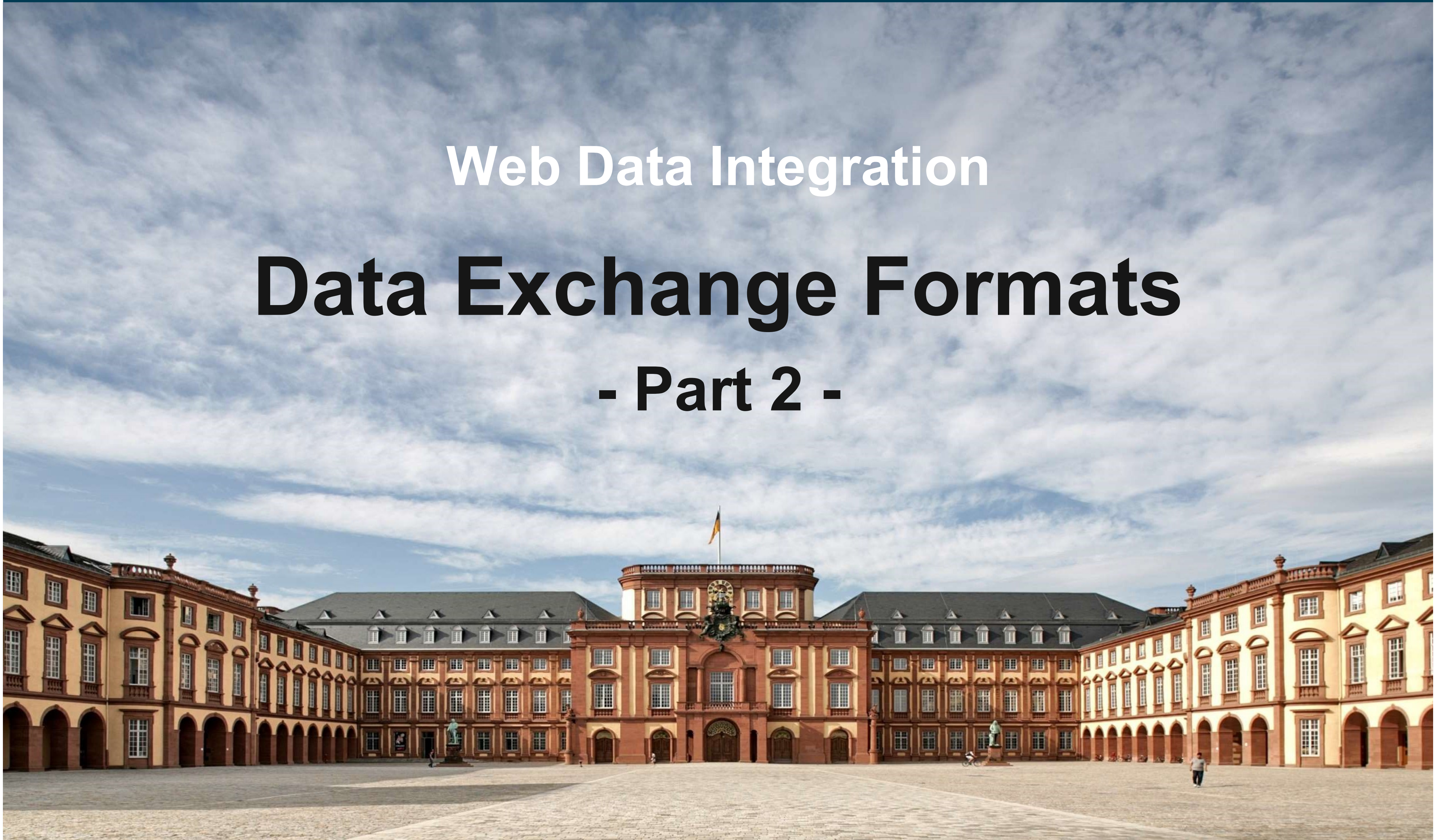
Web Data Integration

Data Exchange Formats

- Part 2 -



Outline

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   3. Extensible Markup Language (XML)
2. Data Exchange Formats - Part II
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      3. RDF Schema
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2.1 JavaScript Object Notation (JSON)

- JavaScript
  - a popular programming language on the Web
  - understood by all Web browsers
  - originally:
    - used for simple interactions (e.g., change image on mouse over)
  - nowadays:
    - also used for complex applications, Ajax (Asynchronous JavaScript and XML)
    - for instance used to implement Google Docs
- JSON
  - is a lightweight data exchange format that uses JavaScript syntax
  - less verbose alternative to XML
  - widely adopted
    - by Web APIs as data exchange format
    - for embedding structured data in the HEAD section of HTML pages

JavaScript Object Notation (JSON)

