http://www.w3.org/2001/XMLSchema#`

Example


http://www.example.org/index.html
http://www.example.org/terms/creation-date
http://purl.org/dc/elements/1.1/creator
August 16, 1999
http://www.example.org/staffid/85740
http://purl.org/dc/elements/1.1/language
en

Example


ex:index.html
exterms:creation-date
dc:creator
August 16, 1999
exstaff:85740
dc:language
en

XML Namespaces

- A **namespace** is a way of identifying a subset of a set of names (e.g., the set of possible names of resources in the Web) which acts as a qualifier for the names in this subset.
- **XML namespaces** are used for providing uniquely named elements and attributes in an XML document.
- **XML namespaces help us eliminate ambiguity in an XML document.** For example, an XML document can use `id` to refer to both identifiers of customers and products if `id` is **prefixed** by an appropriate name space (e.g., http://customers.org and http://products.com).
- A **namespace** is created by creating a URI for it. By qualifying names with the URIs of their namespaces, **anyone can create their own names and properly distinguish them from names with identical spellings created by others**.
- See the **W3C Recommendation "Namespaces in XML 1.0"** available at http://www.w3.org/TR/REC-xml-names/.

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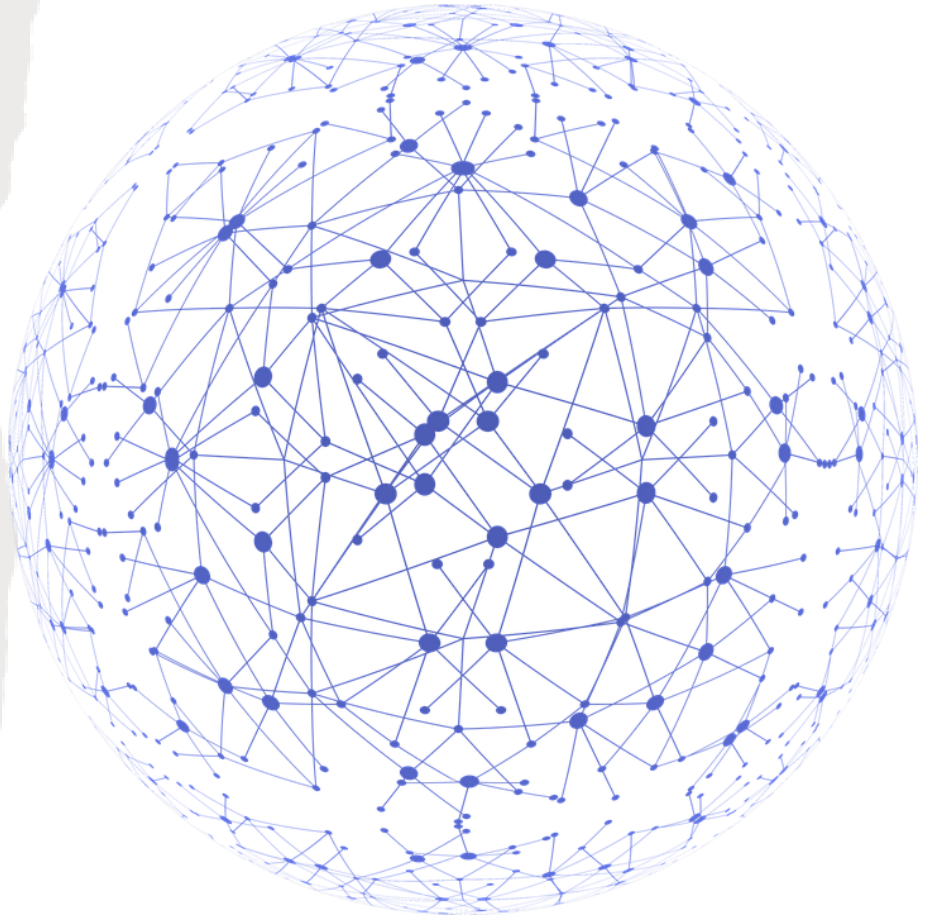


URIrefs as Vocabulary

- Since RDF uses URIrefs instead of words to name things in statements, URIrefs define **vocabularies** in RDF.

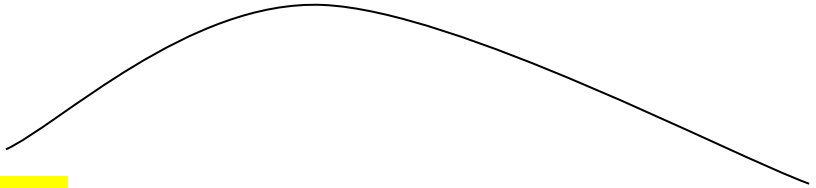
- The URIrefs in RDF vocabularies are typically organized so that they can be represented as a **set of QNames with a common prefix:**
  - A **common namespace URIref is chosen for all terms in** a vocabulary, typically a URIref under the control of whoever is defining the vocabulary.
  - URIrefs that are contained in the vocabulary are formed by **appending individual local names** to the end of the common URIref.

Example

- DBpedia (http://wiki.dbpedia.org/About) is a large knowledge base which has been derived from Wikipedia by extracting various kinds of structured information from Wikipedia editions in 14 languages and combining this information into a huge, cross-domain knowledge base.

- In the DBpedia data set, each thing is identified by a URIref of the form `http://dbpedia.org/resource/Name`, where term "`Name`" is taken from the URL of the source Wikipedia article, which has the form `http://en.wikipedia.org/wiki/Name`.
- Thus, each resource is tied directly to an English-language Wikipedia article.

