NDBI049: **Query Languages**

http://www.ksi.mff.cuni.cz/~svoboda/courses/NDBI049/

Lecture 11

# SPARQL

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# Lecture Outline

**RDF stores**

- Introduction
- Linked Data

**RDF data format**

- Framework, notations

**SPARQL query language**

- Graph patterns
- Filter constraints
- Solution modifiers
- Aggregation
- Query forms

# RDF Stores

Data model

- **RDF triples**
  - Components: **subject**, **predicate**, and **object**
  - Each triple represents a statement about a real-world entity
- Triples can be viewed as **graphs**
  - **Vertices** for subjects and objects
  - **Edges** directly correspond to individual statements

Query language

- **SPARQL**: *SPARQL Protocol and RDF Query Language*

Representatives

- Apache **Jena**, **rdf4j** (Sesame), Algebraix
- *Multi-model*: **MarkLogic**, OpenLink **Virtuoso**

# Linked Data

**Linked Data**

- Method of **publishing structured and interlinked data** in a way that allows for an **automated processing by programs** rather than browsing by human readers

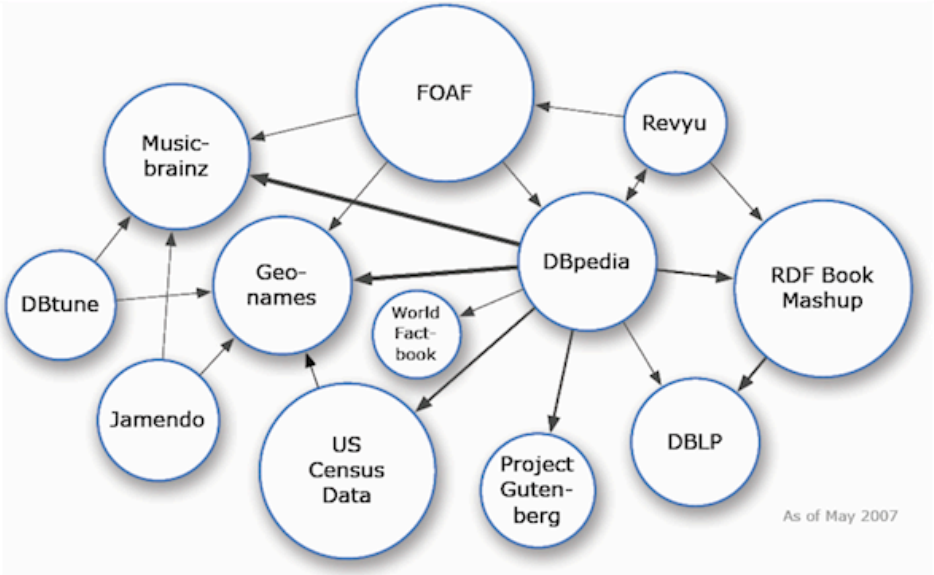
**Principles** of Linked Open Data

- **Identify resources** using URIs or even better using **URLs**
- **Publish data** about resources in standard formats via **HTTP**
- Mutually **interlink resources** to form Web of Data
- Release the data under an **open licence**

# Linked Open Data Cloud

**May 2007**

- 12 datasets




**October 2007**

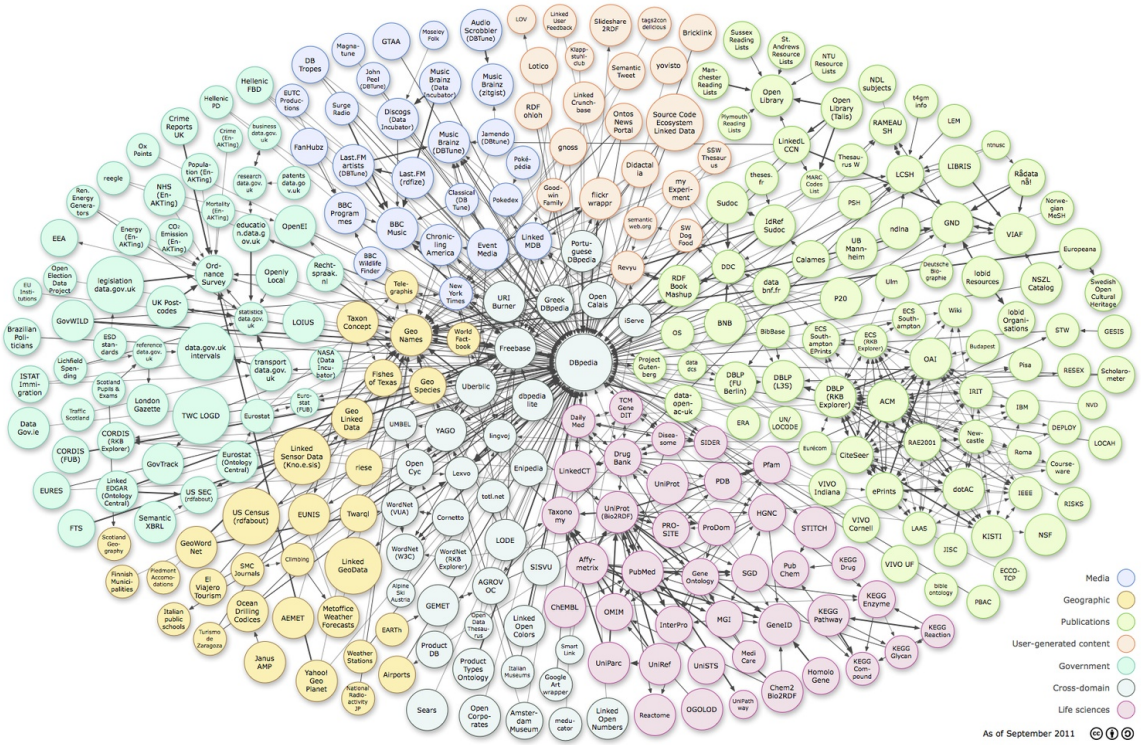
- 25 datasets, 2 billion triples, 2 million links

Source: http://lod-cloud.net/

# Linked Open Data Cloud

**September 2011**

- 295 datasets, 31 billion triples, 504 million links

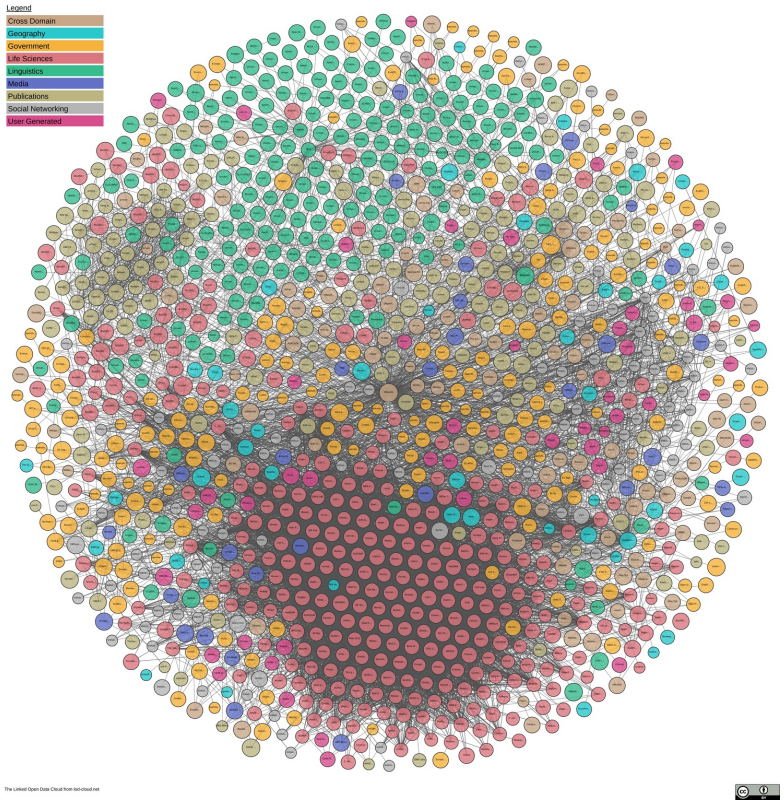



Source: http://lod-cloud.net/

# Linked Open Data Cloud

**March 2019**

- 1239 datasets, 16 thousand dataset links




Source: http://lod-cloud.net/

# RDF

Resource Description Framework

# Introduction

**RDF** = *Resource Description Framework*

- Language for **representing information about resources** in the World Wide Web
  - + a family of related technologies, languages, specifications, …
  - Used in the context of the **Semantic Web**, **Linked Data**, …
- Developed by **W3C**
- Started in 1997
- Versions: 1.0 and 1.1
- W3C recommendations
  - https://www.w3.org/TR/rdf11-concepts/
    - Concepts and Abstract Syntax
  - https://www.w3.org/TR/rdf11-mt/
    - Semantics

# Statements

**Resource** = any real-world entity

- Referents = **resources identified by IRIs**
  - Physical things, documents, abstract concepts, …
  - E.g.: `http://db.cz/movies/medvidek`
- Values = **resources for literals**
  - Numbers, strings, …
  - E.g.: `Medvídek`

**Statement** about resources = one RDF **triple**

- Three components: subject, predicate, and object

Examples

```
<http://db.cz/movies/medvidek>
<http://db.cz/terms#title>
"Medvídek" .
```

```
<http://db.cz/movies/medvidek>
<http://db.cz/terms#actor>
<http://db.cz/actors/trojan> .
```

