Sous la co-tutelle de :
CNRS
ÉCOLE DES PONTS PARISTECH
UNIVERSITÉ GUSTAVE EIFFEL

2024-11-14

Formalization of real query languages and application to theory

 Claire David

 Nadime Francis

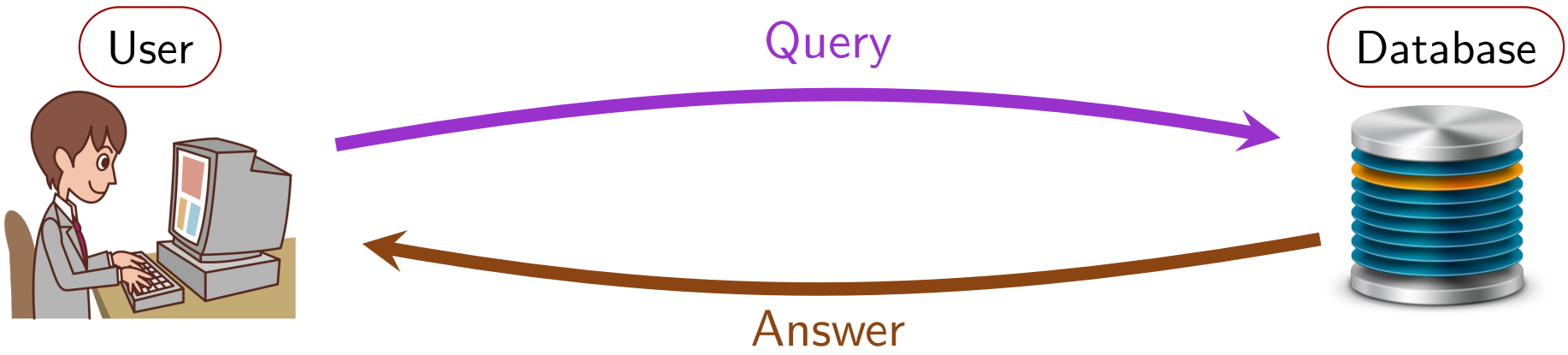
 Victor Marsault

 Antoine Meyer

 Liat Peterfreund

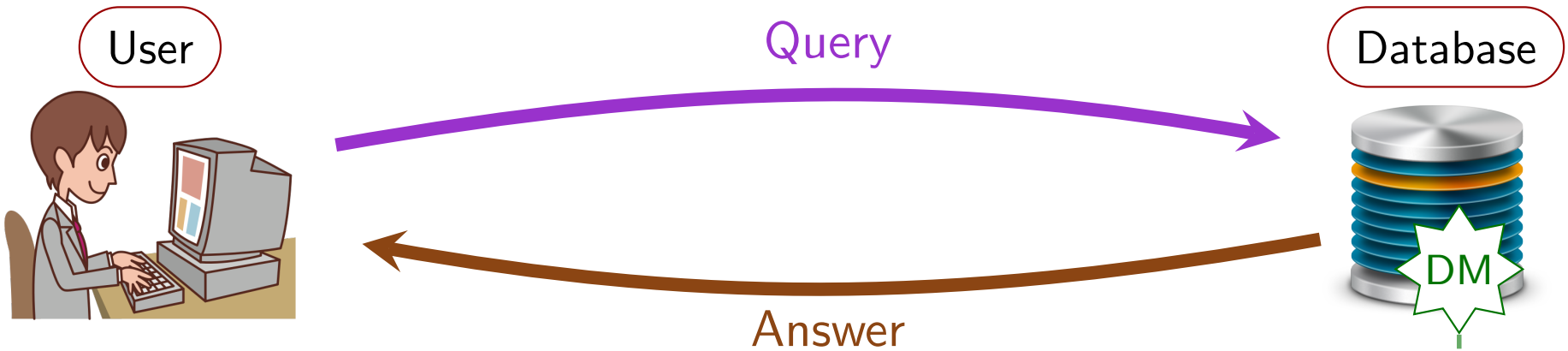
and many other coauthors from academia and industry

