Queries in KGs

Basel Shbita

DSCI 558: Building Knowledge Graphs

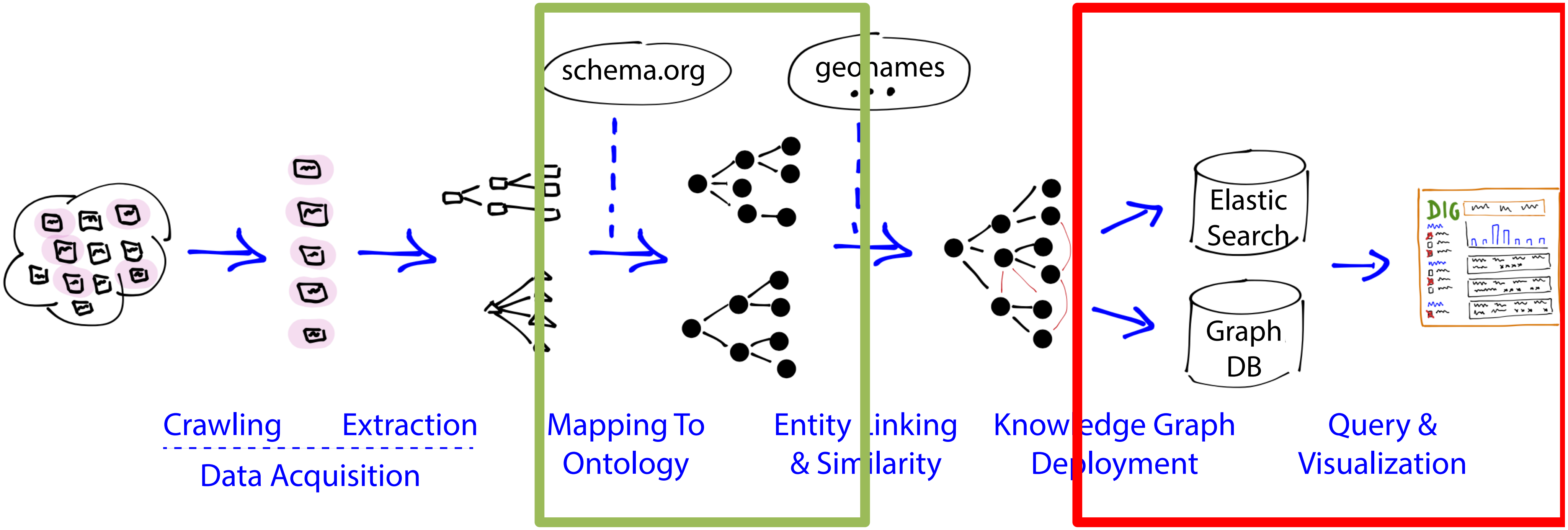
Fall 2020, University of Southern California

* **Some of the slides were provided by:** Jay Pujara, Pedro Szekely, Jose Luis Ambite

Agenda

- Intro
  - Recap
  - Property Graphs
  - RDF vs. Property Graphs
  - RDF triple-stores vs. Graph DBs
  - Back to the Semantic Web
- SPARQL
- Cypher (Neo4j)
- Wikidata

Back to our Canonical Architecture



Crawling

Extraction

Data Acquisition

Mapping To Ontology

Entity Linking & Similarity

Knowledge Graph Deployment

Query & Visualization

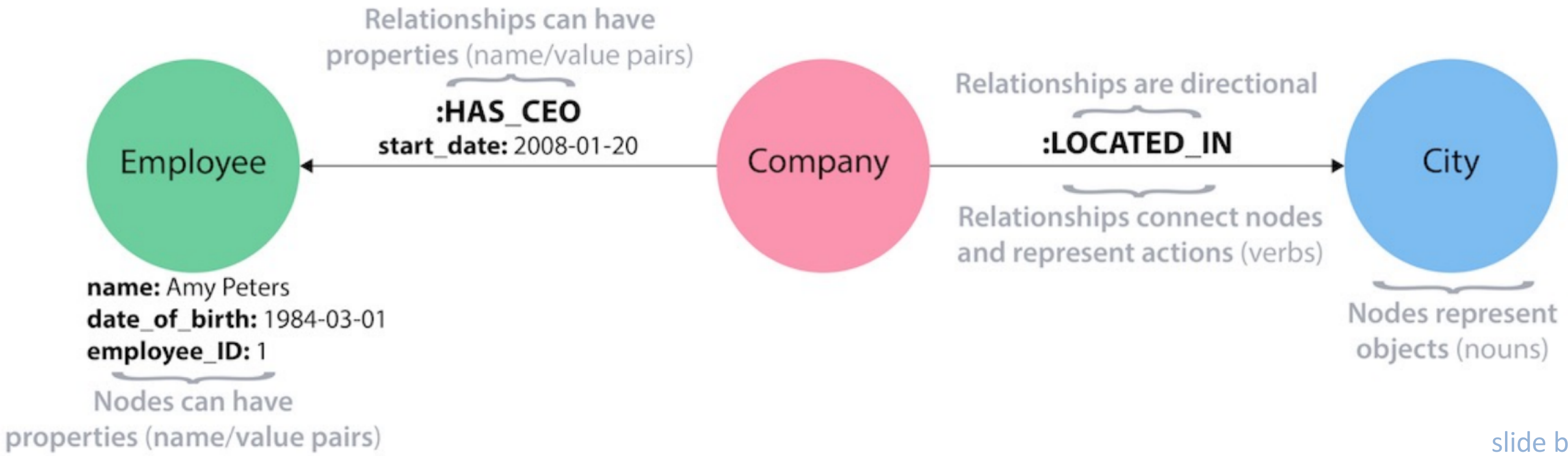
Two weeks ago (RDF(?) for KR)

Today

slide by Basel Shbita

Property Graphs

- Also called Labeled Property Graphs (LPG)
- Framework for representing data and metadata with a graph of nodes and links
  - both nodes and links may have additional key/value pairs ("properties")
  - nodes are "just" nodes, not necessarily URLs
- Link annotations are very useful to assign temporal, spatial, provenance, etc…


Relationships can have properties (name/value pairs)
:HAS_CEO
start_date: 2008-01-20
Employee
Company
Relationships are directional
:LOCATED_IN
City
Relationships connect nodes and represent actions (verbs)
name: Amy Peters
date_of_birth: 1984-03-01
employee_ID: 1
Nodes can have properties (name/value pairs)
Nodes represent objects (nouns)

slide by Basel Shbita

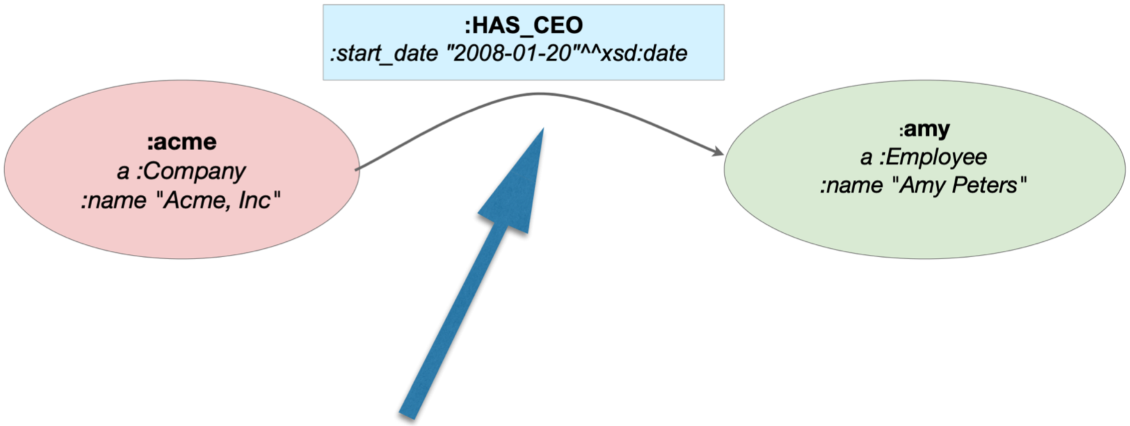
Property Graphs vs. RDF: similarities

- Both represent directed graphs as a basic data structure
- Both have associated graph-oriented query languages
- In practice, both are used as “graph stores”, accessible via HTTP and/or various API-s

slide by Basel Shbita

RDF vs. Property Graphs: differences

- RDF has an emphasis on OWA, and is rooted in the Web via URL-s. Not the case for PG:
  - a PG node is oblivious to what it “contains”: can be a URL, can be a literal
- PG includes the possibility to add simple key/value pairs to “relationships” (i.e., RDF predicates)



These are properties on the link “instance”!

slide by Basel Shbita

RDF triple-stores vs. Graph DBs

- In RDF triple-stores everything is expressed in terms of subject-predicate-object
  - predicates can't have attributes
- In Graph DBs predicates **can** have attributes
- Fair to say that RDF triple-stores are a kind of Graph DB

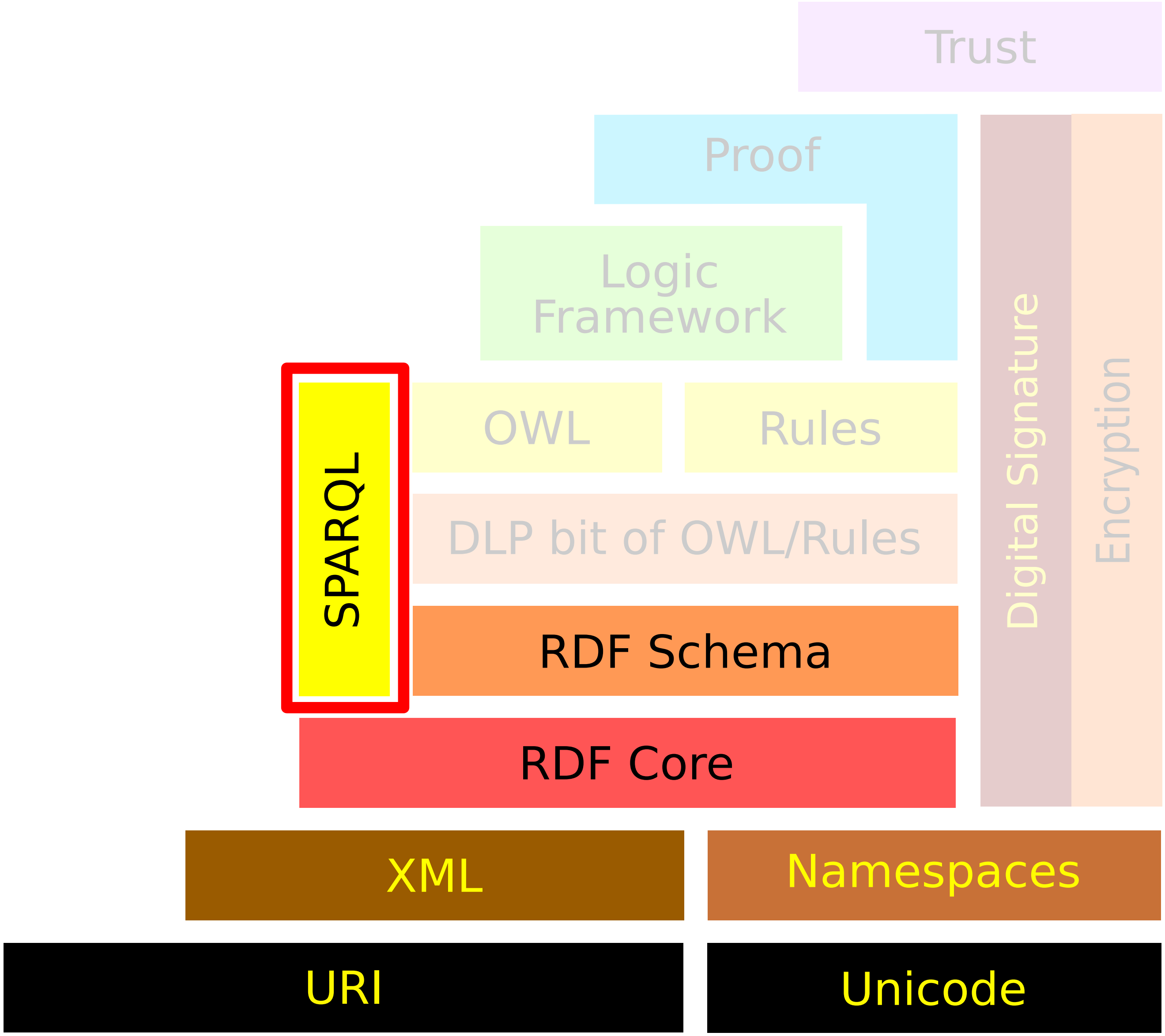
slide by Basel Shbita

RDF triple-stores vs. Graph DBs

RDF triple-stores	Graph DBs
Both designed to store linked data	
focus solely on storing rows of RDF triples	can store various types of graphs, including undirected graphs, weighted graphs, hypergraphs, etc…
edge-centric	node, or property, centric
better for inferences on data	better optimized for graph traversals (degrees of separation or shortest path algorithms)
RDF triple stores are more synonymous with the “semantic web” and the standardized universe of knowledge being stored as RDF	GDBs are seen as more pragmatic rather than academic
use SPARQL as the query language	versatile with query languages: Neo4J has Cypher. Other GDBs support G, GraphLog, GOOD, SoSQL, BiQL, SNQL
Apache Jena, Blazegraph, RDFLib, Virtuoso	Neo4j, ArangoDB, OrientDB