# Statements

Triple components

- **Subject**
  - Describes a resource the given statement is about
  - *IRI* or *blank node identifier*
- **Predicate**
  - Describes the property or characteristic of the subject
  - *IRI*
- **Object**
  - Describes the value of that property
  - *IRI* or *blank node identifier* or *literal*

*Although triples are inspired by natural languages, they have nothing to do with NLP (Natural Language Processing)*

# Example

```
<http://db.cz/movies/medvidek>
  <http://db.cz/terms#title> "Medvídek" .

<http://db.cz/movies/medvidek>
  <http://db.cz/terms#actor> <http://db.cz/actors/machacek> .
<http://db.cz/movies/medvidek>
  <http://db.cz/terms#actor> <http://db.cz/actors/trojan> .

<http://db.cz/movies/medvidek>
  <http://db.cz/terms#year> "2007" .

<http://db.cz/movies/medvidek>
  <http://db.cz/terms#director> _:n18 .
_:n18
  <http://db.cz/terms#firstname> "Jan" .
_:n18
  <http://db.cz/terms#lastname> "Hřebejk" .
```

# Identifiers and Literals

**IRI** = *Internationalized Resource Identifier*

- Absolute (not relative) IRIs with optional fragment identifiers
- RFC 3987
- Unicode characters
- Examples
  - `http://db.cz/movies/medvidek`
  - `http://db.cz/terms#actor`
  - `mailto:svoboda@ksi.mff.cuni.cz`
  - `urn:issn:0167-6423`
- **URLs are often used** in practice $\rightarrow$ information about given resources are then intended to be published / retrieved via standard HTTP

# Identifiers and Literals

**Literals**

- Plain values
  - `"Medvídek"`, `"2007"`
- Typed values
  - `"2007"^^<http://www.w3.org/2001/XMLSchema#int>`
  - XML Schema simple data types are usually used
    - `xsd:string`, `xsd:integer`, `xsd:date`, …
- Strings with language tags
  - `"Medvídek"@cs`
- *Types and language tags cannot be mutually combined*

# Identifiers and Literals

**Blank node identifiers**

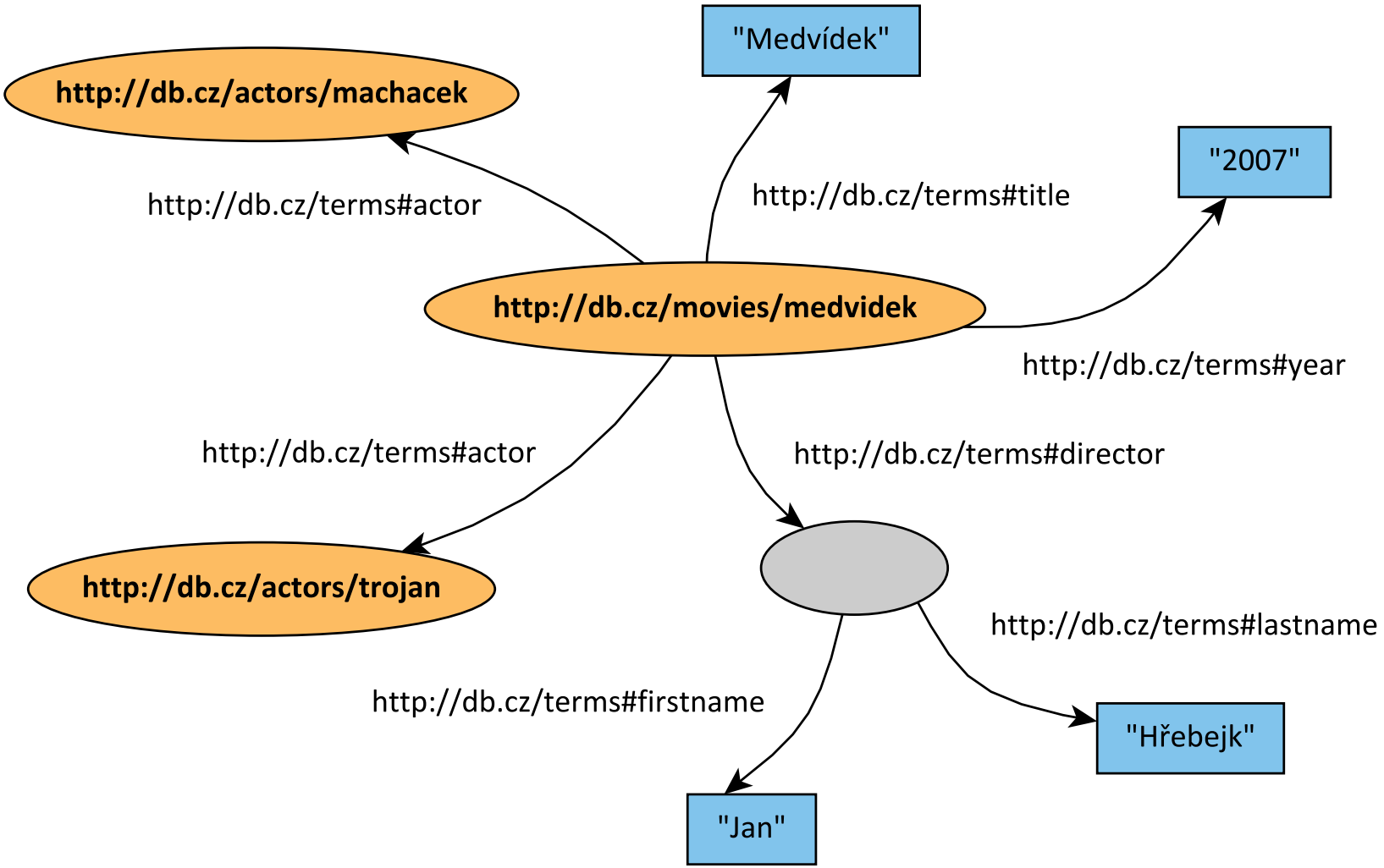
- Blank nodes (anonymous resources)
  - Allow to express statements about resources without explicitly naming (identifying) them
- **Blank node identifiers** only have **local scope of validity**
  - E.g. within a given file, query expression, …
- Particular syntax depends on a serialization format
  - E.g.: `_:node18`

# Data Model

**Directed labeled multigraph**

- Vertices
  - **One vertex** for each distinct **subject and object**
- Edges
  - **One edge** for each individual **triple**
    - Edges are directed $subject \xrightarrow{predicate} object$
    - Property names (predicate IRIs) are used as edge labels

# Example


"Medvídek"
http://db.cz/actors/machacek
"2007"
http://db.cz/terms#actor
http://db.cz/terms#title
http://db.cz/movies/medvidek
http://db.cz/terms#year
http://db.cz/terms#actor
http://db.cz/terms#director
http://db.cz/actors/trojan
http://db.cz/terms#lastname
http://db.cz/terms#firstname
"Hřebejk"
"Jan"

# Serialization

Available approaches

- **N-Triples** notation
  - https://www.w3.org/TR/n-triples/
- **Turtle** notation (*Terse RDF Triple Language*)
  - https://www.w3.org/TR/turtle/
- **RDF/XML** notation
  - XML syntax for RDF
  - https://www.w3.org/TR/rdf-syntax-grammar/
- **JSON-LD** notation
  - JSON-based serialization for Linked Data
  - https://www.w3.org/TR/json-ld/
- …

# N-Triples Notation

RDF **N-Triples** notation = *A line-based syntax for an RDF graph*

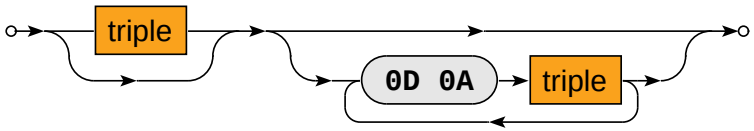
- Simple, line-based, plain text format
- File extension: ***.rdf**
- https://www.w3.org/TR/n-triples/

Example

- *Already presented…*

**Document**

- Statements are terminated by dots, delimited by EOL

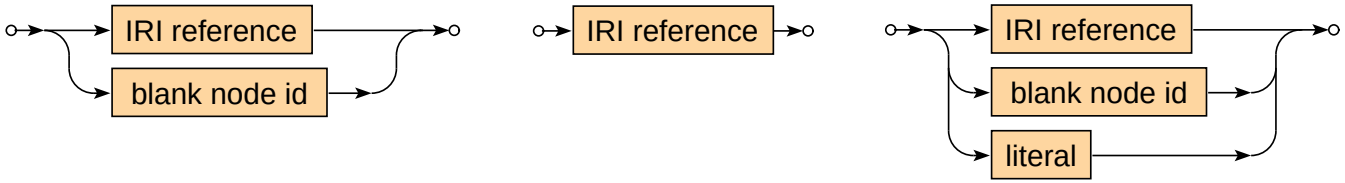


# N-Triples Notation

## Statement

- Individual triple components are delimited by spaces


**Triple components**: subject, predicate, object

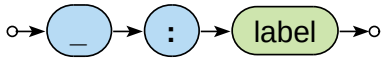


# N-Triples Notation

**IRI reference**

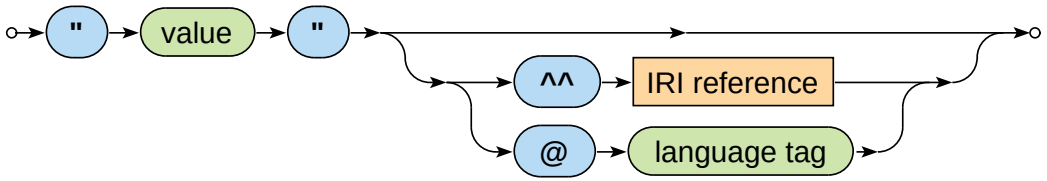
- IRIs are enclosed in angle brackets


**Blank node** identifier




**Literal**

- Literals are enclosed in double quotes



# Turtle Notation

**Turtle** = *Terse RDF Triple Language*

- Compact format with various abbreviations
- File extension: ***.ttl**
- Content type: `text/turtle`
- https://www.w3.org/TR/turtle/