Setting



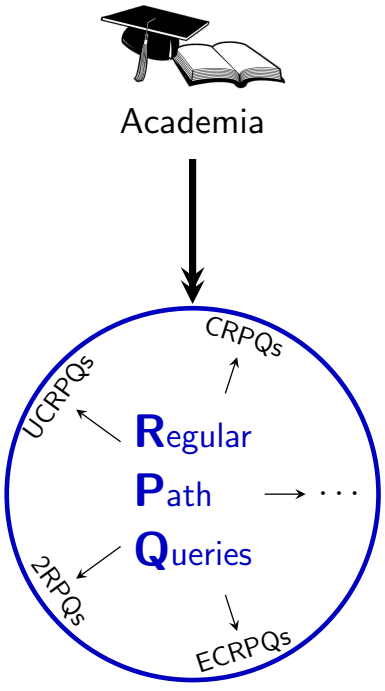
Setting

- Query language
  - "*What can the user write?*"



- Semantics of query
  - "*What data is extracted?*"
- DM = Data model
  - "*How the data is structured*"

Graph query languages: from RPQs to GQL



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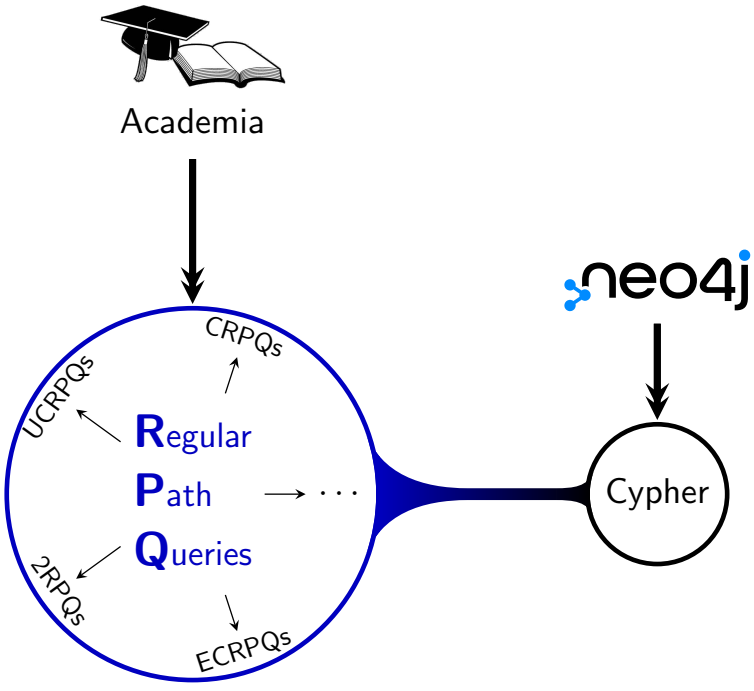