DBpedia (cont'd)



http://dbpedia.org/resource/Greece
https://en.wikipedia.org/wiki/Greece

- The prefix **dbpedia** can be used instead of http://dbpedia.org/resource/
- For example: dbpedia:Greece

URIrefs as Vocabulary (cont'd)

- **RDF** uses this same approach to define its own **vocabulary of terms** with special meanings in RDF:
  - The URIrefs in the RDF vocabulary all begin with `http://www.w3.org/1999/02/22-rdf-syntax-ns#`, conventionally associated with the QName prefix rdf:.
  - The RDF Vocabulary Description Language defines an additional set of terms having URIrefs that begin with `http://www.w3.org/2000/01/rdf-schema#`, conventionally associated with the QName prefix rdfs:.
- Where a specific QName prefix is commonly used in connection with a given set of terms in this way, the QName prefix itself is sometimes used as the **name of the vocabulary**. For example, someone might refer to **"the rdfs: vocabulary".**

URIrefs as Vocabulary (cont'd)

- **Convention:** Organizations typically use a vocabulary's namespace URIref as the URL of a Web resource that provides further information about that vocabulary.

- **Example:** the QName prefix **dc**: with the namespace URIref `http://purl.org/dc/elements/1.1` refers to the **Dublin Core vocabulary**.
  - Accessing this namespace URIref in a Web browser will retrieve additional information about the Dublin Core vocabulary (specifically, RDFS definitions of the Dublin core vocabulary).
  - **Reminder:** this is just a useful convention. RDF does not assume that a namespace URI identifies a retrievable Web resource.

URIrefs as Vocabulary (cont'd)

- Using URIrefs as subjects, predicates, and objects in RDF statements supports the **development and use of shared vocabularies** on the Web.

- People can **discover and begin using vocabularies** already used by others to describe things, reflecting a **shared understanding of those concepts.**

Example

- Consider the triple

```
ex:index.html dc:creator exstaff:85740.
```

The predicate dc:creator, when fully expanded as a URIref, is an **unambiguous reference** to the "creator" attribute in the Dublin Core metadata attribute set, a widely-used set of attributes (properties) for describing a wide range of networked resources (see http://dublincore.org/documents/usageguide/).

The writer of this triple is effectively saying that the relationship between the Web page and the creator of the page is exactly the concept identified by http://purl.org/dc/elements/1.1/creator.

Another person familiar with the Dublin Core vocabulary, or who finds out what dc:creator means (say by looking up its definition on the Web) **will know what is meant by this relationshi**p. In addition, based on this understanding, people can **write programs to behave in accordance with that meaning** when processing triples containing the predicate dc:creator.

Another Example

- The Friend of a Friend (FOAF) vocabulary at http://xmlns.com/foaf/spec/.

- The FOAF project is creating a Web of machine-readable pages (written in RDF) describing people, the links between them and the things they create and do.

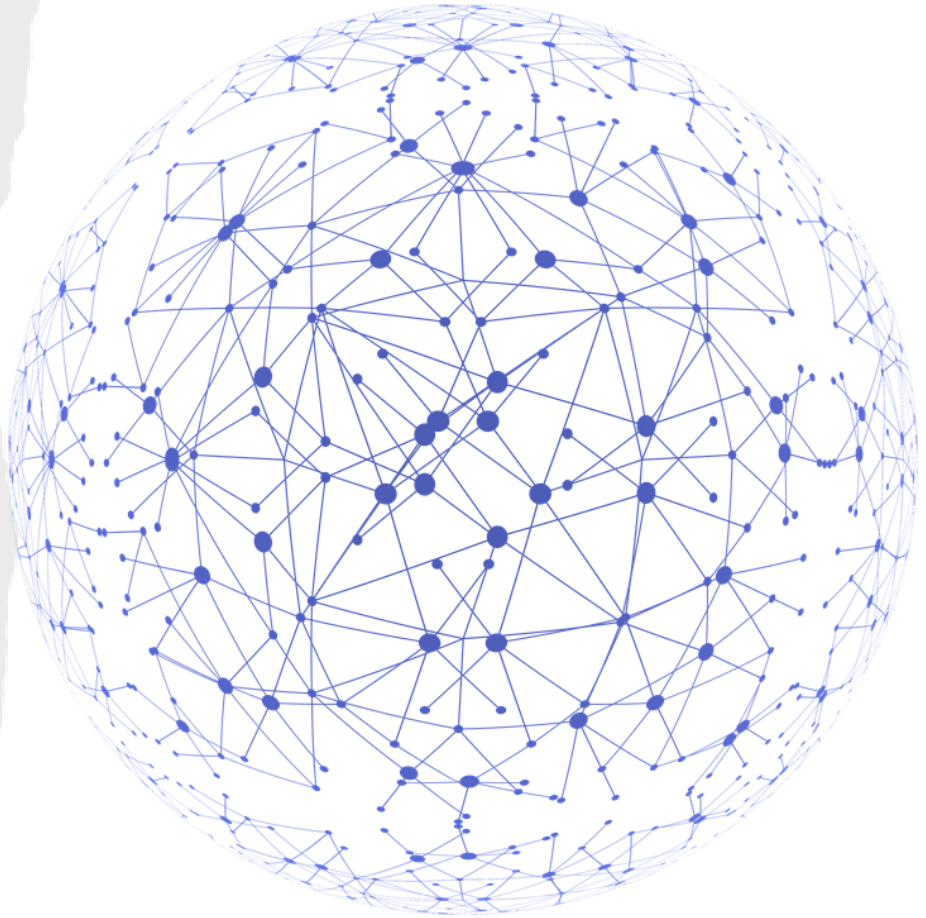
URIrefs as Vocabulary (cont'd)

- RDF gives meaning to the terms defined in the relevant RDF vocabularies rdf: and rdfs:.

- Others have defined the meaning of terms in other important vocabularies e.g., dc:

Presentation Outline

- **Basic concepts of RDF:**
  - Basics: resources, properties, values, statements, triples
  - URIs and URIrefs
  - RDF graphs
  - Literals
  - Shorthand notation: QNames
  - URIrefs as vocabularies
  - Other data modeling concepts: structured values and blank nodes
  - Serialization of RDF graphs: XML/RDF and Turtle



Structured Values in RDF

- Consider the triple:

```
exstaff:85740 exterms:address "1501 Grant Avenue,
          Bedford, Massachusetts 01730" .
```

- What if the address needs to be represented as a **structure** consisting of separate street, city, state, and postal code values? How would this be done in RDF?

