

# Basic Semantic Technologies - KG



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# The Semantic Web Technology Stack (not a piece of cake...)

Most apps use only a subset of the stack

Querying allows fine-grained data access

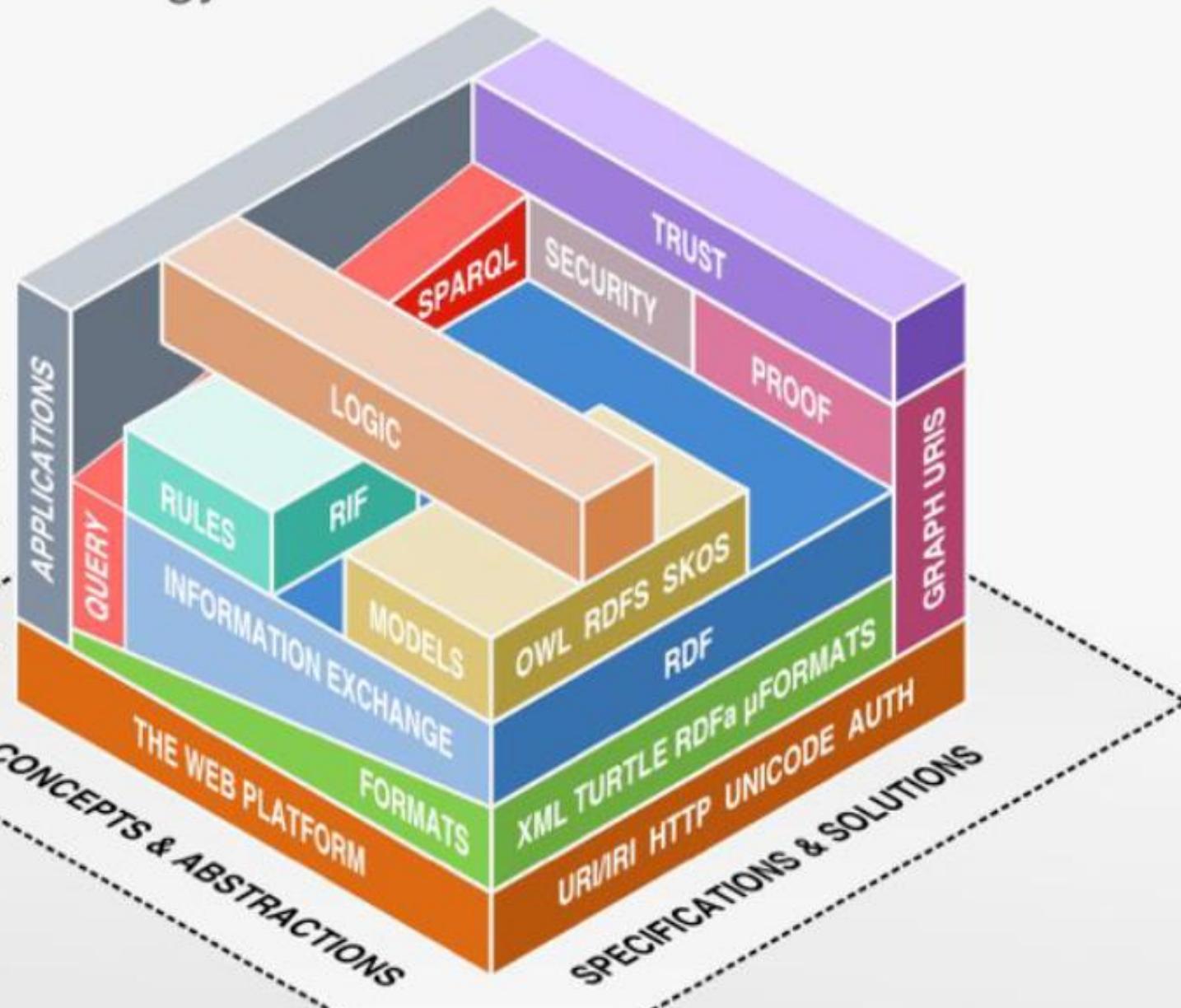
Standardized information exchange is key

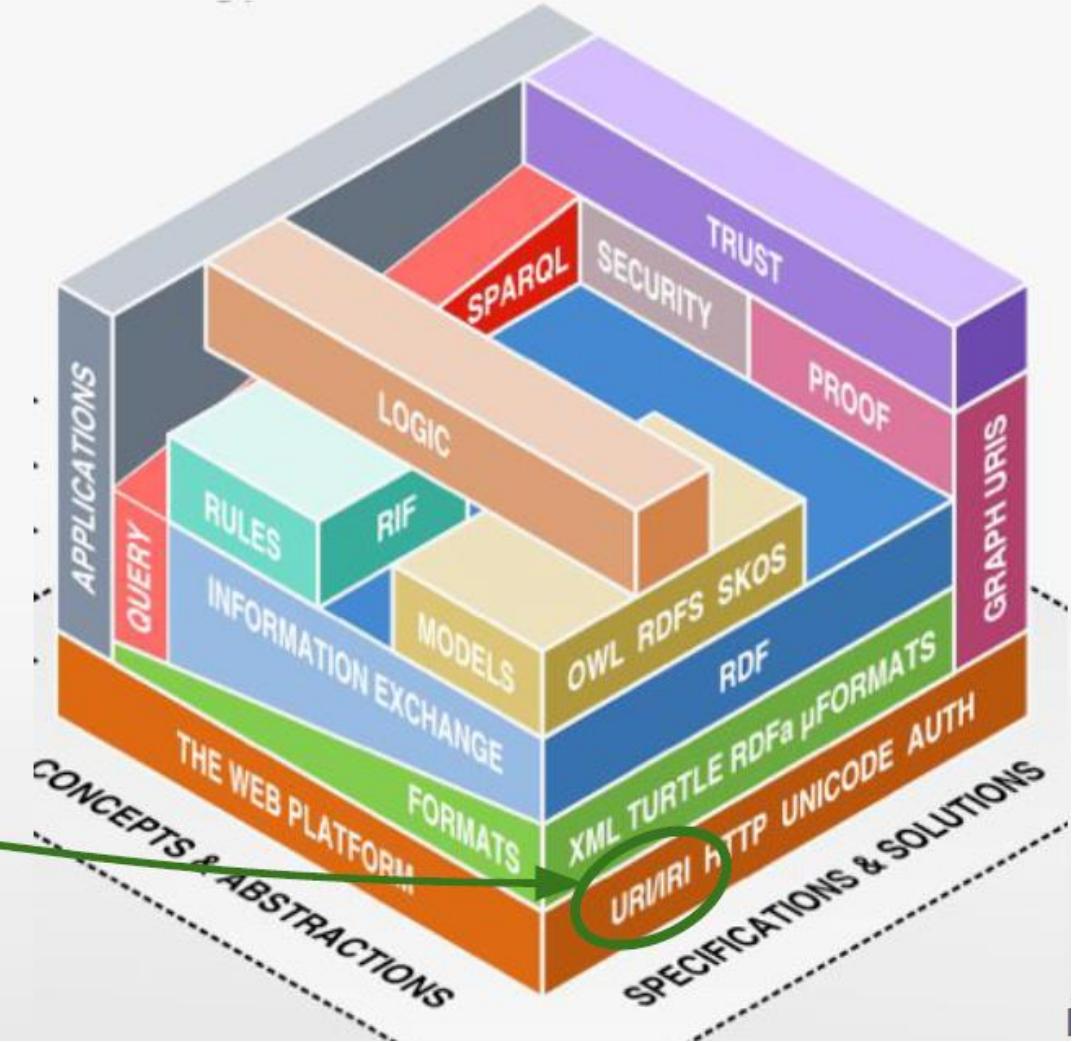
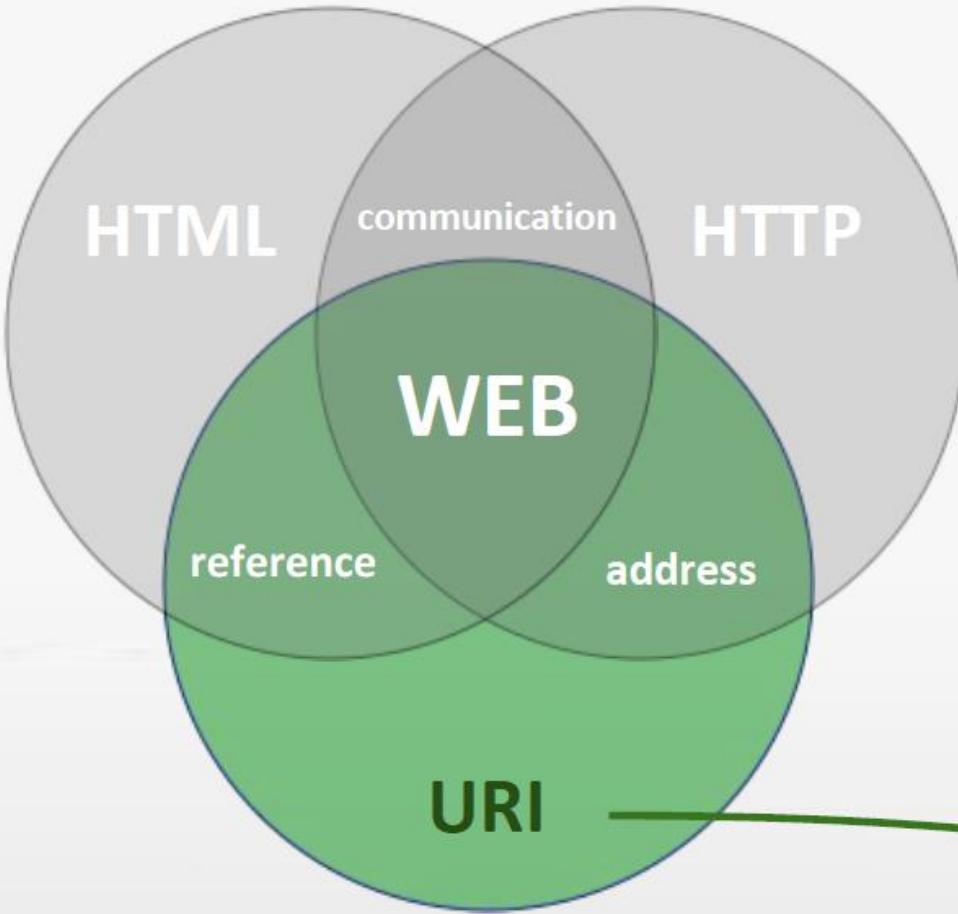
Formats are necessary, but not too important