slide by Basel Shbita

Back to the Semantic Web Layer Cake



Trust

Proof

Logic Framework

SPARQL

OWL

Rules

DLP bit of OWL/Rules

RDF Schema

Digital Signature

Encryption

RDF Core

XML

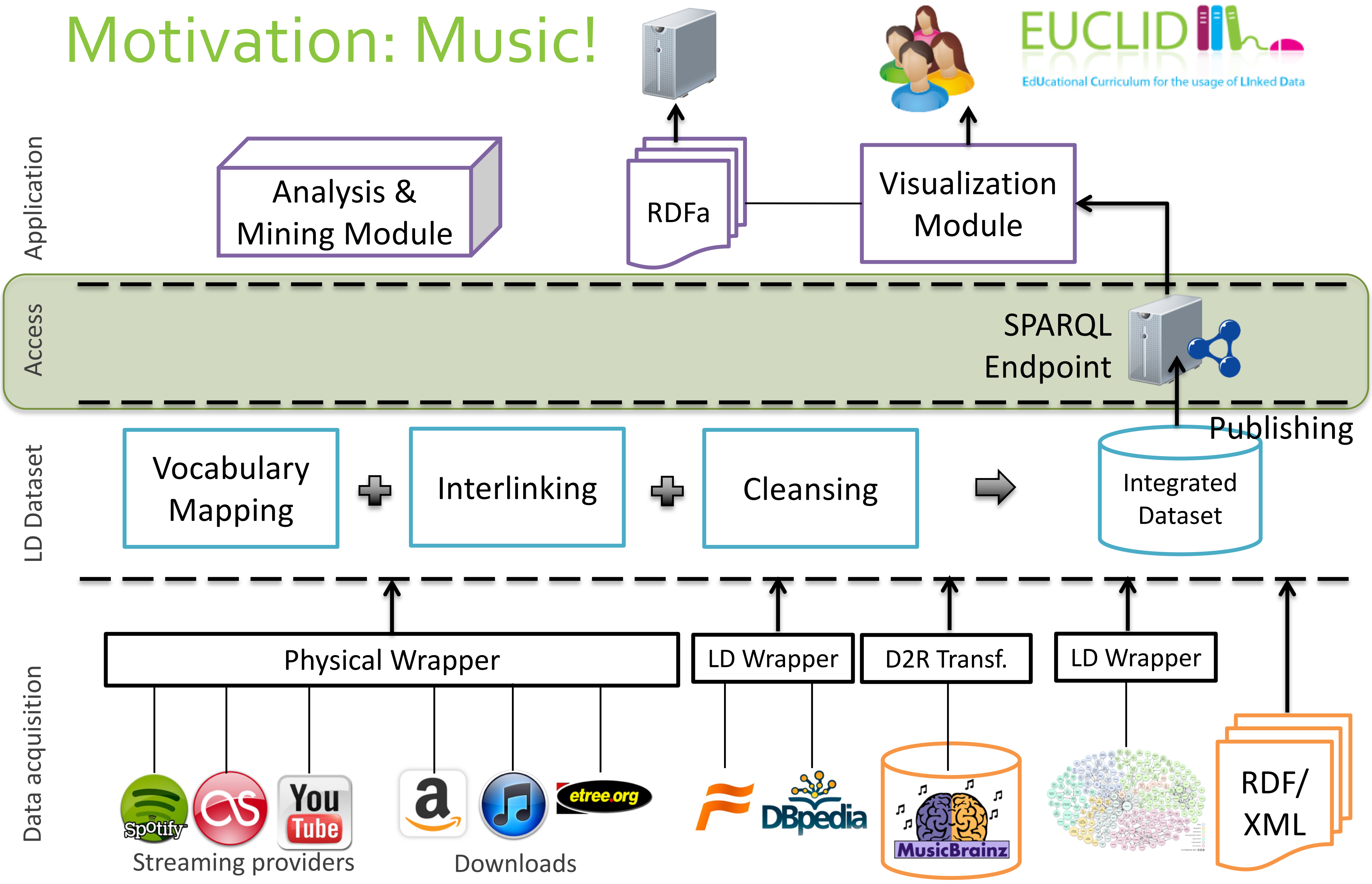
Namespaces

URI

Unicode

slide by Basel Shbita

Motivation: Music!



Musical Content

Metadata

Other content

Agenda

- Intro
- SPARQL
  - Basic SPARQL Syntax
  - Exercises (Linked Movie Database)
  - Graph Patterns
  - Other Query forms
  - Federated queries
- Cypher (Neo4j)
- Wikidata

http://www.w3.org/TR/sparql11-query/

SPARQL

(SPARQL Protocol and RDF Query Language)

SELECT

Get data

ASK

Yes/No questions

CONSTRUCT

Create RDF

DESCRIBE

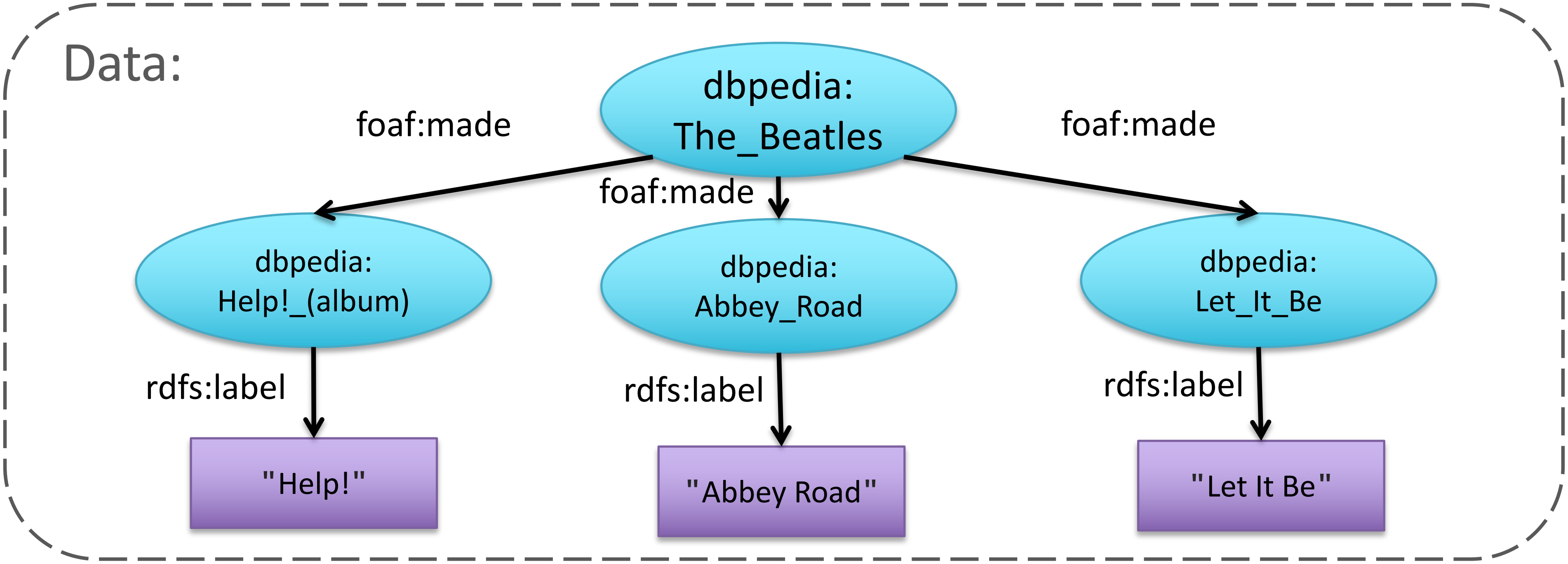
Get some information

slide by Pedro Szekely

slide by Pedro Szekely

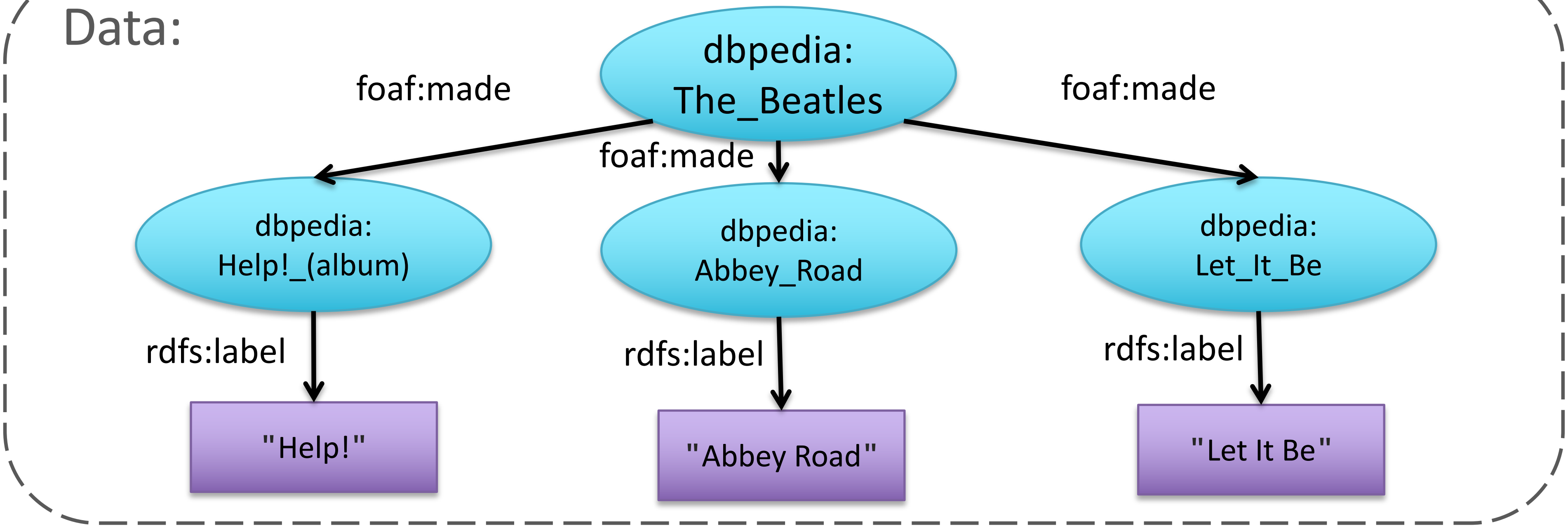
SPARQL Query

EUCLID
EdUcational Curriculum for the usage of LInked Data



SPARQL Query

Data:



dbpedia:
The_Beatles

foaf:made

foaf:made

foaf:made

dbpedia:
Help!_(album)

dbpedia:
Abbey_Road

dbpedia:
Let_It_Be

rdfs:label

rdfs:label

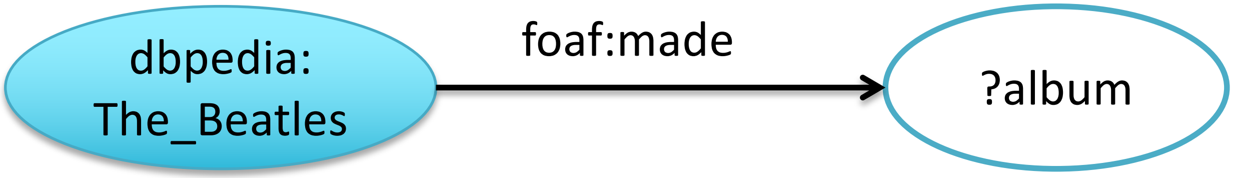
rdfs:label

"Help!"

"Abbey Road"

"Let It Be"

Graph patterns:



dbpedia:
The_Beatles

foaf:made

?album

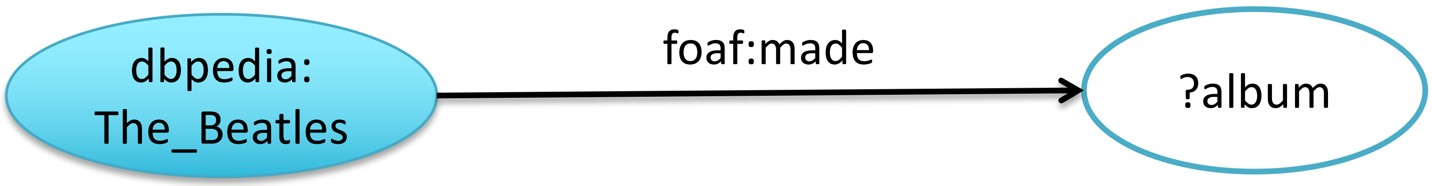
Results:

?album
dbpedia:Help!_(album)
dbpedia:Abbey_Road
dbpedia:Let_It_Be

SPARQL Query

Main idea: **Pattern matching**

- Queries describe sub-graphs of the queried graph
- **Graph patterns** are RDF graphs specified in Turtle syntax, which contain variables (prefixed by either "?" or "$")



- Sub-graphs that match the graph patterns yield a **result**

Simple Query

Data

```
<http://example.org/book/book1>
<http://purl.org/dc/elements/1.1/title>
"SPARQL Tutorial" .
```

Query

```
SELECT ?title
WHERE
{
  <http://example.org/book/book1>
  <http://purl.org/dc/elements/1.1/title>
  ?title .
}
```

Result

title

slide by Pedro Szekely

http://www.w3.org/TR/sparql11-query/

Multiple Matches

Data

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

_:a  foaf:name   "Johnny Lee Outlaw" .
_:a  foaf:mbox   <mailto:jlow@example.com> .
_:b  foaf:name   "Peter Goodguy" .
_:b  foaf:mbox   <mailto:peter@example.org> .
_:c  foaf:mbox   <mailto:carol@example.org> .
```

Query

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?name ?mbox
WHERE
  { ?x foaf:name ?name .
    ?x foaf:mbox ?mbox }
```

Result

name	mbox

slide by Pedro Szekely

http://www.w3.org/TR/sparql11-query/

Blank Nodes

Data

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

_:a  foaf:name   "Alice" .
_:b  foaf:name   "Bob" .
```

Query

```
PREFIX foaf:   <http://xmlns.com/foaf/0.1/>
SELECT ?x ?name
WHERE  { ?x foaf:name ?name }
```

Result

x	name
_:a	
_:b	

slide by Pedro Szekely

http://www.w3.org/TR/sparql11-query/

Creating Values with Expressions

Data

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

_:a  foaf:givenName   "John" .
_:a  foaf:surname  "Doe" .
```

Query

```
PREFIX foaf:   <http://xmlns.com/foaf/0.1/>
SELECT ?name
WHERE  {
   ?P foaf:givenName ?G ;
      foaf:surname ?S
   BIND(CONCAT(?G, " ", ?S) AS ?name)
}
```

Result

name

slide by Pedro Szekely

http://www.w3.org/TR/sparql11-query/

Selection: Restricting the Value of Strings

Data

```
@prefix dc:   <http://purl.org/dc/elements/1.1/> .
@prefix :     <http://example.org/book/> .
@prefix ns:   <http://example.org/ns#> .

:book1  dc:title  "SPARQL Tutorial" .
:book1  ns:price  42 .
:book2  dc:title  "The Semantic Web" .
:book2  ns:price  23 .
```

Query

```
PREFIX foaf:   <http://xmlns.com/foaf/0.1/>
PREFIX  dc:  <http://purl.org/dc/elements/1.1/>
SELECT  ?title
WHERE   { ?x dc:title ?title
          FILTER regex(?title, "^SPARQL")
        }
```

Result

title

slide by Pedro Szekely, Jose Luis Ambite

http://www.w3.org/TR/sparql11-query/

Selection: Restricting Numeric Values

Data

```
@prefix dc:   <http://purl.org/dc/elements/1.1/> .
@prefix :     <http://example.org/book/> .
@prefix ns:   <http://example.org/ns#> .

:book1  dc:title  "SPARQL Tutorial" .
:book1  ns:price  42 .
:book2  dc:title  "The Semantic Web" .
:book2  ns:price  23 .
```

Query

```
PREFIX  dc:  <http://purl.org/dc/elements/1.1/>
PREFIX  ns:  <http://example.org/ns#>
SELECT  ?title ?price
WHERE   { ?x ns:price ?price .
          FILTER (?price < 30.5)
          ?x dc:title ?title . }
```

Result

title	price
"The Semantic Web"	

"SPARQL Tutorial" too expensive

slide by Pedro Szekely, Jose Luis Ambite

http://www.w3.org/TR/sparql11-query/

Some Syntax (Prefix)

Query

```
PREFIX  dc: <http://purl.org/dc/elements/1.1/>
SELECT  ?title
WHERE   { <http://example.org/book/book1> dc:title ?title }
```

URIs in angle brackets as <http://…>

Query

```
PREFIX  dc: <http://purl.org/dc/elements/1.1/>
PREFIX  : <http://example.org/book/>

SELECT  ?title
WHERE   { :book1  dc:title  $title }
```

Empty prefix

Query

```
BASE    <http://example.org/book/>
PREFIX  dc: <http://purl.org/dc/elements/1.1/>

SELECT  ?title
WHERE   { <book1>  dc:title  ?title }
```

