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# PGQL: a Property Graph Query Language

Oskar van Rest
Sungpack Hong
Jinha Kim
Xuming Meng
Hassan Chafi

Oracle Labs
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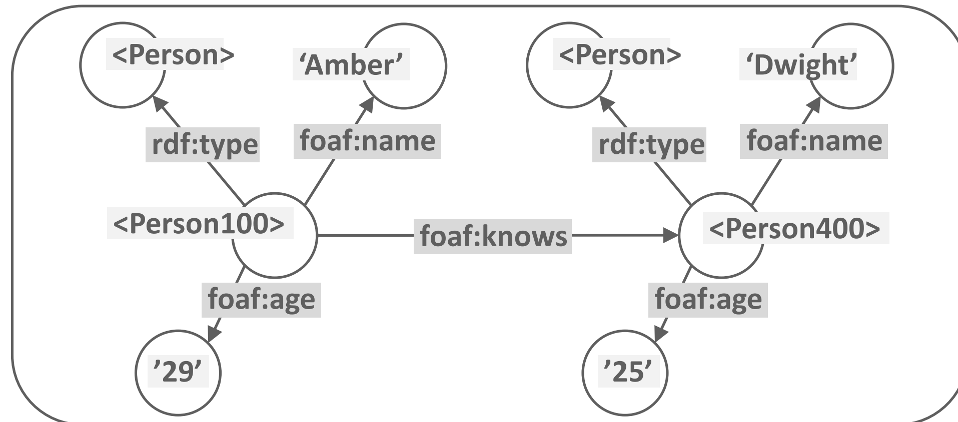
# Query Languages for Graphs

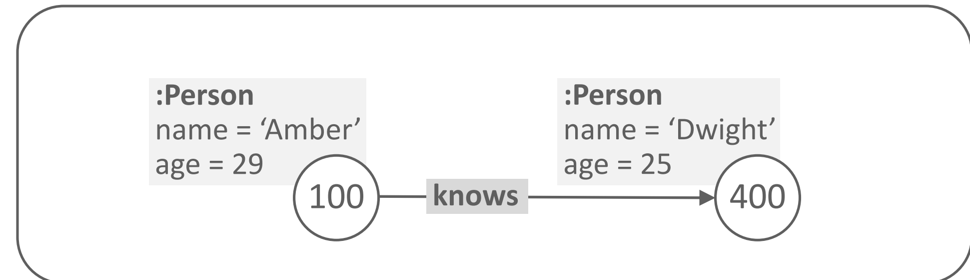
## RDF Graphs




- Standard query language:
  - W3C **SPARQL 1.1**

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

## Property Graphs




- No standard query language
- Existing languages:
  - PGQL (Oracle) ← this presentation
  - Cypher (Neo4j)
  - Gremlin (Tinkerpop)
  - *... (LDBC)*

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https://github.com/oracle/pgql-lang

# PGQL: a Property Graph Query Language

- Very close to SQL
- Aligned with existing database management systems

```
SELECT y.name, e, p, GRAPH{x -[e]-> y}
FROM snGraph IN { SELECT … FROM … WHERE … }
WHERE
   (x:Person WITH name = 'Paul') -[e:likes]-> (y),
   (z:Person WITH name = 'Amber') -/p:likes*/-> (y),
   x.age > y.age
GROUP BY
ORDER BY
LIMIT
OFFSET
```



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# Limitations of other languages (1): Path Queries

- SPARQL
  - Reachability only; no path finding
- Cypher
  - Find *all* paths as default semantics (too expensive)
  - Limited RPQs
- SQL
  - Doesn't allow for naturally expressing path queries (i.e. recursive SQL)

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# Limitations of other languages (2): Graph Construction

- SPARQL
  - Query either returns a result set or a graph → no uniform interface
  - Queries that return graphs cannot be composed
- Cypher
  - Can't construct graphs
- (SQL: can construct tables naturally so no limitation)

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# PGQL: a Property Graph Query Language