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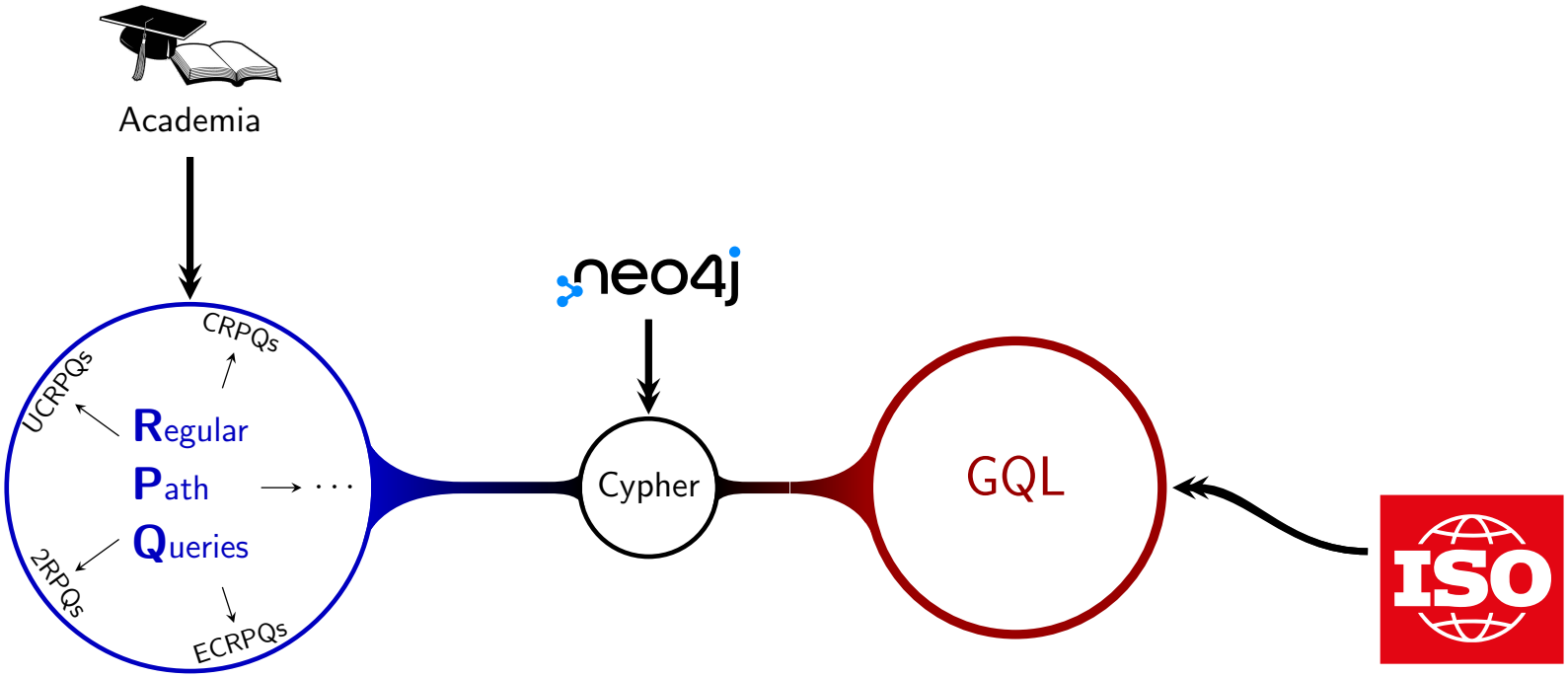