- Structured information is represented in RDF by considering **the aggregate thing to be described** (like John Smith's address) **as a resource**, and then making statements about that new resource.

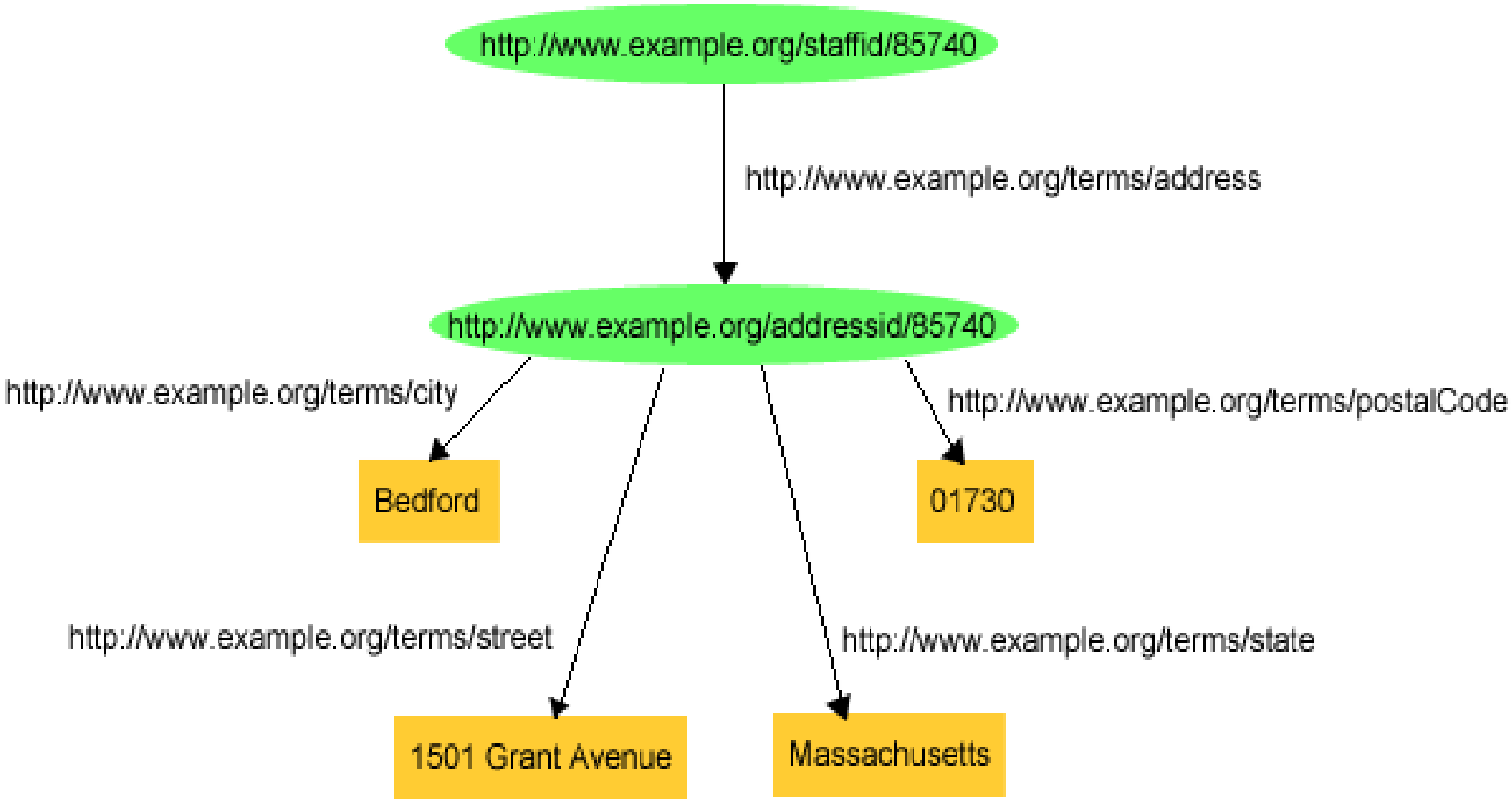
Structured Values in RDF (cont'd)

```
exstaff:85740 exterms:address "1501 Grant Avenue,
              Bedford, Massachusetts 01730" .
```