1. Graph Pattern Matching Queries
2. Path Queries
3. Graph Construction Queries

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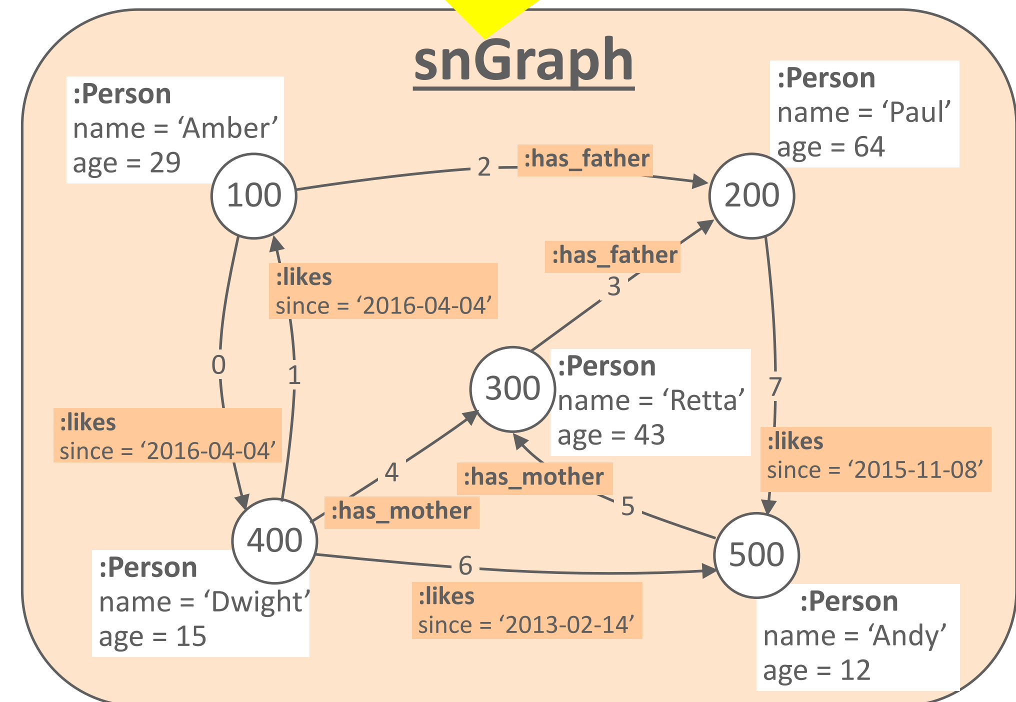
# Property Graph Data Model

- (Named) graph with vertices and edges
- Vertex
  - Unique identifier
  - Set of labels
  - Properties (arbitrary key-value pairs)
- Edge
  - Unique identifier
  - Single label
  - Properties (arbitrary key-value pairs)
  - Direction

A value can be an object of any type (e.g. Integer, String, Set<String>, etc.)

Name of graph ( “Social Network Graph” ➔ snGraph)




Property graph can be schema-less

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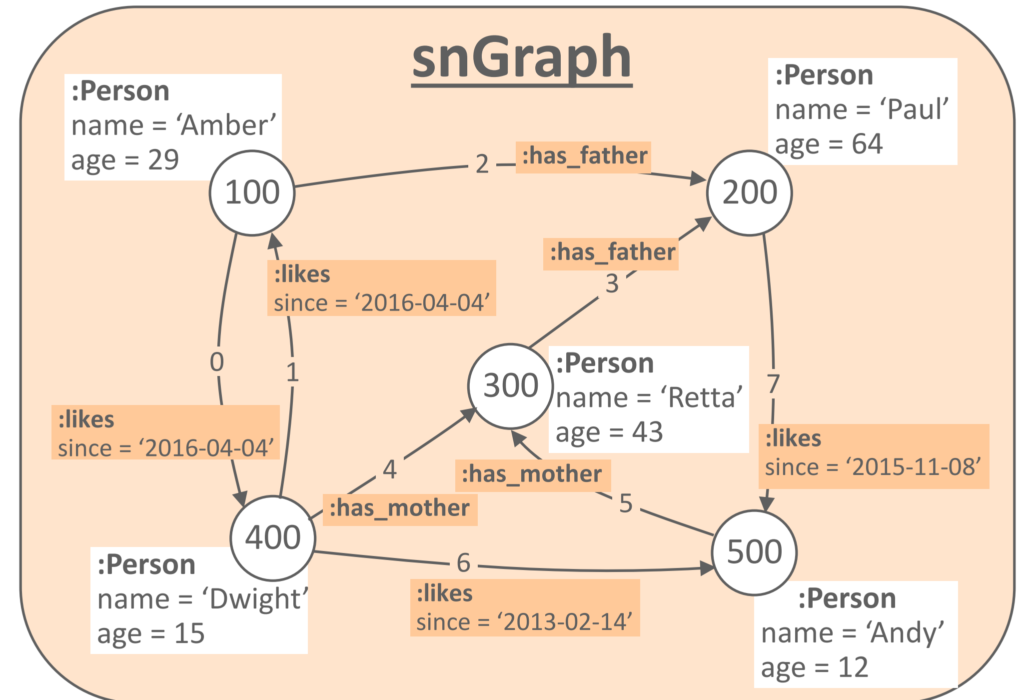
# Example Query