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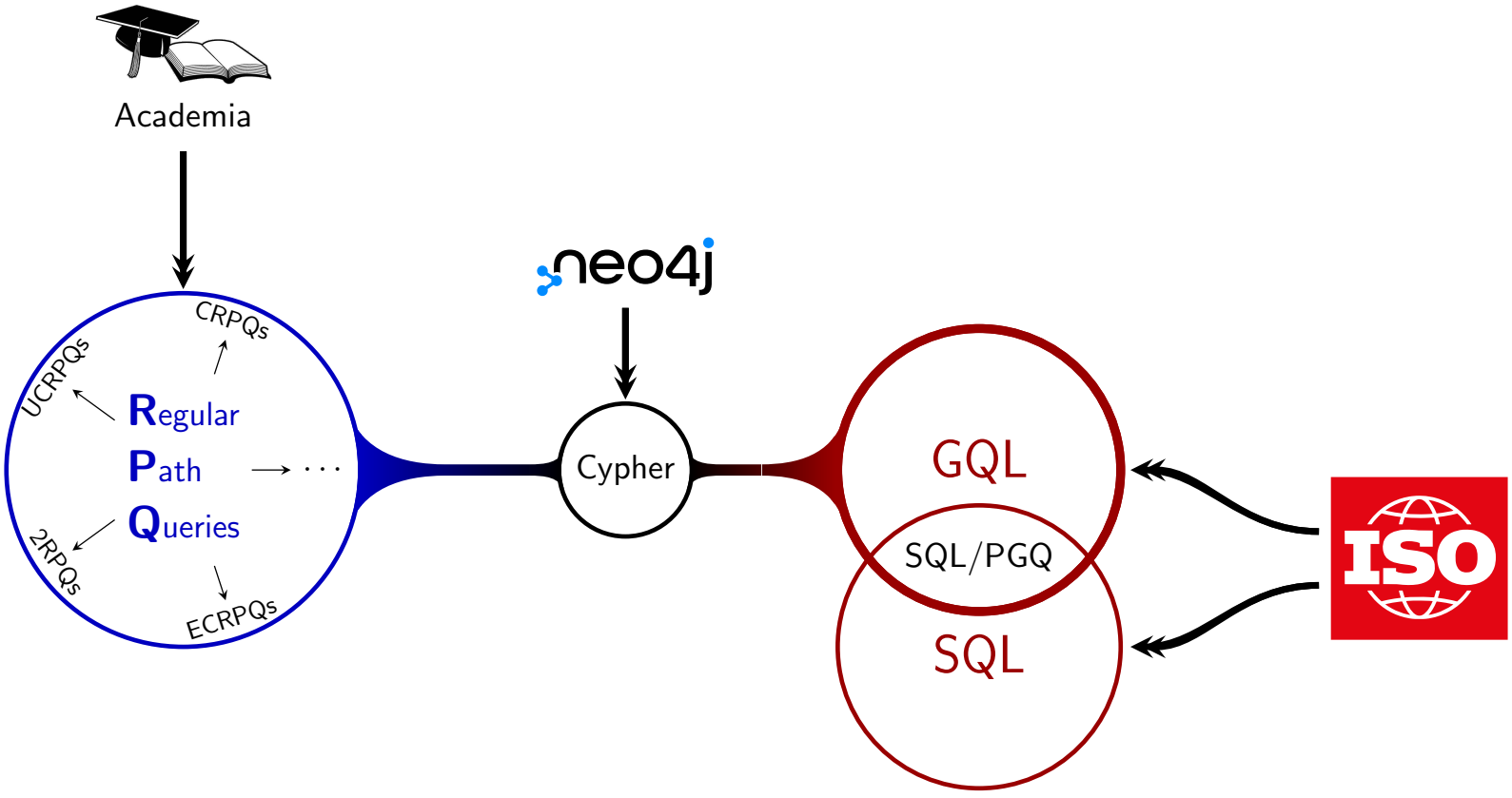