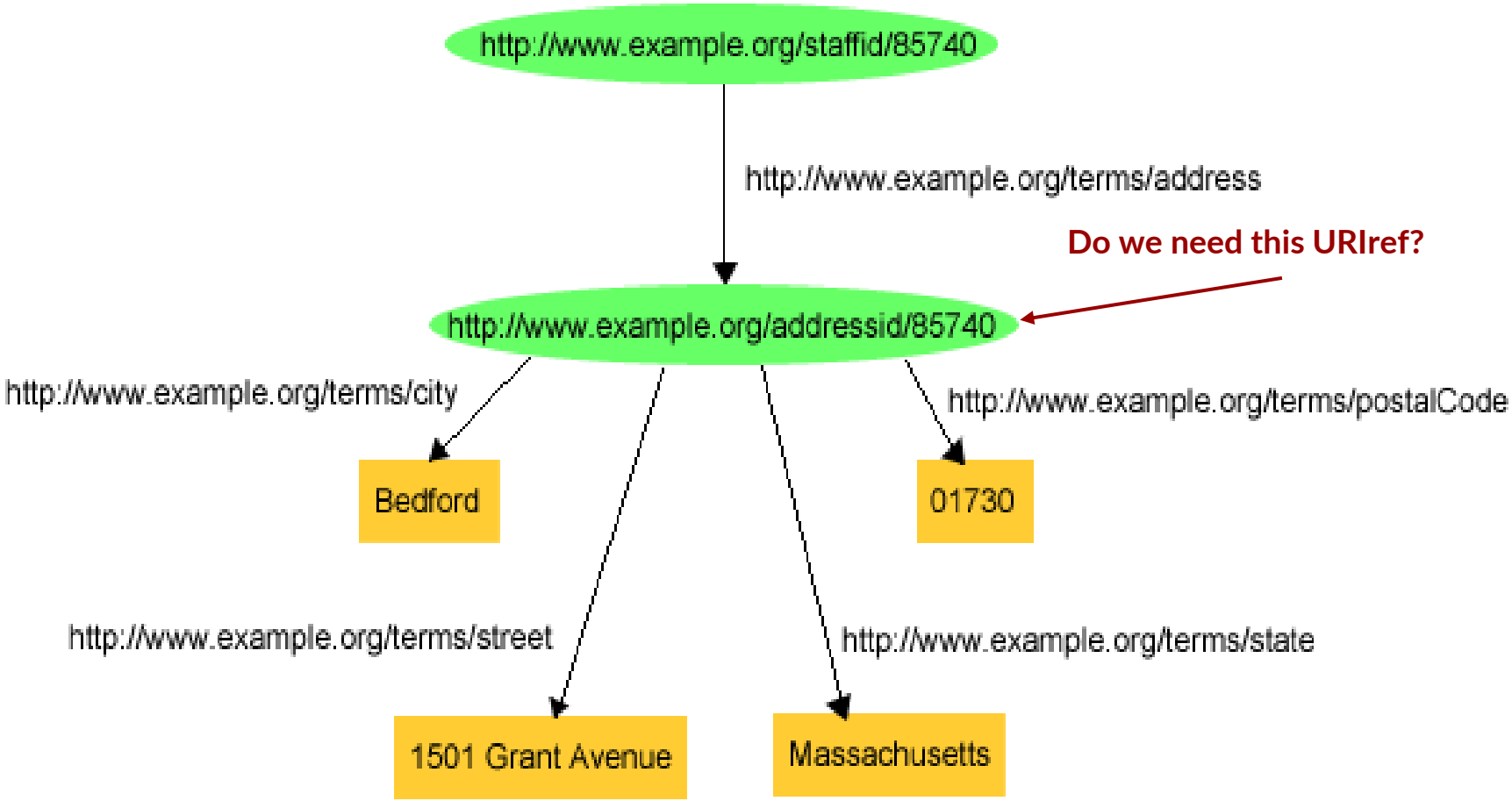
- Or in triples notation:

```
exstaff:85740 exterms:address exaddressid:85740 .
exaddressid:85740 exterms:street "1501 Grant Avenue" .
exaddressid:85740 exterms:city "Bedford" .
exaddressid:85740 exterms:state "Massachusetts" .
exaddressid:85740 exterms:postalCode "01730" .
```

Structured Values in RDF (cont'd)



Structured Values in RDF (cont'd)