"Find friends of Paul that are also friends, or friends of friend, of Amber. The friend should be older than Amber."

```
SELECT y.name, y.age
FROM snGraph
WHERE
  (x:Person WITH name = 'Paul') -[:likes]-> (y:Person)
  (z:Person WITH name = 'Amber') -/:likes*1..2/-> (y)
  z.age > y.age
```



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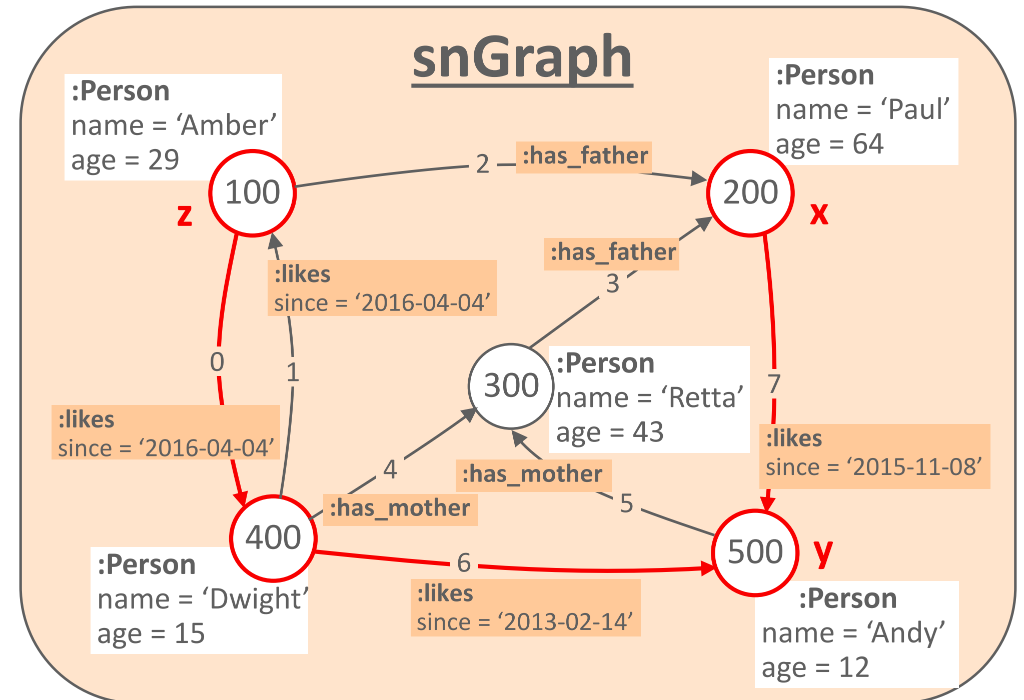
# Example Query

"Find friends of Paul that are also friends, or friends of friend, of Amber. The friend should be younger than Amber."

```
SELECT y.name, y.age
FROM snGraph
WHERE
   (x:Person WITH name = 'Paul') -[:likes]-> (y:Person)
   (z:Person WITH name = 'Amber') -/:likes*1..2/-> (y)
   z.age > y.age
```

Result set

| y.name | y.age |
|---|---|
| 'Andy' | 12 |

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# Type System

- Built-in datatypes:
  - **Basic types**: Integer, String, Double, Set<String>, ...
  - **Graph-specific types**: Vertex, Edge, Path, Graph
- Query result is always a "**result set**"
  - Even graphs are returned in the result set
  - Like in SQL, result set may contain duplicate rows ("bag semantics")

**Built-in functions:**
Vertex: `id(), labels()`
Edge: `id(), label()`
Path: `length(), weight()`
Graph: `numNodes(), numEdges()`

A graph inside the result set

```
SELECT y.name, y.id(), y, e, p, snGraph
FROM snGraph
WHERE
  (x:Person WITH name = 'Paul') -[e:likes]-> (y)
  (z:Person WITH name = 'Amber') -/p:likes*1..2/-> (y)
  z.age > y.age
```

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# Common Query Functionality

- Grouping and aggregation
  - Similar to SQL

```
SELECT x.age, COUNT(*)
FROM snGraph
WHERE
  (x:Person)
GROUP BY x.age AS xAge
HAVING ...
```