Define BASE: no need to write long URIs

slide by Pedro Szekely

http://www.w3.org/TR/sparql11-query/

More Syntax (Blank Nodes)

Query
Fragment

```
?x  a  :Class1 .
[ a :appClass ] :p "v" .
```

Short form

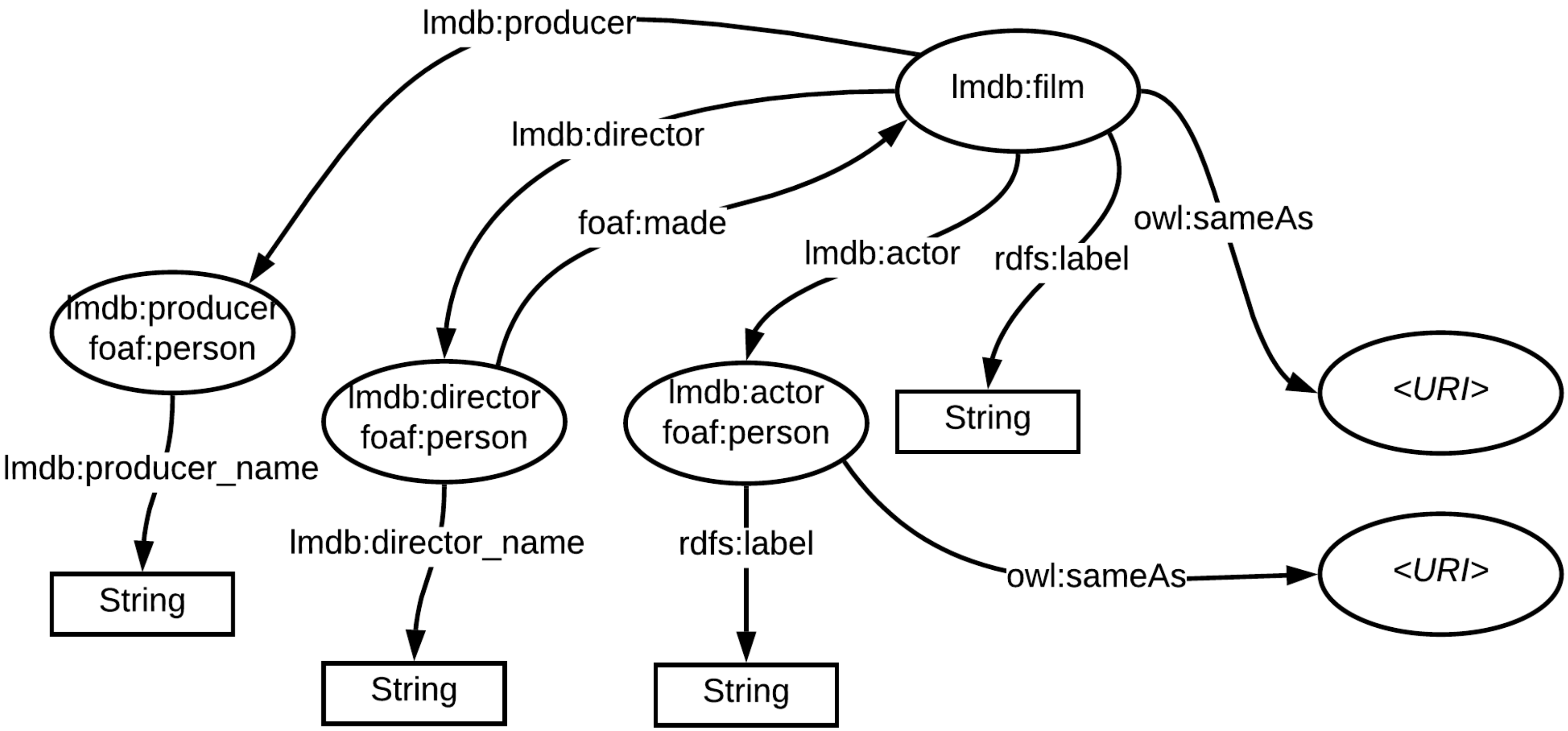
Query
Fragment

```
?x    rdf:type  :Class1 .
_:b0  rdf:type  :appClass .
_:b0  :p        "v" .
```

Long form

http://www.w3.org/TR/sparql11-query/

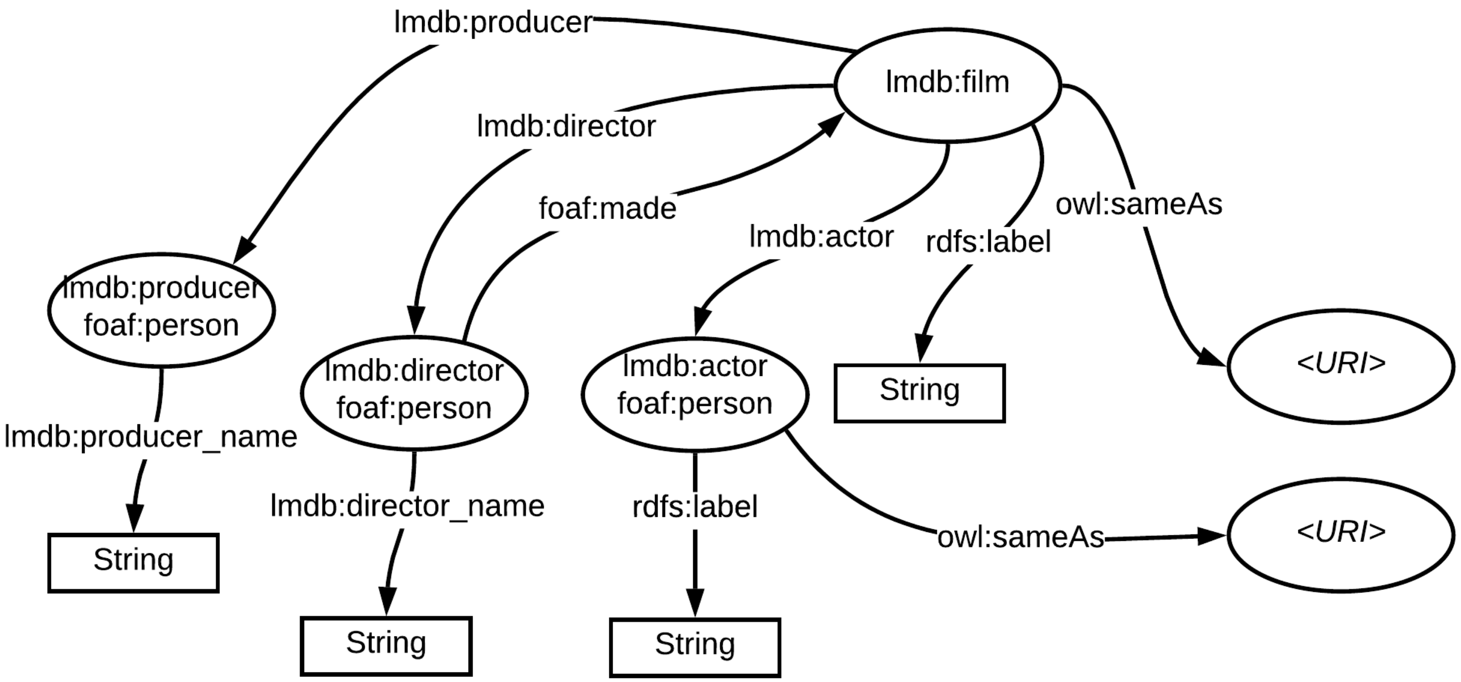
Exercise: Linked Movie Database



rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
rdfs: <http://www.w3.org/2000/01/rdf-schema#>
owl: <http://www.w3.org/2002/07/owl#>
foaf: <http://xmlns.com/foaf/0.1/>
lmdb: <http://data.linkedmdb.org/movie/>

LMDB Exercise 1

- URIs of actors
    - names
    - names of films they starred in



Graph Patterns

- Basic Graph Patterns,
  - where a set of triple patterns must match
- Group Graph Pattern: {}
  - where a set of graph patterns must all match
- Optional Graph patterns: OPTIONAL
  - where additional patterns may extend the solution
- Alternative Graph Pattern: UNION
  - where two or more possible patterns are tried
- Patterns on Named Graphs: GRAPH
  - where patterns are matched against named graphs

http://www.w3.org/TR/sparql11-query/

Group Graph Patterns

Query

```
PREFIX foaf:    <http://xmlns.com/foaf/0.1/>
SELECT ?name ?mbox
WHERE  {
          ?x foaf:name ?name .
          ?x foaf:mbox ?mbox .
       }
```

One basic graph pattern

Query

```
PREFIX foaf:    <http://xmlns.com/foaf/0.1/>
SELECT ?name ?mbox
WHERE  { { ?x foaf:name ?name . }
         { ?x foaf:mbox ?mbox . }
       }
```

Two group graph patterns

slide by Pedro Szekely

http://www.w3.org/TR/sparql11-query/

Scope of Filters

Query
Fragment

```
{   ?x foaf:name ?name .
    ?x foaf:mbox ?mbox .
    FILTER regex(?name, "Smith")
}
```

Query
Fragment

```
{   FILTER regex(?name, "Smith")
    ?x foaf:name ?name .
    ?x foaf:mbox ?mbox .
}
```

Query
Fragment

```
{   ?x foaf:name ?name .
    FILTER regex(?name, "Smith")
    ?x foaf:mbox ?mbox .
}
```

Scope is whole group where filter appears

slide by Pedro Szekely, Jose Luis Ambite

http://www.w3.org/TR/sparql11-query/

Optional Pattern Matching

Data

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

_:a  rdf:type        foaf:Person .
_:a  foaf:name       "Alice" .
_:a  foaf:mbox       <mailto:alice@example.com> .
_:a  foaf:mbox       <mailto:alice@work.example> .

_:b  rdf:type        foaf:Person .
_:b  foaf:name       "Bob" .
```

Query

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?name ?mbox
WHERE  { ?x foaf:name  ?name .
         OPTIONAL { ?x  foaf:mbox  ?mbox }
       }
```

Result

name	mbox
”Alice"	<mailto:alice@example.com>
”Alice”	<mailto:alice@work.example>

slide by Pedro Szekely

http://www.w3.org/TR/sparql11-query/

Multiple Optional Graph Patterns

Data

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

_:a  foaf:name       "Alice" .
_:a  foaf:homepage   <http://work.example.org/alice/> .

_:b  foaf:name       "Bob" .
_:b  foaf:mbox       <mailto:bob@work.example> .
```

Query

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?name ?mbox ?hpage
WHERE  { ?x foaf:name  ?name .
         OPTIONAL { ?x foaf:mbox ?mbox } .
         OPTIONAL { ?x foaf:homepage ?hpage }
       }
```

Result

name	mbox	hpage
”Alice"		<http://work.example.org/alice/>
“Bob”	<mailto:bob@work.example>	

slide by Pedro Szekely

http://www.w3.org/TR/sparql11-query/

UNION

Data

```
@prefix dc10:  <http://purl.org/dc/elements/1.0/> .
@prefix dc11:  <http://purl.org/dc/elements/1.1/> .

_:a  dc10:title     "SPARQL Query Language Tutorial" .
_:a  dc10:creator   "Alice" .
_:b  dc11:title     "SPARQL Protocol Tutorial" .
_:b  dc11:creator   "Bob" .
_:c  dc10:title     "SPARQL" .
_:c  dc11:title     "SPARQL (updated)" .
```

Query

```
PREFIX dc10:  <http://purl.org/dc/elements/1.0/>
PREFIX dc11:  <http://purl.org/dc/elements/1.1/>
SELECT ?title
WHERE  { { ?book dc10:title  ?title } UNION
         { ?book dc11:title  ?title }
       }
```

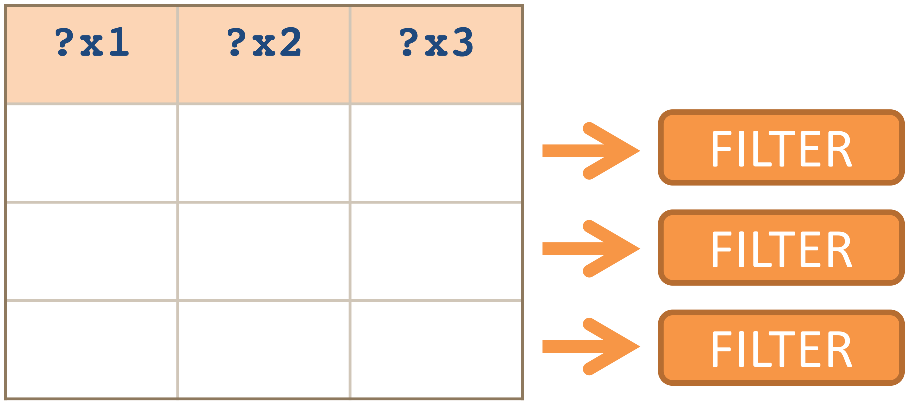
Result

title
"SPARQL Protocol Tutorial"
"SPARQL"
"SPARQL (updated)"
"SPARQL Query Language Tutorial"

slide by Pedro Szekely

http://www.w3.org/TR/sparql11-query/

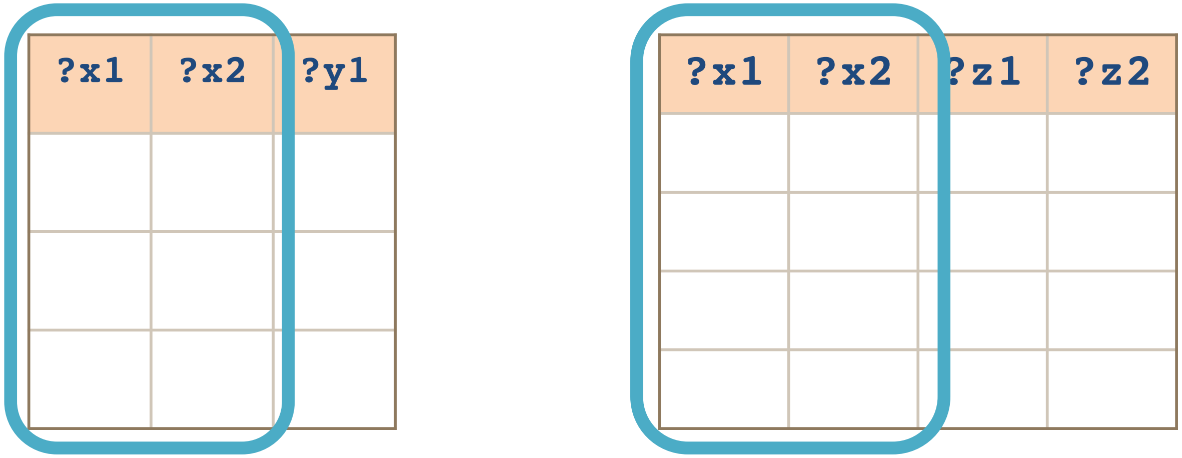
FILTER NOT EXISTS



testing whether a pattern exists
in the data,
given the bindings already
determined by the query pattern

MINUS

Graph Pattern MINUS Graph Pattern



evaluates both its arguments,
then calculates solutions in
the left-hand side that are not
compatible with the solutions
on the right-hand side

Negation: Absence of a Pattern

Data

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

:alice  rdf:type   foaf:Person .
:alice  foaf:name  "Alice" .
:bob    rdf:type   foaf:Person .
```

Query

```
PREFIX  rdf:    <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX  foaf:   <http://xmlns.com/foaf/0.1/>

SELECT ?person
WHERE
{
    ?person rdf:type  foaf:Person .
    FILTER NOT EXISTS { ?person foaf:name ?name }
}
```

Result

person

Can also do FILTER

slide by Pedro Szekely

http://www.w3.org/TR/sparql11-query/

Negation: Removing Possible Solutions

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

:alice  foaf:givenName "Alice" ;
        foaf:familyName "Smith" .

:bob    foaf:givenName "Bob" ;
        foaf:familyName "Jones" .

:carol  foaf:givenName "Carol" ;
        foaf:familyName "Smith" .
```

Data

Query

```
PREFIX :     <http://example/>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>

SELECT DISTINCT ?s
WHERE {
   ?s ?p ?o .
   MINUS {
      ?s foaf:givenName "Bob" .
   }
}
```

Result

s

http://www.w3.org/TR/sparql11-query/

See section 8.3

slide by Pedro Szekely

FILTER vs MINUS, Example

Query "FILTER"

```
SELECT *
{
  ?s ?p ?o
  FILTER NOT EXISTS { ?x ?y ?z }
}
```

Data

```
@prefix : <http://example/> .
:a :b :c .
```

Result "FILTER"

s	p	o

slide by Pedro Szekely

http://www.w3.org/TR/sparql11-query/

FILTER vs MINUS, Example

Query “FILTER”

```
SELECT *
{
  ?s ?p ?o
  FILTER NOT EXISTS { ?x ?y ?z }
}
```

Data

```
@prefix : <http://example/> .
:a :b :c .
```

Result “FILTER”

s	p	o

Query “MINUS”

```
SELECT *
{
   ?s ?p ?o
   MINUS
     { ?x ?y ?z }
}
```

No shared variables!