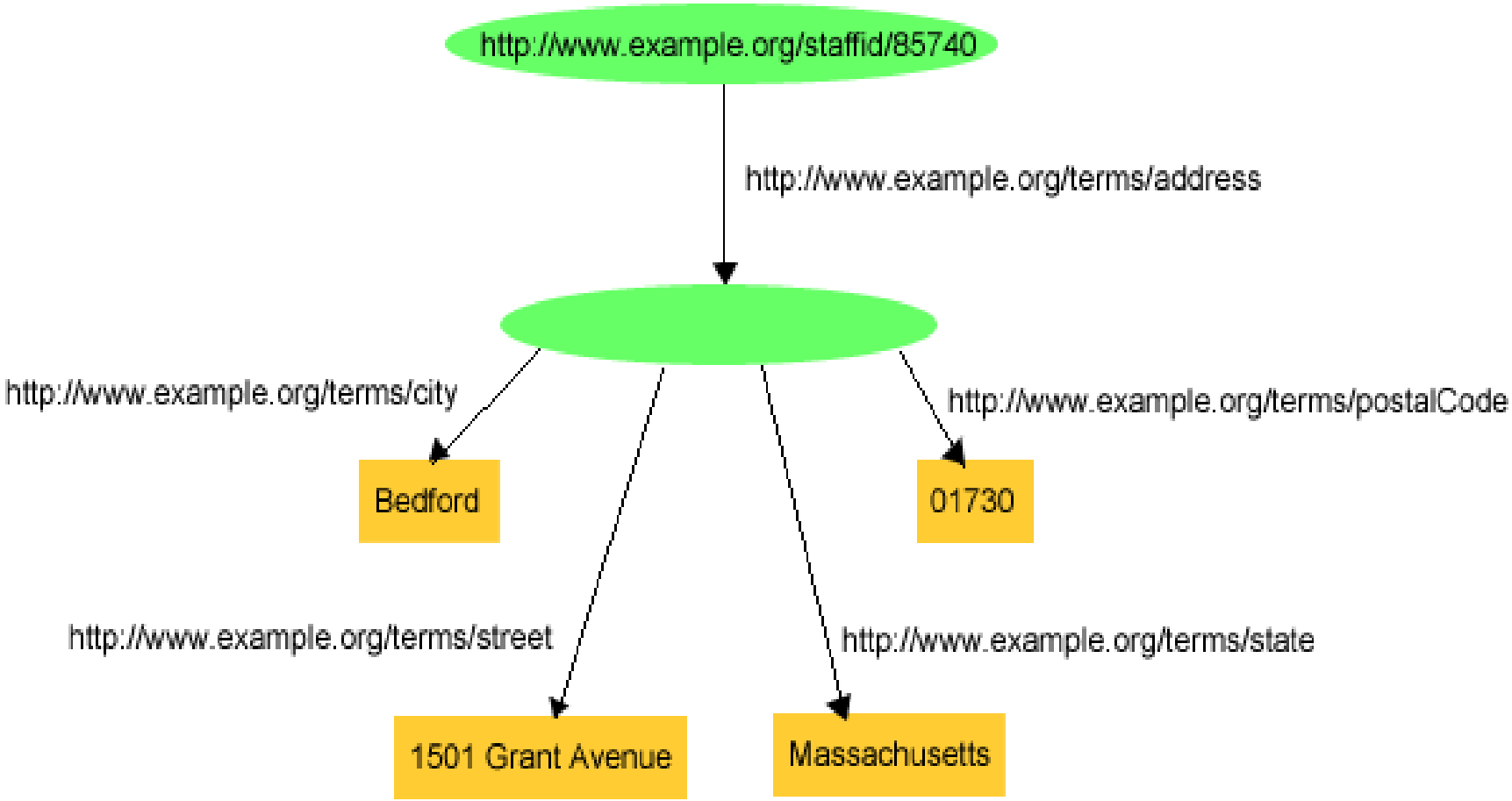


Structured Values in RDF (cont'd)

- This way of representing structured information in RDF can involve generating **numerous "intermediate" URIrefs** such as `exaddressid:85740` to represent aggregate concepts such as 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.

Blank Nodes


http://www.example.org/staffid/85740
http://www.example.org/terms/address
http://www.example.org/terms/city
http://www.example.org/terms/postalCode
Bedford
01730
http://www.example.org/terms/street
http://www.example.org/terms/state
1501 Grant Avenue
Massachusetts

Blank Nodes Using Triples

```
exstaff:85740 exterms:address ??? .
??? exterms:street "1501 Grant Avenue" .
??? exterms:city "Bedford" .
??? exterms:state "Massachusetts" .
??? exterms:postalCode "01730" .
```

- But what about **different blank nodes**? Can we handle them using this notation?

Blank Node Identifiers

```
exstaff:85740 exterms:address _:johnaddress .
_:johnaddress exterms:street "1501 Grant Avenue" .
_:johnaddress exterms:city "Bedford" .
_:johnaddress exterms:state "Massachusetts" .
_:johnaddress exterms:postalCode "01730" .
```

- In a triples representation of a graph, each distinct blank node must be given a **different** blank node identifier.
- Blank node identifiers have significance only within the triples representing a **single** graph.
- Blank node identifiers may only appear as subjects or objects in triples; blank node identifiers **may not be used as predicates** in triples.

Semantics of Blank Nodes

- In terms of **first-order logic**, a blank node corresponds to an **existentially quantified variable** (or a Skolem constant). Thus, a graph with blank nodes is similar to an **existentially quantified first order logic statement** or **a first-order database** in the sense of Reiter:

  Raymond Reiter: Towards a Logical Reconstruction of Relational Database Theory. Appears in the collection: Brodie M. L., Mylopoulos J., and Schmidt J. W. (eds.), On Conceptual Modelling: Perspectives from Artificial Intelligence, Database and Programming Languages, pp. 191-233, Springer-Verlag.

- In terms of the **relational model**, a blank node corresponds to a **marked null value**. Thus, a statement with a blank node identifier is similar to a **tuple in a relation** in the marked nulls model of Imielinski and Lipski:

  Tomasz Imielinski, Witold Lipski Jr.: Incomplete Information in Relational Databases. J. ACM 31(4): 761-791 (1984).

Semantics of Blank Nodes (cont'd)

- The RDF semantics (http://www.w3.org/TR/rdf-mt/) takes this "**existential view**" of blank nodes and defines appropriate semantics for them.

- SPARQL, the standard query language for RDF, considers blank nodes **as constants scoped in the graph where they appear.**

- In practice, it varies how people use blank when they publish linked data.

- For a nice study of the relevant issues see the paper
  Alejandro Mallea, Marcelo Arenas, Aidan Hogan, Axel Polleres.
  On Blank Nodes. Proceedings of the International Semantic Web Conference 2011, pages 421-437.

Blank Nodes (cont'd)

- Blank nodes are useful to represent **n-ary relationships** in RDF e.g., the relationship between John Smith and the street, city, state, and postal code components of his address.

- Blank nodes are also useful to more accurately make statements about **resources that may not have URIs,** but that are described in terms of relationships with other resources that do have URIs.

Example

- When making statements about a person, say Jane Smith, is it natural to use a URI based on that person's email address as her URI, e.g., mailto:jane@example.org ?

- 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.

Example (cont'd)