- Order by, offset, limit
  - Similar to SQL
- Union (all)
  - Similar to SQL

- Subqueries
  - Bottom-up semantics

```
SELECT x.name
FROM snGraph
WHERE
   (x:Person), x.age = maxAge,
   {
     SELECT MAX(x.age) AS maxAge
     WHERE (x:Person)
   }
```

- Filtering using graph patterns
  - EXISTS & NOT EXISTS (like SPARQL)

```
SELECT y.name
FROM snGraph
WHERE
 (:Person WITH name = 'Paul') -[:likes]-> (y)
 NOT EXISTS {
   (:Person WITH name = 'Amber') -[:likes]-> (y)
 }
```

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# Path Queries

- Test for existence of, or retrieve, **arbitrary-length** paths
  - This is a very natural operation on graphs: relationships can be traversed without computing joins
- Two types of path queries:
  - **Reachability queries** *test* for the existence of a paths between pairs of vertices
  - **Path finding queries** *retrieve* paths between pairs of vertices
- Three challenges to overcome (next three slides)

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# Challenge 1: Supporting Regular Path Queries (RPQs)

- What are RPQs?
  - RPQs specify a regular expression over the edges along a path
    - Reachability: test if some path satisfies the RPQ
    - Path finding: return one or more paths that satisfy the RPQ
- Example RPQs in SPARQL 1.1:
  - `{ <http://example/thing> rdf:type/rdfs:subClassOf* ?type }`

    “find all types of http://example/thing”
  - `{ ?x rdf:type|^rdf:type ?y }`

    “find all vertices *x* and *y* such that *x* is a type of *y* or *y* is a type of *x*”
- In the past, RPQs were mostly applied to “labelled graph” (e.g. RDF)
- How to support RPQs over <u>property</u> graphs?

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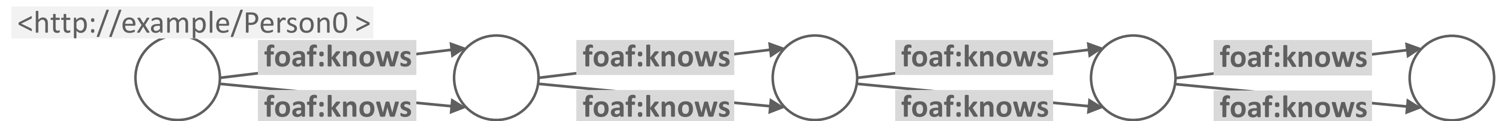
# Challenge 2: Avoiding expensive “all paths” enumeration

- Assume simple SPARQL query:
  - `{ <http://example/Person0> foaf:knows* ?y }`
  - Reachability: O(n + m)
  - All path finding: O(n + $2^m$)




- Should not rely on query planner to translate e.g. an ‘all path finding query’ into a ‘reachability query’
- Use cases that require materialization of all paths are very uncommon

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# Challenge 3: Choosing a path finding semantic

- Different use cases demand for different semantics:
  - Find **single shortest** paths (weighted / minimal hop)
  - Find ***k* shortest** paths (weighted / minimal hop)
  - Find ***k* dissimilar** paths
  - Find ??? paths
- However, multiple “built-in semantics” make the language too complex

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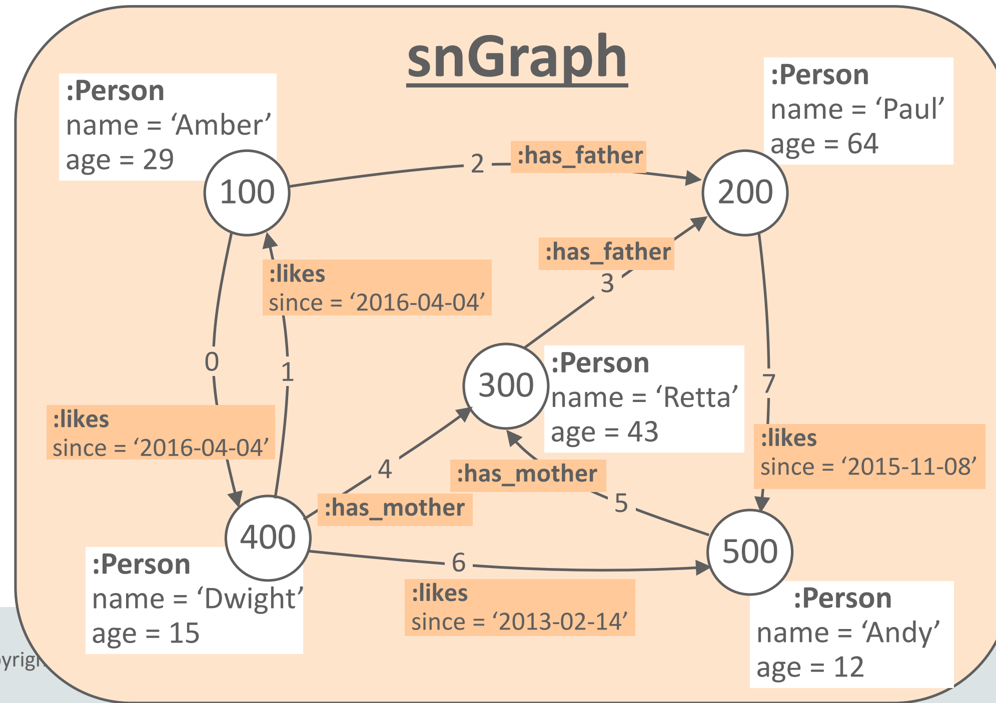
# RPQs for Property Graphs: Composable Path Patterns (1)