The Semantic Web is based on the Web

Linked Data uses a small selection of technologies

LIM





# URI - Uniform Resource Identifier

- A **Uniform Resource Identifier (URI)** defines a simple and extensible schema for worldwide unique identification of abstract or physical resources (RFC 3986).
- A **Resource** can be every object with a clear identity (according to the context of the application)
  - as e.g., web pages, books, locations, persons, relations among objects, abstract concepts, etc.
- URI concept is already established in various domains, as e.g.,
  - the Web (URL),
  - Books and publications (ISBN, ISSN),
  - Digital Object Identifier (DOI).

## Let's try an example:

- I want to have **information** about the Earth from DBpedia.

1

HTTP GET request

Accept Header: text/html

<http://dbpedia.org/resource/Earth>

URI represents *Designatum*



4

HTML Document

2

HTTP/2 303 See Other

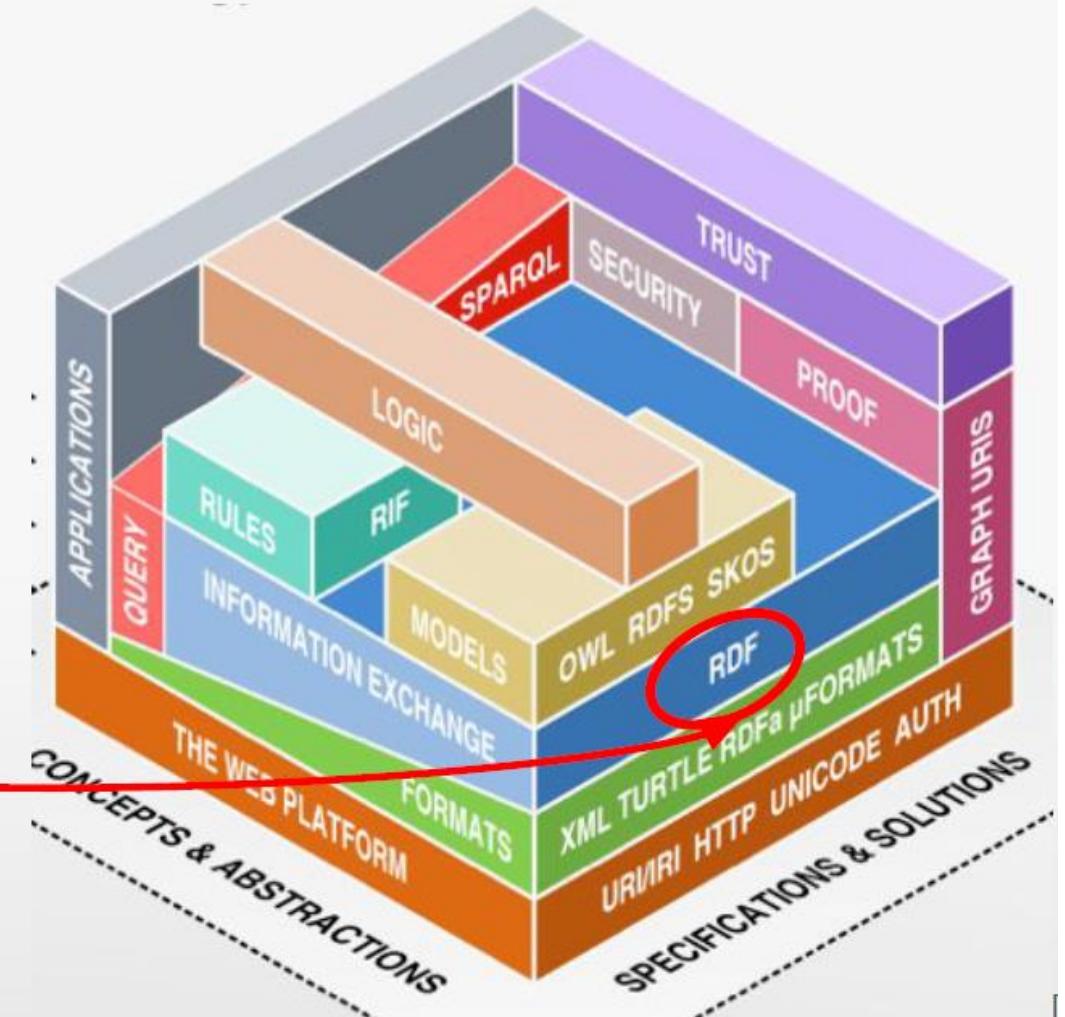
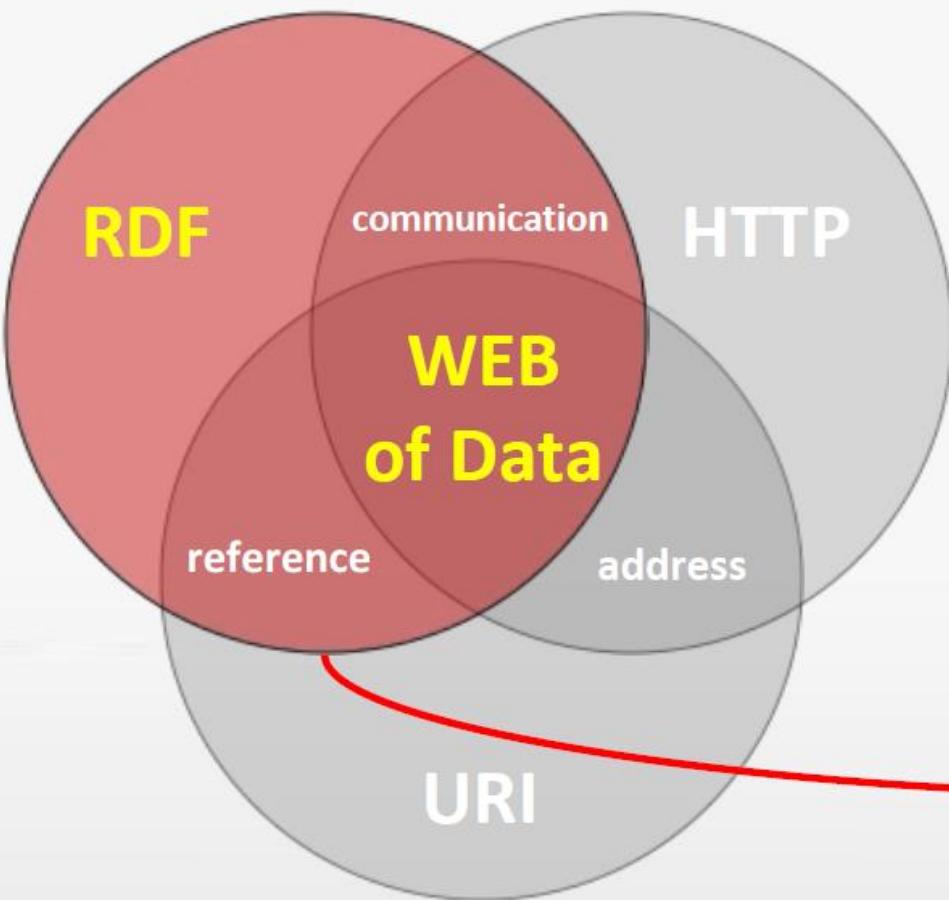
3

<http://dbpedia.org/page/Earth>

URI represents *Designator*

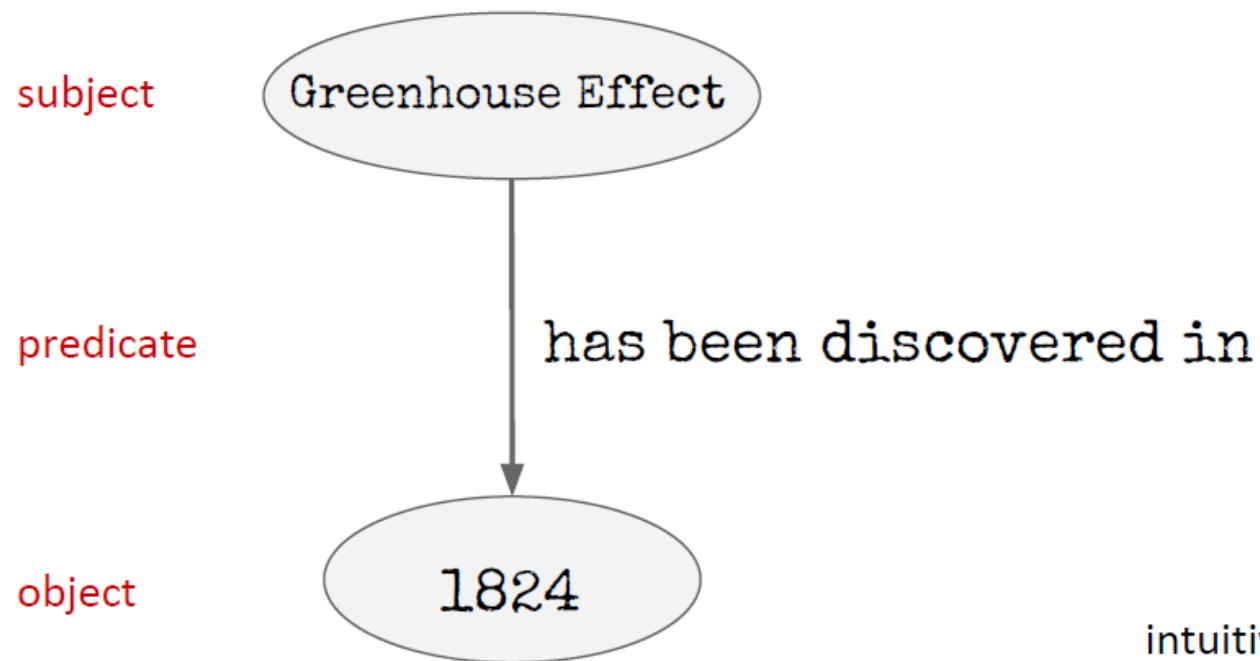
HTTP GET request

Accept Header: text/html



# Knowledge Representation RDF

- How do I represent the following fact:  
***The Greenhouse Effect has been discovered in 1824*** in an intuitive way?