- **Blank nodes to the rescue:** When Jane herself does not have a URI, a blank node provides a more accurate 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" .
```

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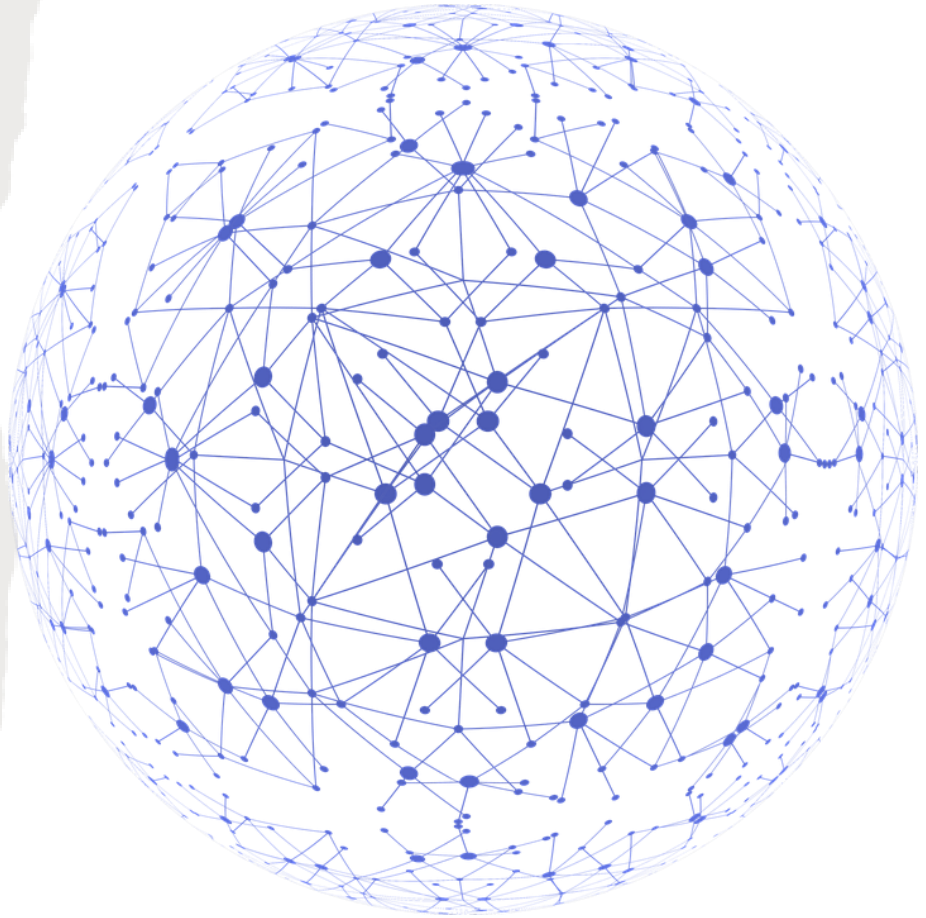


Machine Readable Formats for RDF

RDF has a number of machine readable formats:

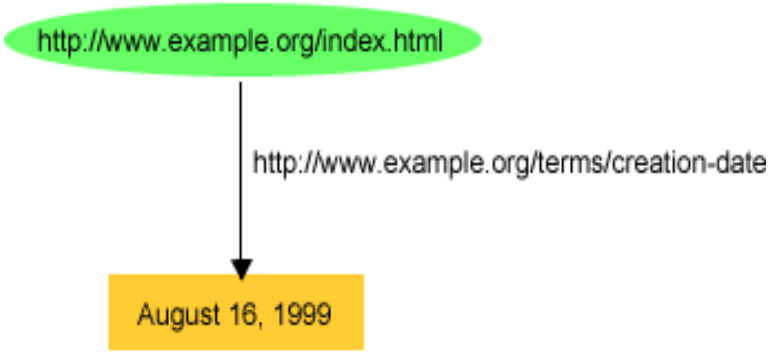
- XML/RDF
- Turtle (Terse RDF Triple Language)
- N3
- …

An XML Syntax for RDF: RDF/XML

- The conceptual model for RDF is a graph.
- RDF provides an XML syntax for **writing down and exchanging RDF graphs**, called **RDF/XML**.
- RDF/XML is **the normative syntax** for writing RDF.

Example

http://www.example.org/index.html has a creation-date whose value is August 16, 1999.



Example in XML/RDF