Result “MINUS”

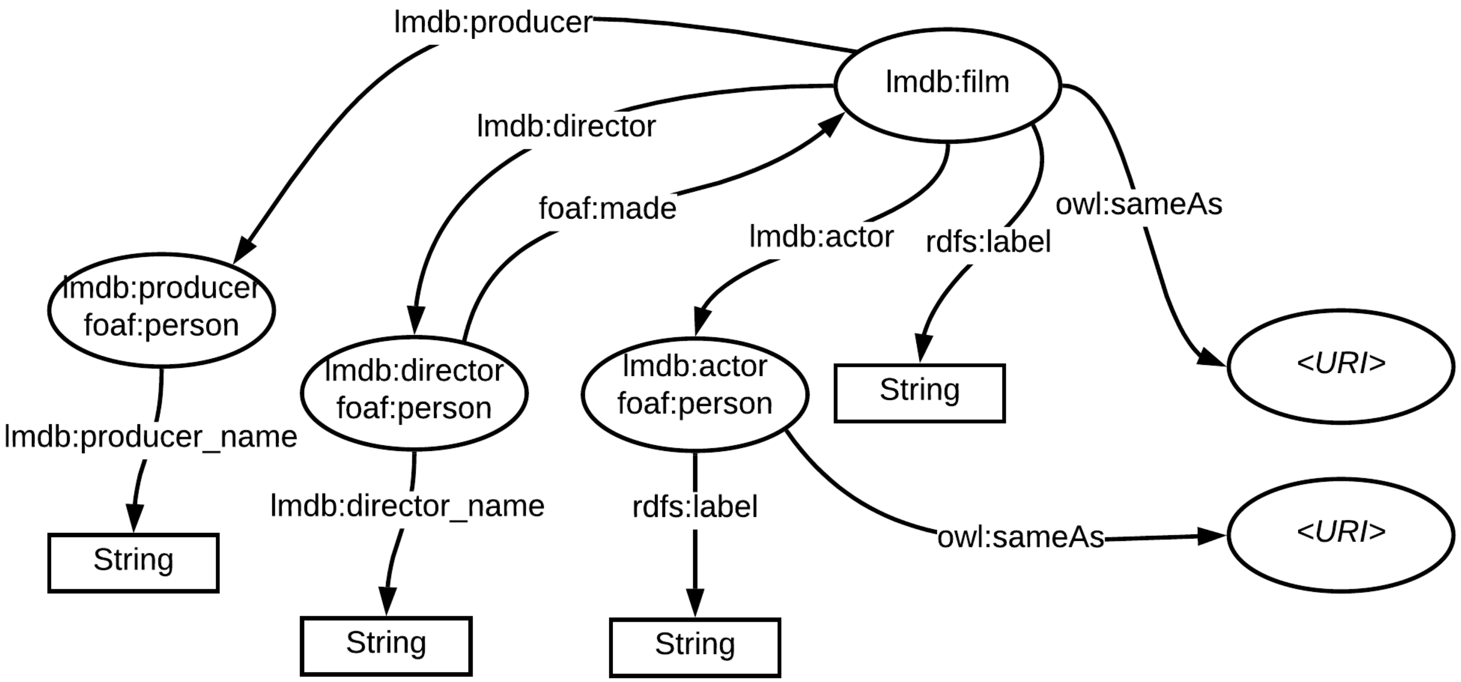
s	p	o

slide by Pedro Szekely, Jose Luis Ambite

http://www.w3.org/TR/sparql11-query/

LMDB Exercise 2

- URIs & name of actors
  - producers but not directors



Brain Teaser: Inner Filter

Data

```
@prefix : <…
:a :p 1 .
:a :q 1 .
:a :q 2 .

:b :p 3.0 .
:b :q 4.0 .
:b :q 5.0 .
```

Query “FILTER”

```
PREFIX : <http://example.com/>
SELECT * WHERE {
        ?x :p ?n
        FILTER NOT EXISTS {
                ?x :q ?m .
                FILTER(?n = ?m)
        }
}
```

Result “FILTER”

x	n

slide by Pedro Szekely

http://www.w3.org/TR/sparql11-query/

Brain Teaser: Inner Filter

Data

```
@prefix : <…
:a :p 1 .
:a :q 1 .
:a :q 2 .

:b :p 3.0 .
:b :q 4.0 .
:b :q 5.0 .
```

Query “FILTER”

```
PREFIX : <http://example.com/>
SELECT * WHERE {
        ?x :p ?n
        FILTER NOT EXISTS {
                ?x :q ?m .
                FILTER(?n = ?m)
        }
}
```

Result “FILTER”

x	n
<http://example.com/b>	3.0

Query “MINUS”

```
PREFIX : <http://example/>
SELECT * WHERE {
        ?x :p ?n
        MINUS {
                ?x :q ?m .
                FILTER(?n = ?m)
        }
}
```

Result “MINUS”

x	n

http://www.w3.org/TR/sparql11-query/

Property Paths

Query
Fragment

```
{ :book1 dc:title|rdfs:label ?displayString }
```

Alternatives: Match one or both possibilities

Query
Fragment

```
{
  ?x foaf:mbox <mailto:alice@example> .
  ?x foaf:knows/foaf:name ?name .
}
```

Sequence: Find the name of any people that Alice knows.

Query
Fragment

```
{
  ?x foaf:mbox <mailto:alice@example> .
  ?x foaf:knows/foaf:knows/foaf:name ?name .
}
```

Sequence: Find the names of people 2 "foaf:knows" links away.

Query
Fragment

```
{
  ?x foaf:mbox <mailto:alice@example> .
  ?x foaf:knows+/foaf:name ?name .
}
```

Arbitrary length match:
Find the names of all the people that can be reached from Alice by “foaf:knows”:

slide by Pedro Szekely, Jose Luis Ambite

http://www.w3.org/TR/sparql11-query/

Property Path Semantics

```
{
  ?x foaf:mbox <mailto:alice@example> .
  ?x foaf:knows/foaf:knows/foaf:name ?name .
}
```

=

```
{
  ?x foaf:mbox <mailto:alice@example> .
  ?x  foaf:knows ?a1 .
  ?a1 foaf:knows ?a2 .
  ?a2 foaf:name ?name .
}
```

=

```
{
  ?x foaf:mbox <mailto:alice@example> .
  ?x  foaf:knows [ foaf:knows [ foaf:name ?name ]] .
}
```

slide by Pedro Szekely

http://www.w3.org/TR/sparql11-query/

BIND: Assigning to Variables

Data

```
@prefix dc:   <http://purl.org/dc/elements/1.1/> .
@prefix :     <http://example.org/book/> .
@prefix ns:   <http://example.org/ns#> .

:book1  dc:title     "SPARQL Tutorial" .
:book1  ns:price     42 .
:book1  ns:discount  0.2 .

:book2  dc:title     "The Semantic Web" .
:book2  ns:price     23 .
:book2  ns:discount  0.25 .
```

Query

```
PREFIX  dc:   <http://purl.org/dc/elements/1.1/>
PREFIX  ns:   <http://example.org/ns#>

SELECT  ?title ?price
{   ?x ns:price ?p .
    ?x ns:discount ?discount
    BIND (?p*(1-?discount) AS ?price)
    FILTER(?price < 20)
    ?x dc:title ?title .
}
```

Result

title	price
"The Semantic Web”	17.25

slide by Pedro Szekely

http://www.w3.org/TR/sparql11-query/

Aggregation

Data

```
@prefix : <http://books.example/> .

:org1 :affiliates :auth1, :auth2 .
:auth1 :writesBook :book1, :book2 .
:book1 :price 9 .
:book2 :price 5 .
:auth2 :writesBook :book3 .
:book3 :price 7 .
:org2 :affiliates :auth3 .
:auth3 :writesBook :book4 .
:book4 :price 7 .
```

Query

```
PREFIX : <http://books.example/>
SELECT (SUM(?lprice) AS ?totalPrice)
WHERE {
  ?org :affiliates ?auth .
  ?auth :writesBook ?book .
  ?book :price ?lprice .
}
GROUP BY ?org
HAVING (SUM(?lprice) > 10)
```

Bindings

?org	?auth	?book	?lprice
:org1	:auth1	:book1	9
:org1	:auth1	:book2	5
:org1	:auth2	:book3	7
:org2	:auth3	:book4	7

21

7

slide by Pedro Szekely

http://www.w3.org/TR/sparql11-query/

Aggregation

Query

```
PREFIX : <http://books.example/>
SELECT (SUM(?lprice) AS ?totalPrice)
WHERE {
  ?org :affiliates ?auth .
  ?auth :writesBook ?book .
  ?book :price ?lprice .
}
GROUP BY ?org
HAVING (SUM(?lprice) > 10)
```

Bindings

?org	?auth	?book	?lprice
:org1	:auth1	:book1	9
:org1	:auth1	:book2	5
:org1	:auth2	:book3	7
~~:org2~~	~~:auth3~~	~~:book4~~	~~7~~

21

7

Result

totalPrice
21

slide by Pedro Szekely

http://www.w3.org/TR/sparql11-query/

Aggregation

Data

```
@prefix : <http://books.example/> .

:org1 :affiliates :auth1, :auth2 .
:auth1 :writesBook :book1, :book2 .
:book1 :price 9 .
:book2 :price 5 .
:auth2 :writesBook :book3 .
:book3 :price 7 .
:org2 :affiliates :auth3 .
:auth3 :writesBook :book4 .
:book4 :price 7 .
```

Query

```
PREFIX : <http://books.example/>
SELECT (SUM(?lprice) AS ?totalPrice)
WHERE {
  ?org :affiliates ?auth .
  ?auth :writesBook ?book .
  ?book :price ?lprice .
}
GROUP BY ?org
HAVING (SUM(?lprice) > 10)
```

Result

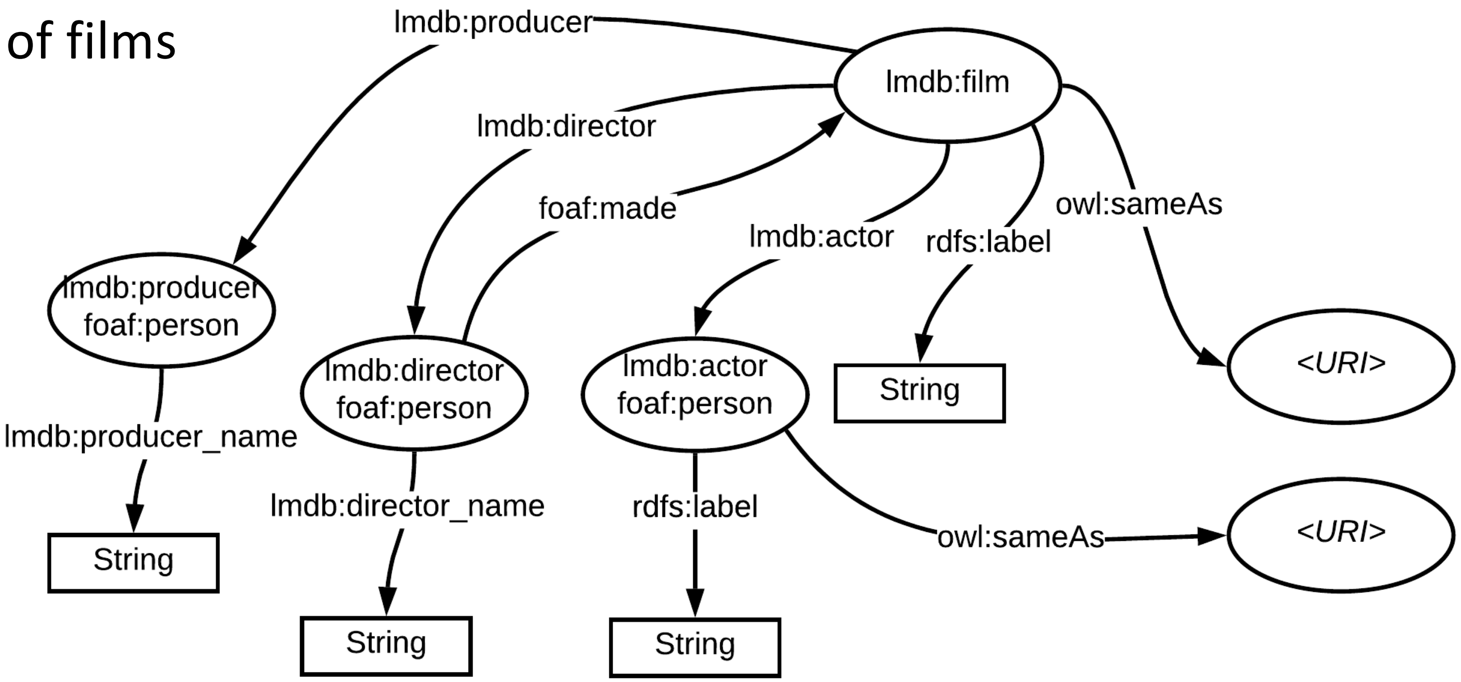
totalPrice
21

slide by Pedro Szekely

http://www.w3.org/TR/sparql11-query/

LMDB Exercise 3

- URIs of actors
  - show names
  - starred in more than 20 films with the same director (not the actor)
    - name of the director
    - number of films