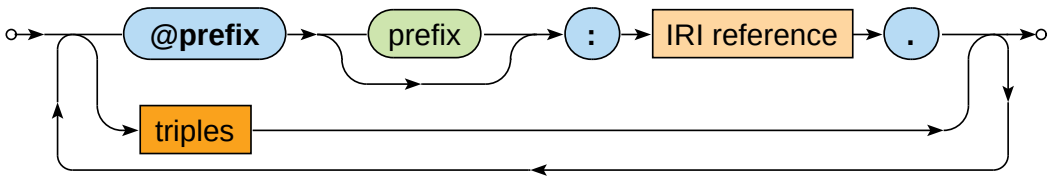
Example

```
@prefix i: <http://db.cz/terms#> .
@prefix m: <http://db.cz/movies/> .
@prefix a: <http://db.cz/actors/> .
m:medvidek
  i:title "Medvídek" ;
  i:actor a:machacek , a:trojan ;
  i:year 2007 ;
  i:director [ i:firstname "Jan" ; i:lastname "Hřebejk" ] .
```

# Turtle Notation

**Document**

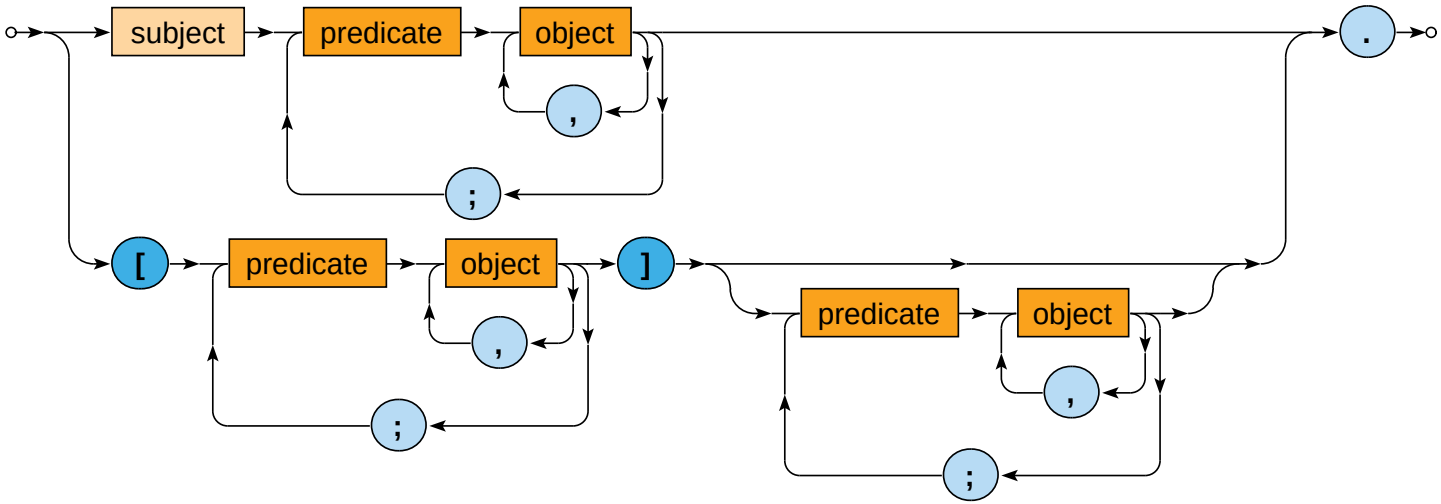
- Contains a **sequence of triples and/or declarations**
- Prefix declarations
  - **Prefixed names** can then be used instead of full IRI references
- Groups of triples
  - Individual groups are terminated by dots



# Turtle Notation

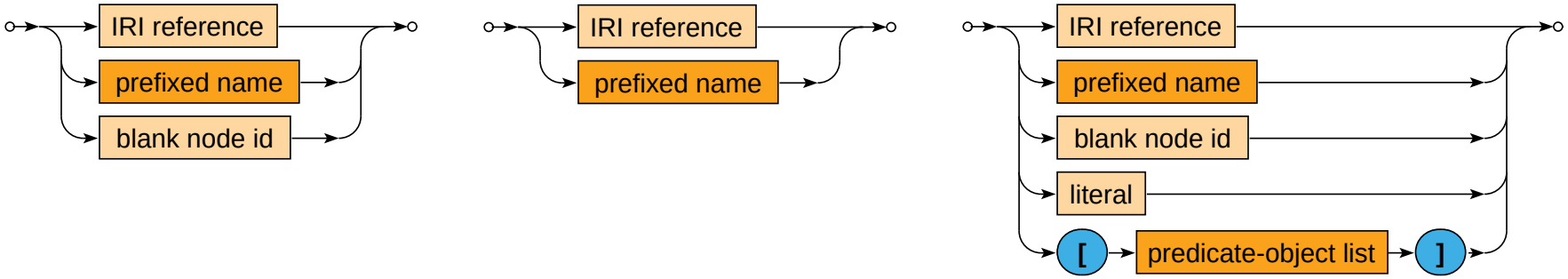
## Triples

- Triples sharing the same subject and object or at least the same subject can be *grouped* together
  - object list for a **shared subject and predicate**
  - predicate-object list for a **shared subject**
- Brackets can be used to define blank nodes

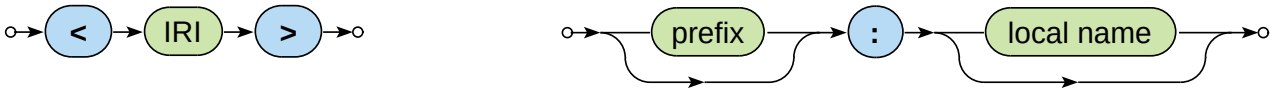


# Turtle Notation

**Triple components**: subject, predicate, object



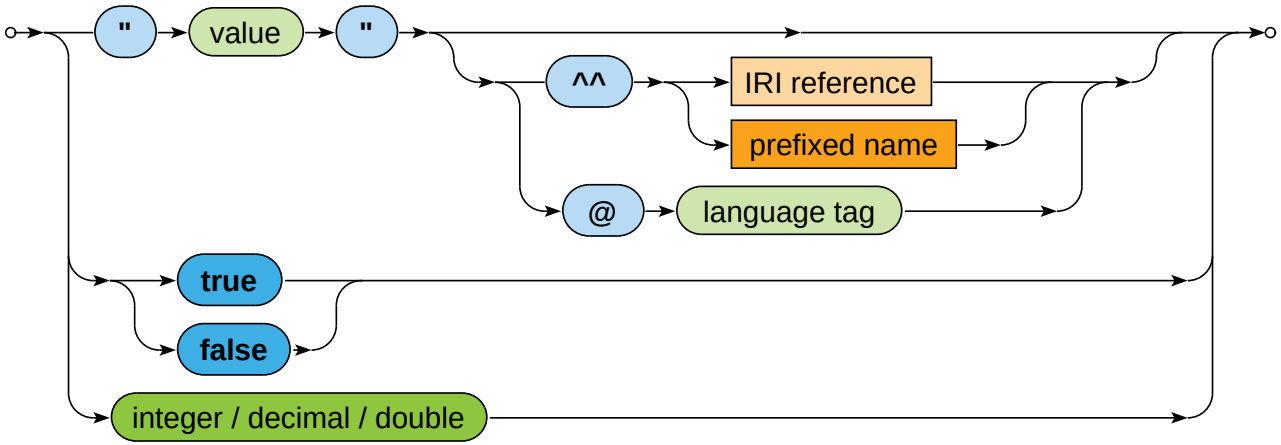

## IRI reference / prefixed name



# Turtle Notation

## Literal

- Traditional literals
  + new abbreviated forms of numeric and boolean literals



# Example

## Example revisited

```
@prefix i: <http://db.cz/terms#> .
@prefix m: <http://db.cz/movies/> .
@prefix a: <http://db.cz/actors/> .
m:medvidek
  i:title "Medvídek" ;
  i:actor a:machacek , a:trojan ;
  i:year 2007 ;
  i:director [ i:firstname "Jan" ; i:lastname "Hřebejk" ] .
```

# RDF Conclusion

**RDF statements**

- Subject, predicate, and object components

**Schema languages**

- RDFS (*RDF Schema*)
- OWL (*Web Ontology Language*)

**Query languages**

- SPARQL (*SPARQL Protocol and RDF Query Language*)

