

# Building the Semantic Web

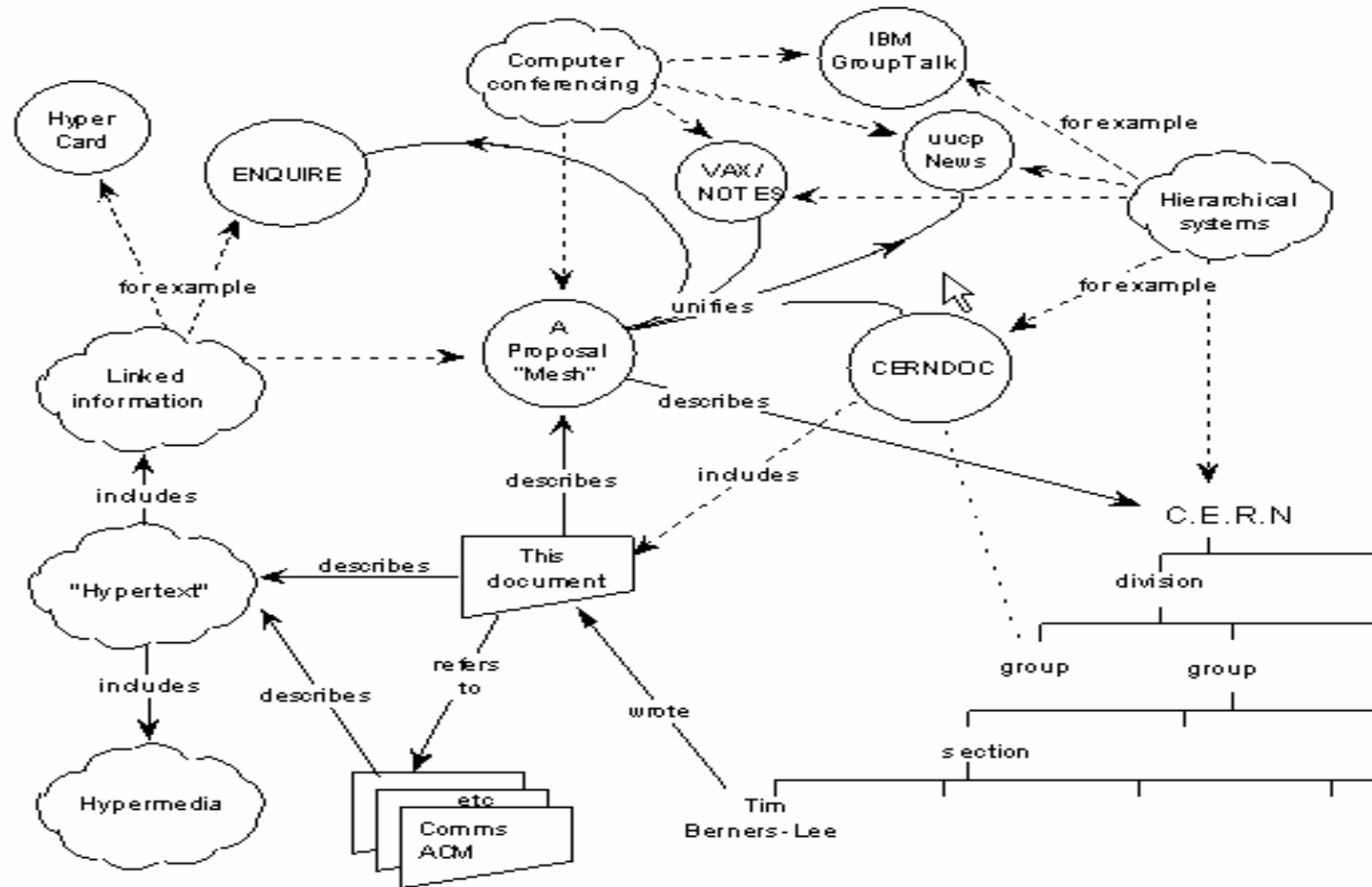
CS 431 - March 27, 2006

Carl Lagoze - Cornell University

## Acknowledgements for various slides and ideas

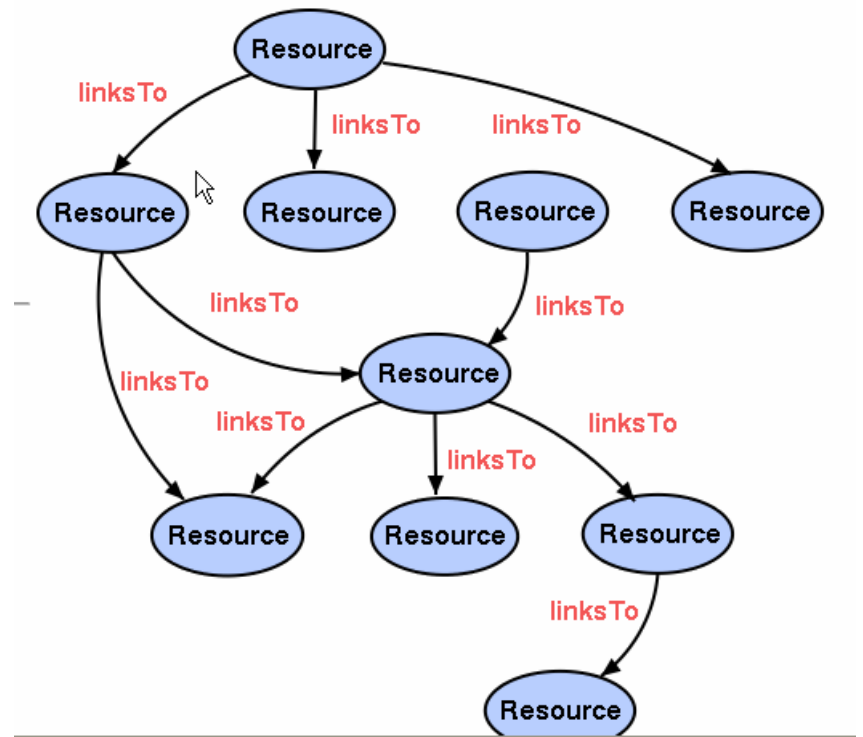
- Ian Horrocks (Manchester U.K.)
- Eric Miller (W3C)
- Dieter Fensel (Berlin)
- Volker Haarslev (Montreal)

## Web of relationships amongst named objects



# Current Web ("Syntactic" Web)

- Untyped resources named by URLs
- Untyped relationships (href with anchor text)
- User oriented - document rendering
- Machines must infer information



# The Information in a Web Page



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- Markup connotes semantics (bold, colors, font...)
- Humans interpret semantics
- Rendering semantics is not clear or available to machines