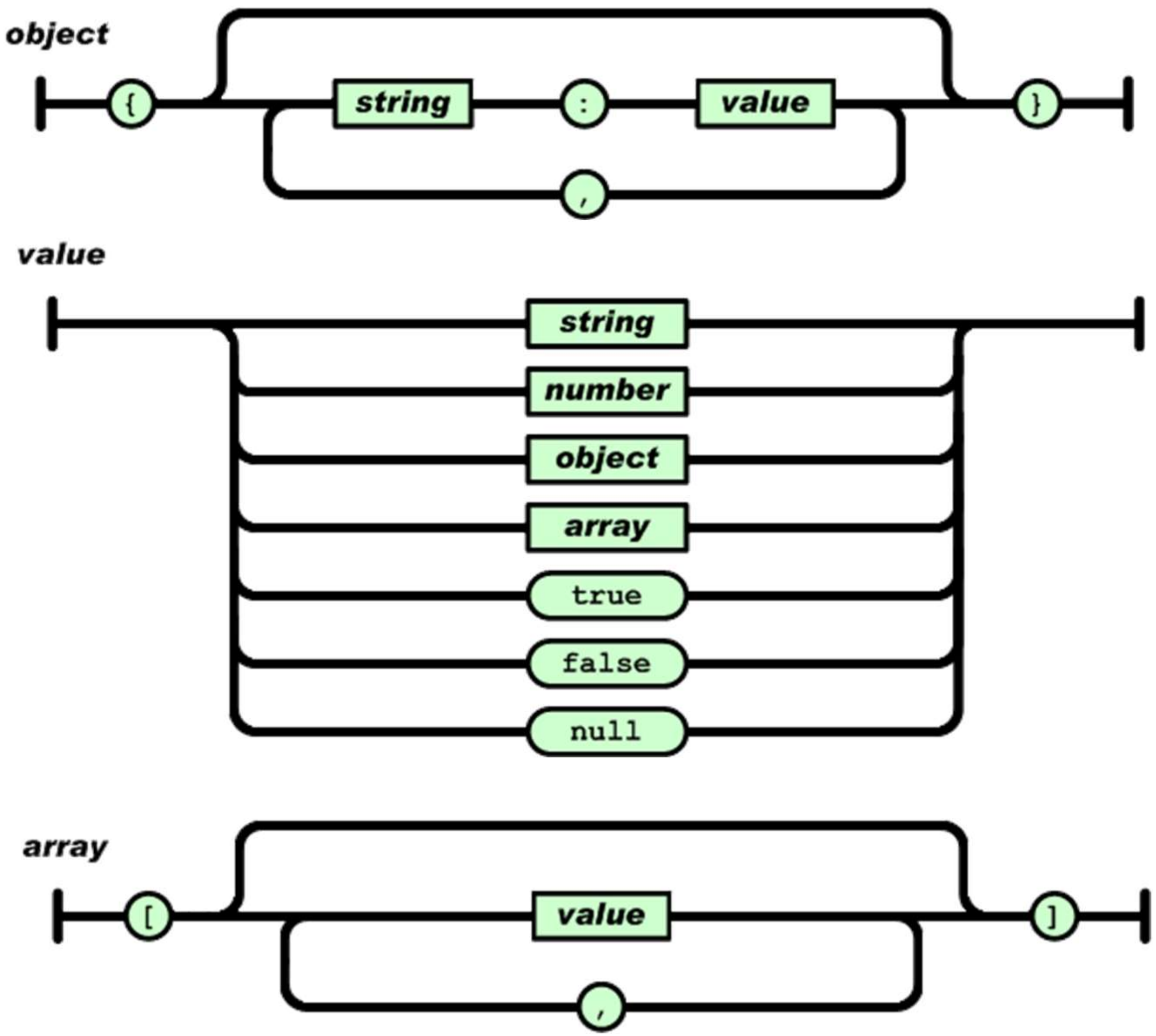
- Basics:
  - objects are noted as in JavaScript
  - objects are enclosed in curly brackets { … }
  - data is organized in key value pairs separated by colons { key : value }
- Example:

```
{ “firstname” : “John” ,
  “lastname” : “Smith” ,
  “age” : 46 }
```

- Simple processing with JavaScript:

```
var obj = JSON.parse(jsonString) ;
var name = obj.firstname + “ “ + obj.lastname ;
var backToString = JSON.stringify(obj)
```

The JSON Syntax



Arrays in JSON

```
{ "id" : 1,
  "name" : “Good book",
  "tags" : [
     “Novel",
     “Fiction"
  ],
  "stock" : {
    "warehouse" : 300,
    "retail" : 20
  }
}
```