- **PATH** construct allows for specifying a path pattern
  - Graph patterns (**WHERE**) can be composed of path patterns
  - Path patterns (**PATH**) can be composed of other path patterns

```
PATH has_parent := (:Person) -[:has_father|has_mother]-> (:Person)
PATH has_ancestor := (:Person) -/has_parent+/-> (:Person)
SELECT x.id(), y.id()
FROM snGraph
WHERE
  (x:Person WITH name = 'Andy') -/has_ancestor/-> (ancestor)
  (y) -/has_ancestor/-> (ancestor),
  x.id() > y.id()
```

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# RPQs for Property Graphs: Composable Path Patterns (1)

- **PATH** construct allows for specifying a path pattern
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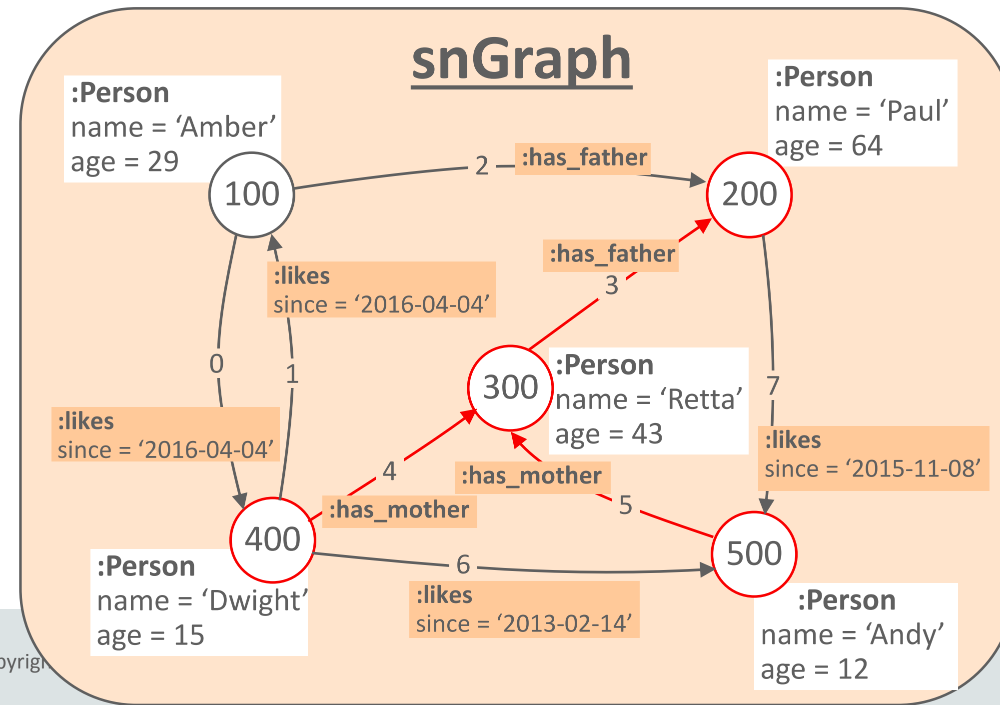
  - Path patterns (**PATH**) can be composed of other path patterns

```
PATH has_parent := (:Person) -[:has_father|has_mother]-> (:Person)
PATH has_ancestor := (:Person) -/has_parent+/-> (:Person)
SELECT x.id(), y.id()
FROM snGraph
WHERE
   (x:Person WITH name = 'Andy') -/has_ancestor/-> (ancestor)
   (y) -/has_ancestor/-> (ancestor),
   x.id() > y.id()
```