## Why is XML not enough?

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## <introduction>

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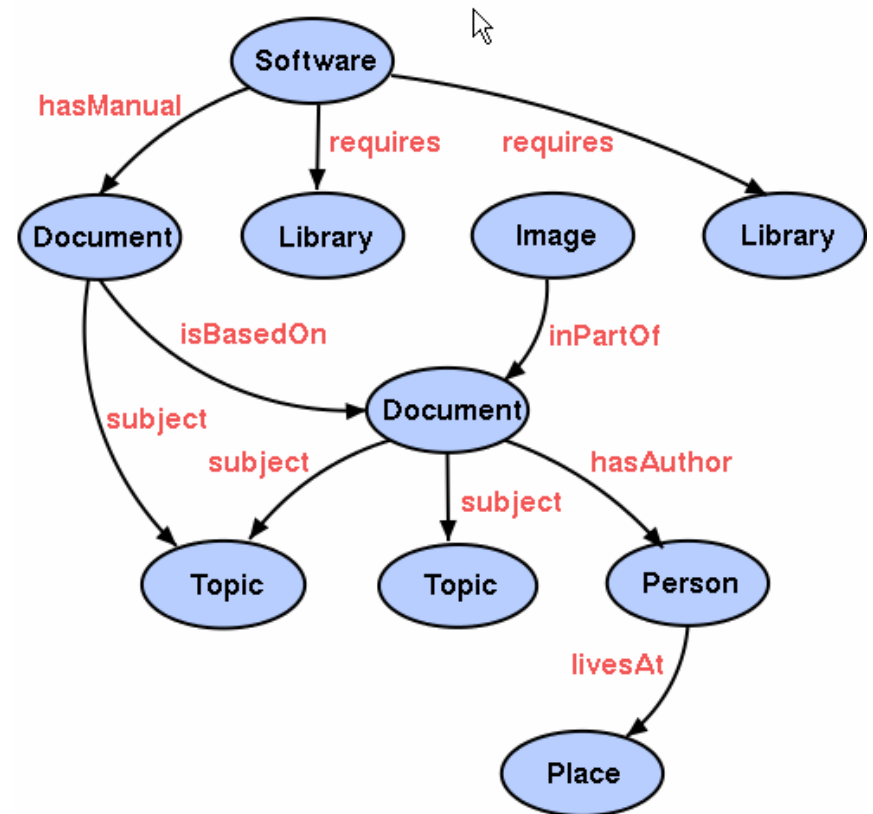
## XMLs helps but not much...

- Descendent of DTD's
  - Mostly a structuring language
  - Doesn't express "meaning" of structure
- Problems with knowledge representation
  - Poor expression of concepts, relationships, and subsumption
  - No basis in formal logic, limited if any basis for reasoning
  - So, can't do:
    - Ford is a "kind of" car
    - VW is a "kind of" car
    - Joe "has a" Ford
    - Sue "has a" VW
    - Joe and Sue both have cars



# Semantic Web

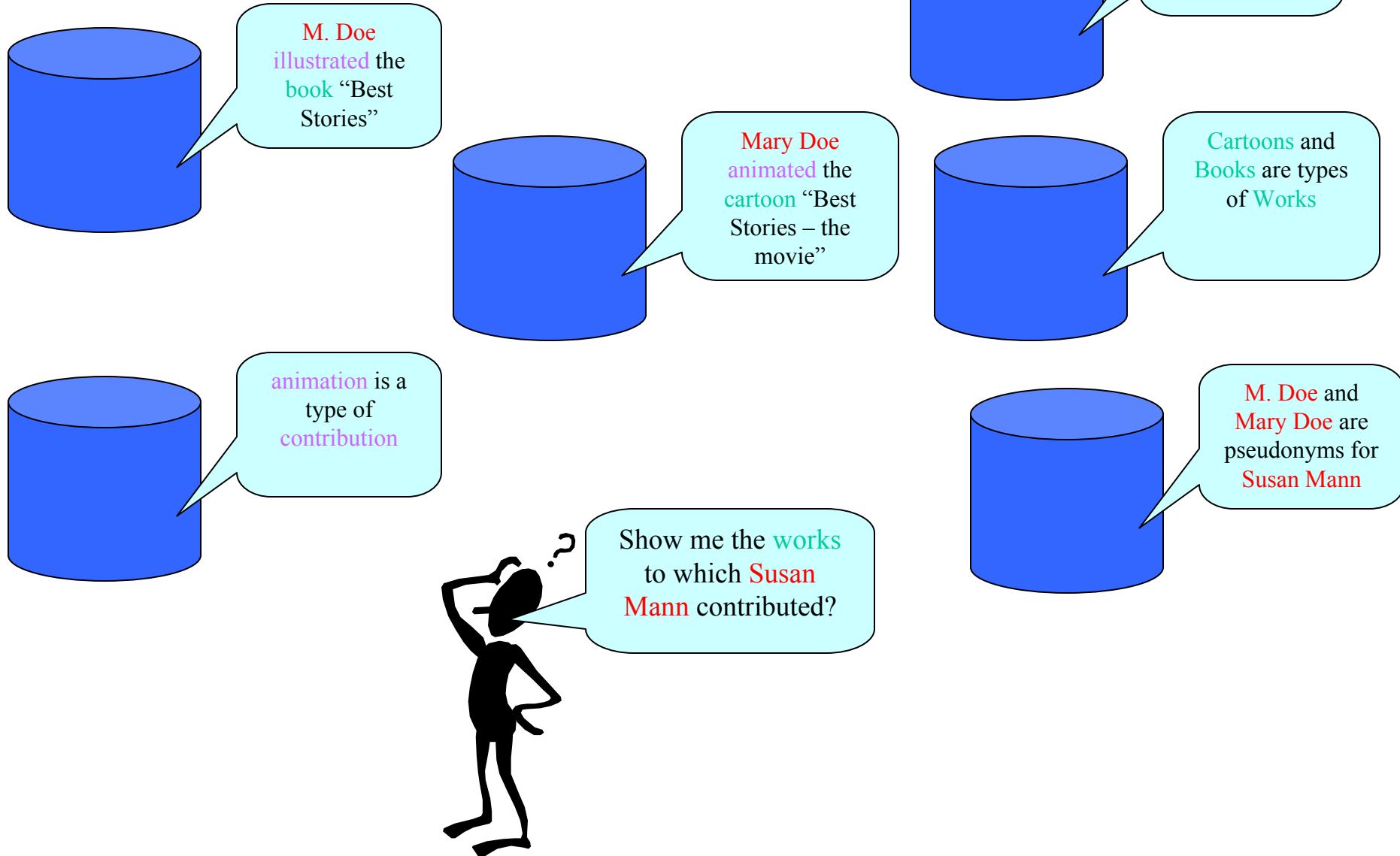
- Resources typed, types defined by URIs
- Relationships typed, types defined by URIs
- Types are structured and are first-class
- Machines can inference