Source: json.org

Nested Objects in JSON

JSON

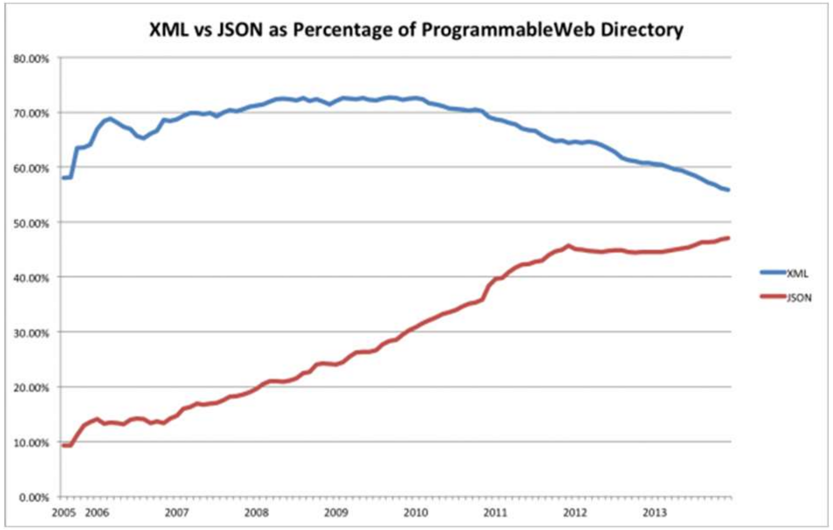
```
{ "firstname" : "John" ,
  "lastname" : "Smith" ,
  "age" : 46 ,
  "employer" : {
     "name" : "Tech Inc." ,
     "address" : {
        "street" : "Main St." ,
        "number" : 14,
        "city" : "Smalltown"
     }
  }
}
```

XML

```
<firstname>John</firstname>
<lastname>Smith</lastname>
<age>46</age>
<employer>
   <name>Tech Inc.</name>
   <address>
     <street>Main St.</street>
     <number>14</number>
     <city>Smalltown</city>
   </address>
</employer>
```

JSON versus XML

- JSON is a lot like XML
  - data model: tree
  - opening/closing tags/brackets
- Differences
  - more compact notation compared to XML
  - no id/idref – JSON data is *strictly* tree shaped
  - less data types (only string, number, and Boolean)
- Adoption
  - XML: Wider adoption in enterprise context
  - JSON: Wider adoption in Web context
  - Programmable Web 2019:
    - 2800 XML APIs vs. 5400 JSON APIS



Processing JSON with Java

- GSON
  - Library for parsing and serializing JSON in Java
  - https://github.com/google/gson
- Class Definition

```
public class Person {
  private String firstname;
  private String lastname;
  private int age;
}
```

```
{ "firstname" : "John" ,
  "lastname" : "Smith" ,
  "age" : 46
}
```

- Object Deserialization

```
Person obj = gson.fromJson(jsonString, Person.class);
```

- Object Serialization

```
String json = gson.toJson(obj);
```

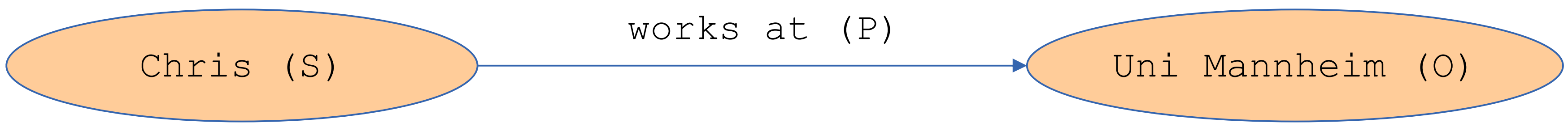
2.2 Resource Description Framework (RDF)

Graph data model designed for sharing data on the Web.

- Applications:
  - annotation of Web pages (RDFa, JSON-LD)
  - publication of data on the Web (Linked Data)
  - exchange of graph data between applications

- View 1: Sentences in form Subject-Predicate-Object (called Triples)

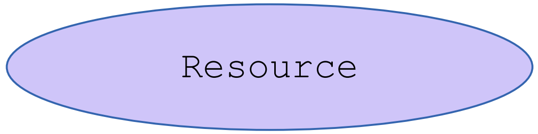
„Chris works at University of Mannheim."



- View 2: Labeled directed graph
  - A set of RDF triples forms a labeled directed graph