# SPARQL Query Language

# SPARQL

**SPARQL Query Language**

- Query language for RDF data
  - **Graph patterns**, optional graph patterns, **subqueries**, negation, **aggregation**, value constructors, …
- Versions: 1.0 (2008), **1.1** (2013)
- W3C recommendations
  - https://www.w3.org/TR/sparql11-query/
  - Altogether 11 parts: query language, update facility, federated queries, protocol, result formats, …

# Sample Data

Graph of **movies** <http://db.cz/movies>

```
@prefix i: <http://db.cz/terms#> .
@prefix m: <http://db.cz/movies/> .
@prefix a: <http://db.cz/actors/> .
m:vratnelahve
  rdf:type i:Movie ; i:title "Vratné lahve" ;
  i:year 2006 ;
  i:actor a:sverak , a:machacek .
m:samotari
  rdf:type i:Movie ; i:title "Samotáři" ;
  i:year 2000 ;
  i:actor a:schneiderova , a:trojan , a:machacek .
m:medvidek
  rdf:type i:Movie ; i:title "Medvídek" ;
  i:year 2007 ;
  i:actor a:machacek , a:trojan ;
  i:director "Jan Hřebejk" .
m:zelary
  rdf:type i:Movie .
```

# Sample Data

Graph of **actors** <http://db.cz/actors>

```
@prefix i: <http://db.cz/terms#> .
@prefix a: <http://db.cz/actors/> .
a:trojan
  rdf:type i:Actor ;
  i:firstname "Ivan" ; i:lastname "Trojan" ;
  i:year 1964 .
a:machacek
  rdf:type i:Actor ;
  i:firstname "Jiří" ; i:lastname "Macháček" ;
  i:year 1966 .
a:schneiderova
  rdf:type i:Actor ;
  i:firstname "Jitka" ; i:lastname "Schneiderová" ;
  i:year 1973 .
a:sverak
  rdf:type i:Actor ;
  i:firstname "Zdeněk" ; i:lastname "Svěrák" ;
  i:year 1936 .
```

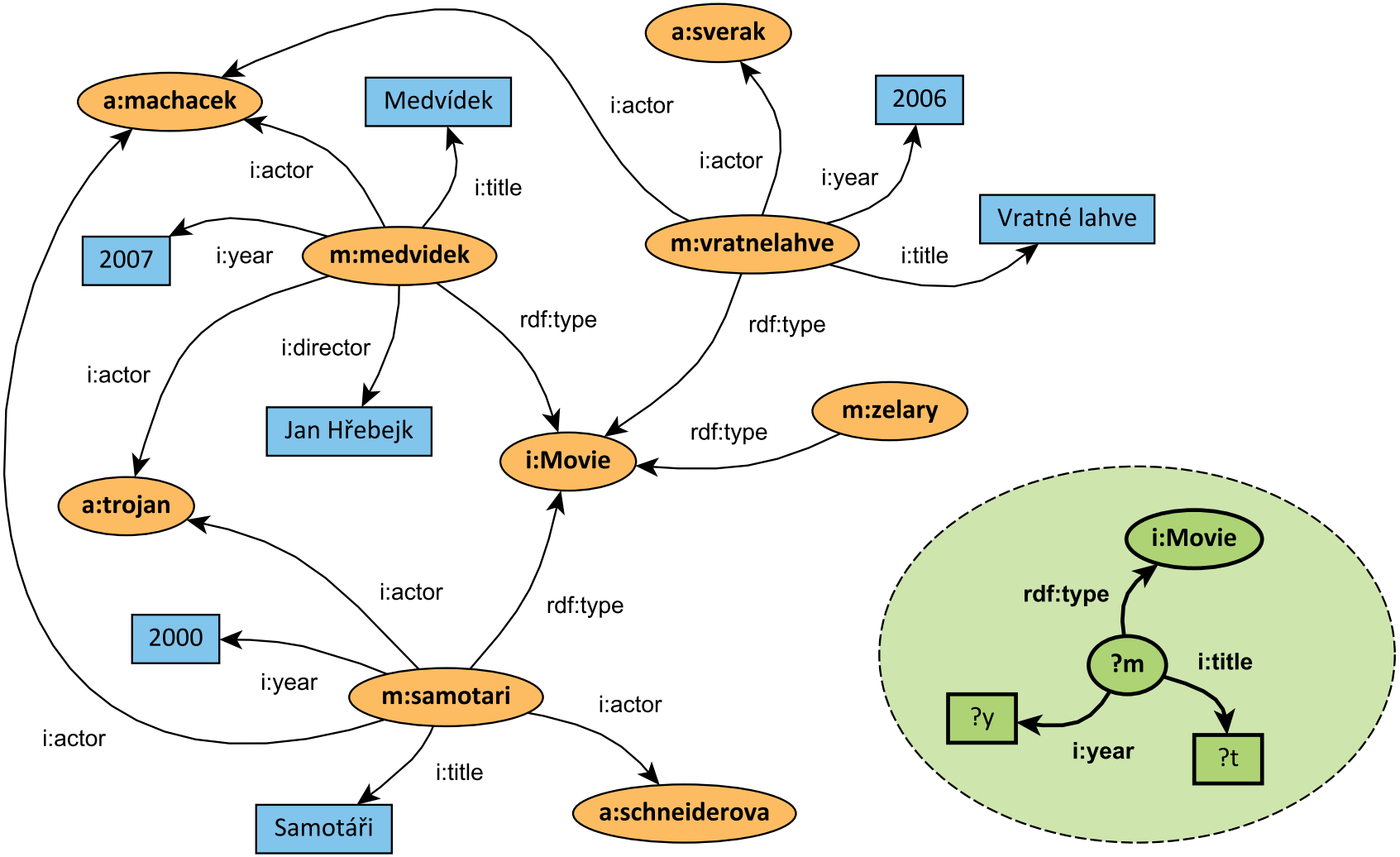
# Sample Query

Find all movies, return their titles and years they were filmed

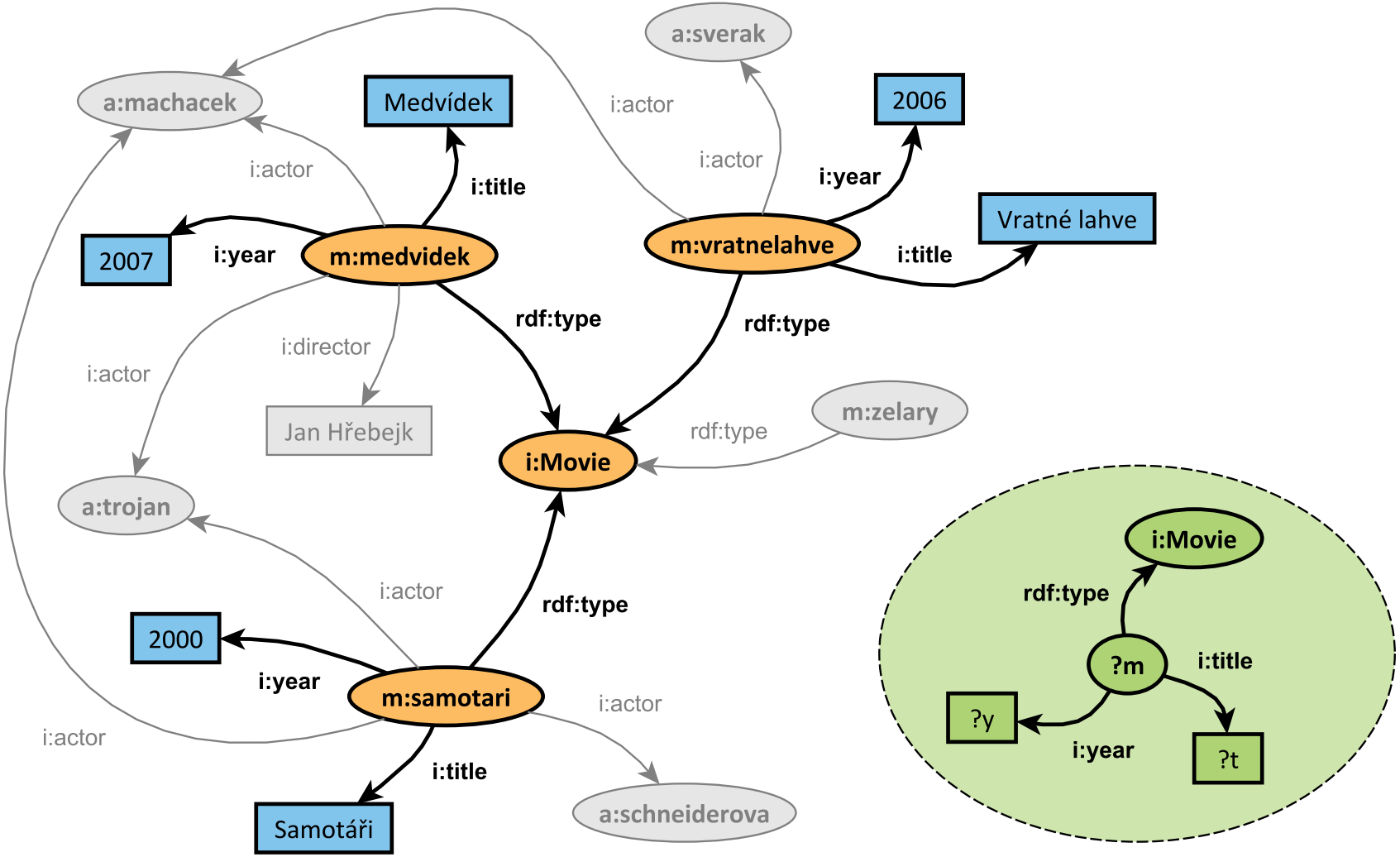
```
PREFIX i: <http://db.cz/terms#>
SELECT ?t ?y
FROM <http://db.cz/movies>
WHERE
  {
    ?m rdf:type i:Movie ;
       i:title ?t ;
       i:year ?y .
  }
ORDER BY ?y
```

| ?t | ?y |
|---|---|
| Samotáři | 2000 |
| Vratné lahve | 2006 |
| Medvídek | 2007 |