Subqueries

Data

```
@prefix : <http://people.example/> .

:alice :name "Alice", "Alice Foo", "A. Foo" .
:alice :knows :bob, :carol .
:bob :name "Bob", "Bob Bar", "B. Bar" .
:carol :name "Carol", "Carol Baz", "C. Baz" .
```

Query

```
PREFIX : <http://people.example/>
SELECT ?y ?minName
WHERE {
  :alice :knows ?y .
  {
    SELECT ?y (MIN(?name) AS ?minName)
    WHERE {
      ?y :name ?name .
    } GROUP BY ?y
  }
}
```

Result

y	minName
???	???
???	???
???	???

http://www.w3.org/TR/sparql11-query/

Subqueries

Data

```
@prefix : <http://people.example/> .

:alice :name "Alice", "Alice Foo", "A. Foo" .
:alice :knows :bob, :carol .
:bob :name "Bob", "Bob Bar", "B. Bar" .
:carol :name "Carol", "Carol Baz", "C. Baz" .
```

Query

```
PREFIX : <http://people.example/>
SELECT ?y ?minName
WHERE {
  :alice :knows ?y .
  {
    SELECT ?y (MIN(?name) AS ?minName)
    WHERE {
      ?y :name ?name .
    } GROUP BY ?y
  }
}
```

slide by Pedro Szekely, Jose Luis Ambite

http://www.w3.org/TR/sparql11-query/

Subqueries

Data

```
@prefix : <http://people.example/> .

:alice :name "Alice", "Alice Foo", "A. Foo" .
:alice :knows :bob, :carol .
:bob :name "Bob", "Bob Bar", "B. Bar" .
:carol :name "Carol", "Carol Baz", "C. Baz" .
```

Query

```
SELECT ?y (MIN(?name) AS ?minName)
WHERE {
  ?y :name ?name .
} GROUP BY ?y
```

Bindings

?y	?name
:alice	"Alice"
:alice	"Alice Foo"
:alice	"A. Foo"
:bob	"Bob"
:bob	"Bob Bar"
:bob	"B. Bar"
:carol	"Carol"
:carol	"Carol Baz"
:carol	"C. Baz"

Result

y	minName
:alice	"A. Foo"
:bob	”B. Bar”
:carol	"C. Baz”

slide by Pedro Szekely

http://www.w3.org/TR/sparql11-query/

Subqueries

Data

```
@prefix : <http://people.example/> .

:alice :name "Alice", "Alice Foo", "A. Foo" .
:alice :knows :bob, :carol .
:bob :name "Bob", "Bob Bar", "B. Bar" .
:carol :name "Carol", "Carol Baz", "C. Baz" .
```

Query

```
PREFIX : <http://people.example/>
SELECT ?y ?minName
WHERE {
  :alice :knows ?y .
  {
    SELECT ?y (MIN(?name) AS ?minName)
    WHERE {
      ?y :name ?name .
    } GROUP BY ?y
  }
}
```

Subquery Result

y	minName
:alice	"A. Foo"
:bob	"Bob Bar”
:carol	"C. Baz”

slide by Pedro Szekely, Jose Luis Ambite

http://www.w3.org/TR/sparql11-query/

Subqueries

Data

```
@prefix : <http://people.example/> .

:alice :name "Alice", "Alice Foo", "A. Foo" .
:alice :knows :bob, :carol .
:bob :name "Bob", "Bob Bar", "B. Bar" .
:carol :name "Carol", "Carol Baz", "C. Baz" .
```

Query

```
PREFIX : <http://people.example/>
PREFIX : <http://people.example/>
SELECT ?y ?minName
WHERE {
  :alice :knows ?y .
  {
    SELECT ?y (MIN(?name) AS ?minName)
    WHERE {
      ?y :name ?name .
    } GROUP BY ?y
  }
}
```

y
:bob
:carol

Subquery Result

Subquery Result

y	minName
:alice	"A. Foo"
:bob	"Bob Bar”
:carol	"C. Baz”

slide by Pedro Szekely, Jose Luis Ambite

http://www.w3.org/TR/sparql11-query/

Subqueries

Query

```
PREFIX : <http://people.example/>
SELECT ?y ?minName
WHERE {
  :alice :knows ?y .
  {
    SELECT ?y (MIN(?name) AS ?minName)
    WHERE {
      ?y :name ?name .
    } GROUP BY ?y
  }
}
```

Return a name (the one with the lowest sort order) for all the people that know Alice and have a name.

Subquery Result

y
:bob
:carol

JOIN

Subquery Result

y	minName
:alice	"A. Foo"
:bob	"Bob Bar”
:carol	"C. Baz”

=

Result

y	minName
:bob	"B. Bar"
:carol	"C. Baz"

slide by Pedro Szekely, Jose Luis Ambite

http://www.w3.org/TR/sparql11-query/

Subqueries

Data

```
@prefix : <http://people.example/> .

:alice :name "Alice", "Alice Foo", "A. Foo" .
:alice :knows :bob, :carol .
:bob :name "Bob", "Bob Bar", "B. Bar" .
:carol :name "Carol", "Carol Baz", "C. Baz" .
```

Query

```
PREFIX : <http://people.example/>
SELECT ?y ?minName
WHERE {
  :alice :knows ?y .
  {
    SELECT ?y (MIN(?name) AS ?minName)
    WHERE {
      ?y :name ?name .
    } GROUP BY ?y
  }
}
```

Result

y	minName
:bob	"B. Bar"
:carol	"C. Baz"

slide by Pedro Szekely, Jose Luis Ambite

http://www.w3.org/TR/sparql11-query/

RDF Dataset =

default graph

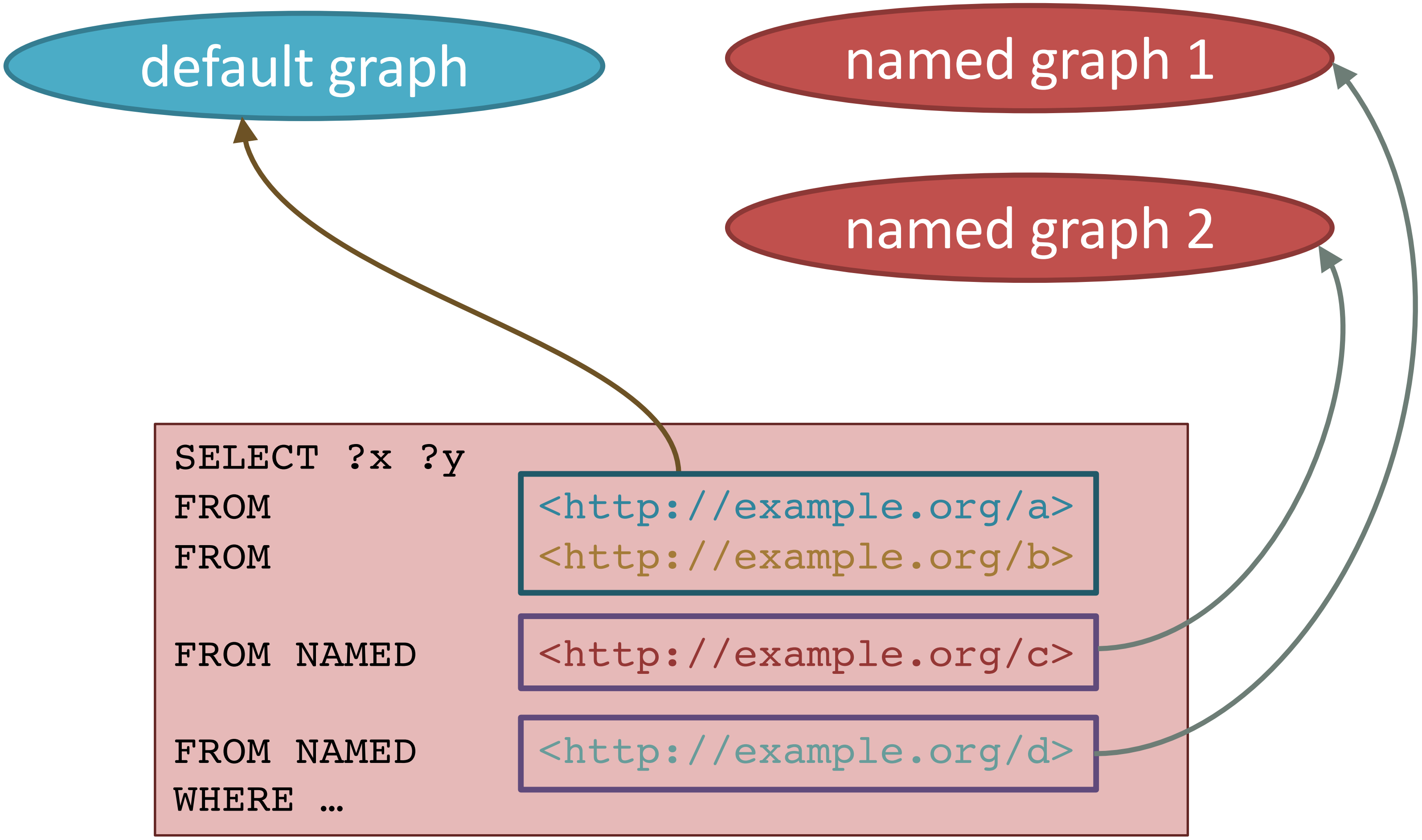
+ named graph 1

+ named graph 2

+ ...

... the SPARQL queries seen so far target the default graph

Specifying Datasets Explicitly



default graph

named graph 1

named graph 2

```
SELECT ?x ?y
FROM        <http://example.org/a>
FROM        <http://example.org/b>

FROM NAMED  <http://example.org/c>

FROM NAMED  <http://example.org/d>
WHERE …
```

Default graph = "RDF merged" graphs in FROM clauses

RDF merge = union N-triples, renaming blank nodes to not conflict

slide by Pedro Szekely, Jose Luis Ambite

RDF Datasets

Default Graph

```
@prefix dc: <http://purl.org/dc/elements/1.1/> .

<http://example.org/bob>    dc:publisher  "Bob" .
<http://example.org/alice>  dc:publisher  "Alice" .
```

Provenance

Named Graph 1: `http://example.org/bob`

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

_:a foaf:name "Bob" .
_:a foaf:mbox <mailto:bob@oldcorp.example.org> .
```

Named Graph 2: `http://example.org/alice`

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

_:a foaf:name "Alice" .
_:a foaf:mbox <mailto:alice@work.example.org> .
```

Graphs can be merged

[Note that blank nodes _:a represent different objects in each of the named graphs!]

slide by Pedro Szekely, Jose Luis Ambite

http://www.w3.org/TR/sparql11-query/

Separate graphs enable you to reason about who said what and when

(provenance)

slide by Pedro Szekely

Provenance Reasoning

prefixes omitted to save space

Default Graph

```
g:graph1 dc:publisher "Bob" .
g:graph1 dc:date "2004-12-06"^^xsd:date .

g:graph2 dc:publisher "Bob" .
g:graph2 dc:date "2005-01-10"^^xsd:date .
```

Named Graph 1 RDF collected on 2004-12-06

```
_:a foaf:name "Alice" .
_:a foaf:mbox <mailto:alice@work.example> .

_:b foaf:name "Bob" .
_:b foaf:mbox <mailto:bob@oldcorp.example.org> .
```

Named Graph 2 RDF collected on 2005-01-10

```
_:a foaf:name "Alice" .
_:a foaf:mbox <mailto:alice@work.example> .

_:b foaf:name "Bob" .
_:b foaf:mbox <mailto:bob@newcorp.example.org> .
```

slide by Pedro Szekely

http://www.w3.org/TR/sparql11-query/

Default Graph

```
g:graph1 dc:publisher "Bob" .
g:graph1 dc:date "2004-12-06"^^xsd:date .

g:graph2 dc:publisher "Bob" .
g:graph2 dc:date "2005-01-10"^^xsd:date .
```

Named Graph 1

```
_:a foaf:name "Alice" .
_:a foaf:mbox <mailto:alice@work.example> .

_:b foaf:name "Bob" .
_:b foaf:mbox <mailto:bob@oldcorp.example.org> .
```

Named Graph 2

```
_:a foaf:name "Alice" .
_:a foaf:mbox <mailto:alice@work.example> .

_:b foaf:name "Bob" .
_:b foaf:mbox <mailto:bob@newcorp.example.org> .
```

?

Result

name	mbox	date
“Bob”	<mailto:bob@oldcorp.example.org>	"2004-12-06"^^xsd:date
“Bob”	<mailto:bob@newcorp.example.org>	"2005-01-10"^^xsd:date

slide by Pedro Szekely

http://www.w3.org/TR/sparql11-query/

Default Graph

```
g:graph1 dc:publisher "Bob" .
g:graph1 dc:date "2004-12-06"^^xsd:date .
g:graph2 dc:publisher "Bob" .
g:graph2 dc:date "2005-01-10"^^xsd:date .
```

Named Graph 1

```
_:a foaf:name "Alice" .
_:a foaf:mbox <mailto:alice@work.example> .
_:b foaf:name "Bob" .
_:b foaf:mbox <mailto:bob@oldcorp.example.org> .
```

Named Graph 2

```
_:a foaf:name "Alice" .
_:a foaf:mbox <mailto:alice@work.example> .
_:b foaf:name "Bob" .
_:b foaf:mbox <mailto:bob@newcorp.example.org> .
```

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX dc:   <http://purl.org/dc/elements/1.1/>
SELECT ?name ?mbox ?date
FROM NAMED <http://example.org/alice>
FROM NAMED <http://example.org/bob>
WHERE
  {  ?g dc:publisher ?name ; dc:date ?date .
     GRAPH ?g
       { ?person foaf:name ?name ; foaf:mbox ?mbox }
  }
```

from Default Graph

from Named Graphs

name	mbox	date
"Bob"	<mailto:bob@oldcorp.example.org>	"2004-12-06"^^xsd:date
"Bob"	<mailto:bob@newcorp.example.org>	"2005-01-10"^^xsd:date

slide by Pedro Szekely, Jose Luis Ambite

http://www.w3.org/TR/sparql11-query/

Take the following four named graphs...

```
<http://grapha.com> = { <a1> <p> <a2> . }
<http://graphb.com> = { <b1> <p> <b2> . }
<http://graphc.com> = { <c1> <p> <c2> . }
<http://graphd.com> = { <d1> <p> <d2> . }
```

```
SELECT ?s WHERE { ?s <p> ?o }
```

will often give <a1>, <b1>, <c1>, <d1>, but this depends on what the default graph is implicitly defined as.

```
FROM <http://grapha.com>
SELECT ?s WHERE { ?s <p> ?o }
```

should give <a1>.

```
FROM NAMED <http://grapha.com>
SELECT ?s WHERE { ?s <p> ?o }
```

should give nothing.

```
FROM <http://grapha.com>
FROM <http://graphb.com>
FROM NAMED <http://graphc.com>
FROM NAMED <http://graphd.com>
SELECT ?s WHERE { ?s <p> ?o }
```

should give <a1>, <b1>.

```
FROM <http://grapha.com>
FROM <http://graphb.com>
FROM NAMED <http://graphc.com>
FROM NAMED <http://graphd.com>
SELECT ?s WHERE { GRAPH ?g { ?s <p> ?o }}
```

should give <c1>, <d1>.