intuitive knowledge representation via a **directed graph**

# Resource Description Framework

- **RDF Statements (RDF-Triple):**

Subject  
**URI**

In RDF the predicate of a statement is referred to as "Property"

**Property  
URI**

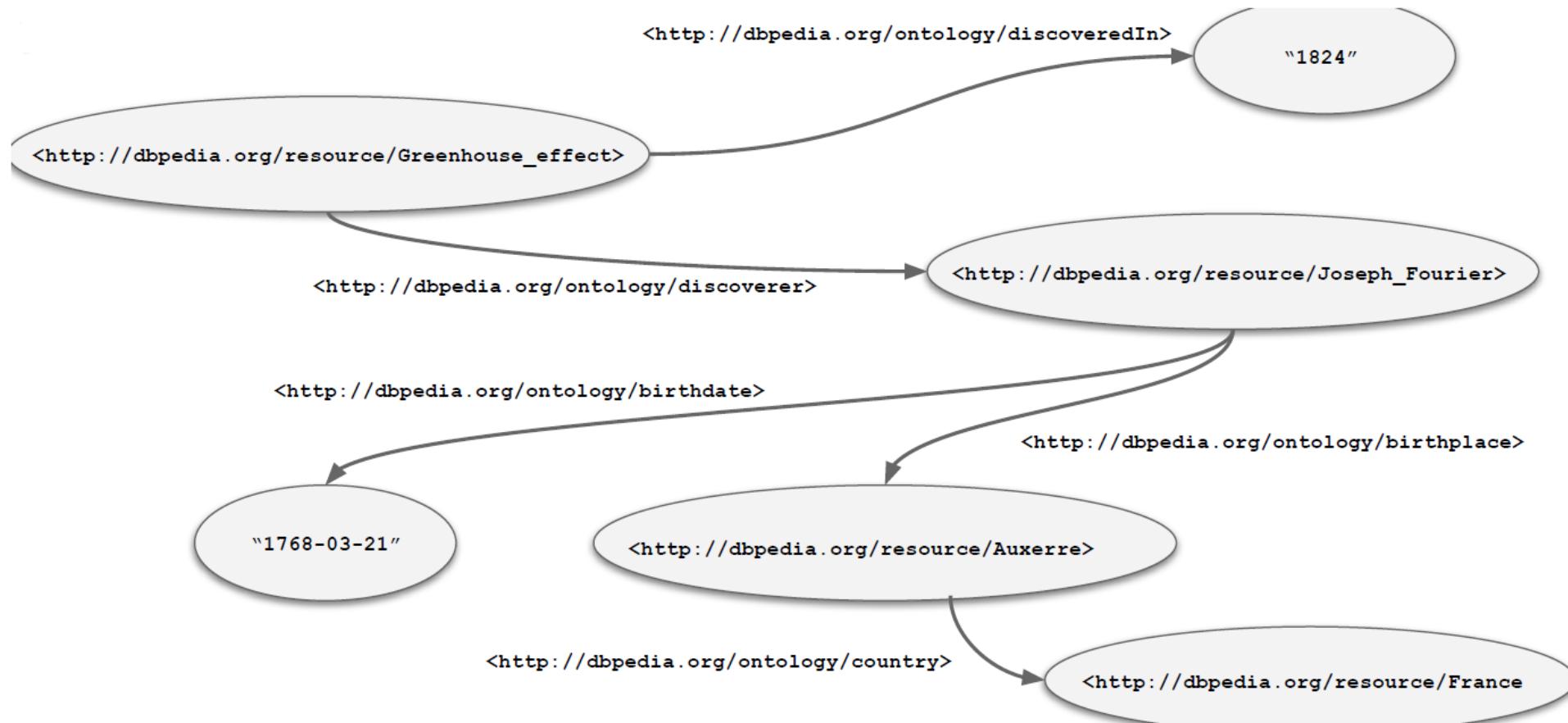
Object / Value  
**URI / Literal**

## N-Triples Serialization

```
<http://dbpedia.org/resource/Greenhouse_effect> <http://dbpedia.org/ontology/discoveredIn> "1824" .
```



# Resource Description Framework





# Resource Description Framework

```
<http://dbpedia.org/resource/Greenhouse_effect> <http://dbpedia.org/ontology/discoveredIn> "1824" .  
<http://dbpedia.org/resource/Greenhouse_effect> <http://dbpedia.org/ontologydiscoverer> <http://dbpedia.org/resource/Joseph_Fourier> .  
<http://dbpedia.org/resource/Greenhouse_effect> <http://purl.org/dc/terms/subject> <http://dbpedia.org/category/Climate_change> .  
<http://dbpedia.org/resource/Greenhouse_effect> <http://purl.org/dc/terms/subject> <http://dbpedia.org/category/Athmosphere> .
```

...

...

...

```
<http://dbpedia.org/resource/Joseph_Fourier> <http://dbpedia.org/ontology/birthdate> "1768-03-21" .  
<http://dbpedia.org/resource/Joseph_Fourier> <http://dbpedia.org/ontology/birthplace> <http://dbpedia.org/resource/Auxerre> .  
<http://dbpedia.org/resource/Joseph_Fourier> <http://dbpedia.org/ontology/field> <http://dbpedia.org/resource/Physicist> .
```

...

...

...

```
<http://dbpedia.org/resource/Auxerre> <http://dbpedia.org/ontology/country> <http://dbpedia.org/resource/France> .  
<http://dbpedia.org/resource/Auxerre> <http://www.w3.org/2003/01/geo/wgs84_pos#lat> "47.798599"^^xsd:float .  
<http://dbpedia.org/resource/Auxerre> <http://www.w3.org/2003/01/geo/wgs84_pos#long> "3.567200"^^xsd:float .
```

...

...

...

Subject

Property

Object

RDF Triples

```
<http://dbpedia.org/resource/Greenhouse_effect> <http://dbpedia.org/ontology/discoveredIn> "1824".  
<http://dbpedia.org/resource/Greenhouse_effect> <http://dbpedia.org/ontologydiscoverer> <http://dbpedia.org/resource/Joseph_Fourier> .  
<http://dbpedia.org/resource/Greenhouse_effect> <http://purl.org/dc/terms/subject> <http://dbpedia.org/category/Climate_change> .  
<http://dbpedia.org/resource/Greenhouse_effect> <http://purl.org/dc/terms/subject> <http://dbpedia.org/category/Athmosphere> .
```

...

...

...

```
<http://dbpedia.org/resource/Joseph_Fourier> <http://dbpedia.org/ontology/birthdate> "1768-03-21".  
<http://dbpedia.org/resource/Joseph_Fourier> <http://dbpedia.org/ontology/birthplace> <http://dbpedia.org/resource/Auxerre> .  
<http://dbpedia.org/resource/Joseph_Fourier> <http://dbpedia.org/ontology/field> <http://dbpedia.org/resource/Physicist> .
```

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...

...

```
<http://dbpedia.org/resource/Auxerre> <http://dbpedia.org/ontology/country> <http://dbpedia.org/resource/France> .  
<http://dbpedia.org/resource/Auxerre> <http://www.w3.org/2003/01/geo/wgs84_pos#lat> "47.798599"^^xsd:float .  
<http://dbpedia.org/resource/Auxerre> <http://www.w3.org/2003/01/geo/wgs84_pos#long> "3.567200"^^xsd:float .
```

...

...

...

**Individuals (Entities)**

```
<http://dbpedia.org/resource/Greenhouse_effect> <http://dbpedia.org/ontology/discoveredIn> "1824" .  
<http://dbpedia.org/resource/Greenhouse_effect> <http://dbpedia.org/ontologydiscoverer> <http://dbpedia.org/resource/Joseph_Fourier> .  
<http://dbpedia.org/resource/Greenhouse_effect> <http://purl.org/dc/terms/subject> <http://dbpedia.org/category/Climate\_change> .  
<http://dbpedia.org/resource/Greenhouse_effect> <http://purl.org/dc/terms/subject> <http://dbpedia.org/category/Athmosphere> .
```

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...

```
<http://dbpedia.org/resource/Joseph_Fourier> <http://dbpedia.org/ontology/birthdate> "1768-03-21" .  
<http://dbpedia.org/resource/Joseph_Fourier> <http://dbpedia.org/ontology/birthplace> <http://dbpedia.org/resource/Auxerre> .  
<http://dbpedia.org/resource/Joseph_Fourier> <http://dbpedia.org/ontology/field> <http://dbpedia.org/resource/Physicist> .
```

...