# Sample Query



# Sample Query



# Graph Pattern Matching

Graph patterns

- **Basic graph pattern**
  - Based on ordinary **triples with variables**
    - `?variable` or `$variable`
- More complicated graph patterns
  - E.g. group, optional, minus, …

**Graph pattern matching**

- Our goal is to find all **subgraphs of the data graph that are matched by the query graph pattern**
  - I.e. subgraphs of the data graph that are identical to the query graph pattern with variables substituted by particular terms
- One **matching subgraph** = one **solution** = one **row of a table**

# Graph Pattern Matching

**Query result** = **solution sequence** = ordered multiset of solutions

| ?t | ?y |
|---|---|
| Samotáři | 2000 |
| Vratné lahve | 2006 |
| Medvídek | 2007 |

```
{
  { (?t, "Samotáři"), (?y, "2000") },
  { (?t, "Vratné lahve"), (?y, "2006") },
  { (?t, "Medvídek"), (?y, "2007") }
}
```

**Solution** = set of variable bindings

| ?t | ?y |
|---|---|
| Samotáři | 2000 |

```
{ (?t, "Samotáři"), (?y, "2000") }
```

**Variable binding** = pair of a variable name and a value it is assigned

| ?t |
|---|
| Samotáři |

```
(?t, "Samotáři")
```

# Graph Pattern Matching

**Compatibility of solutions**

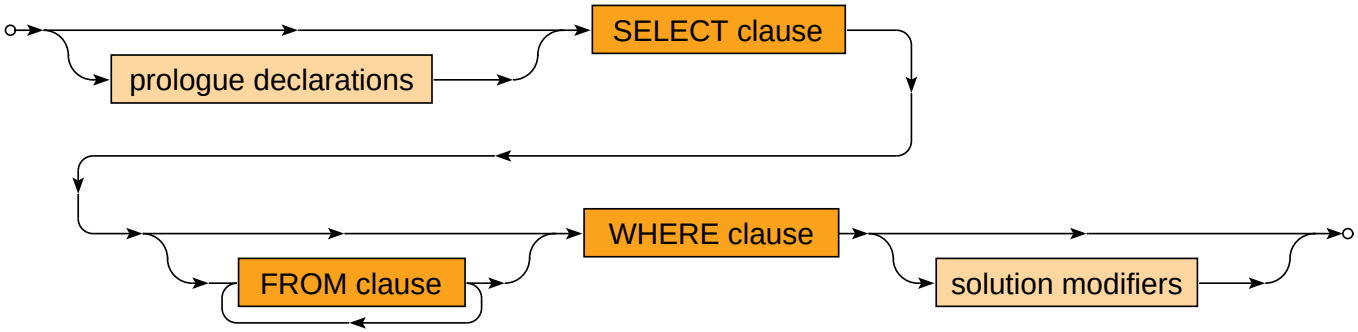
- Two solutions are mutually compatible if and only if all the variables they share are pairwise bound to identical values

Examples

- Compatible solutions
  - `{ (?m, m:samotari), (?t, "Samotáři") }`
    `{ (?m, m:samotari), (?y, "2000") }`
- Incompatible solutions
  - `{ (?m, m:samotari), (?t, "Samotáři") }`
    `{ (?m, m:medvidek), (?y, "2007") }`

# Select Queries

**SELECT** queries

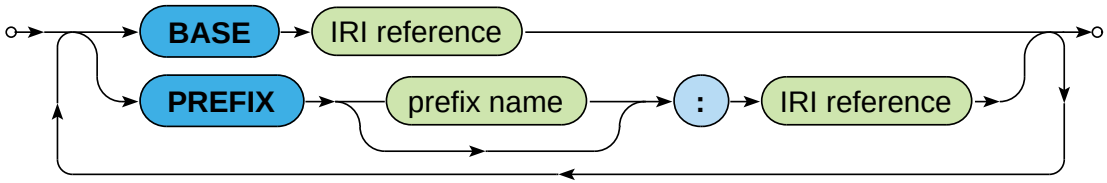



- **Prologue declarations** – `PREFIX`, `BASE`
- Main clauses
  - `SELECT` – **variables to be projected**
  - `FROM` – **data graphs to be queried**
  - `WHERE` – **graph patterns to be matched**
- **Solution modifiers** – `ORDER BY`, …

# Prologue Declarations

**Prologue declarations**

- Allow to simplify IRI references by declaring **base IRIs**




**BASE** clause

- At most **one base IRI** can be defined
- All **relative IRI references** are then related to this base IRI

**PREFIX** clause

- **Several base IRIs** are defined, each is associated with a name
  - These names must be distinct, one of them can be empty
- All **prefixed names** are then related to the respective base IRIs

# Prologue Declarations

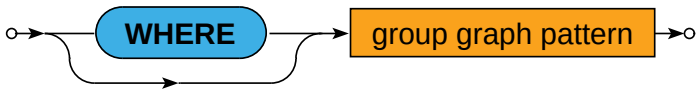
Examples

- When `BASE <http://db.cz/>` is defined,
  then a relative IRI reference `terms#Movie`
  is interpreted as `http://db.cz/terms#Movie`
- When `PREFIX i: <http://db.cz/>` is defined,
  then a prefixed name `i:terms#Movie`
  is interpreted as `http://db.cz/terms#Movie`

# Where Clause

**WHERE** clause

- Describes one **group graph pattern**




Types of **graph patterns**

- **Basic** – triple patterns to be matched
- **Group** – set of graph patterns to be matched
- **Optional** – graph pattern to be matched only if possible
- **Alternative** – two or more alternative graph patterns
- …

Graph patterns can be inductively combined into complex ones

# Basic Graph Pattern

**Basic** graph pattern (block of triples)

One or more triple patterns to be all matched

- Ordinary **triples** separated by `.`
  - E.g. `s p1 o1 . s p1 o2 . s p2 o3 .`
- May contain variables
  - E.g. `?var` or `$var`
- Turtle abbreviations also permitted
  - **Object lists** using `,` or **predicate-object lists** using `;`
    - E.g. `s p1 o1 , o2 ; p2 o3 .`
  - **Blank nodes** using `[]`
    - Act as non-selectable variables
    - I.e. do not enforce to be matched only by blank nodes in data!

# Basic Graph Pattern

Interpretation

- **All the involved triples must be matched**
  - I.e. we combine them as if they were in conjunction
  - More precisely…
    - Each triple pattern is evaluated to its solution sequence
    - **All combinations** of **compatible solutions** are then found
- Note that all the variables need to be bound
  - I.e. if any of the involved variables cannot be bound at all, then the entire basic graph pattern cannot be matched!

# Basic Graph Pattern: Example

Titles and years of all movies

```
PREFIX i: <http://db.cz/terms#>
SELECT ?t ?y
FROM <http://db.cz/movies>
WHERE
  {
    ?m rdf:type i:Movie . # triple 1
    ?m i:title ?t .       # triple 2
    ?m i:year ?y .        # triple 3
  }
```

| ?t | ?y |
|---|---|
| Vratné lahve | 2006 |
| Samotáři | 2000 |
| Medvídek | 2007 |

# Basic Graph Pattern: Example

$[\![t_1]\!] =$

| ?m |
|---|
| m:vratnelahve |
| m:samotari |
| m:medvidek |
| m:zelary |

$[\![t_2]\!] =$

| ?m | ?t |
|---|---|
| m:vratnelahve | Vratné lahve |
| m:samotari | Samotáři |
| m:medvidek | Medvídek |

$[\![t_3]\!] =$

| ?m | ?y |
|---|---|
| m:vratnelahve | 2006 |
| m:samotari | 2000 |
| m:medvidek | 2007 |

| ?t | ?y |
|---|---|
| Vratné lahve | 2006 |
| Samotáři | 2000 |
| Medvídek | 2007 |

# Equality of Terms

**IRIs**

**Literals**

- Plain values must be identical
- And when **types** / **language tags** are specified,
  these must be identical as well
  - E.g.: `"Medvídek"@cs != "Medvídek"`