RDF Basic Concepts

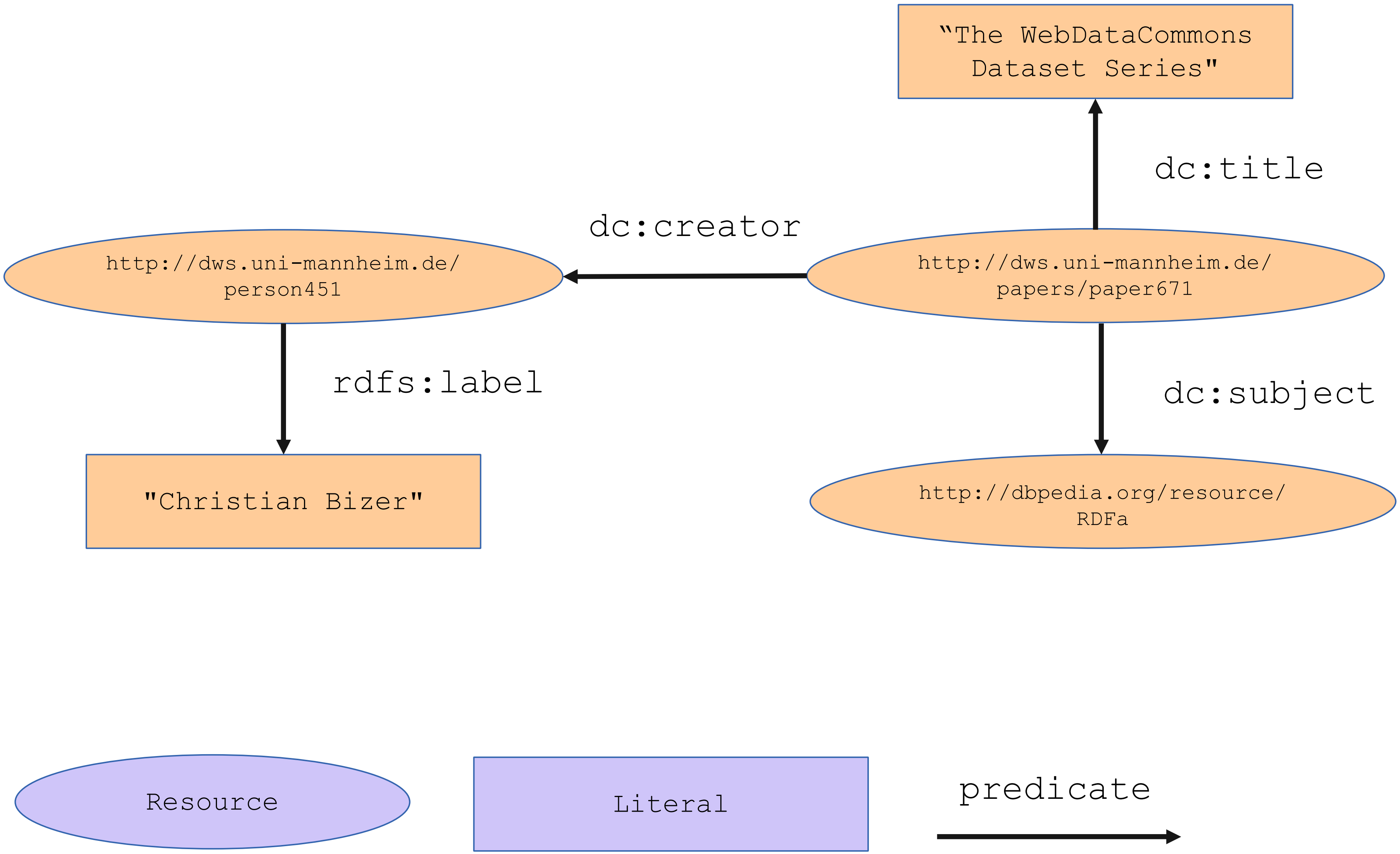
- Resources
  - everything (a person, a place, a web page, …) is a resource
  - are identified by URI references
  - may have one or more types (e.g. foaf:Person)



- Literals
  - are data values, e.g., strings or integers
  - may only be objects, not subjects of triples
  - may have a data type or a language tag

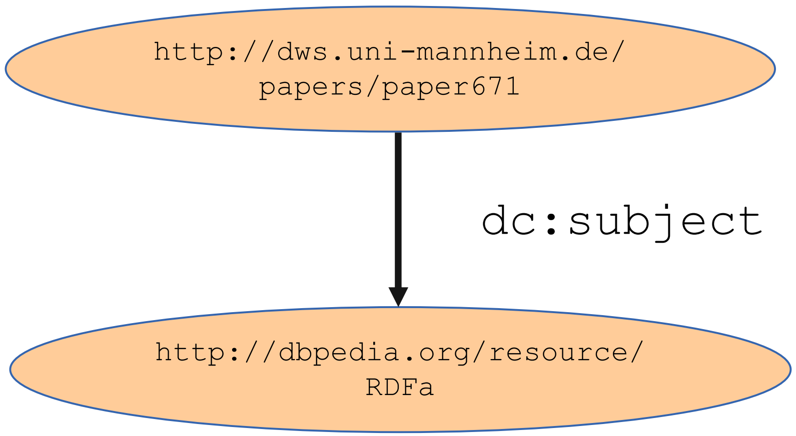
- Predicates (Properties)
  - connect resources to other resources
  - connect resources to literals

RDF as a Labeled Directed Graph



The Role of URIs in RDF

– In a typical database or XML document, identifiers are unique only with respect to the database or XML document.
  - they have no meaning outside the database/document
– RDF uses URI's as global identifiers for resources
  - hence, all data is connected to its origin
  - multiple data sets can refer to each other
  - lays the foundation for a global data space
– Advantage
  - global references between data items are possible (Linked Data)
– Disadvantage
  - RDF is rather verbose.
  - ➔ most syntaxes use QNames (e.g. dc:subject).