...

...

```
<http://dbpedia.org/resource/Auxerre> <http://dbpedia.org/ontology/country> <http://dbpedia.org/resource/France> .  
<http://dbpedia.org/resource/Auxerre> <http://www.w3.org/2003/01/geo/wgs84_pos#lat> "47.798599"^^xsd:float .  
<http://dbpedia.org/resource/Auxerre> <http://www.w3.org/2003/01/geo/wgs84_pos#long> "3.567200"^^xsd:float .
```

...

...

...

Classes

<http://dbpedia.org/resource/Greenhouse\_effect> <http://dbpedia.org/ontology/discoveredIn> "1824".  
<http://dbpedia.org/resource/Greenhouse\_effect> <http://dbpedia.org/ontologydiscoverer> <http://dbpedia.org/resource/Joseph\_Fourier> .  
<http://dbpedia.org/resource/Greenhouse\_effect> <http://purl.org/dc/terms/subject> <http://dbpedia.org/category/Climate\_change> .  
<http://dbpedia.org/resource/Greenhouse\_effect> <http://purl.org/dc/terms/subject> <http://dbpedia.org/category/Athmosphere> .

...

...

...

<http://dbpedia.org/resource/Joseph\_Fourier> <http://dbpedia.org/ontology/birthdate> "1768-03-21".  
<http://dbpedia.org/resource/Joseph\_Fourier> <http://dbpedia.org/ontology/birthplace> <http://dbpedia.org/resource/Auxerre> .  
<http://dbpedia.org/resource/Joseph\_Fourier> <http://dbpedia.org/ontology/field> <http://dbpedia.org/resource/Physicist> .

...

...

...

<http://dbpedia.org/resource/Auxerre> <http://dbpedia.org/ontology/country> <http://dbpedia.org/resource/France> .  
<http://dbpedia.org/resource/Auxerre> <http://www.w3.org/2003/01/geo/wgs84\_pos#lat> "47.798599"^^xsd:float .  
<http://dbpedia.org/resource/Auxerre> <http://www.w3.org/2003/01/geo/wgs84\_pos#long> "3.567200"^^xsd:float .

...

...

...

Literals

```
<http://dbpedia.org/resource/Greenhouse_effect> <http://dbpedia.org/ontology/discoveredIn> "1824" .  
<http://dbpedia.org/resource/Greenhouse_effect> <http://dbpedia.org/ontologydiscoverer> <http://dbpedia.org/resource/Joseph_Fourier> .  
<http://dbpedia.org/resource/Greenhouse_effect> <http://purl.org/dc/terms/subject> <http://dbpedia.org/category/Climate_change> .  
<http://dbpedia.org/resource/Greenhouse_effect> <http://purl.org/dc/terms/subject> <http://dbpedia.org/category/Athmosphere> .  
...  
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<http://dbpedia.org/resource/Joseph_Fourier> <http://dbpedia.org/ontology/birthdate> "1768-03-21" .  
<http://dbpedia.org/resource/Joseph_Fourier> <http://dbpedia.org/ontology/birthplace> <http://dbpedia.org/resource/Auxerre> .  
<http://dbpedia.org/resource/Joseph_Fourier> <http://dbpedia.org/ontology/field> <http://dbpedia.org/resource/Physicist> .  
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<http://dbpedia.org/resource/Auxerre> <http://dbpedia.org/ontology/country> <http://dbpedia.org/resource/France> .  
<http://dbpedia.org/resource/Auxerre> <http://www.w3.org/2003/01/geo/wgs84_pos#lat> "47.798599"^^xsd:float .  
<http://dbpedia.org/resource/Auxerre> <http://www.w3.org/2003/01/geo/wgs84_pos#long> "3.567200"^^xsd:float .  
...  
...  
...
```

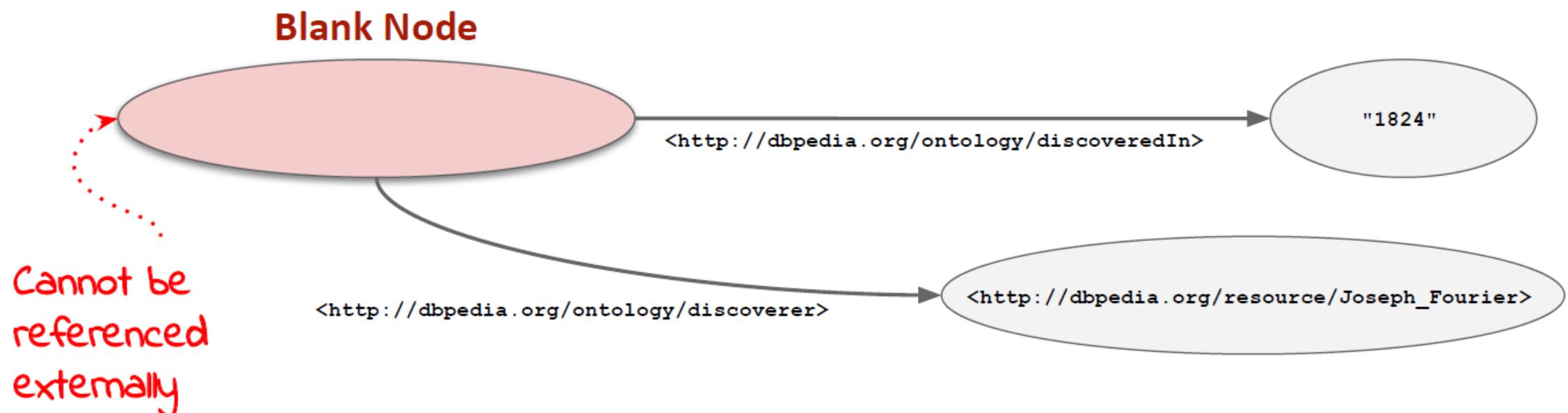
## Properties

# RDF Literals and Data Types

- Typed literals can be expressed via **XML Schema datatypes**.
- Namespace for typed literals:  
`http://www.w3.org/2001/XMLSchema#`
- Examples:  
`"Semantics"^^<http://www.w3.org/2001/XMLSchema#string>`  
`"1161.00"^^<http://www.w3.org/2001/XMLSchema#float>`  
`"2015-08-02"^^<http://www.w3.org/2001/XMLSchema#date>`
- **Language Tags** denote the (natural) language of the text:
  - Example:  
`"Semantik"@de , "Semantics"@en`

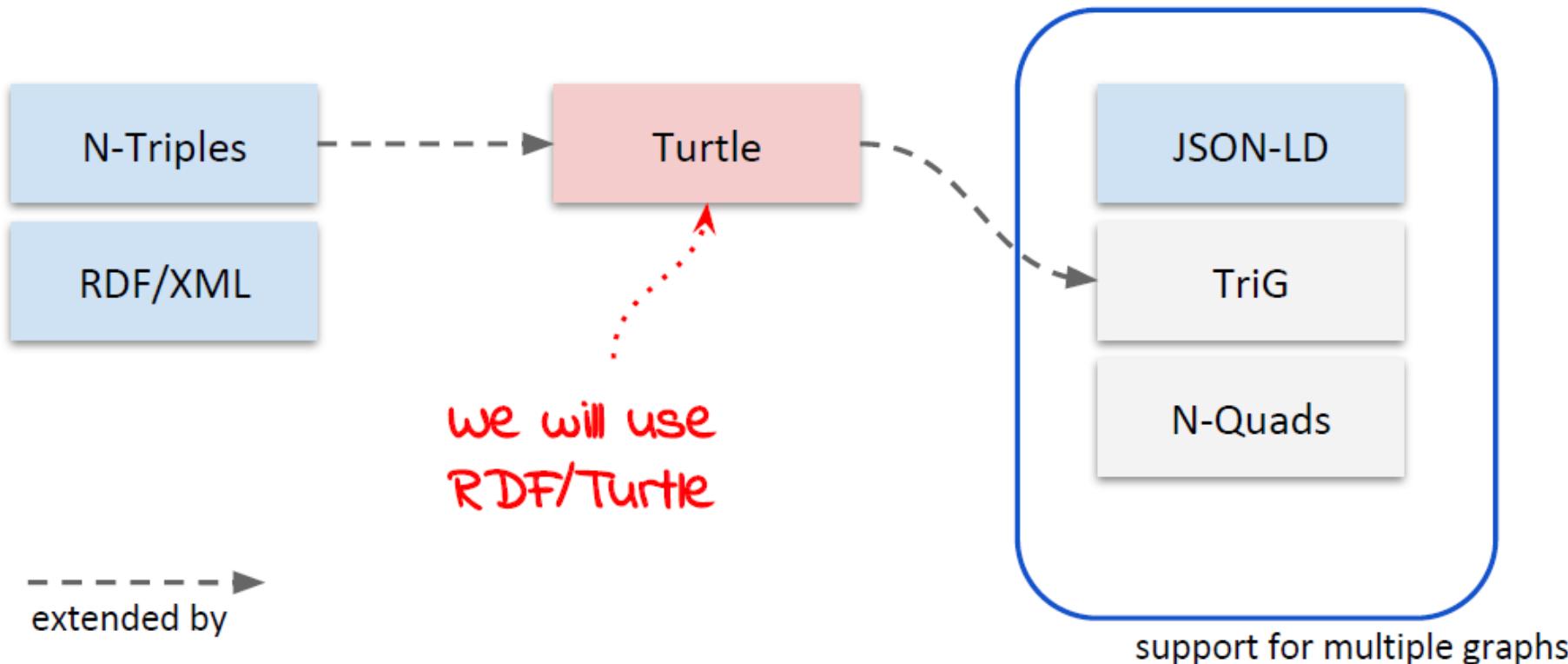
# RDF Blank Nodes

- **Blank Nodes**
  - denote **existence of an individual** with specific attributes, but **without providing an identification or reference**.