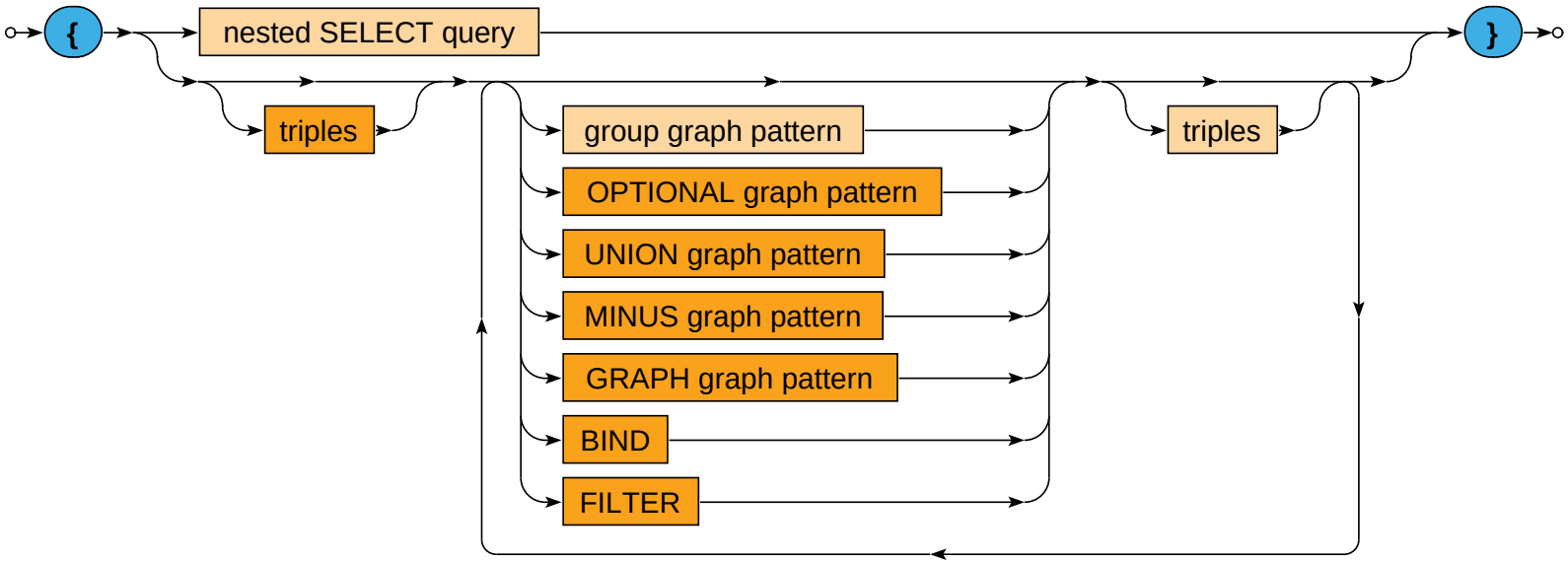
**Blank nodes**

- Blank nodes in query patterns act as **non-selectable variables**
- **Labels of blank nodes** in
  data graphs / query graph patterns / query results
  **may not refer to the same nodes despite being the same**
  - I.e. the scope of validity is always local only

# Group Graph Pattern

**Group** graph pattern

Set of graph patterns to be all matched



# Group Graph Pattern

Two modes

- **Nested SELECT query**
  - Only with SELECT and WHERE clauses and solution modifiers i.e. without FROM clause
- **Set of graph patterns** interleaved by **triple blocks**

Interpretation

- **All the involved graph patterns must be matched**
  - I.e. we combine them as if they were in conjunction

Notes

- Empty group patterns `{}` are also allowed

# Optional Graph Pattern

**OPTIONAL** graph pattern

One group graph pattern is tried to be matched


Interpretation

- **When the optional part does not match,**
  **it creates no bindings but does not eliminate the solution**

# Optional Graph Pattern: Example

Movies together with their directors when possible

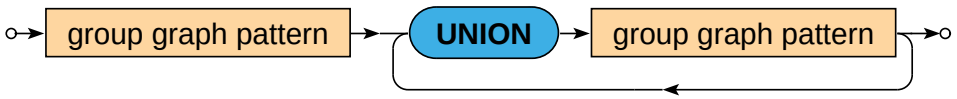
```
PREFIX i: <http://db.cz/terms#>
SELECT ?t ?y ?d
FROM <http://db.cz/movies>
WHERE
  {
    ?m rdf:type i:Movie ;
       i:title ?t ;
       i:year ?y .
    OPTIONAL { ?m i:director ?d . }
  }
```

| ?t | ?y | ?d |
|---|---|---|
| Vratné lahve | 2006 | |
| Samotáři | 2000 | |
| Medvídek | 2007 | Jan Hřebejk |

# Alternative Graph Pattern

**UNION** graph pattern

Two or more group graph patterns are to be matched




Interpretation

- Standard set **union** of the involved query results

# Minus Graph Pattern

**MINUS** graph pattern

One group graph pattern removing compatible solutions


Interpretation

- **Solutions of the first pattern are preserved if and only if they are not compatible with any solution of the second pattern**
  - I.e. minus graph pattern does not correspond to the standard set minus operation!

# Minus Graph Pattern: Example

Titles of movies that have no director

```
PREFIX i: <http://db.cz/terms#>
SELECT ?t
FROM <http://db.cz/movies>
WHERE
  {
    ?m rdf:type i:Movie ;
       i:title ?t .                                    # pattern 1
    MINUS { ?m rdf:type i:Movie ; i:director ?d . } # pattern 2
  }
```

| ?t |
| --- |
| Vratné lahve |
| Samotáři |

# Minus Graph Pattern: Example

$[\![p_1]\!] =$

| ?m | ?t |
|---|---|
| m:vratnelahve | Vratné lahve |
| m:samotari | Samotáři |
| m:medvidek | Medvídek |

$[\![p_2]\!] =$

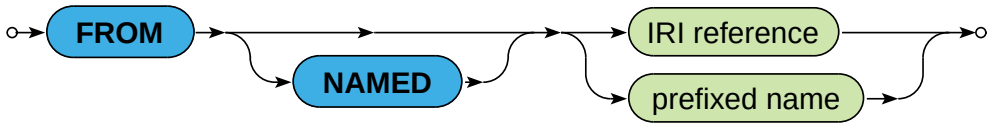
| ?m | ?d |
|---|---|
| m:medvidek | Jan Hřebejk |

| ?t |
|---|
| Vratné lahve |
| Samotáři |

# From Clause

**FROM** clause

- Defines data graphs to be queried




**Dataset** = **collection of graphs to be queried**

- One default graph
  - Merge of all the declared graphs from unnamed FROM clauses
  - Empty when no unnamed FROM clause is provided
- Zero or more named graphs

**Active graph** = used for the evaluation of graph patterns

- The default graph unless changed using GRAPH graph pattern

# From Clause: Example

Names of actors who played in *Medvídek* movie

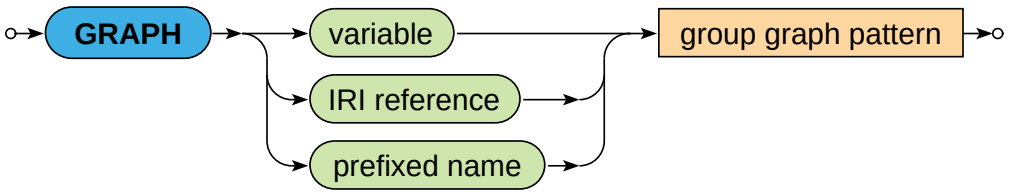
```
PREFIX i: <http://db.cz/terms#>
PREFIX m: <http://db.cz/movies/>
SELECT ?f ?l
FROM <http://db.cz/movies>
FROM <http://db.cz/actors>
WHERE
  {
    m:medvidek i:actor ?a .
    ?a i:firstname ?f ; i:lastname ?l .
  }
```

| ?f | ?l |
|---|---|
| Jiří | Macháček |
| Ivan | Trojan |

# Graph Graph Pattern

**GRAPH** graph pattern

Pattern evaluated with respect to a particular named graph




- **Changes the active graph** for a given group graph pattern
  - `GRAPH <http://db.cz/actors> { … }`
- We can also consider all the named graphs
  - `GRAPH ?g { … }`

# Graph Graph Pattern: Example

Names of actors who played in *Medvídek* movie

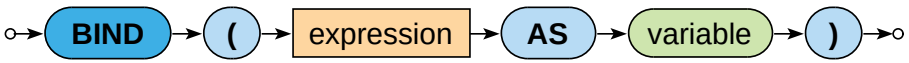
```
PREFIX i: <http://db.cz/terms#>
PREFIX m: <http://db.cz/movies/>
SELECT ?f ?l
FROM <http://db.cz/movies>
FROM NAMED <http://db.cz/actors>
WHERE
  {
    m:medvidek i:actor ?a .
    GRAPH <http://db.cz/actors> {
      ?a i:firstname ?f ; i:lastname ?l .
    }
  }
```

| ?f | ?l |
|---|---|
| Jiří | Macháček |
| Ivan | Trojan |

# Variable Assignments

**BIND** *graph pattern*

Explicitly assigns a value to a given variable

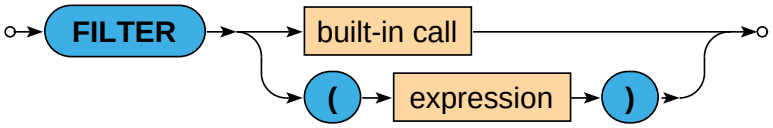



- This variable must not yet be bound!