```
FROM <http://grapha.com>
FROM NAMED <http://graphb.com>
SELECT ?s WHERE {
   GRAPH <http://grapha.com> { ?s <p> ?o }}
```

should give nothing. ...etc.

http://answers.semanticweb.com/questions/11509/what-is-the-difference-between-from-and-from-named

Controlling the Output

```
SELECT ?name
WHERE { ?x foaf:name ?name ; :empId ?emp }
ORDER BY ?name DESC(?emp)
```

Ordering the solutions

```
PREFIX foaf:    <http://xmlns.com/foaf/0.1/>
SELECT DISTINCT ?name
WHERE { ?x foaf:name ?name }
```

Eliminating duplicates

```
SELECT  ?name
WHERE   { ?x foaf:name ?name }
LIMIT   5
OFFSET  10
```

Selecting a range of results

slide by Pedro Szekely

http://www.w3.org/TR/sparql11-query/

SPARQL

SELECT

Get data

ASK

Yes/No questions

CONSTRUCT

Create RDF

DESCRIBE

Get some information

http://www.w3.org/TR/sparql11-query/

SELECT vs CONSTRUCT

SELECT

Result: table of bindings

x	n
<http://example.com/b>	3.0
<http://example.com/a>	1

CONSTRUCT

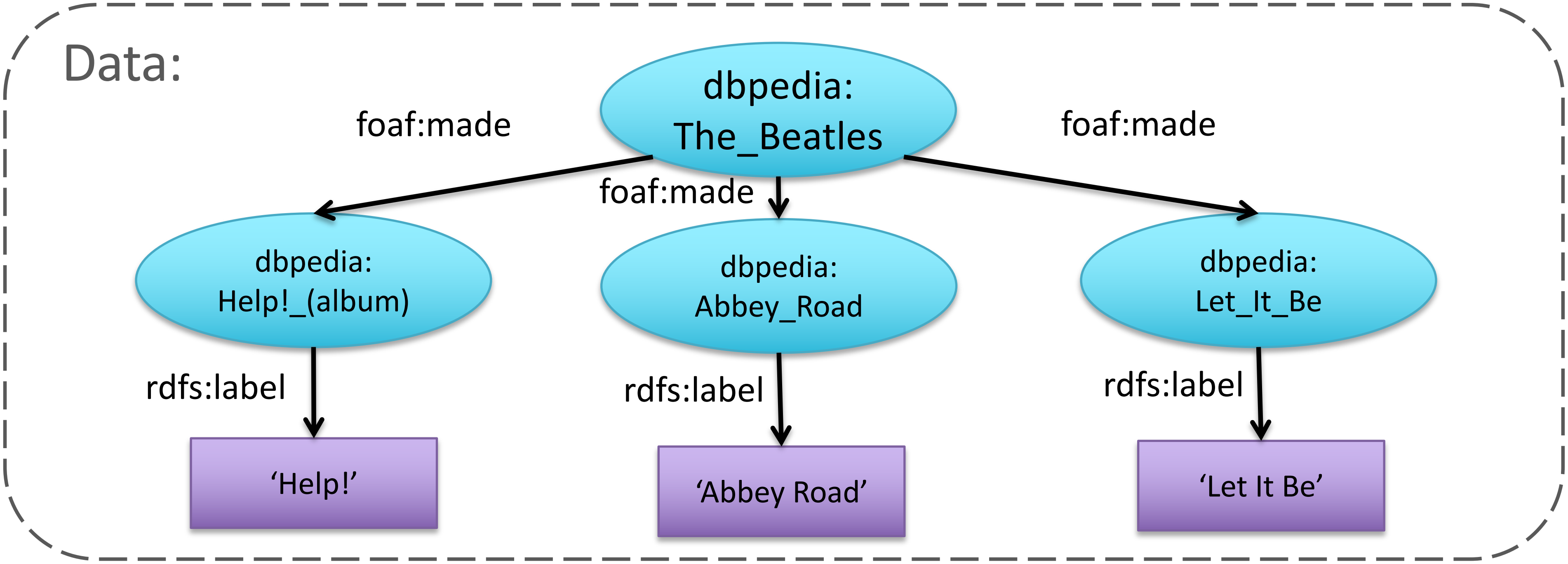
Result: RDF

```
@prefix vcard: <http://www.w3.org/2001/vcard-rdf/3.0#> .

_:v1 vcard:N          _:x .
_:x vcard:givenName  "Alice" .
_:x vcard:familyName "Hacker" .

_:v2 vcard:N          _:z .
_:z vcard:givenName  "Bob" .
_:z vcard:familyName "Hacker" .
```

slide by Pedro Szekely

http://www.w3.org/TR/sparql11-query/

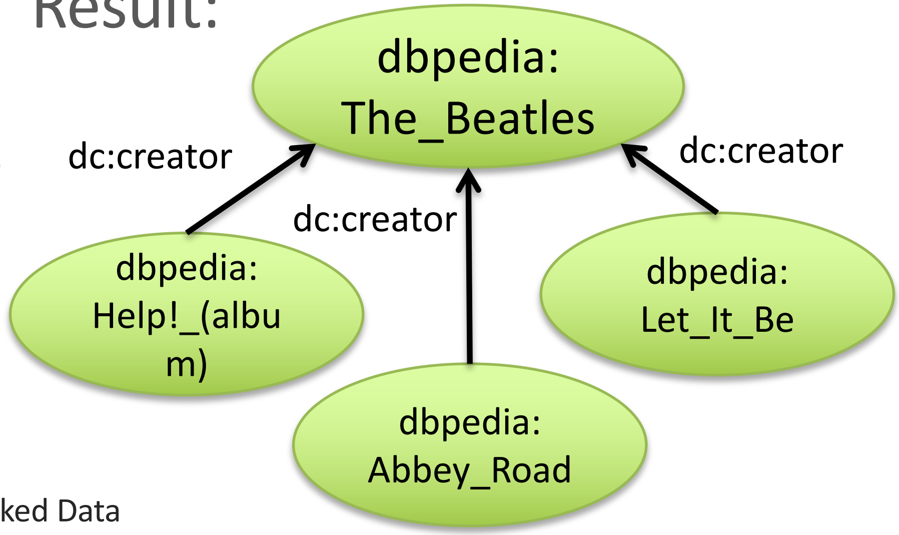
Query Form: CONSTRUCT



Query:

```
CONSTRUCT {
  ?album dc:creator dbpedia:The_Beatles .}
WHERE {
  dbpedia:The_Beatles foaf:made ?album .}
```

Result:



Query Form: CONSTRUCT

Subsets of results

- It is possible to combine the query with **solution modifiers** (ORDER BY, LIMIT, OFFSET)

Query: *Create the dc:creator descriptions for the 10 most recent albums and their tracks recorded by 'The Beatles'.*

```
PREFIX dbpedia: <http://dbpedia.org/resource/>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX music-ont: <http://purl.org/ontology/mo/>
PREFIX dc: <http://purl.org/dc/elements/1.1/>
CONSTRUCT {
  ?album dc:creator dbpedia:The_Beatles .
  ?track dc:creator dbpedia:The_Beatles .}
WHERE {
  dbpedia:The_Beatles foaf:made ?album .
  ?album music-ont:track ?track ;
         dc:date ?date .
} ORDER BY DESC(?date)
  LIMIT 10
```

Query Form: CONSTRUCT

Assigning Variables

- The value of an expression can be added to a solution mapping by binding a new variable (which can be further used and returned)
- The BIND form allows to assign a value to a variable from a BGP

Query: *Calculate the duration of the tracks from ms to s, and store the value using the dbpedia-ont:runtime property .*

```
PREFIX dbpedia: <http://dbpedia.org/resource/>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX music-ont: <http://purl.org/ontology/mo/>
PREFIX dbpedia-ont: <http://dbpedia.org/ontology/>
CONSTRUCT { ?track dbpedia-ont:runtime ?secs .}
WHERE {
  dbpedia:The_Beatles foaf:made ?album .
  ?album music-ont:track ?track .
  ?track music-ont:duration ?duration .
  BIND((?duration/1000) AS ?secs) .}
```

CONSTRUCTing a Graph

Data

```
_:a    foaf:givenname   "Alice" .
_:a    foaf:family_name "Hacker" .
_:b    foaf:firstname   "Bob" .
_:b    foaf:surname     "Hacker" .
```

Query

```
PREFIX foaf:    <http://xmlns.com/foaf/0.1/>
PREFIX vcard:   <http://www.w3.org/2001/vcard-rdf/3.0#>
CONSTRUCT { ?x  vcard:N _:v .
            _:v vcard:givenName ?gname .
            _:v vcard:familyName ?fname }
WHERE {
    { ?x foaf:firstname ?gname } UNION { ?x foaf:givenname   ?gname } .
    { ?x foaf:surname   ?fname } UNION { ?x foaf:family_name ?fname } .
 }
```

Result Data

```
@prefix vcard: <http://www.w3.org/2001/vcard-rdf/3.0#> .

_:v1 vcard:N          _:x .
_:x vcard:givenName  "Alice" .
_:x vcard:familyName "Hacker" .

_:v2 vcard:N          _:z .
_:z vcard:givenName  "Bob" .
_:z vcard:familyName "Hacker" .
```

Convert from
“foaf”
to
“vcard”

slide by Pedro Szekely

Query Form: ASK

- Namespaces are added with the ‘PREFIX’ directive
- Statement patterns that make up the graph are specified between brackets (“{}”)

Query: *Is Paul McCartney member of ‘The Beatles’?*

```
PREFIX dbpedia: <http://dbpedia.org/resource/>
PREFIX dbpedia-ont: <http://dbpedia.org/ontology/>
ASK WHERE { dbpedia:The_Beatles dbpedia-ont:bandMember
                           dbpedia:Paul_McCartney.}
```

Results:

true

Query: *Is Elvis Presley member of ‘The Beatles’?*

```
PREFIX dbpedia: <http://dbpedia.org/resource/>
PREFIX dbpedia-ont: <http://dbpedia.org/ontology/>
ASK WHERE { dbpedia:The_Beatles dbpedia-ont:bandMember
                           dbpedia:Elvis_Presley.}
```

Results:

false

Federated Queries

- Allows merging data distributed across the Web

Data available at

http://people.example.org/sparql

```
:people15   foaf:name     "Alice" .
```

Data

```
<http://example.org/myfoaf/I>
<http://xmlns.com/foaf/0.1/knows>
<http://example.org/people15> .
```

Query

```
PREFIX foaf:   <http://xmlns.com/foaf/0.1/>
SELECT ?name
FROM <http://example.org/myfoaf.rdf>
WHERE
{
  <http://example.org/myfoaf/I> foaf:knows ?person .
  SERVICE <http://people.example.org/sparql> {
    ?person foaf:name ?name . }
}
```

Result Data

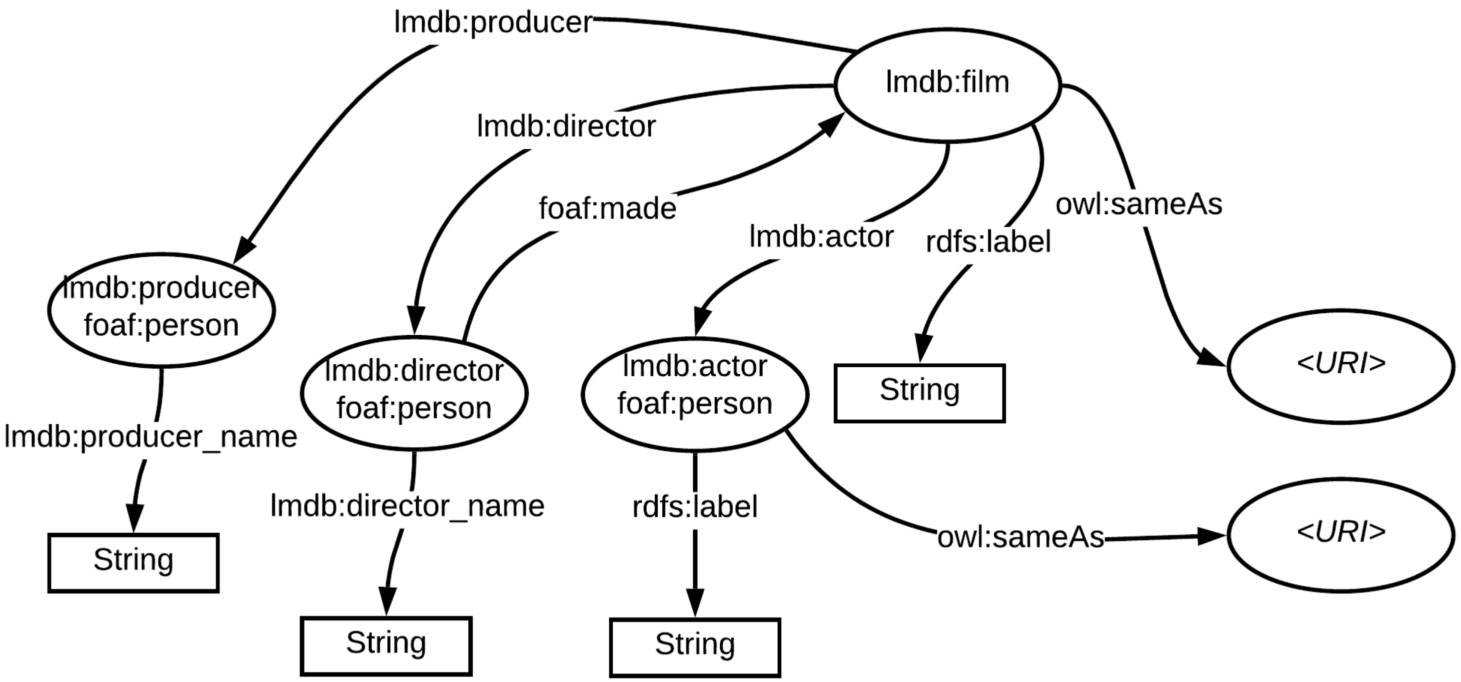
name
"Alice"

slide by Basel Shbita

https://www.w3.org/TR/sparql11-federated-query/

LMDB Exercise 4

- URIs of actors
  - names
  - bios (!)

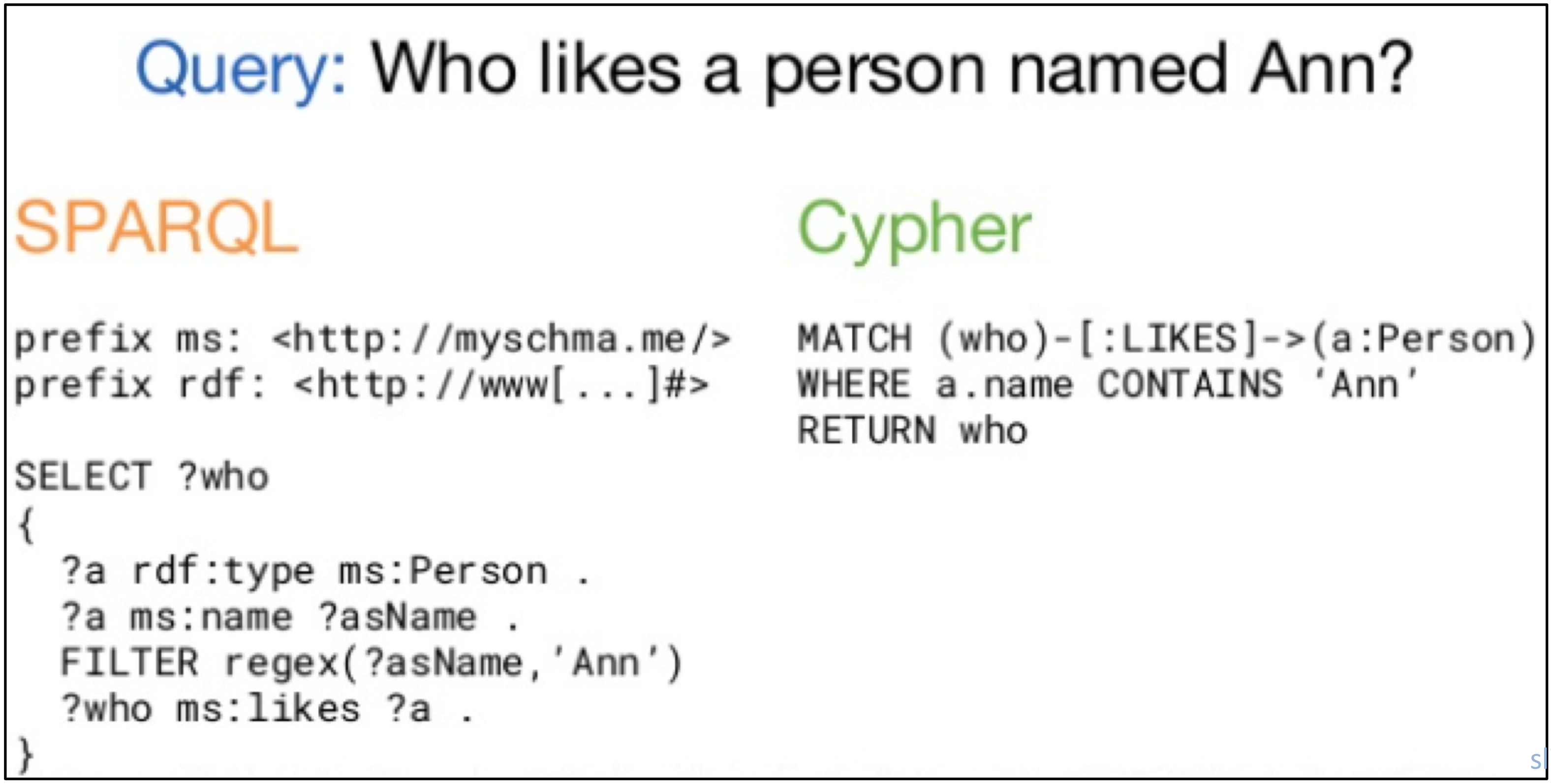


Agenda

- Intro
- SPARQL
- Cypher (Neo4j)
  - Demo
- Wikidata

Cypher (Neo4j)

- Neo4j
  - Graph Database (not an RDF triple-store)
  - Follows the “Labeled Property Graph Data Model“
- Cypher
  - Neo4j’s QUERY LANGUAGE



Query: Who likes a person named Ann?

SPARQL