Result set

| x.id() | y.id() |
| --- | --- |
| 500 | 400 |
| 500 | 300 |

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# RPQs for Property Graphs: Composable Path Patterns (2)

- Not just edge labels, but also properties:
  - Inlined property constraint

```
PATH has_new_friend := () -[:likes WITH since > '2016-01-01']-> ()
```

  - Cross-constraint on properties

```
PATH has_older_friend := (x) -[:likes]-> (y) WHERE y.age > x.age
```

- Cross-constraints in path pattern allow for **comparing data along paths**
  - More expressive than traditional RPQs (e.g. SPARQL)
- All constraints can be processed *during* path traversal
  - No need to find all paths and then filter out invalid paths

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# Path Finding (1)

- PGQL's semantics:
  - **Reachability**

```
SELECT y, y.id()
WHERE
  (x@100) -/:likes+/-> (y)
```

(x@100) is shorthand for (x **WITH** id() = 100)

  - Single **min-hop shortest** path

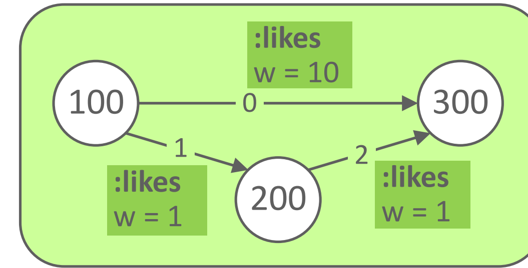
```
SELECT p, p.length()
WHERE
  (x@100) -/p:likes+/-> (y)
```

  - Single **weighted shortest** path

```
SELECT p, p.length(), p.weight()
WHERE
  (x@100) -/p'w':likes+/-> (y)
```

Edge property to minimize. More complex weight functions can be specified by constructing "weighted graph" via subquery.

Input graph




| y | y.id() |
|---|---|
| 300 | 300 |
| 200 | 200 |

| p | p.length() |
|---|---|
| 100 —0→ 300 | 1 |
| 100 —1→ 200 | 1 |

| p | p.length() | p.weight() |
|---|---|---|
| 100 —1→ 200 —2→ 300 | 2 | 2 |
| 100 —1→ 200 | 1 | 1 |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# Path Finding (2)

- What about returning *multiple* paths?
  - User-defined path-finding functions?

```
SELECT $kDissimilarPaths(snGraph, x, y, 20)
FROM snGraph
WHERE
  (x@1) -/:likes*/-> (y)
```

Example: for each source-destination pair x, y, return k = 20 *dissimilar* paths

  - Not entirely clear yet

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# Graph Construction

- Graph construction queries allow for:
  - Decomposing complex query into simpler ones
  - Creating SQL-like Views
  - Running queries in sequence
- SPARQL allows for constructing a graph, but:
  - Query either returns a result set or a graph ➔ no uniform interface
  - Queries can only be composed of queries that return tables; not of queries that return graphs

Graph construction in SPARQL

```
PREFIX foaf:    <http://xmlns.com/foaf/0.1/>
PREFIX vcard:   <http://www.w3.org/2001/vcard-rdf/3.0#>
CONSTRUCT   { <http://example.org/person#Alice> vcard:FN ?name }
WHERE       { ?x foaf:name ?name }
```

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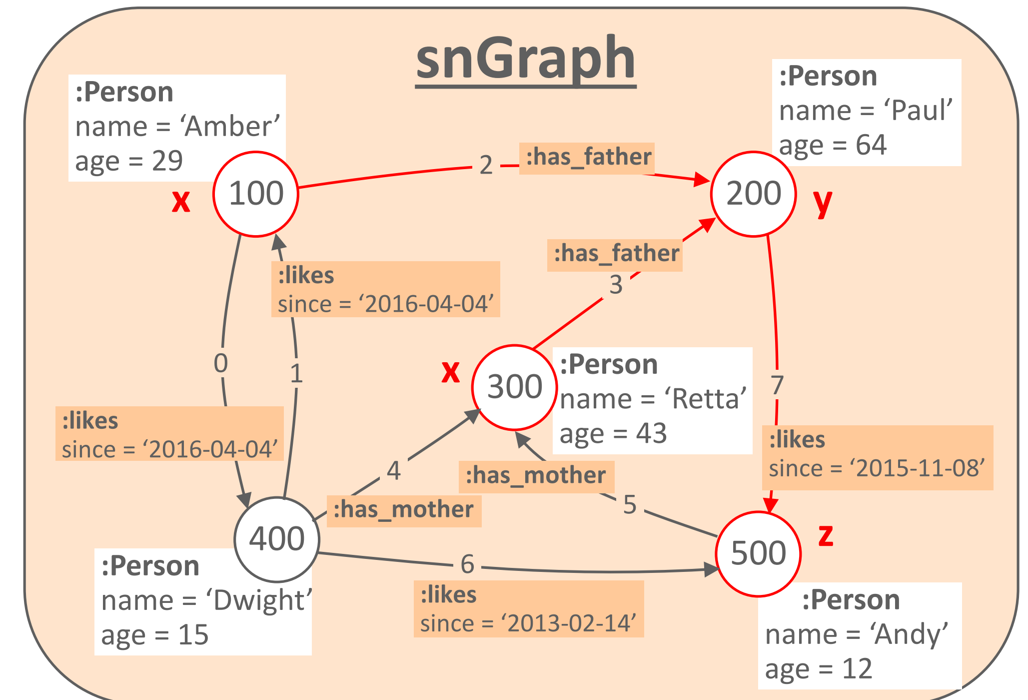
# The GRAPH Construct