# Filter Constraints

**FILTER** constraints

Impose constraints on variables and their values




- **Only solutions satisfying the given condition are preserved**
- Does not create any new variable bindings!
- Always applied on the entire group graph pattern
  i.e. evaluated at the very end

# Filter Constraints: Example

Movies filmed in 2005 or later where *Ivan Trojan* played

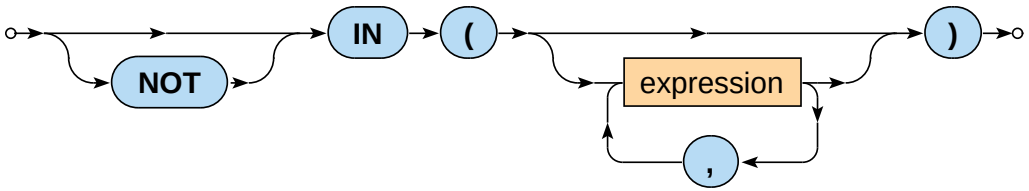
```
PREFIX i: <http://db.cz/terms#>
PREFIX a: <http://db.cz/actors/>
SELECT ?t ?y
FROM <http://db.cz/movies>
WHERE
  {
    ?m rdf:type i:Movie ;
       i:title ?t ;
       i:year ?y .
    FILTER (
      (?y >= 2005) &&
      EXISTS { ?m i:actor a:trojan . }
    )
  }
```

| ?t | ?y |
|---|---|
| Medvídek | 2007 |

# Filter Constraints

Relational expressions

- **Comparisons**
  - =, !=, <, <=, =>, >
  - Unbound variable < blank node < IRI < literal
- **Set membership tests**
  - `IN` and `NOT IN`




Numeric expressions

- Unary / binary **arithmetic operators** +, −, ∗, /

# Filter Constraints

Primary expressions

- **Literals** – numeric, boolean, RDF triples
- **Variables**
- Built-in calls
- Parentheses

**Boolean expressions**

- Logical connectives
  - Conjunction `&&`, disjunction `||`, negation `!`
- **3-value logic** because of unbound variables (NULL values)
  - `true`, `false`, `error`

# Filter Constraints

Built-in calls

- **Term accessors**
  - `STR` – lexical form of an IRI or literal
  - `LANG` – language tag of a literal
  - `DATATYPE` – data type of a literal
- **Variable tests**
  - `BOUND` – true when a variable is bound to a value
  - `isIRI`, `isBLANK`, `isLITERAL`

# Filter Constraints

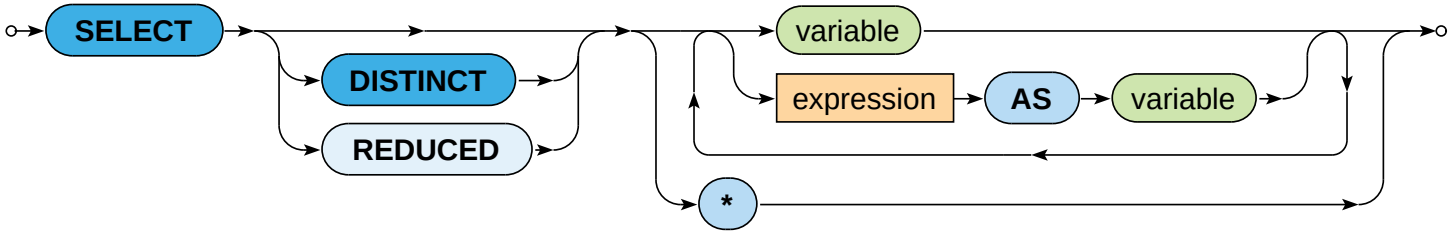
Built-in calls

- **Existence tests**
  - `EXISTS`
    - True when a provided group graph pattern is evaluated to at least one solution
  - `NOT EXISTS`

# Select Clause

**SELECT clause**

- Enumerates variables to be included in the query result




- Asterisk ∗ selects all the variables

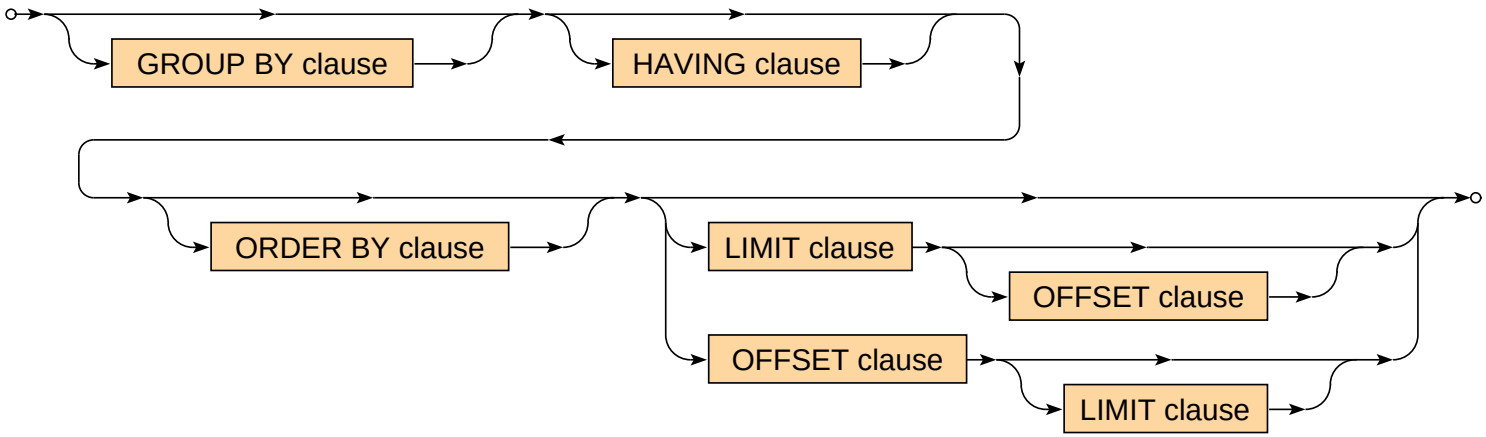
Solution modifiers

- `DISTINCT` – **duplicate solutions are removed**
- `REDUCED` – some duplicate solutions may be removed (implementation-dependent behavior)

# Solution Modifiers

**Solution modifiers** – modify the entire solution sequence

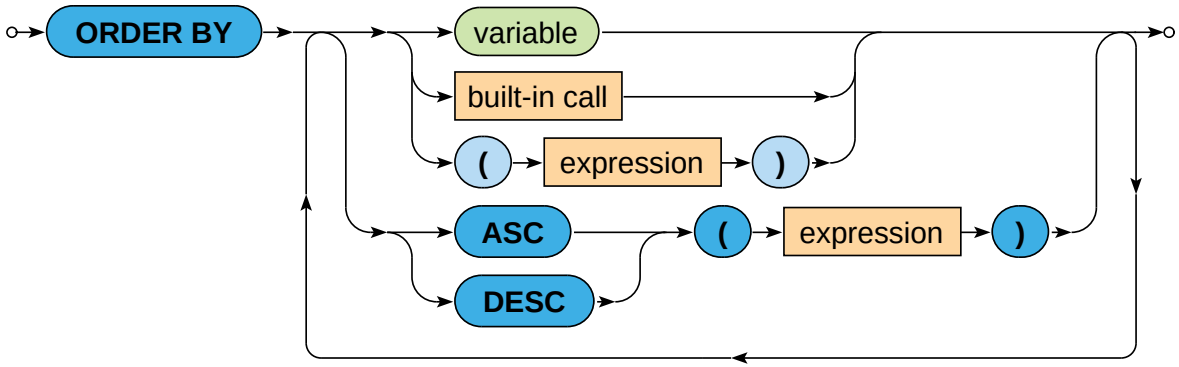
- Aggregation
  - `GROUP BY` and `HAVING`
- Ordering
  - `ORDER BY`
  - `LIMIT` and `OFFSET`



# Solution Modifiers

**ORDER BY** clause

- Defines the order of solutions within the query result

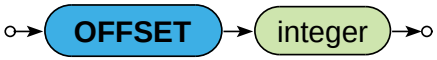



- `ASC(…)` = **ascending** (default)
- `DESC(…)` = **descending**

# Solution Modifiers

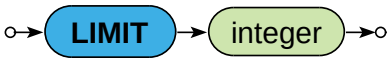
**OFFSET** clause

- **Skips a certain number of solutions** in the query result




**LIMIT** clause

- **Limits the number of solutions** in the query result



# Solution Modifiers: Example

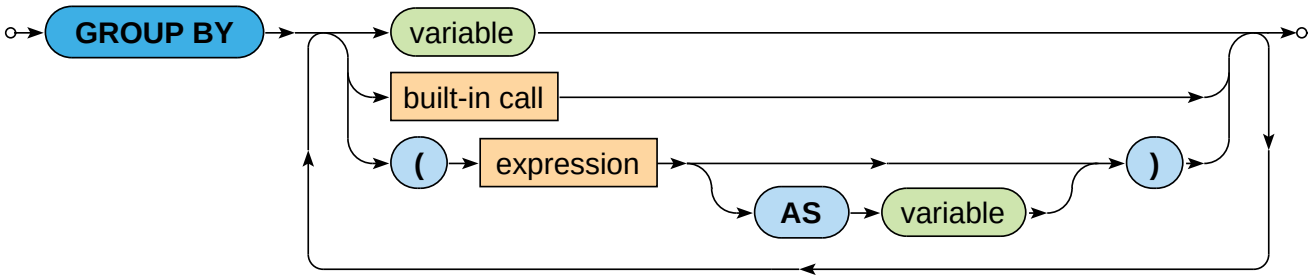
```
PREFIX i: <http://db.cz/terms#>
SELECT ?t ?y
FROM <http://db.cz/movies>
WHERE
  {
    ?m rdf:type i:Movie ;
       i:title ?t ;
       i:year ?y .
  }
ORDER BY DESC(?y) ASC(?t)
OFFSET 1
LIMIT 5
```