## Why do we “need” a semantic web?

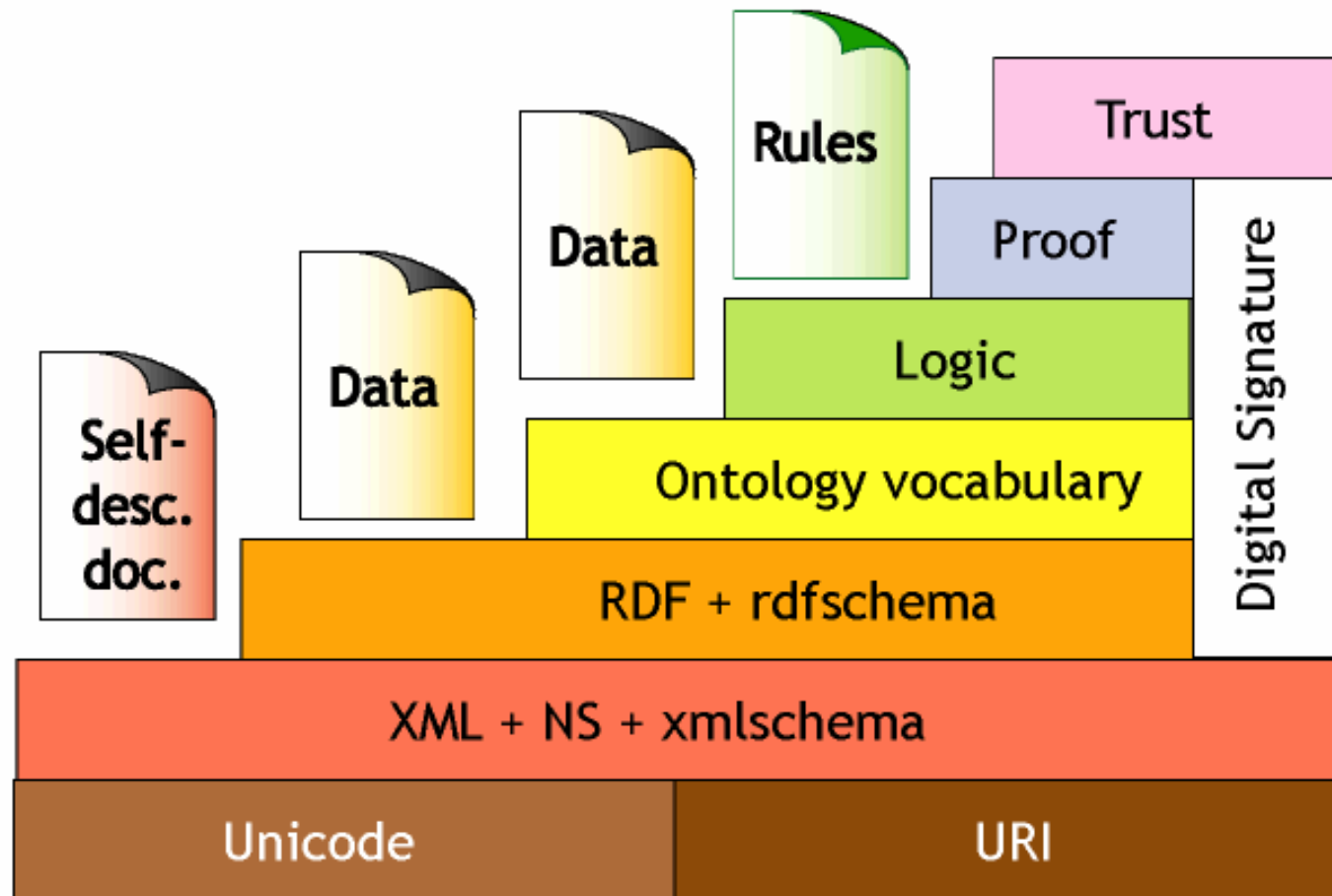
- Keyword search engines will continue to improve but...
  - High recall, low precision
  - Results sensitive to vocabulary
  - Result granularity is single web page
  - They don't capture “meaning”
- In constrained domains (i.e., not across the entire web) better information management, knowledge representation makes sense
- “*Maybe*” a common infrastructure for KR will lead to web-wide “*semantics*”
- Some of these tools are useful right now (e.g., Project 2)

# Motivating the "Semantic Web"

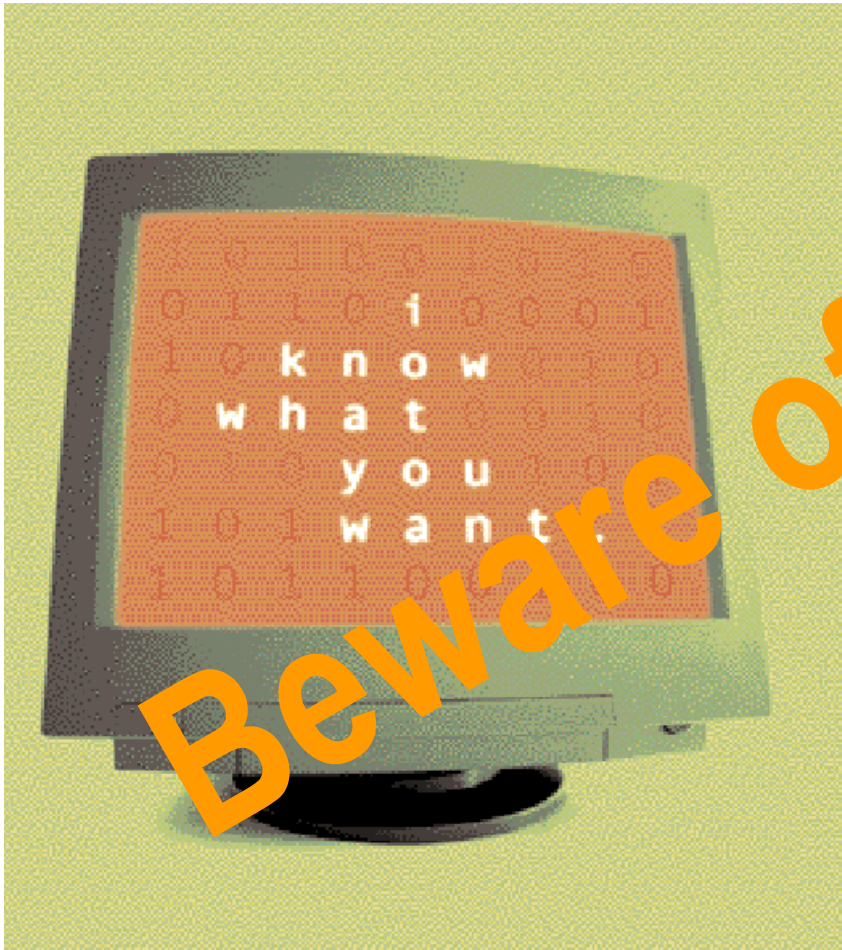


# Components of the Semantic Web

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Scientific American, May 2001:



# THE SEMANTIC WEB

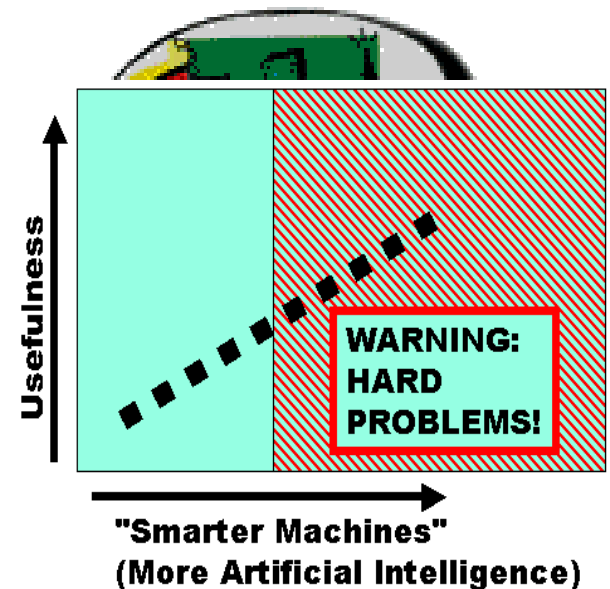
A new form of Web content  
that is meaningful to computers  
will unleash a revolution of new abilities

by  
TIM BERNERS-LEE,  
JAMES HENDLER and  
ORA LASSILA

PHOTO CREDIT HERE

# Beware of the Hype

- Hype seems to suggest that Semantic Web means: "semantics + web = AI"
  - "A new form of Web content that is meaningful to computers will unleash a revolution of new abilities"
- More realistic to think of it as meaning: "semantics + web + AI = more useful web"
  - Realising the complete "vision" is too hard for now (probably)
  - But we can make a start by adding [semantic annotation](#) to web resources



# Knowledge Representation

- **Objects/Instances/Individuals**
  - Elements of the domain of discourse
  - Equivalent to constants in FOL
- **Types/Classes/Concepts**
  - Sets of objects sharing certain characteristics
  - Equivalent to unary predicates in FOL
- **Relations/Properties/Roles**
  - Sets of pairs (tuples) of objects
  - Equivalent to binary predicates in FOL
- Such languages are/can be:
  - Well understood
  - Formally specified
  - (Relatively) easy to use
  - Amenable to machine processing

There has been lots of work on Knowledge Representation but...

“The challenge of the Semantic Web is to find a representation language powerful enough to support automated reasoning but simple enough to be usable”

**“All tractable languages are useless;  
all useful languages are intractable”**



# Challenges of Web to KR

- Scale
- Distributed
- Dynamic
- Paradoxes
- Incomplete language
  - Closed world vs. open world assumptions

# Modeling & Encoding Knowledge: RDF

- RDF (Resource Description Format)
- Provides enabling technology for richly-structured information
  - Support for and integration of multiple independent vocabularies
- Rich data model supporting notions of distinct entities and properties
  - Formal model with basis in logic
- Expressible in machine readable manner (e.g., XML)

# RDF Components

- Formal data model
  - Syntax for interchange of data
  - Schema Type system (schema model)
  - Syntax for machine-understandable schemas
  - Query and profile protocols
- 
- Ontologies layered on top via extensions to base RDF language (DAML, OIL, OWL)

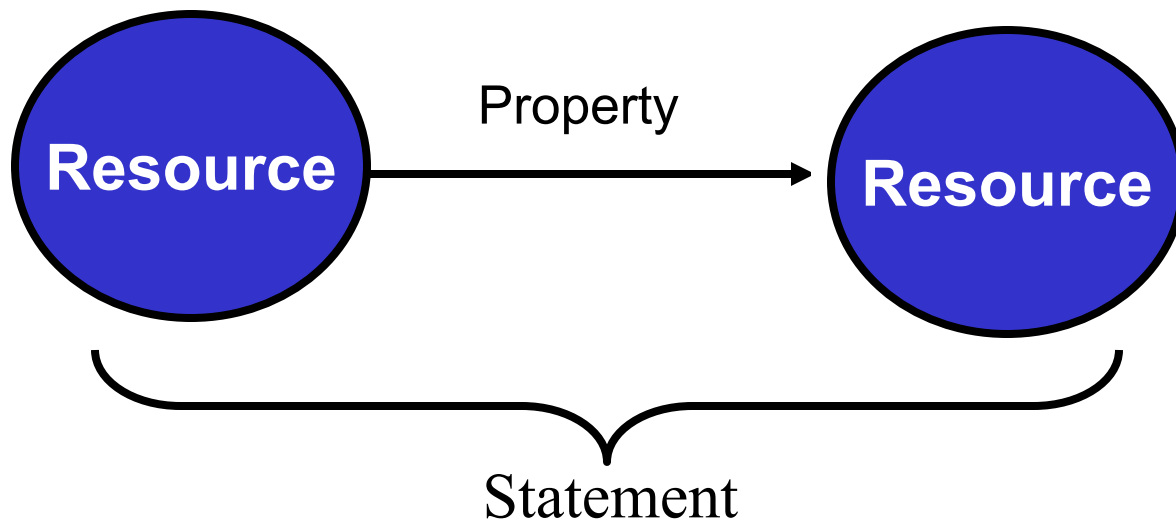
# RDF Data Model

- Provides underlying structural foundation for the expression of application (instance) data models
  - for consistent encoding, exchange and processing of information
  - Provides for a basis for interoperability
- Individual communities can then define and express semantics on the basic model
- Model is distinct from the syntax for expressing it
  - XML
  - N3
  - triple notation
  - relational databases (triple-stores in tables)

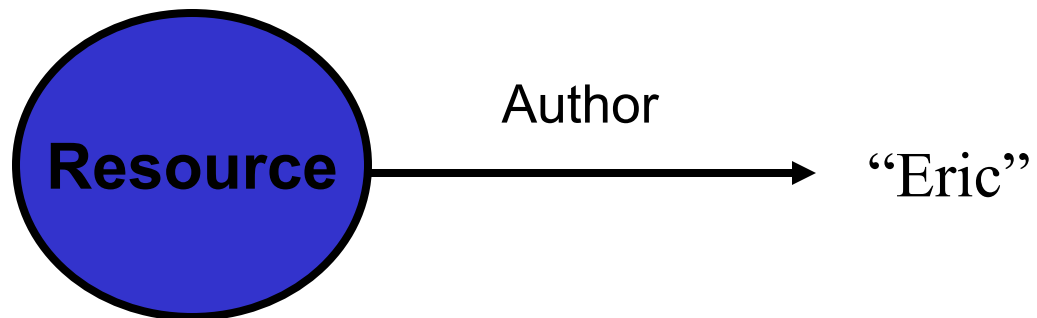
# RDF Data Model

- Directed labeled graphs
- Model elements
  - Resource
  - Property
  - Value
  - Statement
  - Containers
- Nodes are all identified using URIs