```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
           xmlns:exterms="http://www.example.org/terms/">
     <rdf:Description rdf:about="http://www.example.org/index.html">
        <exterms:creation-date>August 16, 1999</exterms:creation-date>
     </rdf:Description>
</rdf:RDF>
```

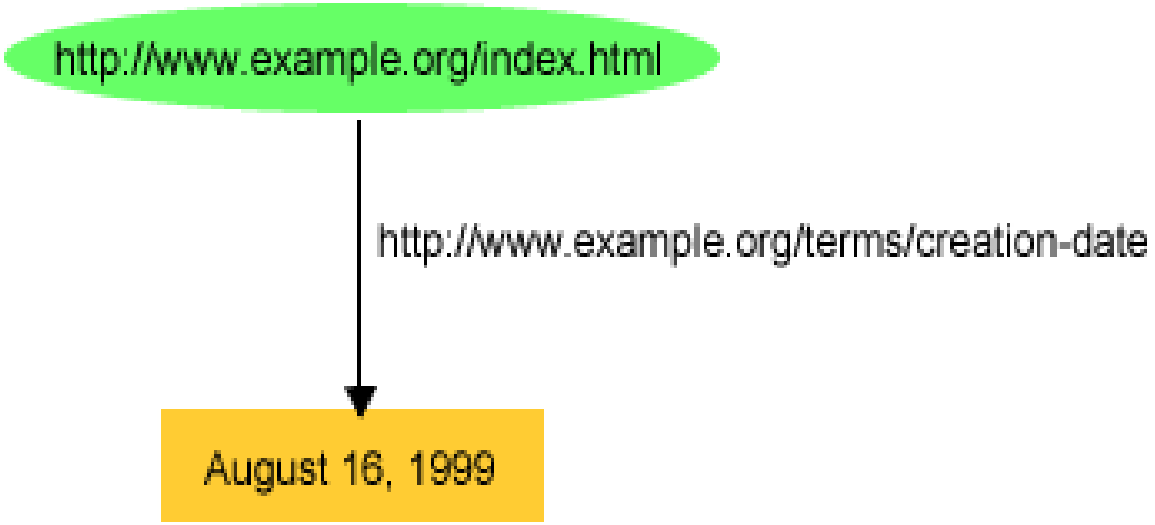
Turtle

- **Turtle** provides another textual syntax for writing down and exchanging RDF graphs.

- **Turtle** is based on the **triple notation** we used so far, but also includes some additional syntactic means to **simplify the specification** of RDF graphs.

Example I

http://www.example.org/index.html has a creation-date whose value is August 16, 1999.



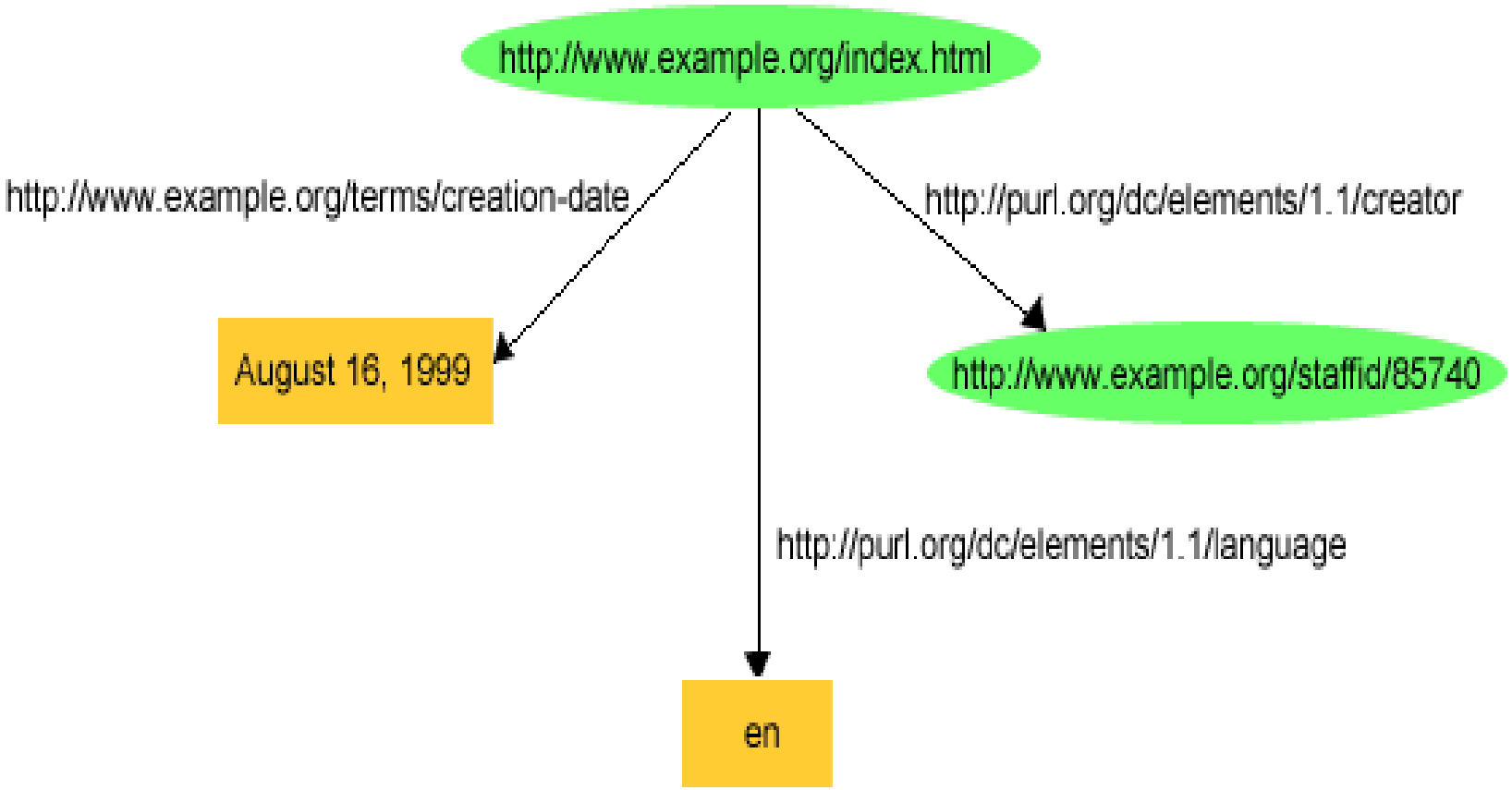
Example I in Turtle

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

<http://www.example.org/index.html>
                    exterms:creation-date "August 16, 1999“ .
```

- **Notation:** The `@prefix` keyword in the first two lines declares namespaces `rdf:` and `exterms:`

Example II


http://www.example.org/index.html
http://www.example.org/terms/creation-date
http://purl.org/dc/elements/1.1/creator
August 16, 1999
http://www.example.org/staffid/85740
http://purl.org/dc/elements/1.1/language
en

Example II Using Triples

```
<http://www.example.org/index.html>
   <http://purl.org/dc/elements/1.1/creator>
                                  <http://www.example.org/staffid/85740> .

<http://www.example.org/index.html>
         <http://www.example.org/terms/creation-date> "August 16, 1999" .


<http://www.example.org/index.html>

     <http://purl.org/dc/elements/1.1/language> "en" .
```