```
prefix ms: <http://myschma.me/>
prefix rdf: <http://www[...]#>

SELECT ?who
{
  ?a rdf:type ms:Person .
  ?a ms:name ?asName .
  FILTER regex(?asName,'Ann')
  ?who ms:likes ?a .
}
```

Cypher

```
MATCH (who)-[:LIKES]->(a:Person)
WHERE a.name CONTAINS ‘Ann’
RETURN who
```

slide by Basel Shbita

Agenda

- Intro
- SPARQL
- Cypher (Neo4j)
- Wikidata
  - Why we Wikidata
  - The Wikidata Model
  - Demo

Why we Wikidata

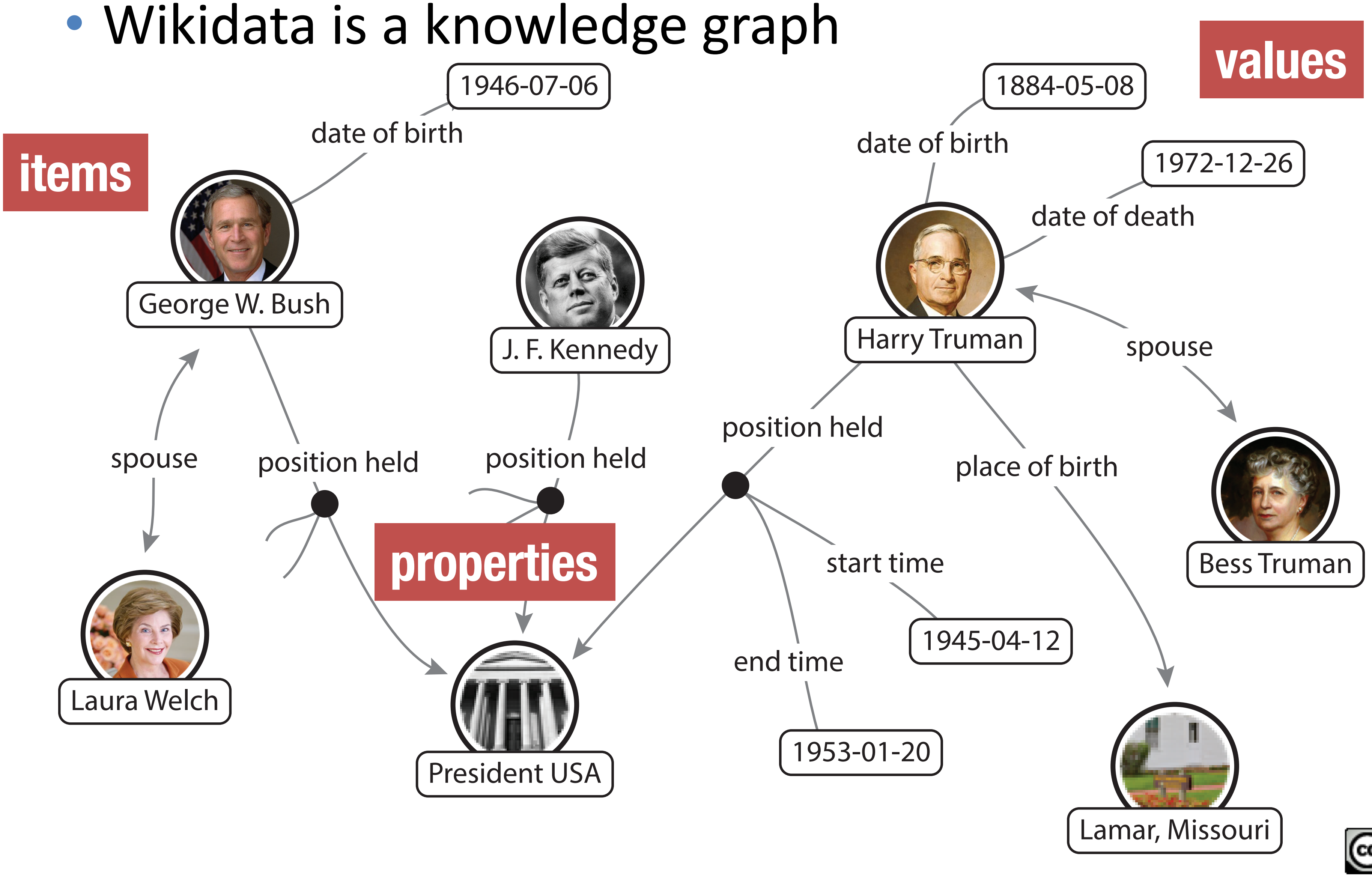
- Free
  - The data in Wikidata is published under the Creative Commons Public Domain Dedication 1.0.
- Collaborative
  - Data is entered and maintained by Wikidata editors, who decide on the rules of content creation and management. Automated bots also enter data into Wikidata.
- Multilingual
  - Editing, consuming, browsing, and reusing the data is fully multilingual. Data entered in any language is immediately available in all other languages.
- A secondary database
  - Wikidata records not just statements, but also their sources, and connections to other databases.
- Collecting structured data
  - Imposing a high degree of structured organization allows for easy reuse of data by Wikimedia projects and third parties, and enables computers to process and “understand” it.
- Support for Wikimedia wikis
  - Wikidata assists Wikipedia with more easily maintainable information boxes and links to other languages.
- Anyone in the world
  - Anyone can use Wikidata for any number of different ways by using its application programming interface, *the SPARQL endpoint and the JSON and RDF dumps.*

https://www.wikidata.org/wiki/Wikidata:Introduction

slide by Pedro Szekely

The Wikidata Data Model

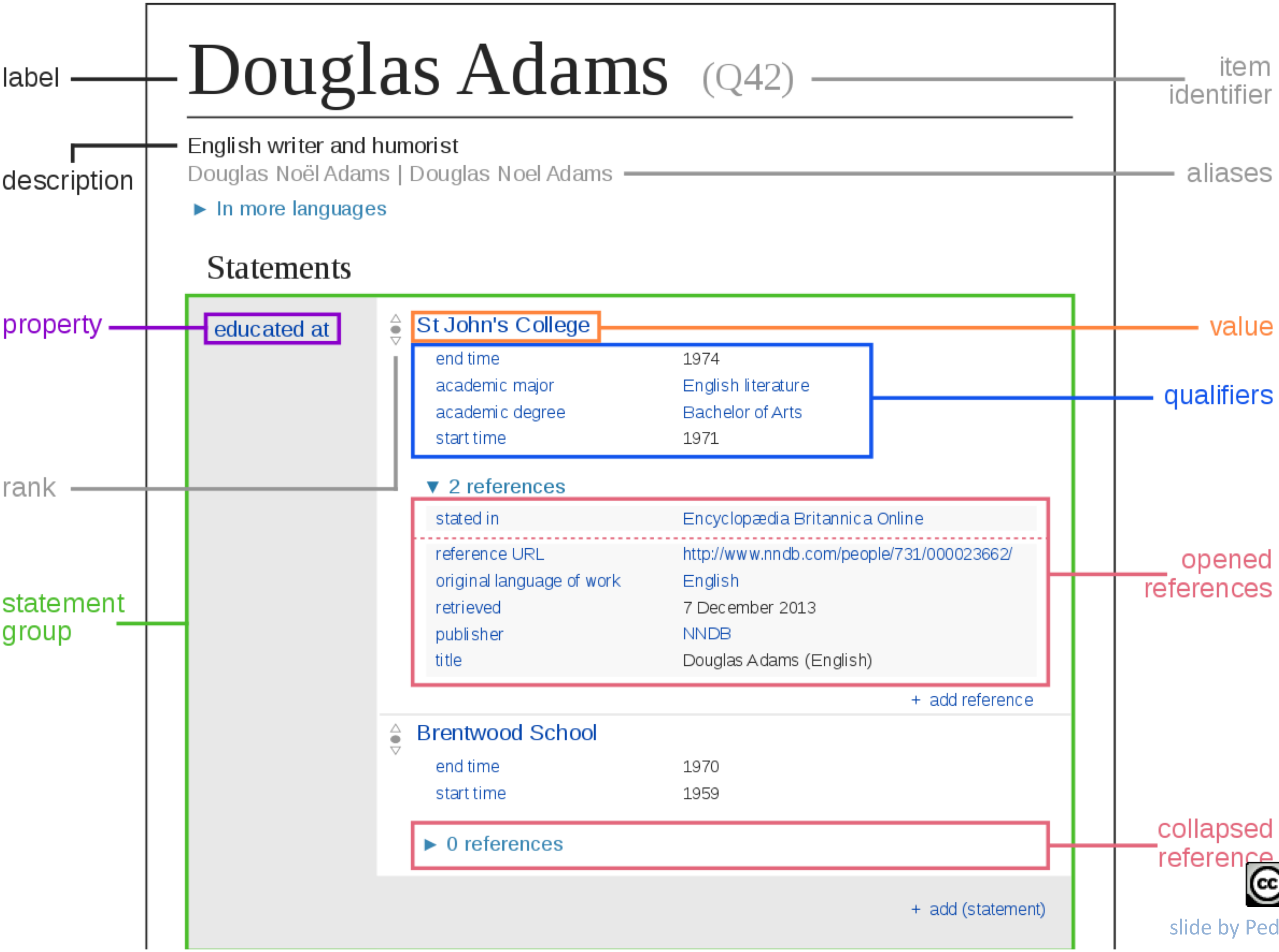
- Wikidata is a knowledge graph



https://www.wikidata.org/wiki/Wikidata:Introduction

slide by Pedro Szekely

Data Model



Douglas Adams (Q42)

English writer and humorist

Douglas Noël Adams | Douglas Noel Adams

► In more languages

Statements

educated at

St John's College

end time	1974
academic major	English literature
academic degree	Bachelor of Arts
start time	1971

▼ 2 references

stated in	Encyclopædia Britannica Online

reference URL	http://www.nndb.com/people/731/000023662/
original language of work	English