## RDF Model Primitives



## Simple Example

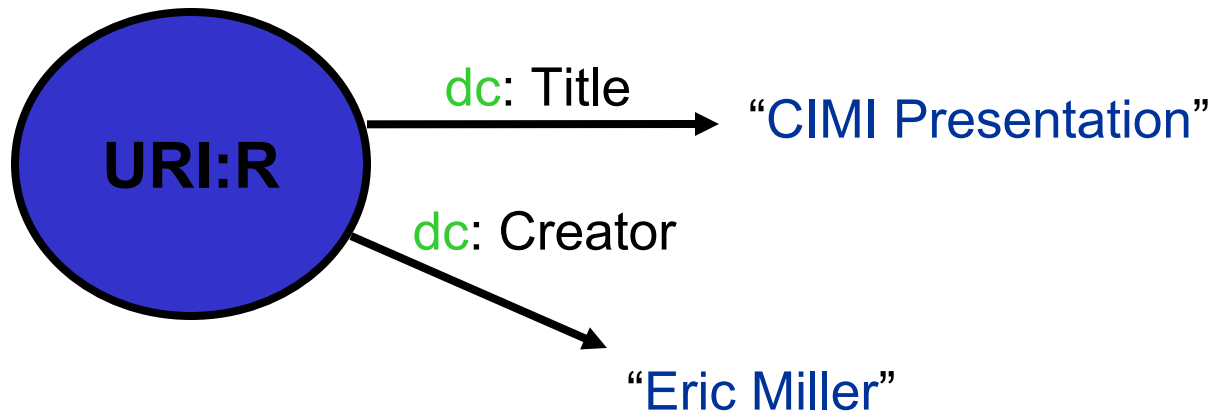


## RDF Syntax

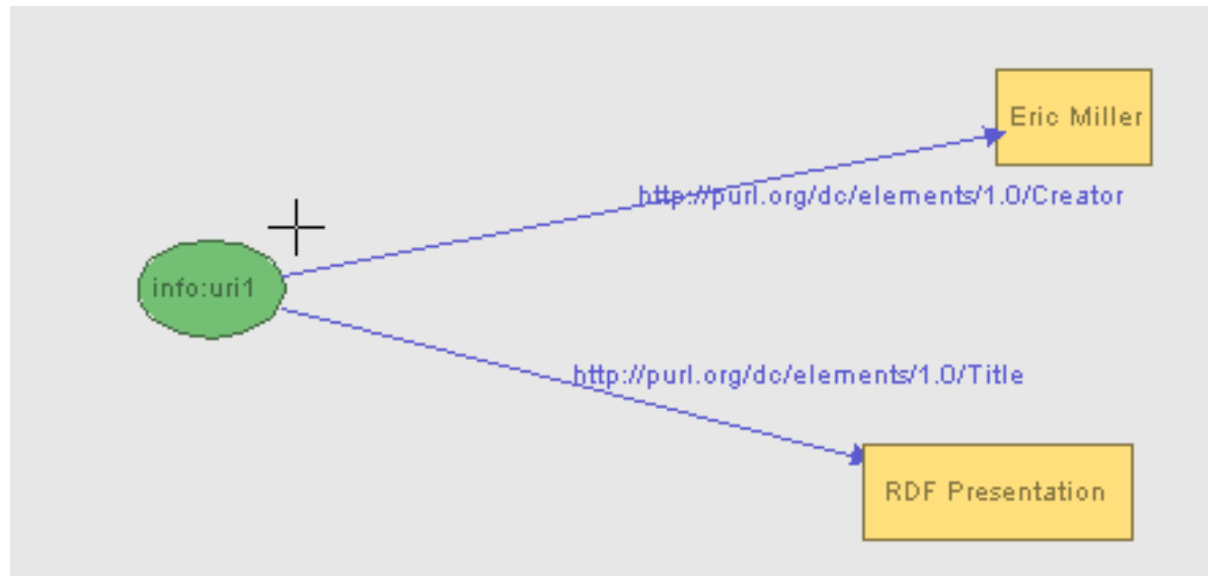
- RDF Model defines a formal relationships among resources, properties and values
- Syntax is required to...
  - Store instances of the model into files
  - Communicate files from one application to another
- XML is one well-supported syntax, N3 is another



# RDF Model Example #1



## RDF Syntax Example #1



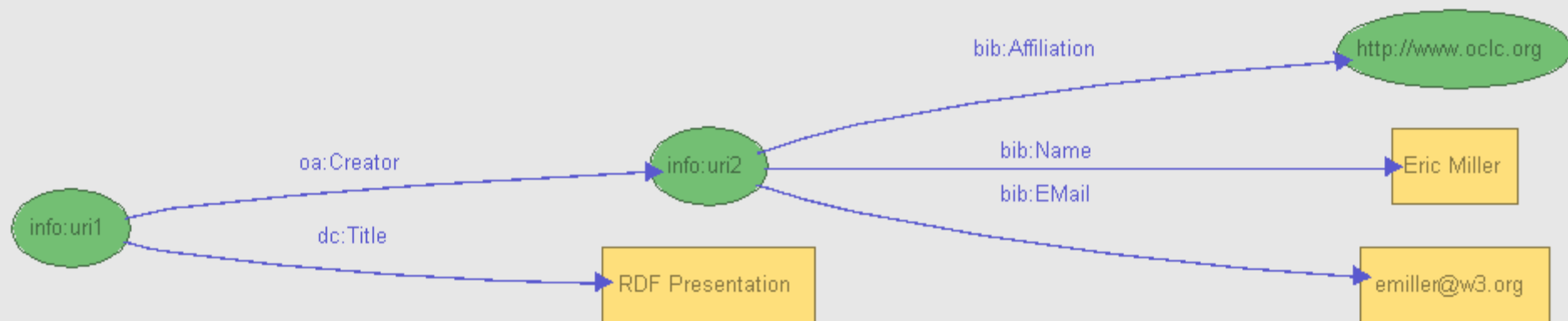
```
<?xml version="1.0"?>
<rdf:RDF xmlns:gss="http://www.w3.org/2001/11/IsaViz/graphstylesheets#"
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:xsd="http://www.w3.org/2001/XMLSchema#" xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
  xmlns:dc="http://purl.org/dc/elements/1.0/">
  <rdf:Description rdf:about="info:uri1">
    <dc:Title>RDF Presentation</dc:Title>
    <dc:Creator>Eric Miller</dc:Creator>
  </rdf:Description>
</rdf:RDF>
```