- The GRAPH construct allows for specifying a graph production pattern with:
  - Vertices / edges / paths from WHERE clause
  - New vertices / edges / properties (not shown)

```
SELECT GRAPH{ (x) -[e]-> (y) } AS myGraph
FROM snGraph
WHERE
  (x) -[e:has_father|has_mother]-> (y),
  (y) -[:likes]-> (z)
```

myGraph

| |
|---|
| :Person name = 'Amber' age = 29 (100) —2 :has_father→ (200) :Person name = 'Paul' age = 64 |
| :Person name = 'Retta' age = 43 (300) —3 :has_father→ (200) :Person name = 'Paul' age = 64 |




Graph are returned inside the result set!

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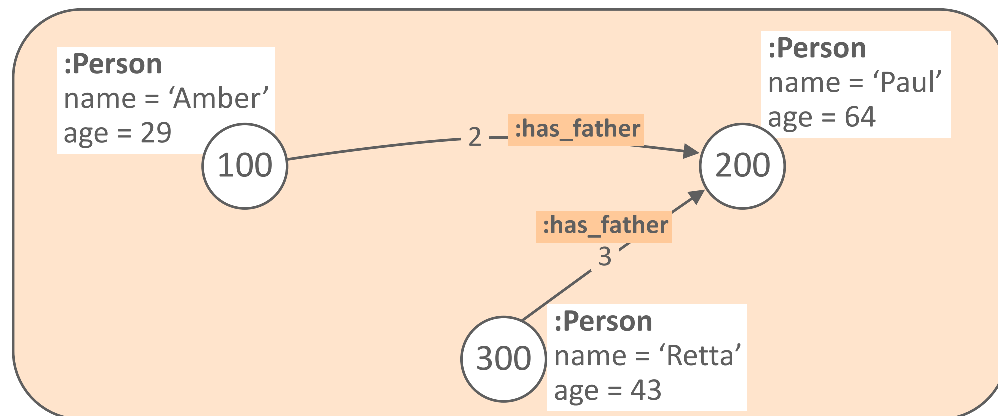
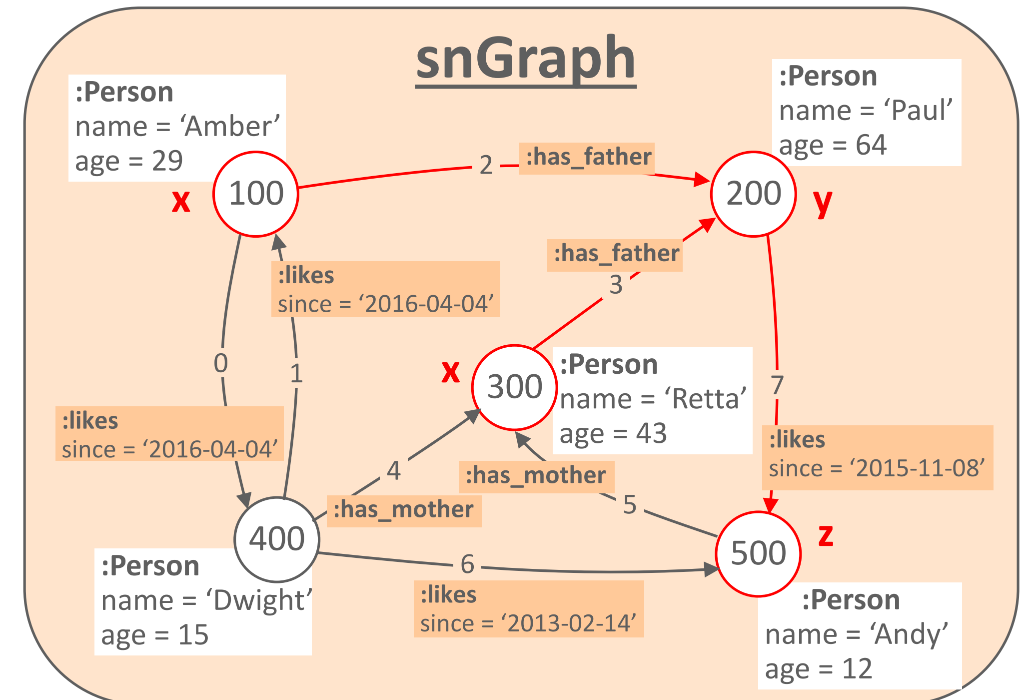
# The UNION Aggregate