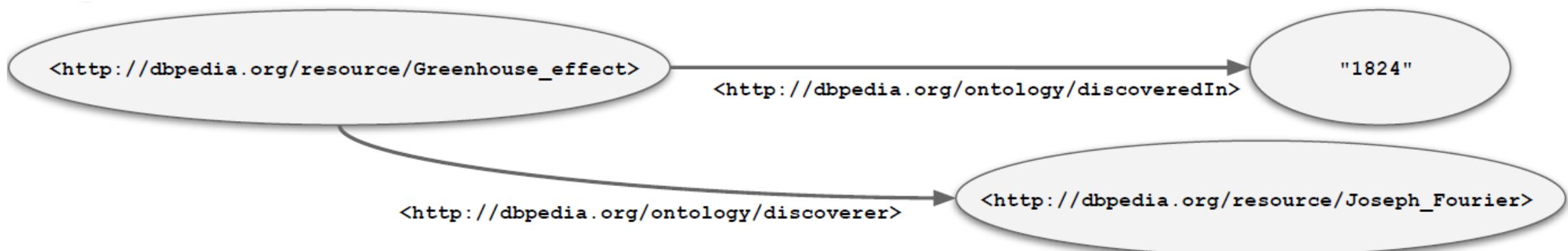


# RDF Serialization

- RDF comes with several different **serialization formats**:
  - N-Triples, RDF/XML, JSON, Turtle, TriG, N-Quads, RDFa, ...



# RDF Turtle Serialization

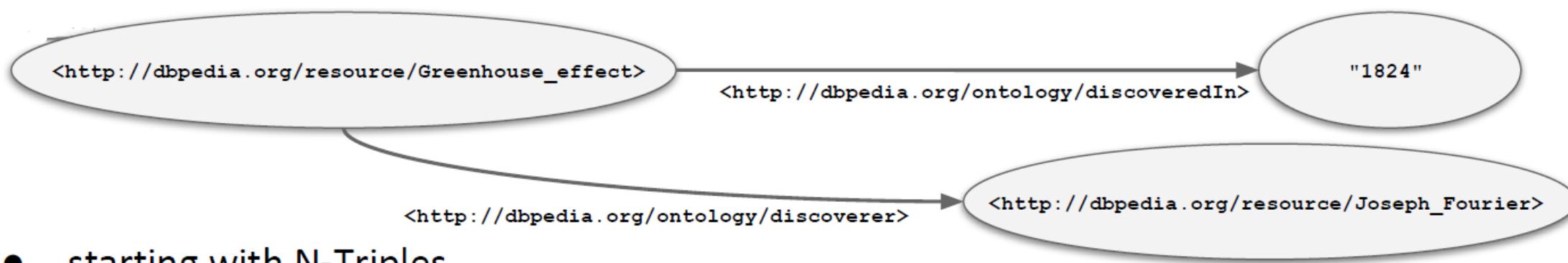


- **Turtle (Terse RDF Triple Language) Notation**
  - extension of N-Triples

```
@prefix dbo: <http://dbpedia.org/ontology/> .  
@base <http://dbpedia.org/resource/> .  
  
<Greenhouse_effect> dbo:discoveredIn "1824" .  
  
<Greenhouse_effect> dbo:discoverer <Joseph_Fourier> .
```

RDF/Turtle allows  
shortcuts and  
abbreviations for  
readability

# RDF Turtle Serialization



- starting with N-Triples

```
<http://dbpedia.org/resource/Greenhouse_effect> <http://dbpedia.org/ontology/discoveredIn> "1824" .  
<http://dbpedia.org/resource/Greenhouse_effect> <http://dbpedia.org/ontology/discoverer>  
<http://dbpedia.org/resource/Joseph_Fourier> .
```

```
@prefix dbo: <http://dbpedia.org/ontology/> .  
@base <http://dbpedia.org/resource/> .  
  
<Greenhouse_effect> dbo:discoveredIn "1824" .  
<Greenhouse_effect> dbo:discoverer <Joseph_Fourier> .
```

**@prefix directive** associates prefix-label with URI

**@base directive** provides URI to complement all relative URIs

# RDF Turtle Serialization

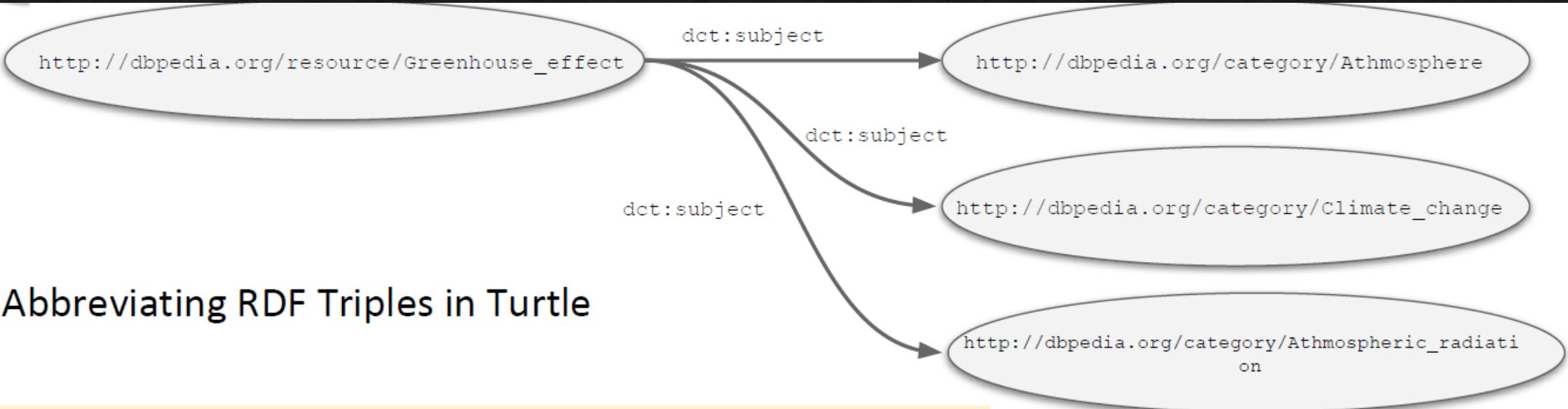


- Abbreviating RDF Triples in Turtle

```
@prefix dbo: <http://dbpedia.org/ontology/> .  
@base <http://dbpedia.org/resource/> .  
<Greenhouse_effect> dbo:discoveredIn "1824" ;  
    dbo:discoverer <Joseph_Fourier> .
```

semicolon indicates that subsequent triples have the same subject  
**(predicate list)**

# RDF Turtle Serialization

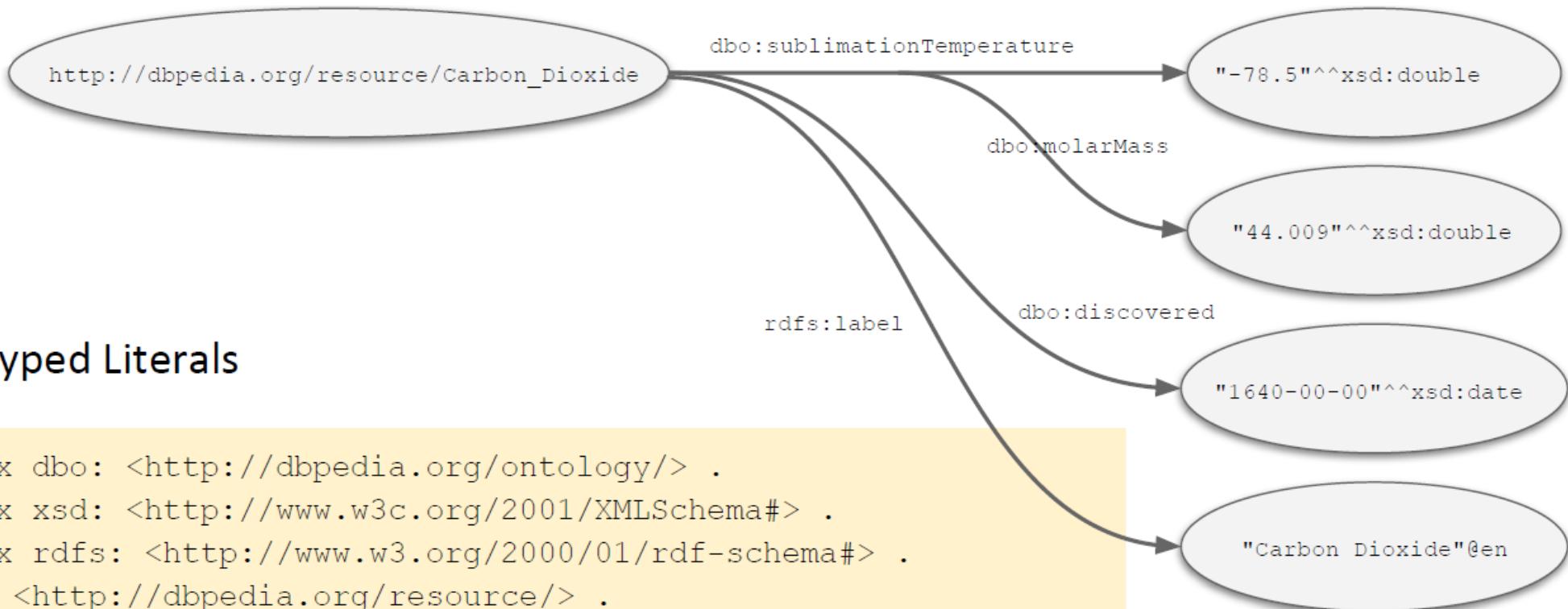


- Abbreviating RDF Triples in Turtle

```
@prefix dct: <http://purl.org/dc/terms/> .  
@prefix dbc: <http://dbpedia.org/category/> .  
@base      <http://dbpedia.org/resource/> .  
  
<Greenhouse_effect> dct:subject dbc:Athmosphere ,  
                      dbc:Climate_change ,  
                      dbc:Athmospheric_radiation .
```