## N3 Syntax - Example #1

```
@prefix :          <#> .

<info:uri>
  <http://purl.org/dc/elements/1.0/Creator>
    "Eric Miller" ;
  <http://purl.org/dc/elements/1.0/Title>
    "RDF Presentation" .
```

## RDF Model Example #2



## RDF/XML Syntax Example #2


```
<?xml version="1.0"?>
<rdf:RDF xmlns:gss="http://www.w3.org/2001/11/IsaViz/graphstylesheets#"
  xmlns:oa="http://agents.org/elements#" xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:xsd="http://www.w3.org/2001/XMLSchema#" xmlns:bib="http://www.bib.org/persons#"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#" xmlns:dc="http://purl.org/dc/elements/1.0/"
  xml:base="file:/C:/IsaViz/tmp/tmp41406.rdf">
  <rdf:Description rdf:about="info:uri2">
    <bib:Affiliation rdf:resource="http://www.oclc.org"/>
    <bib:EMail>emiller@w3.org</bib:EMail>
    <bib:Name>Eric Miller</bib:Name>
  </rdf:Description>
  <rdf:Description rdf:about="info:uri1">
    <oa:Creator rdf:resource="info:uri2"/>
    <dc:Title>RDF Presentation</dc:Title>
  </rdf:Description>
</rdf:RDF>
```

## N3 Syntax Example #2

```
@prefix oa: <http://agents.org/elements#> .
@prefix bib: <http://www.bib.org/persons#> .
@prefix dc: <http://purl.org/dc/elements/1.0/> .
@prefix :      <#> .

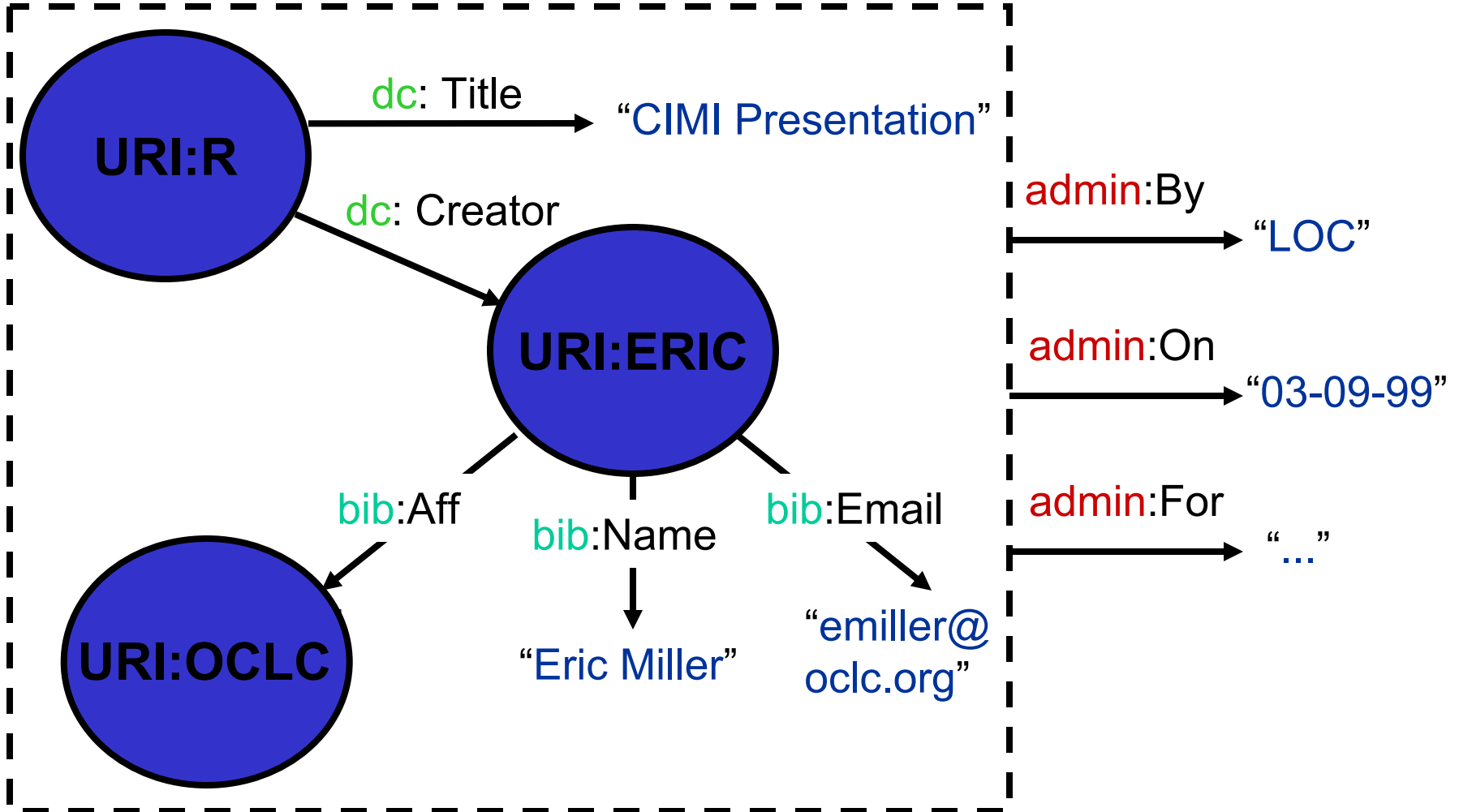
<info:uri2>
  <bib:Affiliation>
    <http://www.oclc.org> ;
  <bib:EMail>
    "emiller@w3.org" ;
  <bib:Name>
    "Eric Miller" .

<info:uri1>
  <oa:Creator>
    <info:uri2> ;
  <dc:Title>
    "RDF Presentation" .
```



# RDF Model Example #3

## Reification



## RDF Containers

- Permit the aggregation of several values for a property
- Express multiple aggregation semantics
  - unordered
  - sequential or priority order
  - alternative



# RDF Containers

- Bag
  - unordered grouping
- Sequence
  - ordered grouping
- Alternatives
  - alternate values
    - need to choose
  - at least one value
  - first value is default or preferred value

## RDF - Bag

- Unordered group
- "Carl Lagoze and Stuart Weibel are co-authors"

<BIB:Author>

<Bag>

<li> Carl Lagoze </li>

<li> Stuart Weibel </li>

</Bag>

</BIB:Author>

## RDF - Sequence

- Ordered or priority group
- "Carl Lagoze is primary author and Stuart Weibel is second author"

```
<BIB:Author>
```

```
<Seq>
```

```
<li> Carl Lagoze </li>
```

```
<li> Stuart Weibel </li>
```

```
</Seq>
```