Language Tags and Data Types

- RDF literals may have language tags or data types (but not both)
- Examples:

Literal

ex:Muenchen ex:hasName "München"@de .
ex:Muenchen ex:hasName "Munich"@en .
ex:Muenchen ex:hasPopulation "1356594 "^^xsd:integer .
ex:Muenchen ex:hasFoundingYear "1158-01-01"^^xsd:date .

- RDF uses the XML Schema data types
- Be careful, the following three literals are different:
  - "München"
  - "München"@de
  - "München"^^xsd:string

RDF Syntaxes

There are various syntaxes for serializing RDF graphs.

1. N-Triples and Turtle: Plain text syntaxes
2. RDF/XML: RDF serialization in XML
3. RDFa: Syntax for embedding RDF into HTML pages
4. JSON-LD: RDF serialization in JSON

N-Triples and Turtle

- N-Triples is a line-based, plain text serialization format for RDF graphs

```
<http://www.dws.uni-mannheim.de/teaching/wdi>
<http://purl.org/dc/elements/1.1/subject>
<http://dbpedia.org/resource/RDFa> .

<http://www.dws.uni-mannheim.de/teaching/wdi>
<http://purl.org/dc/elements/1.1/title>
"Web Data Integration"@en .
```

Point marks end of triple

URIs are enclosed by <>

Literals enclosed by " "

- Turtle extends N-Triples with QNames

```
@BASE <http://www.dws.uni-mannheim.de/teaching/>
@PREFIX dc: <http://purl.org/dc/elements/1.1/>
@PREFIX dbpedia: <http://dbpedia.org/resource/>

:wdi dc:subject dbpedia:RDFa .

:wdi dc:title "Web Data Integration"@en .
```

Empty prefix refers to BASE namespace

RDF/XML

- XML-based serialization format for RDF

- Describing resources:

```
<rdf:Description rdf:about="http://www.dws.uni-mannheim.de/teaching/wdi">
    <dc:creator>Christian Bizer</dc:creator>
</rdf:Description>
```

- Resource with a type:

```
<rdf:Description rdf:about="http://www.dws.uni-mannheim.de/teaching/wdi">
    <rdf:type rdf:resource="http://www.dws.uni-mannheim.de/teaching/Course"/>
    <dc:creator>Christian Bizer</dc:creator>
</rdf:Description>
```

- Alternative notation:

```
<dws:Course rdf:about="http://www.dws.uni-mannheim.de/teaching/wdi" />
```

JSON-LD

- JSON syntax for RDF used for embedding RDF into the HEAD section of HTML pages

```
<script type="application/ld+json">
{
  "@context": "http://schema.org",
  "@type": "Organization",
  "url": "http://www.example.com",
  "name": "Unlimited Ball Bearings Corp.",
  "contactPoint": {
    "@type": "ContactPoint",
    "telephone": "+1-401-555-1212",
    "contactType": "Customer service"
  }
}
</script>
```

https://json-ld.org/
https://developers.google.com/search/docs/guides/intro-structured-data

2.3 RDF Schema

Language for defining RDF vocabularies.

- RDF schema provides for defining:
  - classes (that are used as types) and
  - properties (that are used as predicates)
- Example of a RDF schema vocabulary definition:

```
dws:Teacher rdf:type rdfs:Class .
dws:Course rdf:type rdfs:Class .
dws:teaches rdf:type rdf:Property .
```

- RDF triples using the vocabulary:

```
dws:ChrisBizer rdf:type dws:Teacher .
dws:WebDataIntegration rdf:type dws:Course .
dws:ChrisBizer dws:teaches dws:WebDataIntegration .
```

Classes and Properties may form Hierarchies

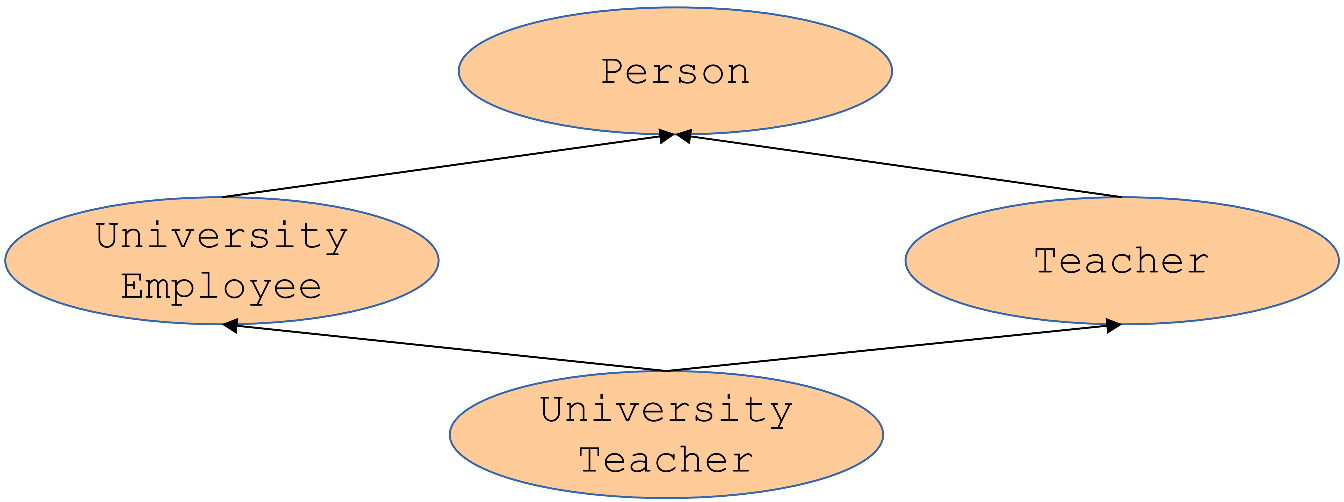
- Subclass Definition

```
dws:UniversityTeacher rdfs:subClassOf dws:Teacher .
```