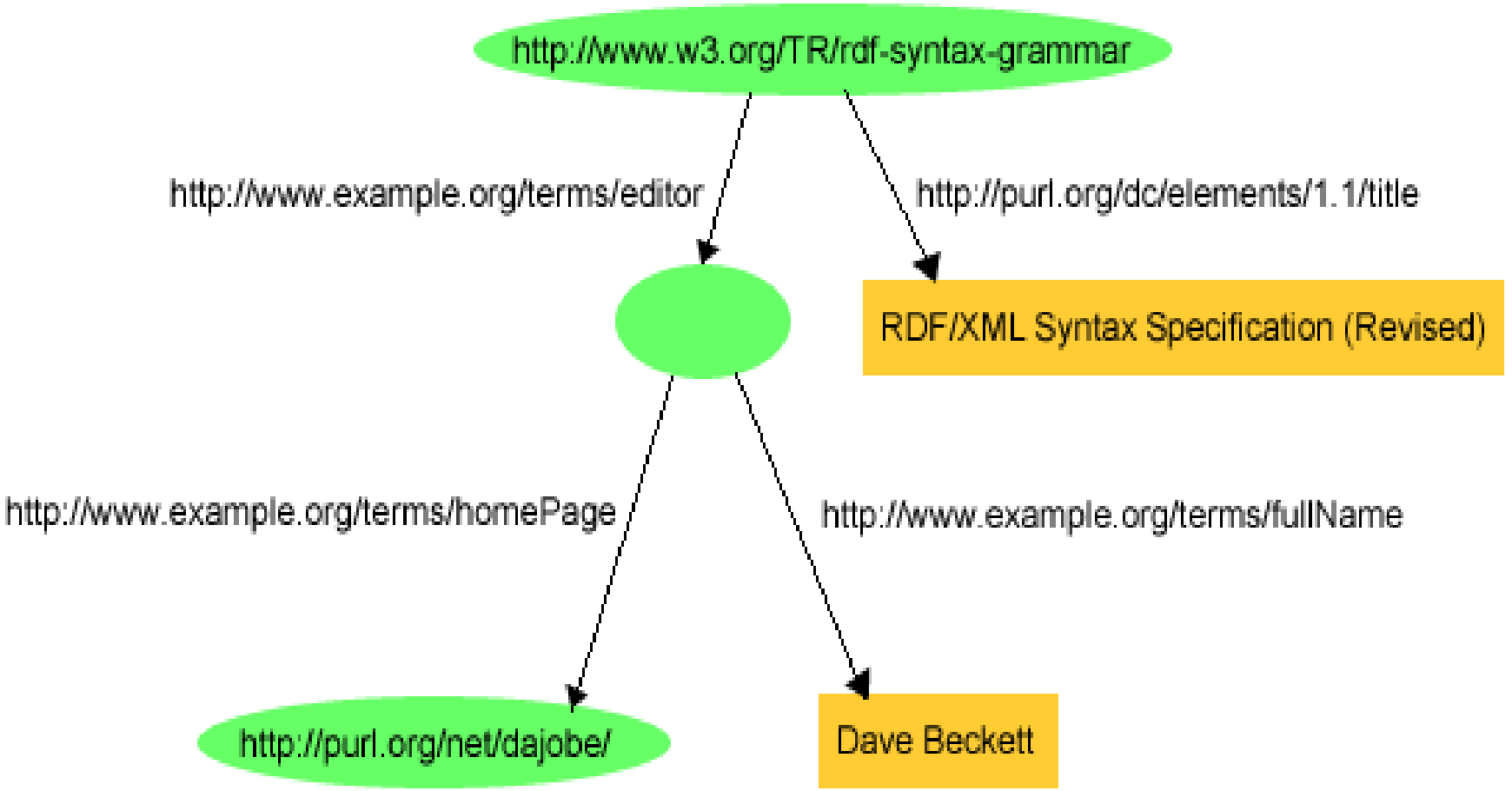
Example II Using Turtle

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

<http://www.example.org/index.html>
   exterms:creation-date "August 16, 1999";
   dc:language "en";
   dc:creator <http://www.example.org/staffid/85740>.
```

- **Notation:** In this case Turtle allows the semi-colon to separate **predicate-object pairs** for the same subject. A list of such pairs is terminated with a period.

Blank Nodes in Turtle



Blank Nodes in Turtle (cont'd)

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

<http://www.w3.org/TR/rdf-syntax-grammar>
    dc:title "RDF/XML Syntax Specification (Revised)";
    exterm:editor _:abc.

 _:abc
    exterms:fullName "Dave Beckett";
    exterms:homePage <http://purl.org/net/dajobe/>.
```

- **Notation:** Blank node identifiers are used.

Anonymous Blank Nodes

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

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

- **Notation:** This is reminiscent of notations for complex objects from the area of database systems.

Summary

- In RDF, **statements** about a domain are encoded by **triples**.
- **Triples** are of the form

  subject predicate object .
- The **subject** of a triple must be a **URIref or a blank node.**
- The **predicate** of a triple must be a **URIref**.
- The **object** of a triple must be a **URIref, a literal or a blank node**.
- Literals are not allowed as subjects or predicates. Blank nodes are not allowed as predicates.
- **Definition:** An **RDF graph** is a set of RDF triples.

RDF 1.1

- RDF, as we presented it, became a W3C standard in 2004. This is now referred as **RDF 1.0.**
- In 2014, **RDF1.1** was defined. It is a simple extension of RDF1.0.

What's New in RDF 1.1

- Identifiers are IRIs.
- **All literals have a data type.**
- Literals with a language tag have data type rdf:langString.
- The **concept of RDF dataset was defined.** An **RDF dataset** is a collection of RDF graphs. We will see again this concept when we discuss the query language SPARQL.
- Compatible XSD data types were specified.
- The datatype **rdf:HTML was introduced so that we can have objects of triples to be HTML code.**
- More serialization formats: RDF/XML, RDFa, N-Triples, N-Quads, Turtle, TriG and JSON-LD.

- You can see more details in https://www.w3.org/TR/rdf11-new/ .

Readings

- Chapter 2 of the book “Foundations of Semantic Web Technologies” or Chapters 2 and 3 of the Semantic Web Primer available from http://www.csd.uoc.gr/~hy566/ .

- The following material from the Semantic Web Activity Web page on RDF http://www.w3.org/RDF/ :
  - RDF Primer (https://www.w3.org/TR/2014/NOTE-rdf11-primer-20140225/RDF Primer (https://www.w3.org/TR/2014/NOTE-rdf11-primer-20140225/ and https://www.w3.org/TR/2004/REC-rdf-primer-20040210/)
  - Resource Description Framework (RDF): Concepts and Abstract Syntax (https://www.w3.org/TR/2014/REC-rdf11-concepts-20140225/)
  - The Turtle language (https://www.w3.org/TR/2014/REC-turtle-20140225/)

- Check out the content published at the RDF namespace URI:
  - http://www.w3.org/1999/02/22-rdf-syntax-ns#

  where you will find an RDF Schema description of the RDF vocabulary given in RDF/XML!

- The DBpedia project (http://dbpedia.org/AboutThe DBpedia project (http://dbpedia.org/About), a nice application of RDF and Linked Data (http://linkeddata.org/).