**comma** indicates that subsequent triples have same subject and property  
**(object list)**

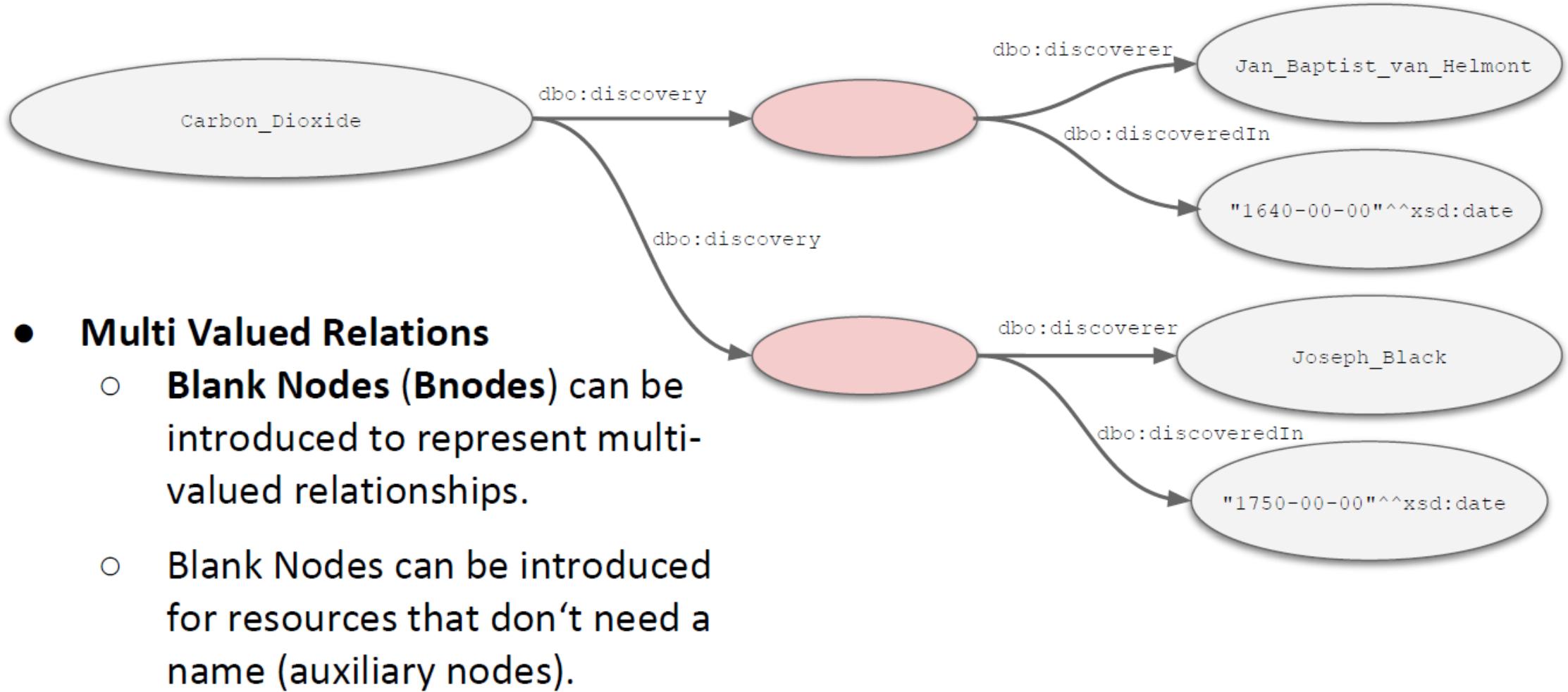
# RDF Turtle - Literals



- Typed Literals

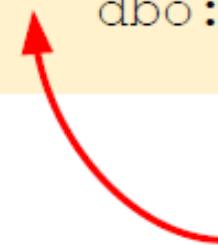
```
@prefix dbo: <http://dbpedia.org/ontology/> .  
@prefix xsd: <http://www.w3c.org/2001/XMLSchema#> .  
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .  
@base <http://dbpedia.org/resource/> .  
  
<Carbon_Dioxide> dbo:sublimationTemperature "-78.5"^^xsd:double ;  
    dbo:molarMass "44.009"^^xsd:double ;  
    dbo:discovered "1640-00-00"^^xsd:date ;  
    rdfs:label "Carbon Dioxide"@en .
```

# RDF Turtle - Blank Nodes



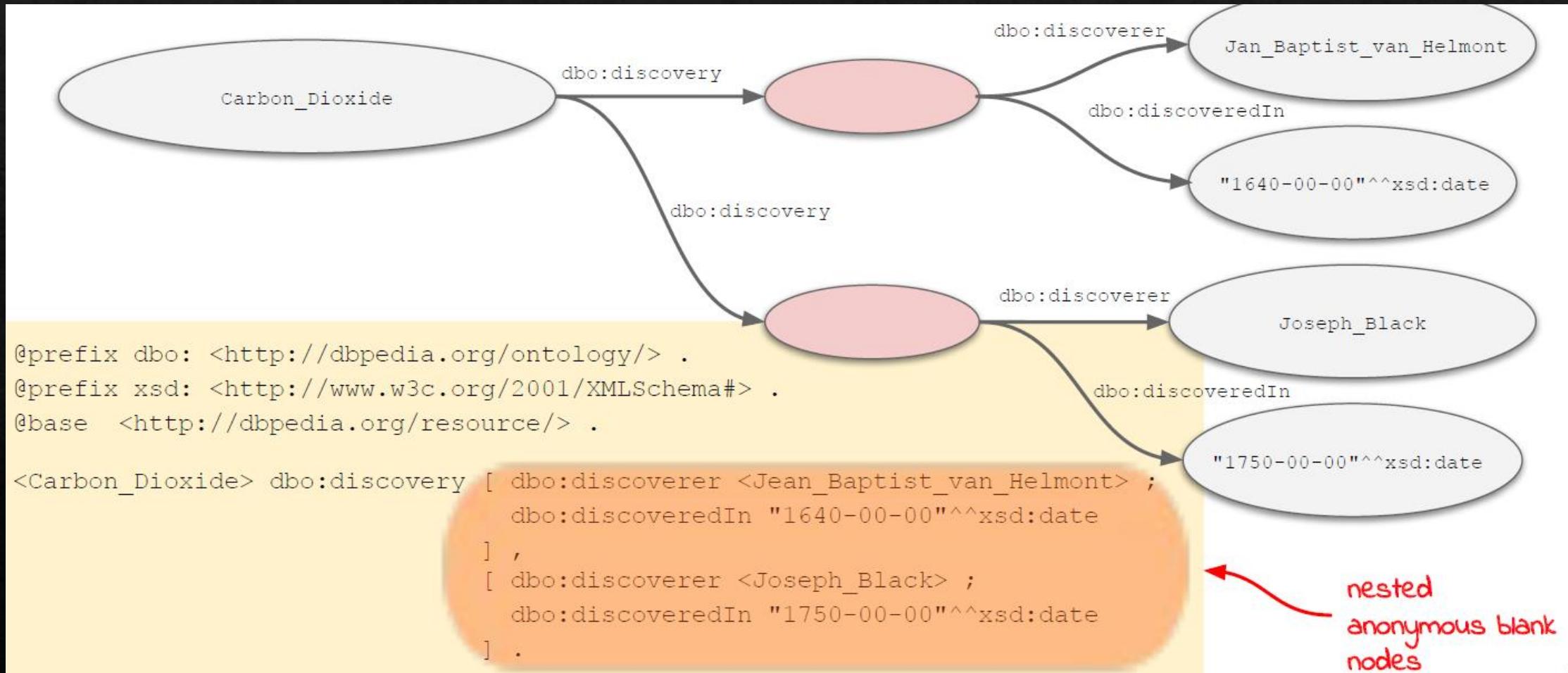
# RDF Turtle - Blank Nodes

```
@prefix dbo: <http://dbpedia.org/ontology/> .  
@prefix xsd: <http://www.w3c.org/2001/XMLSchema#> .  
@base <http://dbpedia.org/resource/> .  
[] dbo:discoverer <Jan_Baptist_van_Helmont> ;  
    dbo:discoveredIn "1640-00-00"^^xsd:date .
```