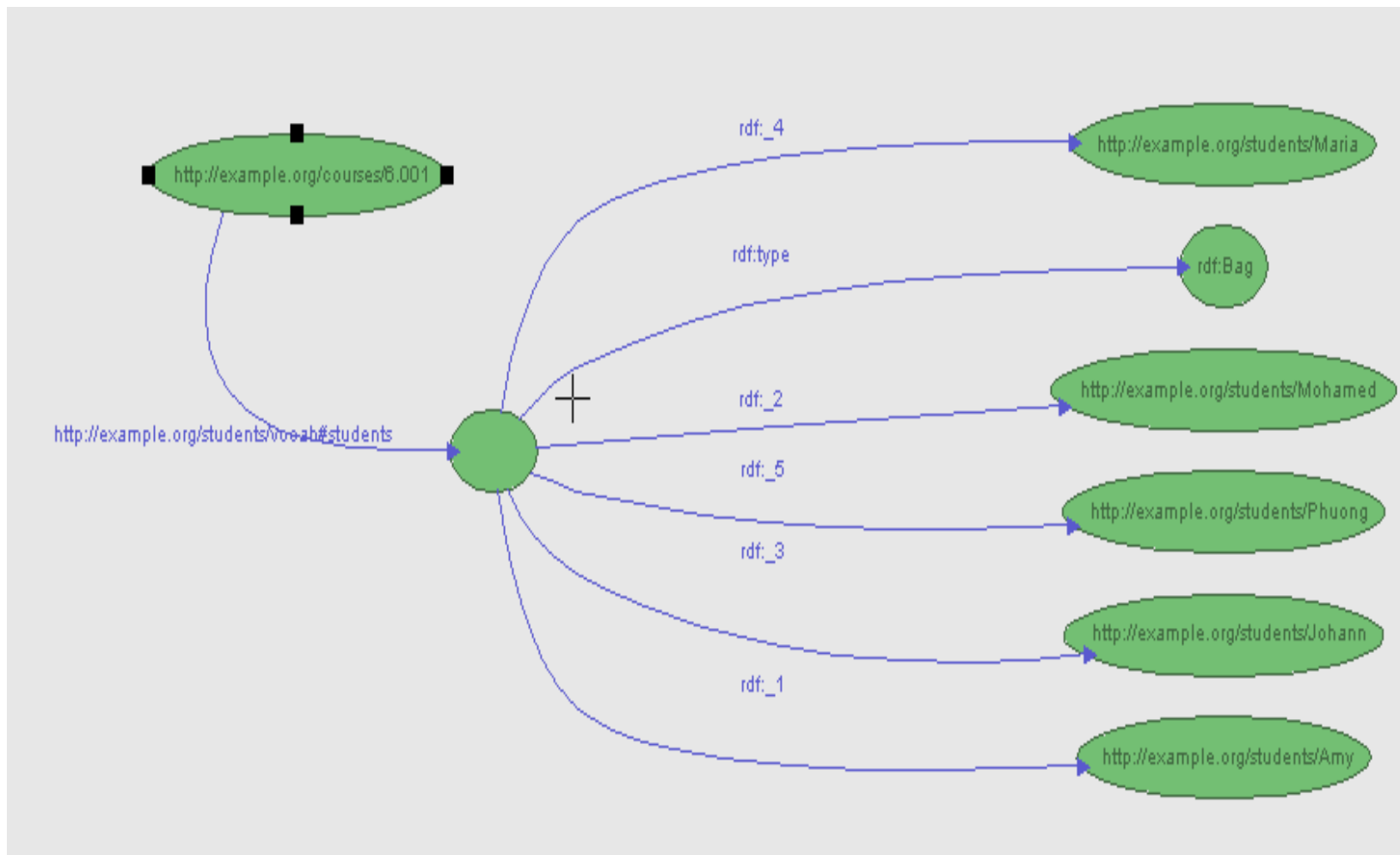
```
</BIB:Author>
```

## RDF - Alt

- Client chooses one of several values
- First value is default
- "The distance is 15 kilometers or 9.3 miles"

```
<DC:Coverage>  
  <Alt>  
    <li> 15KM </li>  
    <li> 9.3M </li>  
  </Alt>  
</DC:Coverage>
```

# Container Example



# RDF/XML for Container

```
<?xml version="1.0"?>
<rdf:RDF xmlns:gss="http://www.w3.org/2001/11/lsaViz/graphstylesheets#"
  xmlns:j.0="http://example.org/students/vocab#" xmlns:oa="http://agents.org/elements#"
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:xsd="http://www.w3.org/2001/XMLSchema#" xmlns:bib="http://www.bib.org/persons#"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#" xmlns:s="http://example.org/packages/vocab#"
  xmlns:dc="http://purl.org/dc/elements/1.0/"
  xml:base="file:/C:/Documents and Settings/Carl Lagoze/Desktop/ex2rdf.n3">
  <rdf:Description rdf:about="http://example.org/courses/6.001">
    <j.0:students>
      <rdf:Bag>
        <rdf:li rdf:resource="http://example.org/students/Amy"/>
        <rdf:li rdf:resource="http://example.org/students/Mohamed"/>
        <rdf:li rdf:resource="http://example.org/students/Johann"/>
        <rdf:li rdf:resource="http://example.org/students/Maria"/>
        <rdf:li rdf:resource="http://example.org/students/Phuong"/>
      </rdf:Bag>
    </j.0:students>
  </rdf:Description>
</rdf:RDF>
```