retrieved	7 December 2013
publisher	NNDB
title	Douglas Adams (English)

+ add reference

Brentwood School

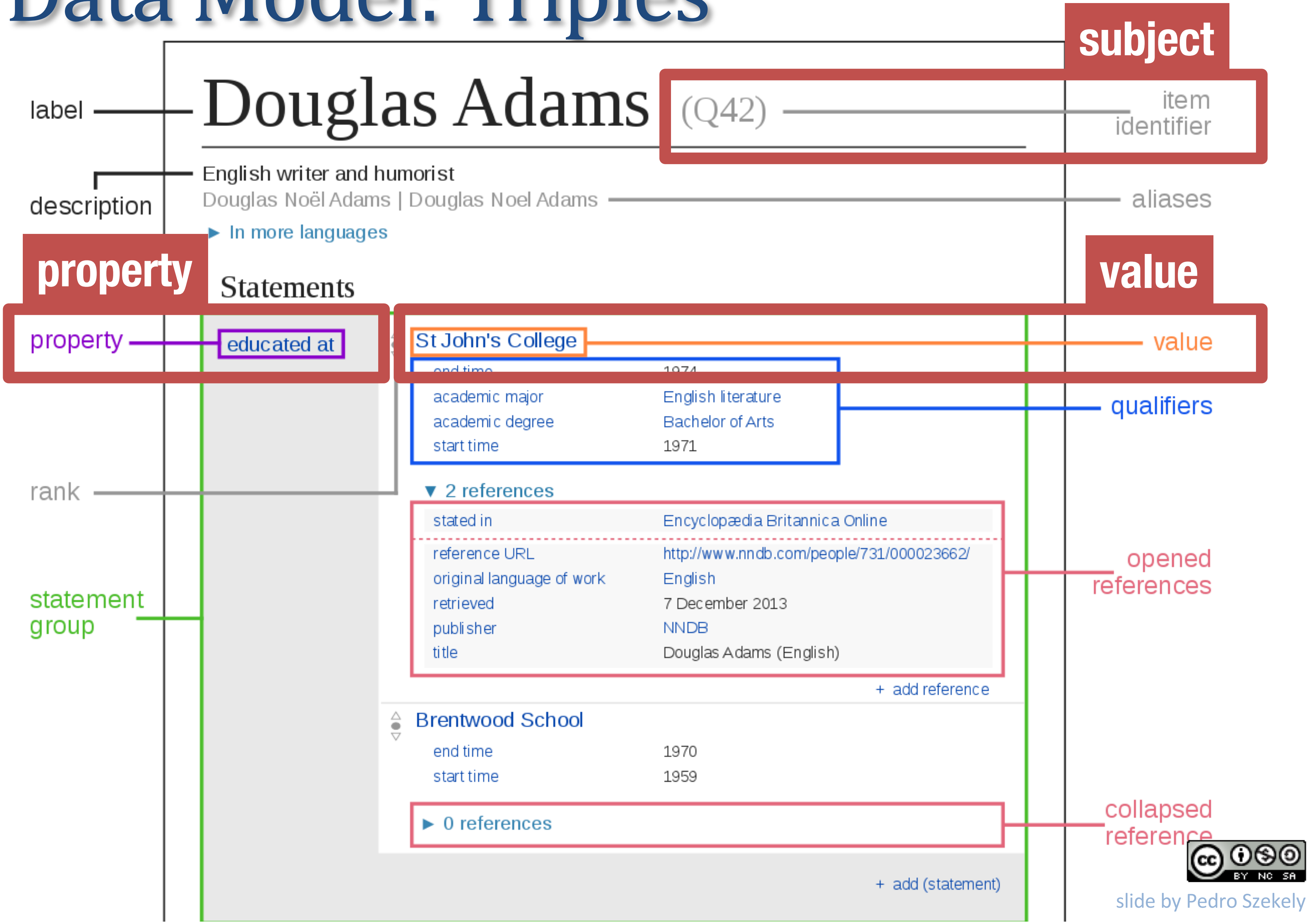
end time	1970
start time	1959

► 0 references

+ add (statement)

slide by Pedro Szekely

Data Model: Triples



Douglas Adams (Q42)

English writer and humorist

Douglas Noël Adams | Douglas Noel Adams

▶ In more languages

Statements

educated at

St John's College

end time	1974
academic major	English literature
academic degree	Bachelor of Arts
start time	1971

▼ 2 references

stated in	Encyclopædia Britannica Online
reference URL	http://www.nndb.com/people/731/000023662/
original language of work	English
retrieved	7 December 2013
publisher	NNDB
title	Douglas Adams (English)

+ add reference

Brentwood School

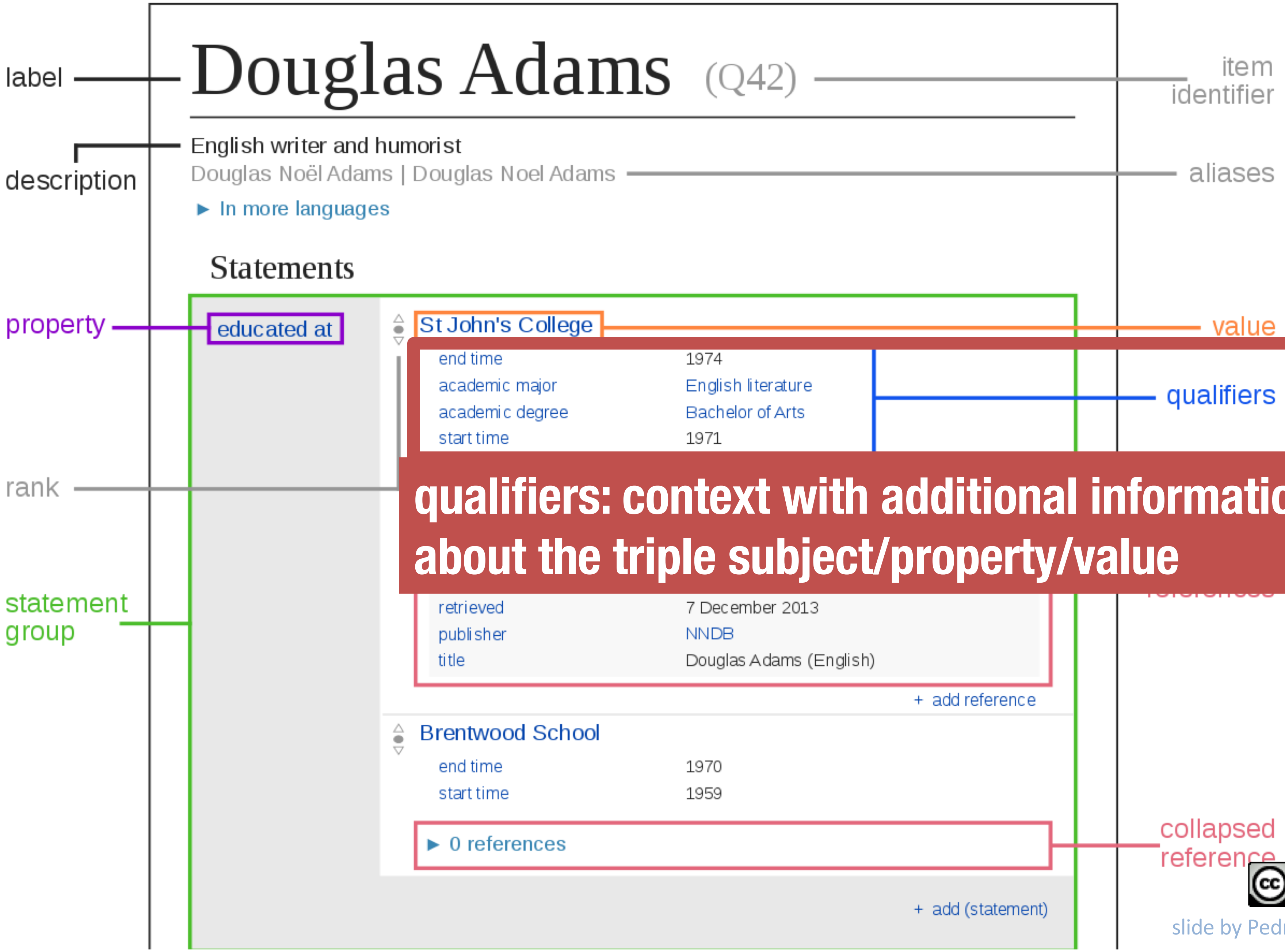
end time	1970
start time	1959

▶ 0 references

+ add (statement)

slide by Pedro Szekely

Data Model: Qualifiers



Douglas Adams (Q42)

English writer and humorist

Douglas Noël Adams | Douglas Noel Adams

▶ In more languages

Statements

educated at

St John's College

end time	1974
academic major	English literature
academic degree	Bachelor of Arts
start time	1971

retrieved	7 December 2013
publisher	NNDB
title	Douglas Adams (English)

+ add reference

Brentwood School

end time	1970
start time	1959

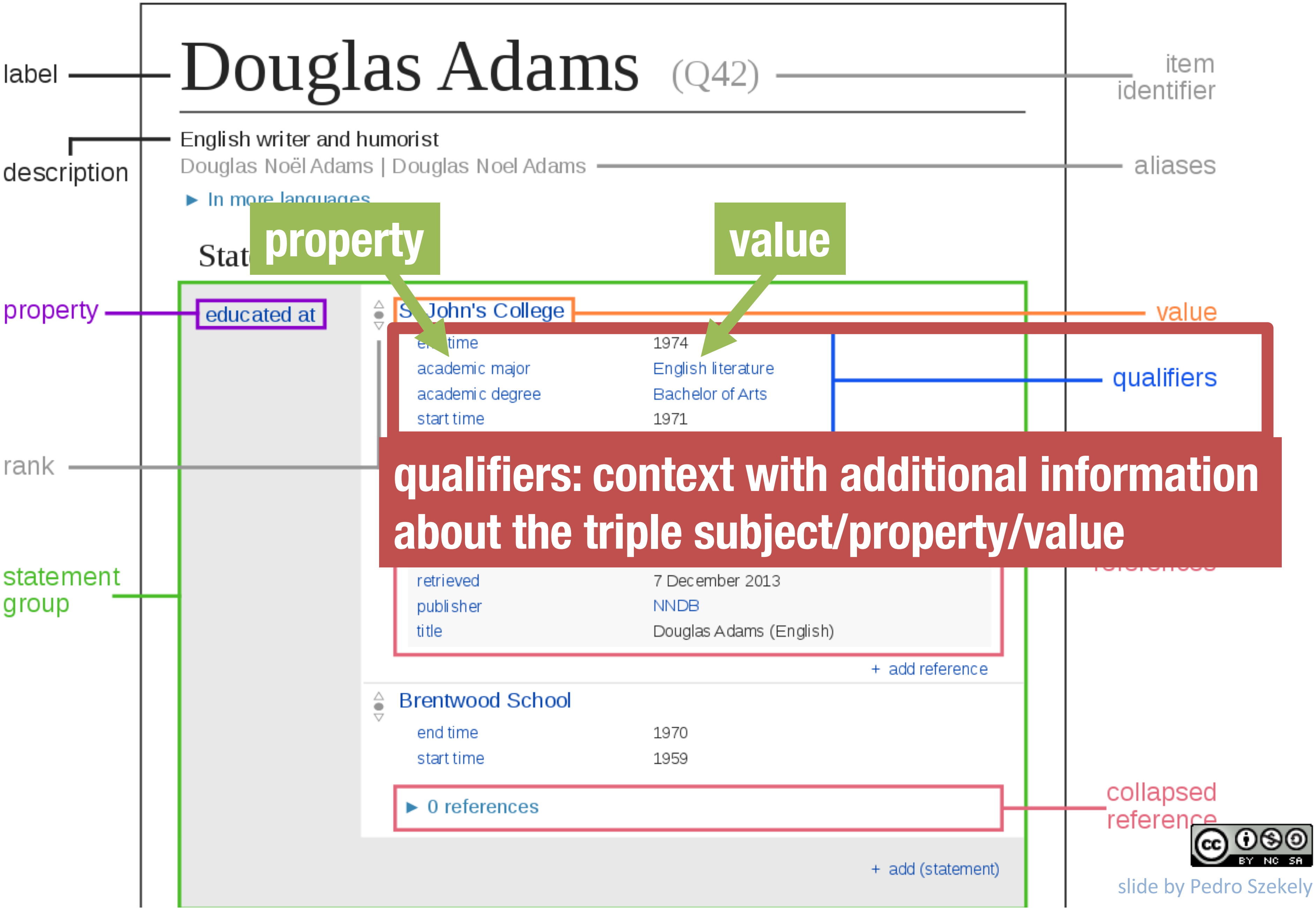
▶ 0 references

+ add (statement)

qualifiers: context with additional information about the triple subject/property/value

slide by Pedro Szekely

Data Model: Qualifiers = property + value



Douglas Adams (Q42)

English writer and humorist

Douglas Noël Adams | Douglas Noel Adams

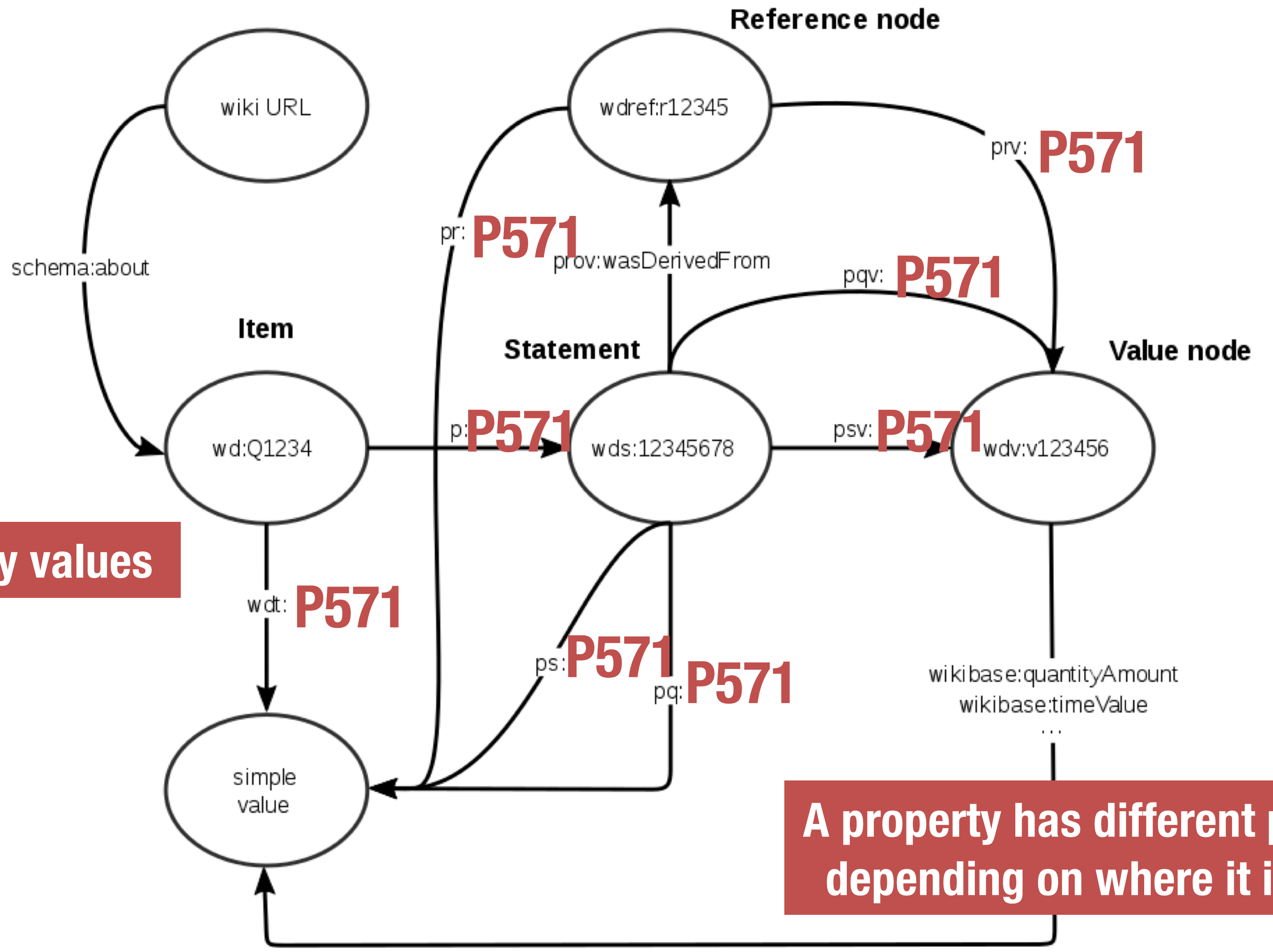
▶ In more languages

Stat

educated at	St John's College	
	end time	1974
	academic major	English literature
	academic degree	Bachelor of Arts
	start time	1971
	retrieved	7 December 2013
	publisher	NNDB
	title	Douglas Adams (English)
	+ add reference	
	Brentwood School	
	end time	1970
	start time	1959
	▶ 0 references	
	+ add (statement)	

qualifiers: context with additional information about the triple subject/property/value

Wikidata RDF Model



truthy values

A property has different prefixes depending on where it is used

slide by Pedro Szekely