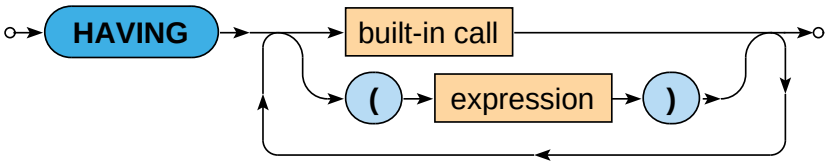
| ?t | ?y |
|---|---|
| Vratné lahve | 2006 |
| Samotáři | 2000 |

# Aggregation

**GROUP BY** + **HAVING** clauses

- Standard aggregation over a solution sequence



# Aggregation: Example

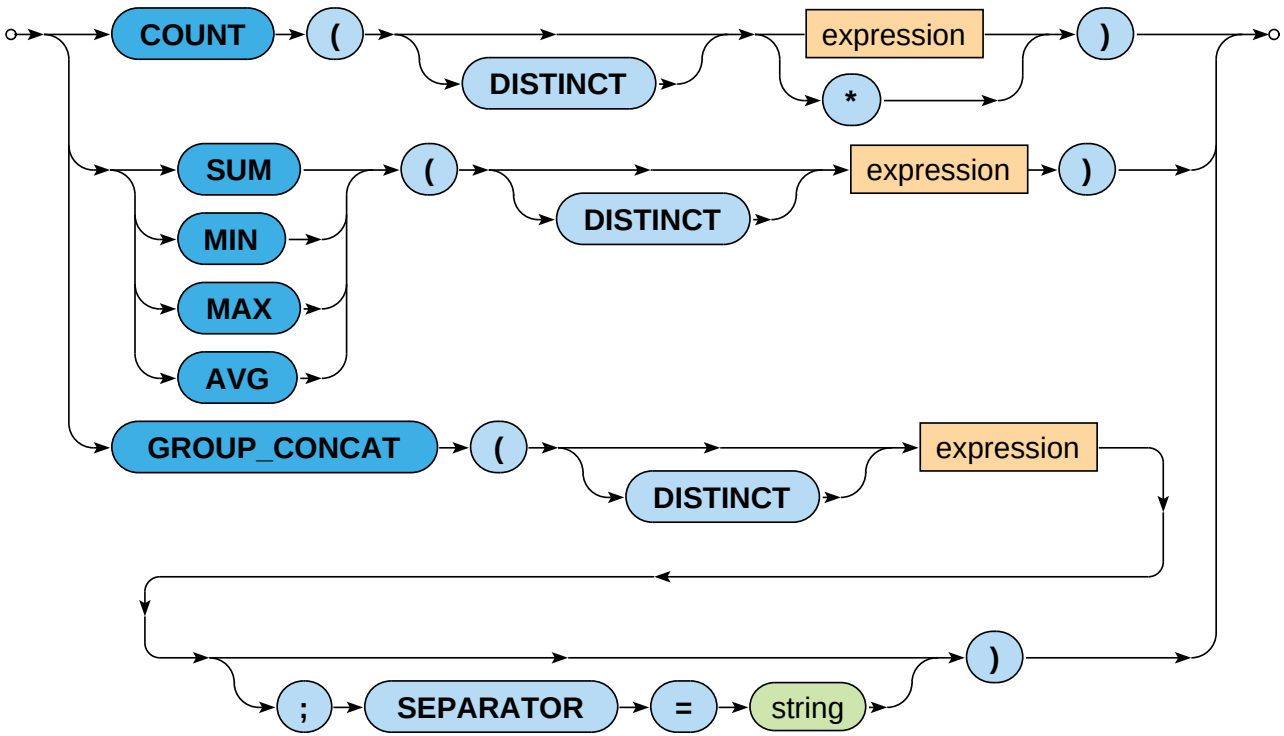
Numbers of actors in movies with at most 2 actors

```
PREFIX i: <http://db.cz/terms#>
SELECT ?t (COUNT(?a) AS ?c)
FROM <http://db.cz/movies>
WHERE
  {
    ?m rdf:type i:Movie ;
       i:title ?t ;
       i:actor ?a .
  }
GROUP BY ?m ?t
HAVING (?c <= 2)
ORDER BY ?c ?t
```

| ?t | ?c |
|---|---|
| Medvídek | 2 |
| Vratné lahve | 2 |

# Aggregation

**Aggregate** functions



# Query Forms

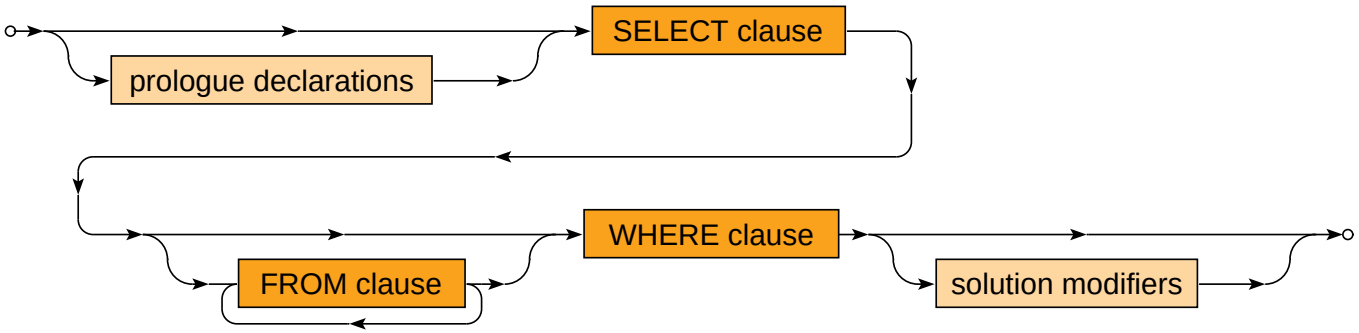
**Query forms**

- **SELECT**
  - Finds solutions matching a provided graph pattern
- ASK
  - Checks whether at least one solution exists
- DESCRIBE
  - Retrieves a graph with data about selected resources
- **CONSTRUCT**
  - Creates a new graph according to a provided pattern

# Select Query Form

**SELECT** query form

Finds solutions matching a provided graph pattern



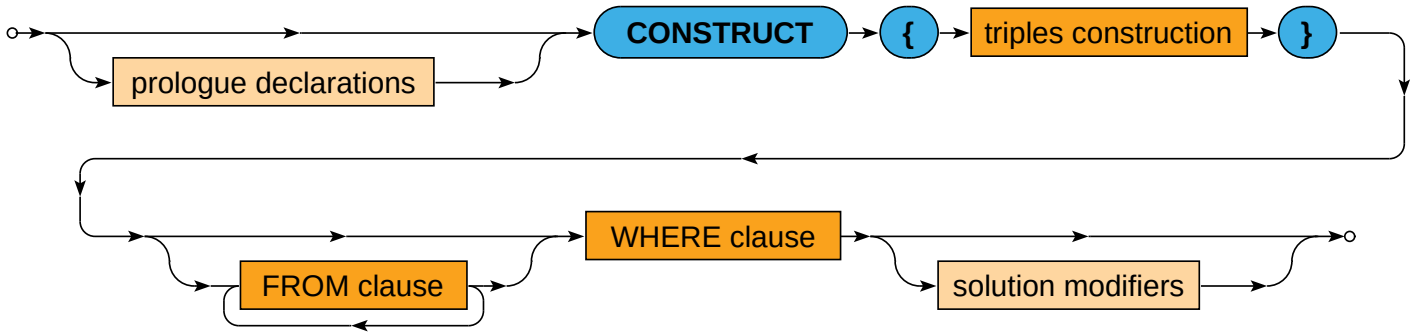

Result

- **Solution sequence** = ordered multiset of solutions

# Construct Query Form

**CONSTRUCT** query form

Creates a new graph according to a provided pattern




Result

- **RDF graph** constructed according to a group graph pattern
  - Unbound or invalid triples are not involved

# Construct Query Form: Example

```
PREFIX i: <http://db.cz/terms#>
CONSTRUCT
  {
    ?a i:name concat(?f, " ", ?l) .
  }
FROM <http://db.cz/actors>
WHERE
  {
    ?a rdf:type i:Actor ;
       i:firstname ?f ;
       i:lastname ?l .
  }
```

```
<http://db.cz/actors/trojan> i:name "Ivan Trojan" .
<http://db.cz/actors/machacek> i:name "Jiří Macháček" .
<http://db.cz/actors/schneiderova> i:name "Jitka Schneiderová" .
<http://db.cz/actors/sverak> i:name "Zdeněk Svěrák" .
```

# Lecture Conclusion

**SPARQL**

- **Query forms**
  - `SELECT`, `ASK`, `DESCRIBE`, `CONSTRUCT`
- **Graph patterns**
  - Basic, group, optional, alternative, minus
  - Variable assignments
  - Filters
- **Solution modifiers**
  - `DISTINCT`, `REDUCED`
  - `GROUP BY`, `HAVING`
  - `ORDER BY`, `LIMIT`, `OFFSET`