- Subproperty Definition

```
dws:CourseName rdfs:subPropertyOf dc:title .
```

- Implication: All dws:UniversityTeachers are also dws:Teachers
- Multiple inheritance is allowed



Domain and Range Definitions

- RDF Schema provides for defining domains and ranges of properties:

```
dws:teaches rdf:type rdf:Property .
dws:teaches rdfs:domain dws:Teacher .
dws:teaches rdfs:range dws:Course .
```

- Implications:
  1. All resources that have a `dws:teaches` property are of `rdf:type dws:Teacher.`
  2. All objects of `dws:teaches` triples are of `rdf:type dws:Course.`
- Domains and ranges are inherited to subproperties

RDF Schema Reasoning

- Given the RDF schema

```
dws:Teacher rdfs:subClassOf foaf:Person .
dws:teaches rdfs:domain dws:Teacher .
dws:teaches rdfs:range dws:Course .
```

- and the single triple

```
dws:ChrisBizer dws:teaches dws:WebDataIntegration .
```

- A machine (reasoning engine) can infer (conclude) that

```
dws:ChrisBizer rdf:type dws:Teacher .
dws:ChrisBizer rdf:type foaf:Person .
dws:WebDataIntegration rdf:type dws:Course .
```

- OWL (Web Ontology Language)
  - provides for more expressive definitions and inferences
  - see course: IE650 Knowledge Graphs

Purpose of RDF Schema

- Recap: XML Schema defines *allowed* structures
- In contrast: RDF Schema does *not* constrain anything

- Purpose of XML Schema
  - validation of XML documents
- Purpose of RDF Schema
  - machine interpretability of RDF data
    - by inferring additional triples
    - by setting links (correspondences) between different RDF terms
      e.g. `dws:Teacher rdfs:subClassOf foaf:Person`
  - NOT validation
  - W3C SHACL Shapes Constraint Language provide for RDF validation
    https://www.w3.org/TR/shacl/

2.4 SPARQL

Language for querying RDF graphs.

- Queries are expressed in the form of triple patterns
- Query results are tabular and given as XML, JSON, or CSV
- The SPARQL Protocol is used to query remote endpoints
- Example query:

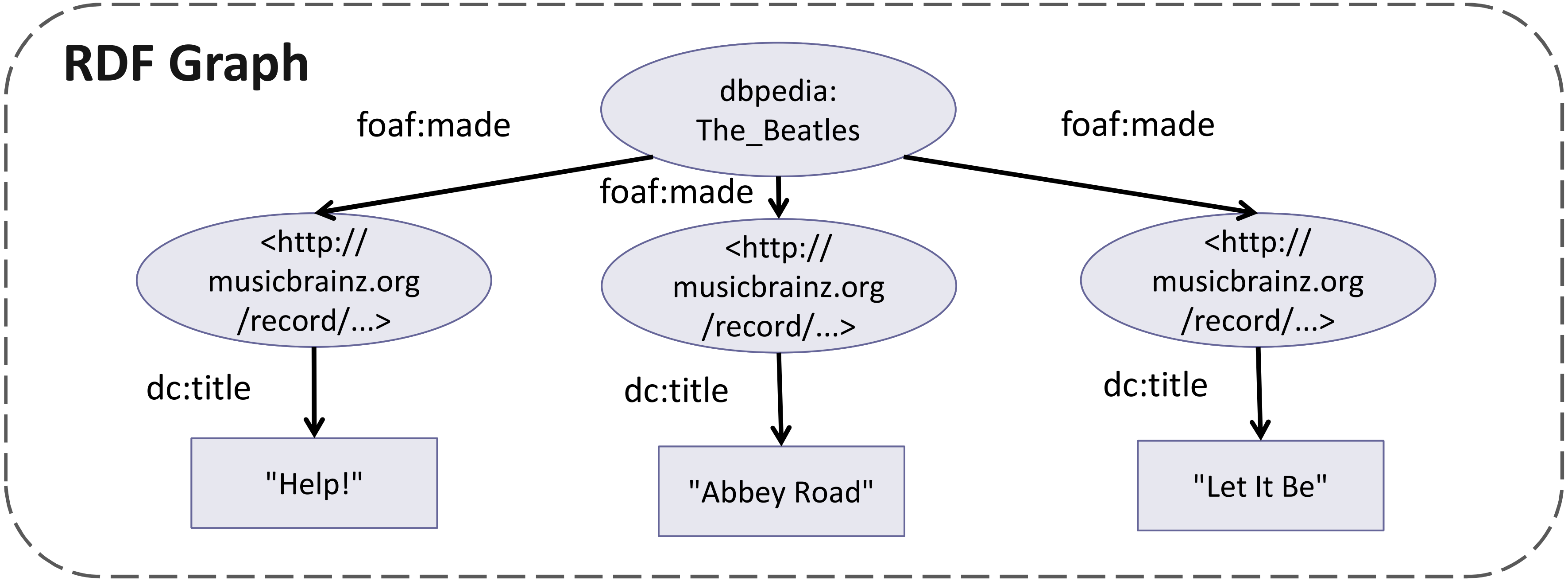
```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?name ?email
WHERE {
  ?person rdf:type foaf:Person .
  ?person foaf:name ?name .
  ?person foaf:mbox ?email .
}
```