# N3 for Container

```
# Base: file:/C:/Documents and Settings/Carl Lagoze/Desktop/ex2rdf.n3
@prefix :      <#> .

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

# RDF meta-model

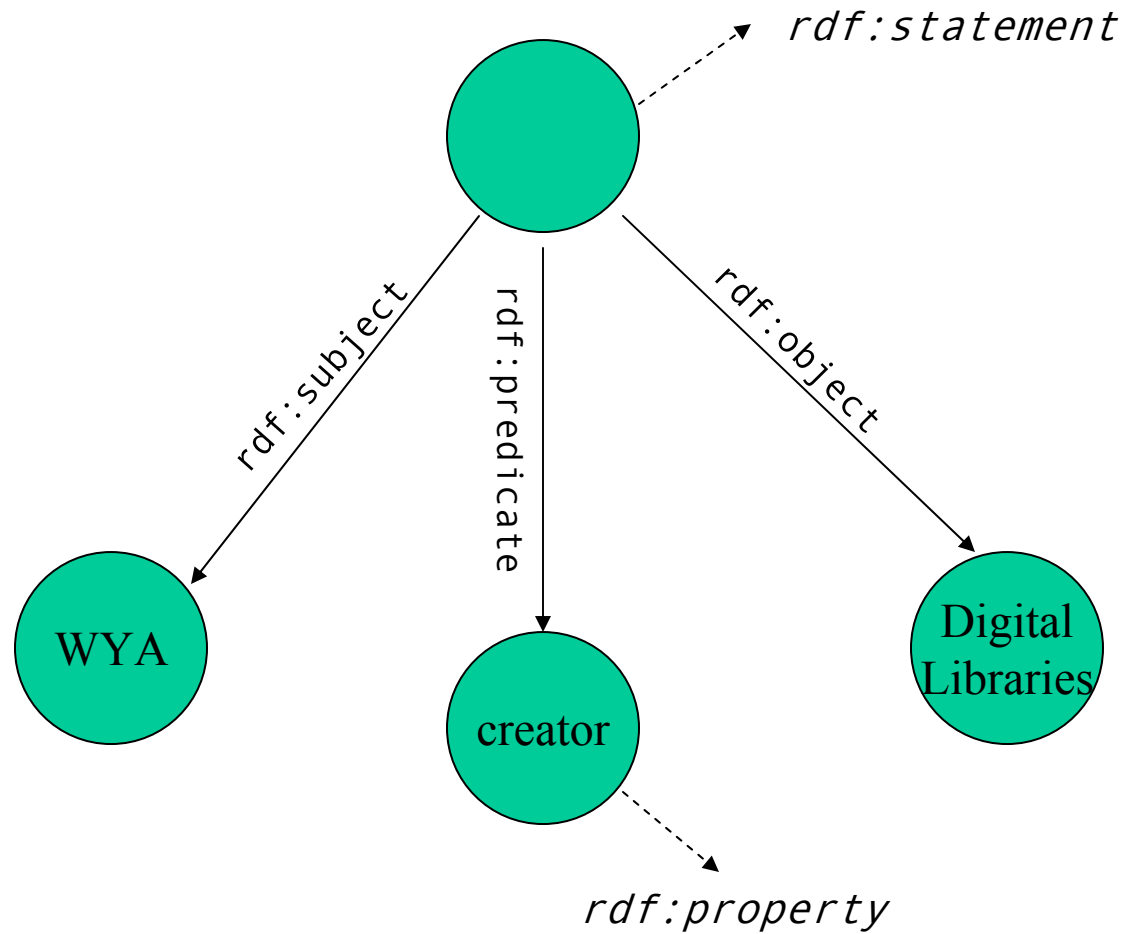
- RDF basic types
  - `rdf:Resource` - everything that can be identified (with a URI)
  - `rdf:Property` - specialization of a resource expressing a binary relation between two resources
  - `Rdf:type` - predefined property to express that subject of property is considered to be an *instance* of that category or class defined by the value of the property
  - `rdf:statement` - a triple with properties `rdf:subject`, `rdf:predicate`, `rdf:object`
- An RDF statement is a triple consisting of a resource (subject), a property and a second resource (object)
  - (`:s` `:p` `:o`)
- Expressible also as binary relations
  - $P(S,O)$  - e.g., `Title(R, "War & Peace")`



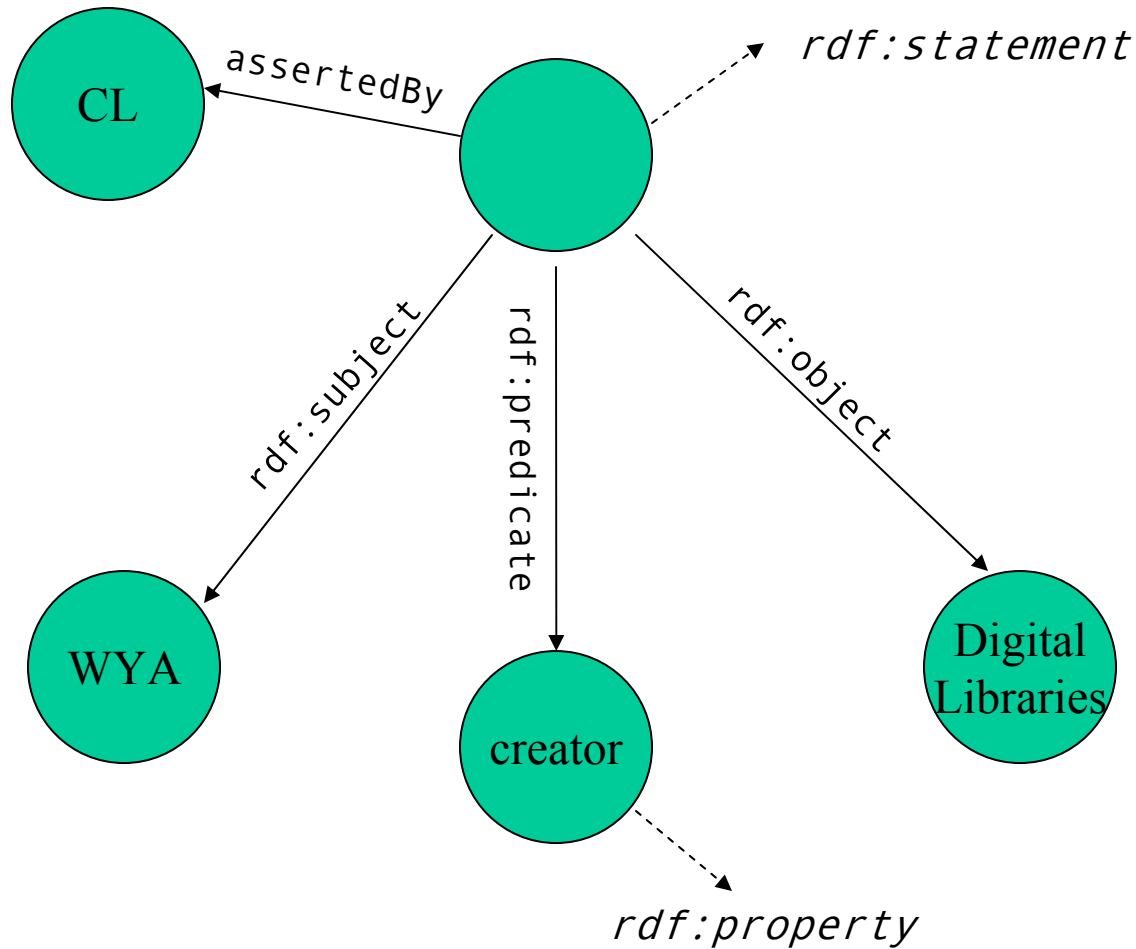
# RDF triple model

| explicit triple           | Allows inference  |
|---------------------------|---|
| <code>{ :s :p :o }</code> | <code>{ :s rdf:type rdf:Resource }</code><br><code>{ :p rdf:type rdf:Property }</code><br><code>{ :o rdf:type rdf:Resource }</code> |

# RDF statements and basic types



# Reification - Statements about statements



"CL says 'WYA wrote Digital Libraries'"