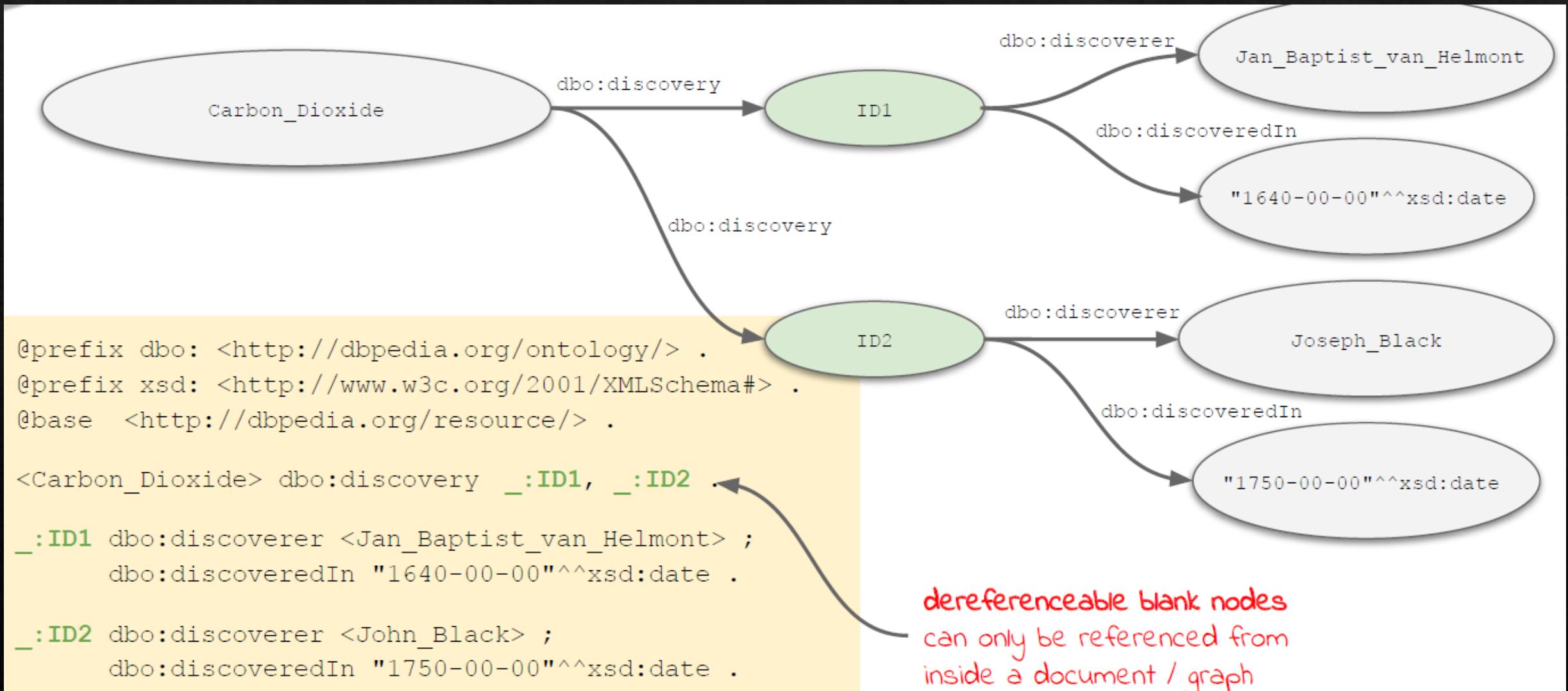


anonymous blank node as subject

# RDF Turtle - Nested

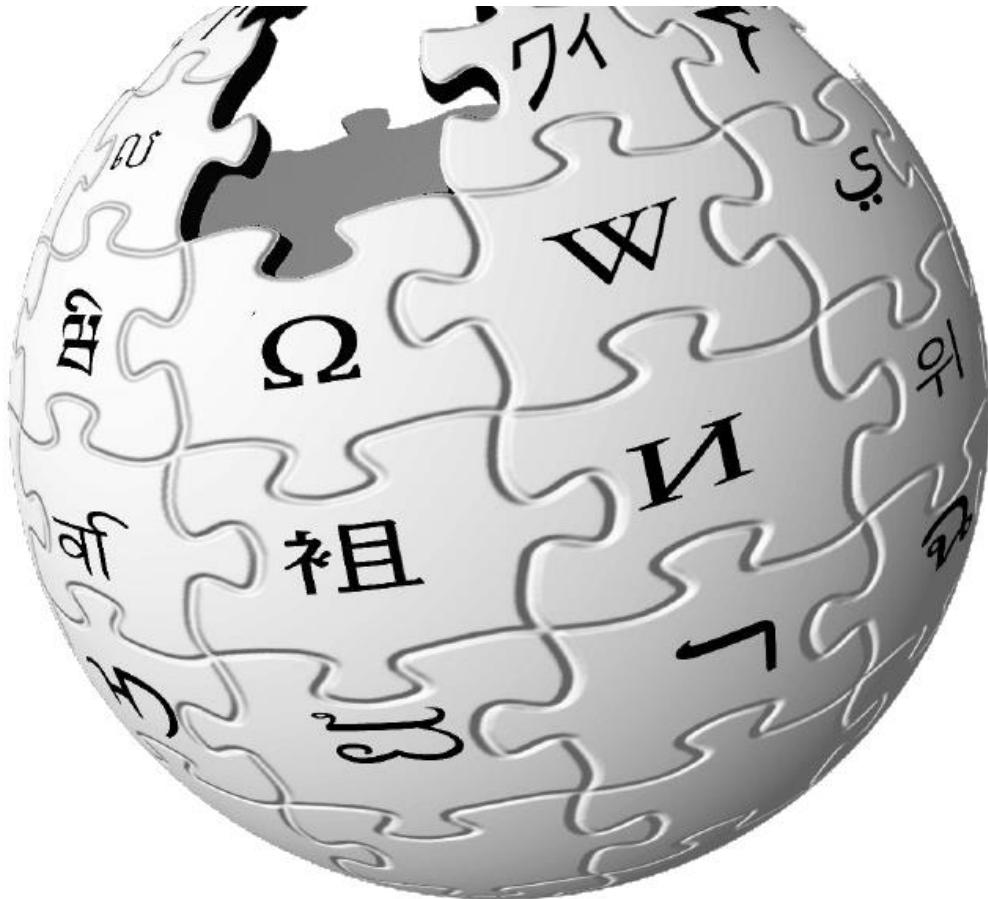


# RDF Turtle - Blank Nodes



# COMPLEX TURTLE RDFs





# WIKIPEDIA

*The Free Encyclopedia*

“Wikipedia states that Carbon Dioxide has been discovered by Jan Baptist van Helmont.”

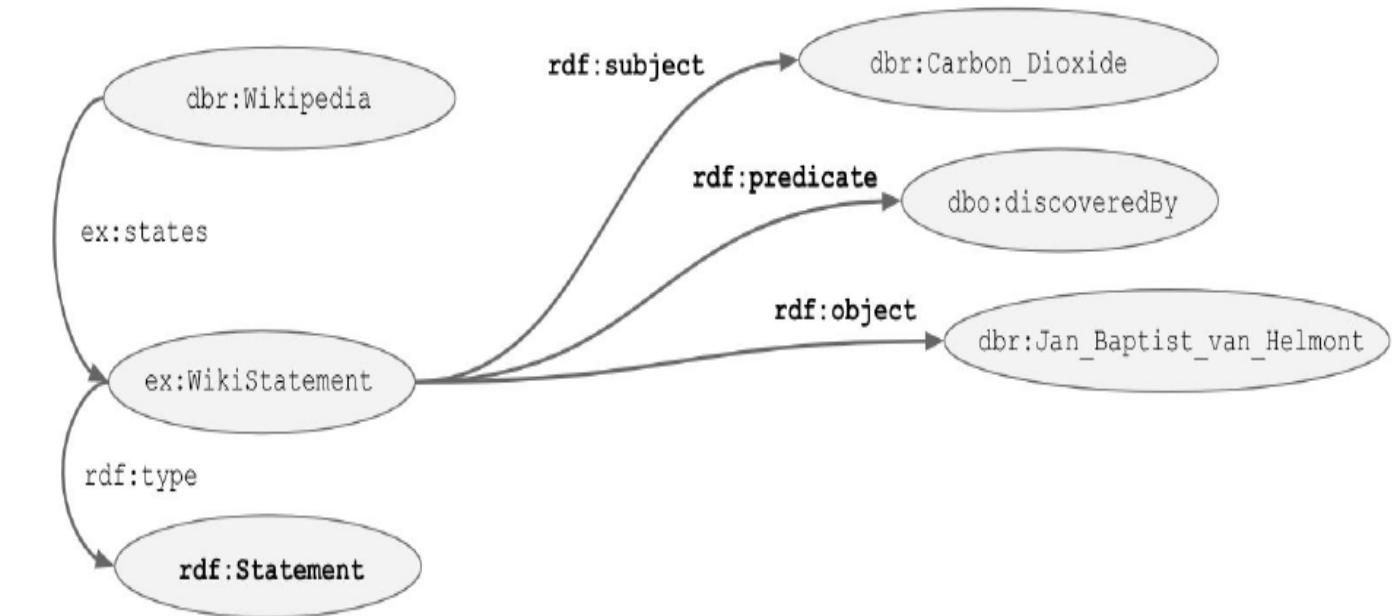


**Jan Baptist van Helmont**  
Dutch chemist  
1580-1644

# RDF Reification

- RDF also permits the interleaving of statements, i.e. to make statements about statements
- Example:
  - Wikipedia states that **Carbon Dioxide was discovered by Jan Baptist van Helmont**
    - **Part 1:** Carbon Dioxide was discovered by Jan Baptist van Helmont
    - dbr:Carbon\_Dioxide dbo:discoveredBy dbr:Jan\_Baptist\_van\_Helmont
    - .
  - **Part 2:** Wikipedia states
  - dbr:Wikipedia ex:states ????