Prefix definition

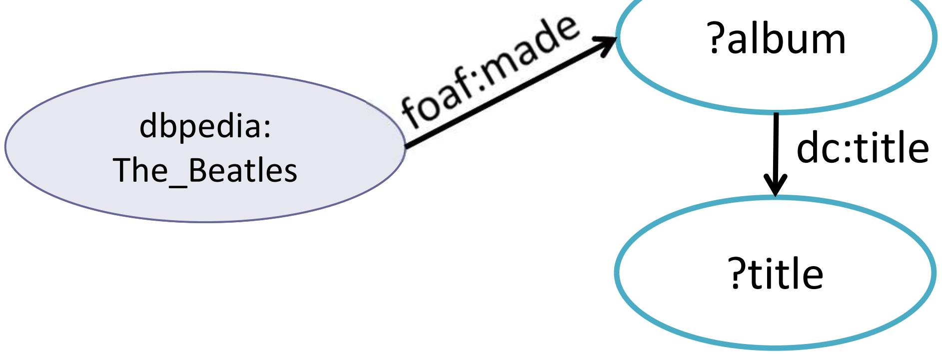
Result definition

Triple patterns
(?x = variables)

Triple Pattern Matching



Triple Pattern



Query Result

?album	?title
<http://...>	"Help!"
<http://...>	"Abbey Road"
<http://...>	"Let It Be"

Source: EUCLID - Querying Linked Data

Optional Triple Patterns

- Declaring triple patterns as OPTIONAL allows you to get query results even if only a subset of the patterns matches

  `WHERE { A OPTIONAL { B } }`

- Keep all solutions from A whether or not there is a matching solution for B
- Important for querying endpoints with a lot of missing values
- Example:

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX dbo: <http://dbpedia.org/ontology/>

SELECT ?name ?birth ?death
WHERE {
     ?person foaf:name ?name .
     ?person dbo:birthDate ?birth .
     OPTIONAL { ?person dbo:deathDate ?death . }

}
```

FILTER Clauses

- FILTER clauses keep only solutions that fulfil a condition (expression must evaluate to true)
- Example

```
PREFIX : <http://dbpedia.org/resource/>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX dbo: <http://dbpedia.org/ontology/>

SELECT ?name ?birth
WHERE {
        ?person dbo:birthPlace :Berlin .
        ?person dbo:birthDate ?birth .
        ?person foaf:name ?name .
        FILTER (?birth < "1900-01-01"^^xsd:date) .
}
```

- Comparators: `=  !=  <  >  <=  >=`
- Logical Operators: `&&  ||  !`
- Functions: SUBSTR(), regex(), month(now()), isURI(), …
  - more functions: http://www.w3.org/TR/sparql11-query/#SparqlOps

Solution Modifiers

- Sort results

```
ORDER BY ?name
```

- Restrict number of results

```
LIMIT 100
```

- Page over result list

```
LIMIT 100
OFFSET 0
```

```
LIMIT 100
OFFSET 100
```

```
PREFIX : <http://dbpedia.org/resource/>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX dbo: <http://dbpedia.org/ontology/>

SELECT ?name ?birth
WHERE {
        ?person dbo:birthPlace :Berlin .
        ?person dbo:birthDate ?birth .
        ?person foaf:name ?name .
}
ORDER BY ?name
LIMIT 10
OFFSET 100
```

Exercise: Querying DBpedia 1

- Question 1: What is the population and the area code of Mannheim?
  - http://dbpedia.org/resource/Mannheim
- Query tool
  - http://dbpedia.org/snorql/

Solution: Querying DBpedia 1

- Question: What is the population and the area code of Mannheim?
- SPARQL Query:

```
PREFIX : <http://dbpedia.org/resource/>
PREFIX dbo: <http://dbpedia.org/ontology/>

SELECT ?population ?areacode
WHERE {
:Mannheim dbo:populationMetro ?population .
:Mannheim dbo:areaCode ?areacode .
}
```

- Result:

SPARQL results:

population	areacode
2362046	"0621"

Exercise: Querying DBpedia 2

- Question 2: Find all Settlements in Germany that have a population of more than 100,000 people?
- Query tool
  - http://dbpedia.org/snorql/

Solution: Querying DBpedia 2

- Question: Find all settlements in Germany that have a populationMetro of more than 100,000 people?
- SPARQL Query:

```
PREFIX : <http://dbpedia.org/resource/>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX dbo: <http://dbpedia.org/ontology/>

SELECT ?city ?population
WHERE {
?city rdf:type dbo:Settlement .
?city dbo:country :Germany .
?city dbo:populationMetro ?population .
FILTER (?population > "100000"^^xsd:nonNegativeInteger)
}
```

- Result:

SPARQL results:

city	population
:Munich_Metropolitan_Region	5991144
:Hamburg	5107429
:Hamburg_Metropolitan_Region	5100000
:Hannover–Braunschweig–Göttingen–Wolfsburg_Metropolitan_Region	3900000
:Stuttgart_Metropolitan_Region	5300000
:Central_German_Metropolitan_Region	2400000
:Ruhr	10680783
:Berlin	6144600
:Berlin/Brandenburg_Metropolitan_Region	6004857
:Frankfurt_Rhein-Main_Regional_Authority	2295588
:Frankfurt_Rhine-Main	5808518
:Rhine-Neckar	2362000
:Rhine-Ruhr	10680783

2.5 Processing RDF in Java: Jena

- Jena is a popular framework for processing RDF in Java
- Download: https://jena.apache.org/
- Capabilities
  - supports various RDF syntaxes
  - SPARQL query language
  - RDF Schema and OWL reasoning
  - various storage back ends
- Central concepts
  - model (i.e., RDF graphs): `class Model`
  - resource: `class Resource`

Processing RDF in Java: Jena

- Read a graph from a URL (or local file):

```
model.read("http://dbpedia.org/resource/Mannheim");
```

- Navigating through a model

```
Resource mannheim =
     model.getResource("http://dbpedia.org/resource/
                              Mannheim");

Literal areaCode =  mannheim.getProperty(
    "http://dbpedia.org/ontology/areaCode")
    .getLiteral();
```

Querying a Local Model with SPARQL

```
String queryString = "SELECT ?x ...";

Query query = QueryFactory.create(queryString);

QueryExecution qexec =
    QueryExecutionFactory.create(query, model);

ResultSet results = qexec.execSelect();

while(results.hasNext()) {

  QuerySolution sol = results.next();
    String s = sol.get("x").toString();
    ...

}
```

Querying a Public SPARQL Endpoint

- Many RDF data sources provide SPARQL endpoints
  - e.g. DBpedia, Linked GeoData, EU Open Data Portal, …
  - List of public endpoints: https://labs.mondeca.com/sparqlEndpointsStatus/index.html

- Access with Jena

```
String queryString = "SELECT ...";
String endpoint = "http://dbpedia.org/sparql";
Query query = QueryFactory.create(queryString);
QueryExecution qexec =
    QueryExecutionFactory.sparqlService(endpoint, query);
ResultSet RS = qexec.executeSelect();
```

Wrap-up: Data Exchange Formats

- Data is provided on the Web using various exchange formats
  - CSV, XML, JSON, RDF, ….
- Exchange formats provide us with syntaxes for transferring data
- Exchange formats do not solve the actual data integration challenges:
  1. Do two records describe the same real-world entity?
  2. Which elements in different schemata have the same meaning?
  3. Which conflicting values from different sources should I trust?
- These challenges will be the topics of the upcoming lectures
- Still, which format should I use for my application?
  - Answer depends more on social than on technical factors:
    - What formats are already used by others in wider application domain?
    - What formats can the programming language of choice read and write out of the box?

3. References

- Standards and specifications
  - JSON: http://www.json.org/
  - RDF: http://www.w3.org/TR/rdf11-concepts/
  - RDF Schema: http://www.w3.org/TR/rdf-schema/
  - SPARQL: http://www.w3.org/TR/sparql11-overview/
- Tutorials
  - GSON: https://github.com/google/gson
  - RDF: https://www.w3.org/TR/rdf-primer/
  - JENA: http://jena.apache.org/documentation/
  - Euclid Curriculum covering SPARQL: http://www.euclid-project.eu/
- Course
  - IE 650 Knowledge Graphs