Can be used in combination with GROUP BY too: construct a graph for each group (not shown)

- The UNION aggregate merges a set of graphs into a single (large) graph

```
SELECT UNION(GRAPH{ (x) -[e]-> (y) }) AS myGraph
FROM snGraph
WHERE
  (x) -[e:has_father|has_mother]-> (y),
  (y) -[:likes]-> (z)
```

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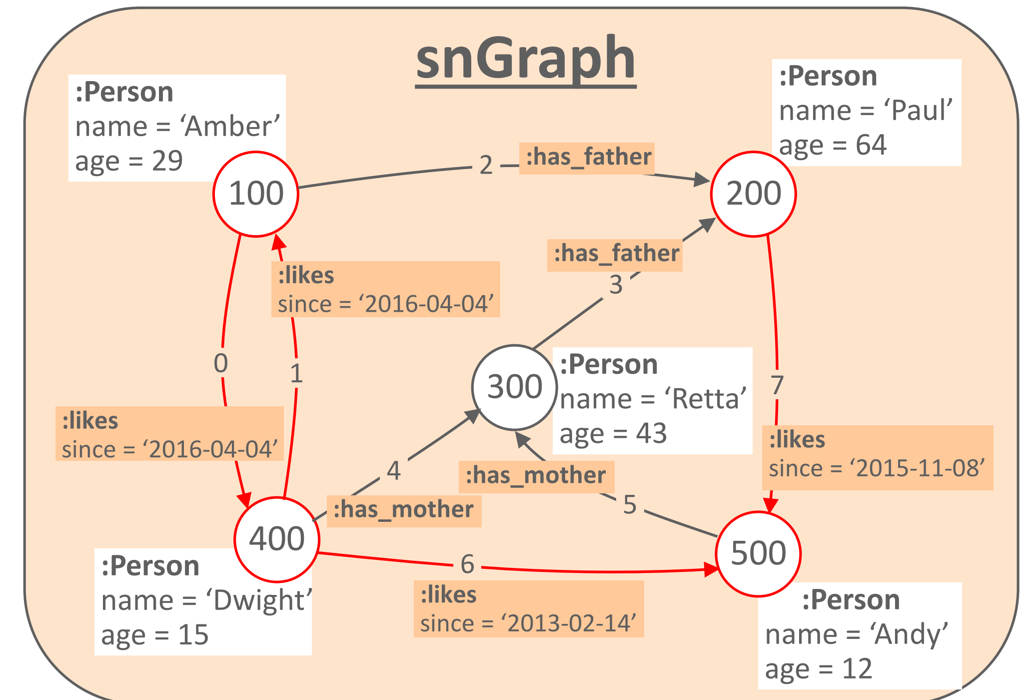
# Query composition with queries that return graphs

- Composition of queries that return tables is similar to SQL (not shown)
- But PGQL can also compose queries that return graphs:

```
SELECT COUNT(*)
FROM likesGraph IN {
  SELECT UNION(GRAPH{*}) AS likesGraph
  FROM snGraph
  WHERE () -[:likes]-> ()
}
WHERE
  (n)
```

Result:

| COUNT(*) |
|---|
| 4 |

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https://github.com/oracle/pgql-lang

# Conclusion

- PGQL: a Property Graph Query Language
  - Close to SQL and aligned with existing database management systems
  - Graph pattern matching + SQL-like functionality
  - Path Queries
    - RPQs on Property Graphs
    - Reachability + Shortest path finding
  - Graph Construction
    - GRAPH: specify a production pattern
    - UNION: take the union of a set of graphs
    - Can compose queries that return a table / graph

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