# RDF Reification



```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .  
@prefix dbr <http://dbpedia.org/resource/> .  
@prefix dbo <http://dbpedia.org/ontology/> .  
@prefix ex: <http://example.org/test#> .
```

```
dbr:Wikipedia ex:states ex:WikiStatement .  
ex:WikiStatement a rdf:Statement ;  
    rdf:subject dbr:Carbon_Dioxide ;  
    rdf:predicate dbo:discoveredBy ;  
    rdf:object dbr:Jan_Baptist_van_Helmont .
```

# The Semantic Web Technology Stack (not a piece of cake...)

Most apps use only a subset of the stack

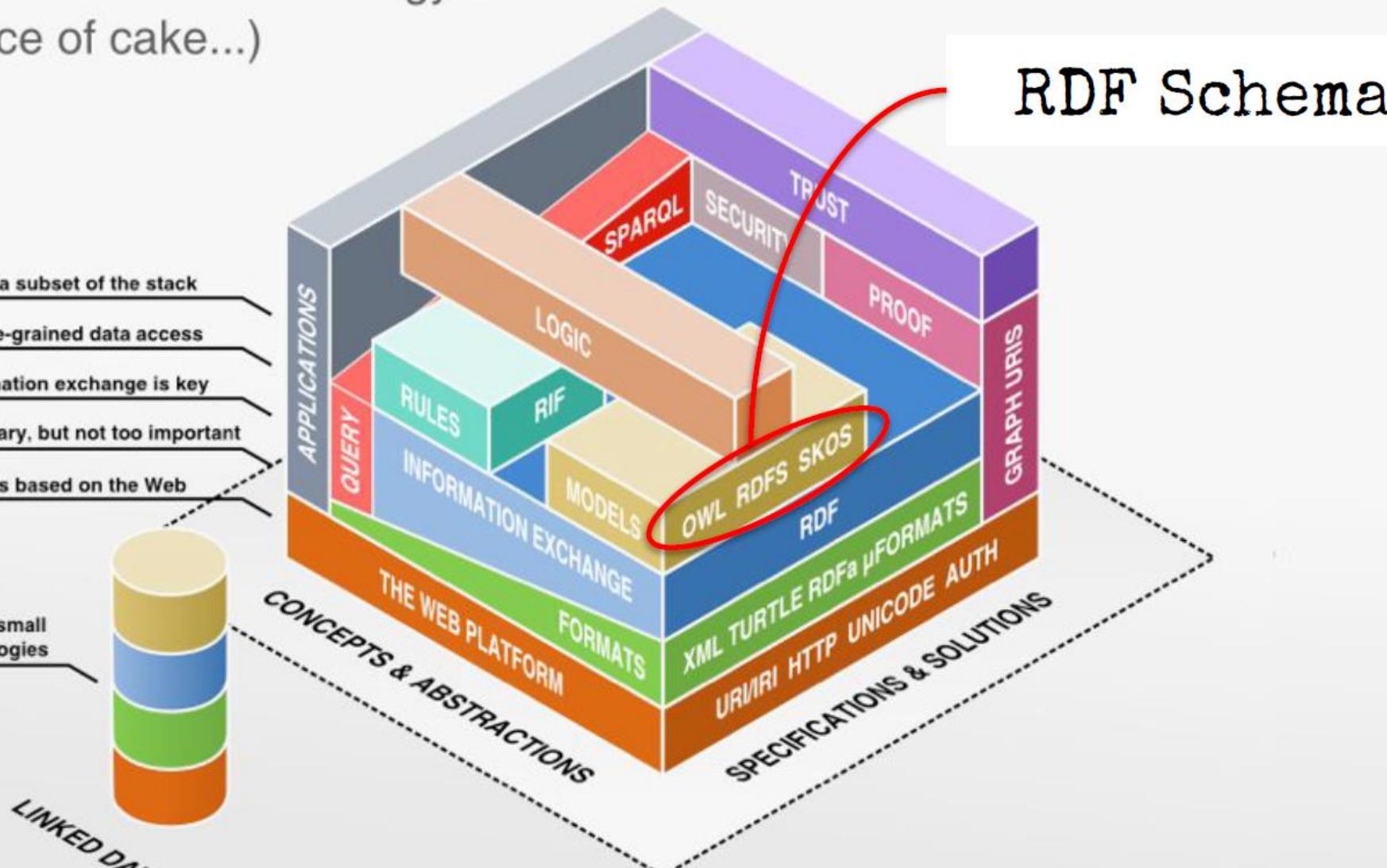
Querying allows fine-grained data access

Standardized information exchange is key

Formats are necessary, but not too important

The Semantic Web is based on the Web

Linked Data uses a small selection of technologies





## RDF Schema

- RDF Schema, officially called “RDF Vocabulary Description Language”
- RDF Schema allows:
  - Definition of **classes** via `rdfs:Class`
  - Class instantiation in RDF via `rdf:type`
  - Example:

```
:Greenhouse_gas    rdf:type rdfs:Class .  
:Carbon_dioxide    rdf:type :Greenhouse_gas .
```



Carbon\_dioxide  $\in$  greenhouse\_gas



## RDF Schema

- Definition of **properties** via `rdf:Property`
- Definition of **property restrictions on domain and range** via `rdfs:domain` and `rdfs:range`
- Example

<code>:Person</code>	<code>rdf:type</code>	<code>rdfs:Class</code> .
<code>:Thing</code>	<code>rdf:type</code>	<code>rdfs:Class</code> .
<code>:discoverer</code>	<code>rdf:type</code>	<code>rdf:Property</code> .
<code>:discoverer</code>	<code>rdfs:domain</code>	<code>:Thing</code> .
<code>:discoverer</code>	<code>rdfs:range</code>	<code>:Person</code> .

  
discoverer  $\subseteq$  Thing x Person

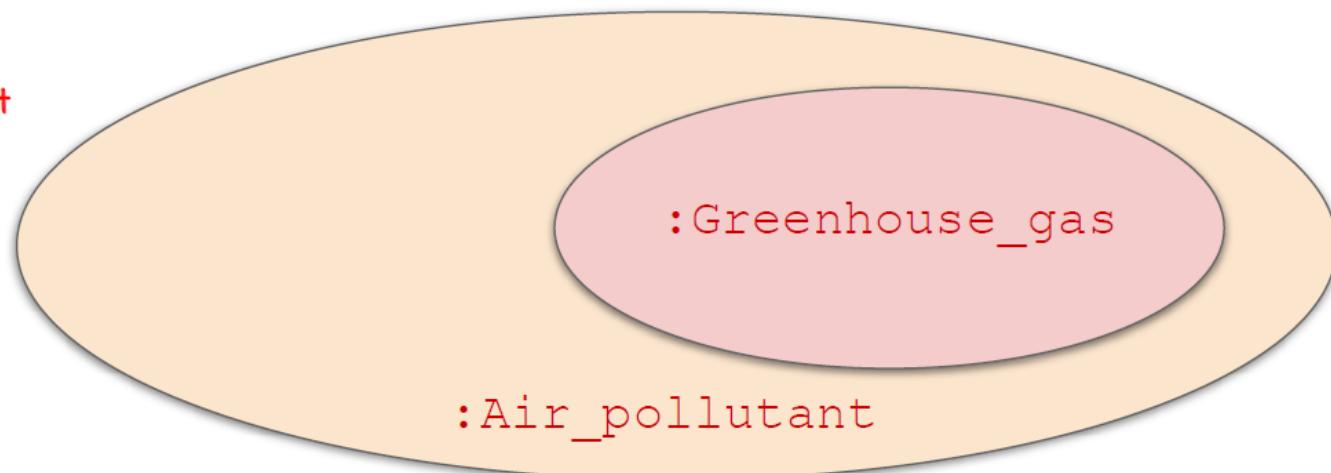


## RDF Schema

- Definition of **hierarchical relationships**:
  - Subclasses and superclasses via `rdfs:subClassOf`
  - Example:

`:Greenhouse_gas rdfs:subClassOf :Air_pollutant .`

$\text{greenhouse\_gas} \subseteq \text{Air\_pollutant}$





## RDF Schema

- Definition of **hierarchical relationships**:
  - **Subclasses and superclasses** via `rdfs:subClassOf`
  - Example:  
`:Greenhouse_gas rdfs:subClassOf :Air_pollutant .`
  - **Subproperties and superproperties** via `subPropertyOf`
  - Example:  
`:sublimationTemperature rdfs:subPropertyOf :temperature .`



## Some more RDF Schema

- Further RDFS properties:
  - **rdfs:seeAlso**  
defines a relation of a resource to another, which explains it
  - **rdfs:isDefinedBy**  
subproperty of `rdfs:seeAlso`, defines the relation of a resource to its definition
  - **rdfs:comment**  
comment, usually as text
  - **rdfs:label**  
„readable“ name of a resource (contrary to ID)



## RDF Schema Example

```
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .  
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .  
@prefix owl: <http://www.w3.org/2002/07/owl#>  
@prefix : <http://example.org/Climate#> .
```

```
:Greenhouse_gas      rdf:type      rdfs:Class ;  
                      rdfs:subClassOf :Air_pollutant .  
  
:Person              rdf:type      rdfs:Class .  
:Scientist           rdfs:subClassOf :Person .  
:Physicist           rdfs:subClassOf :Scientist .  
:Chemist             rdfs:subClassOf :Scientist .
```

Class Definitions

```
:discoverer        rdf:type      rdf:Property ;  
                     rdfs:domain owl:Thing .  
                     rdfs:range   :Person .
```

Property Definitions

```
:Carbon_dioxide     rdf:type      :Greenhouse_gas ;  
                     :discoverer  :Jan_Baptist_van_Helmont ;  
                     :discoverer  :Joseph_Black .  
  
:Jan_Baptist_van_Helmont  rdf:type      :Physicist .  
:Joseph_Black         rdf:type      :Chemist ;  
                     rdfs:label   "Joseph Black"@en ;  
                     rdfs:label   "约瑟夫·布莱克"@zh
```

Instance Definitions