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- GQL (2024) standard query language for property graphs
- SQL/PGQ (2023) support for querying property graphs from SQL

General flow of our work

1 Formalize

- Collaboration with private actors
- Access to database engine and/or documentation
- Produce formal semantics of query languages

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1. **Formalize**
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   - "Strange" decisions
   - Discrepancies with theoretical models
   - Goals and needs

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3. **Apply to theory**
   - Propose theoretical models closer to reality
   - Adapt algorithms
   - Propose features in line with practice

2019

Formalization of
Cypher (Neo4j)
[FG+18; GG+19]

2019 2022

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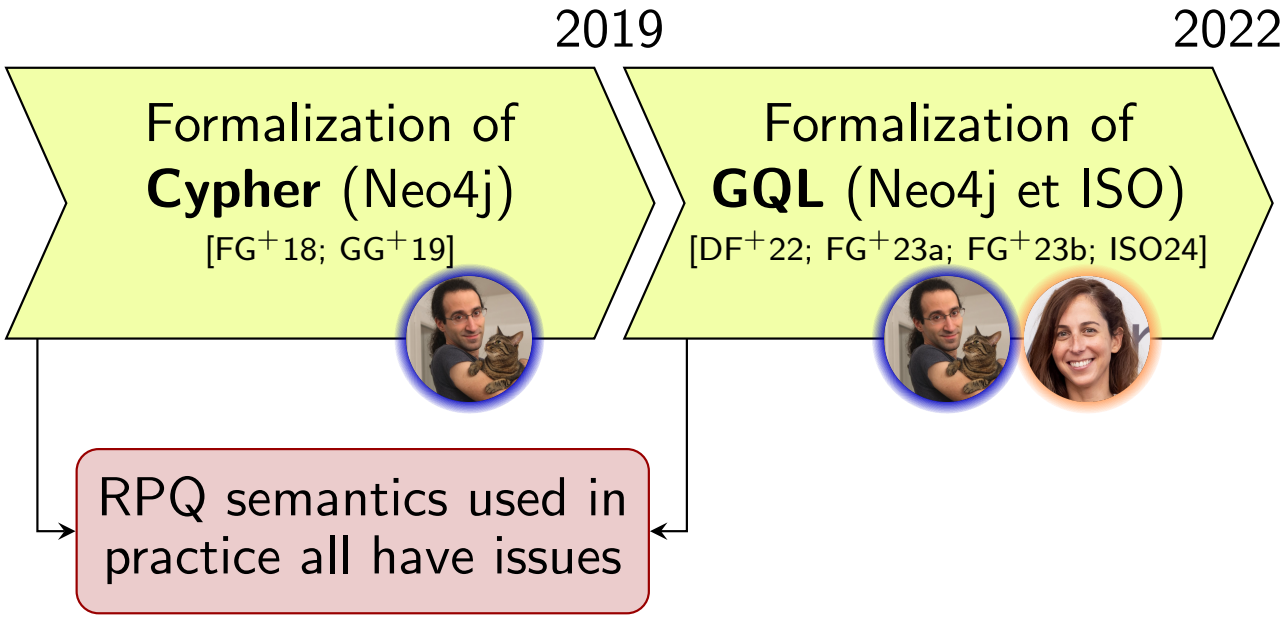
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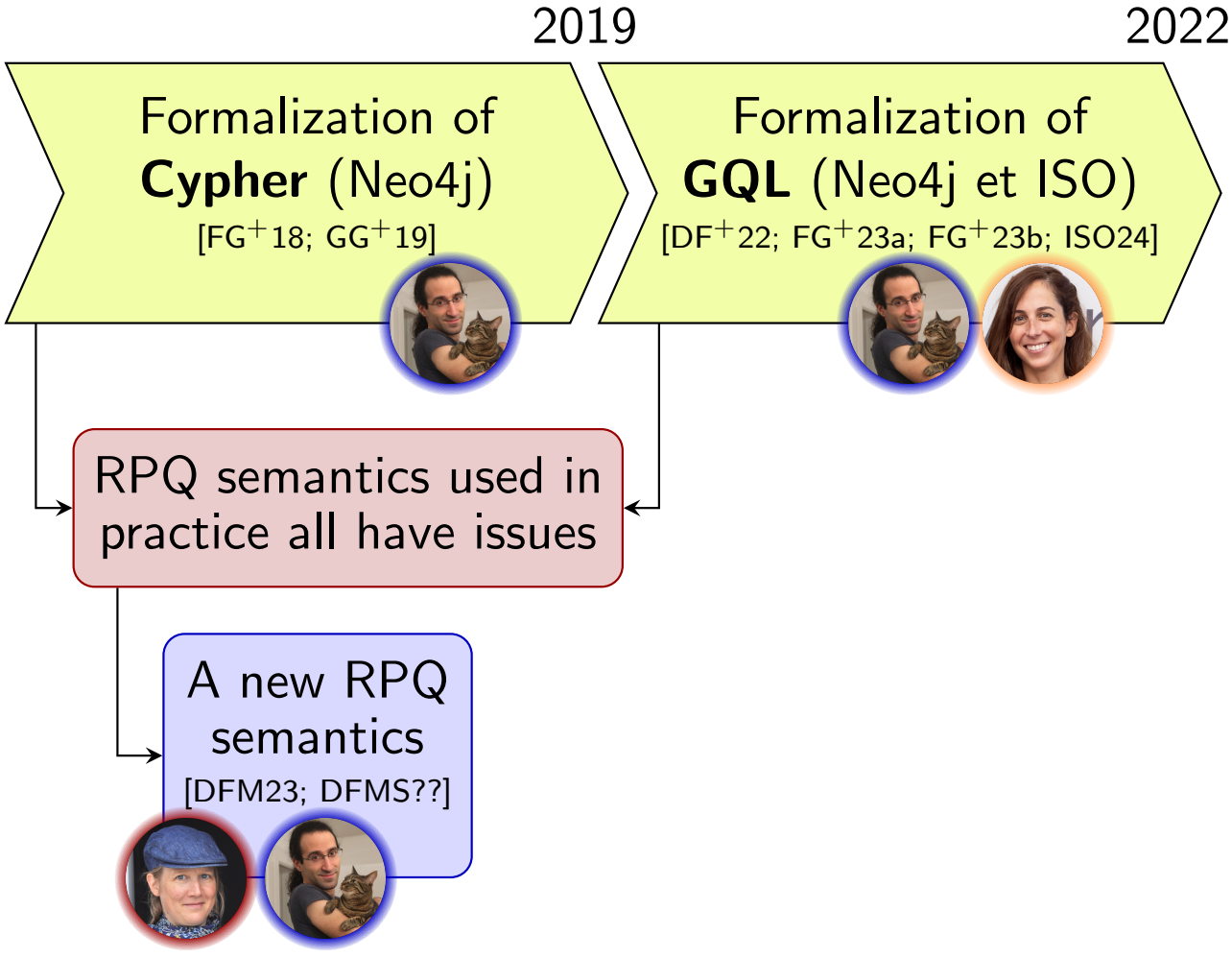
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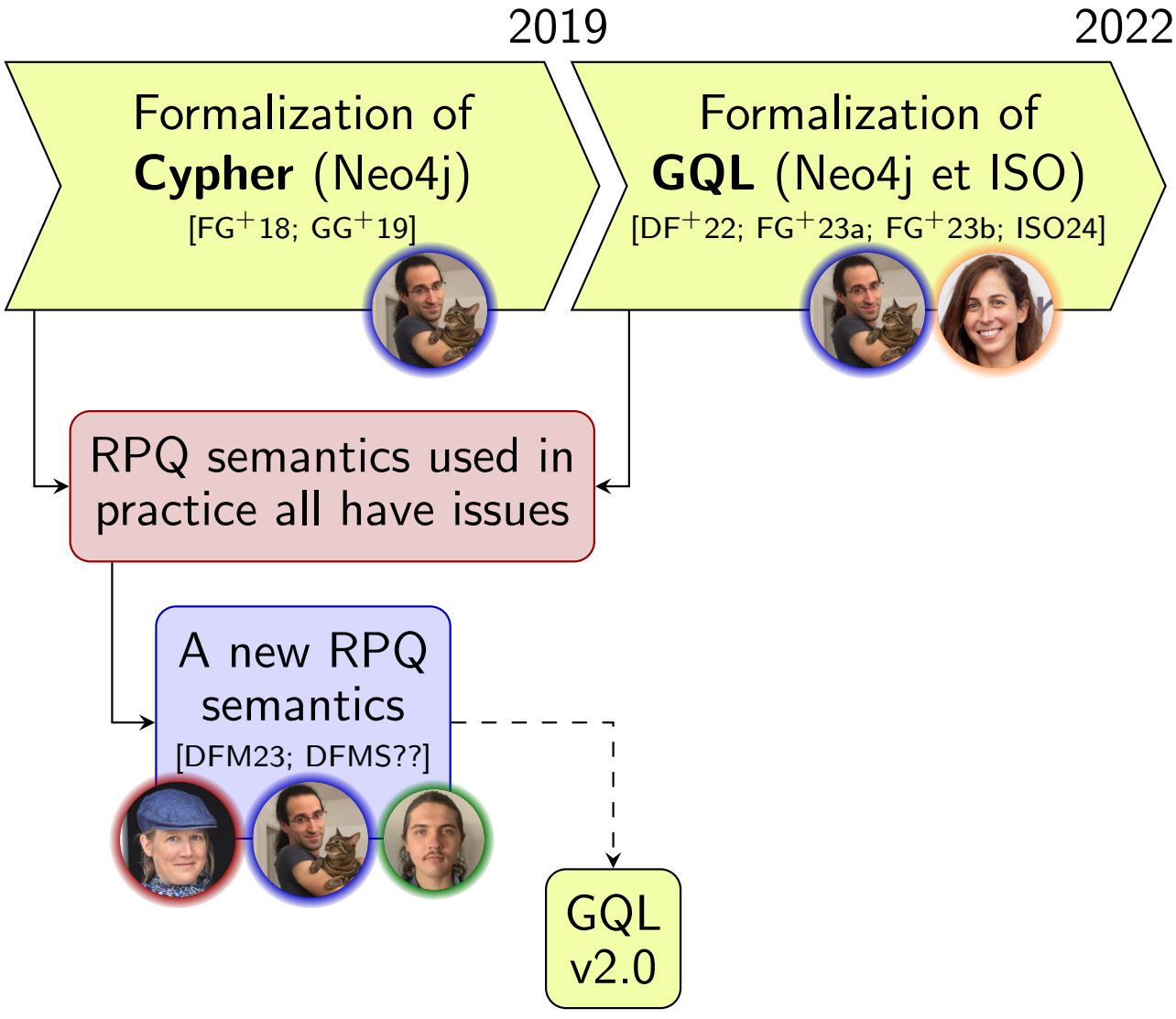
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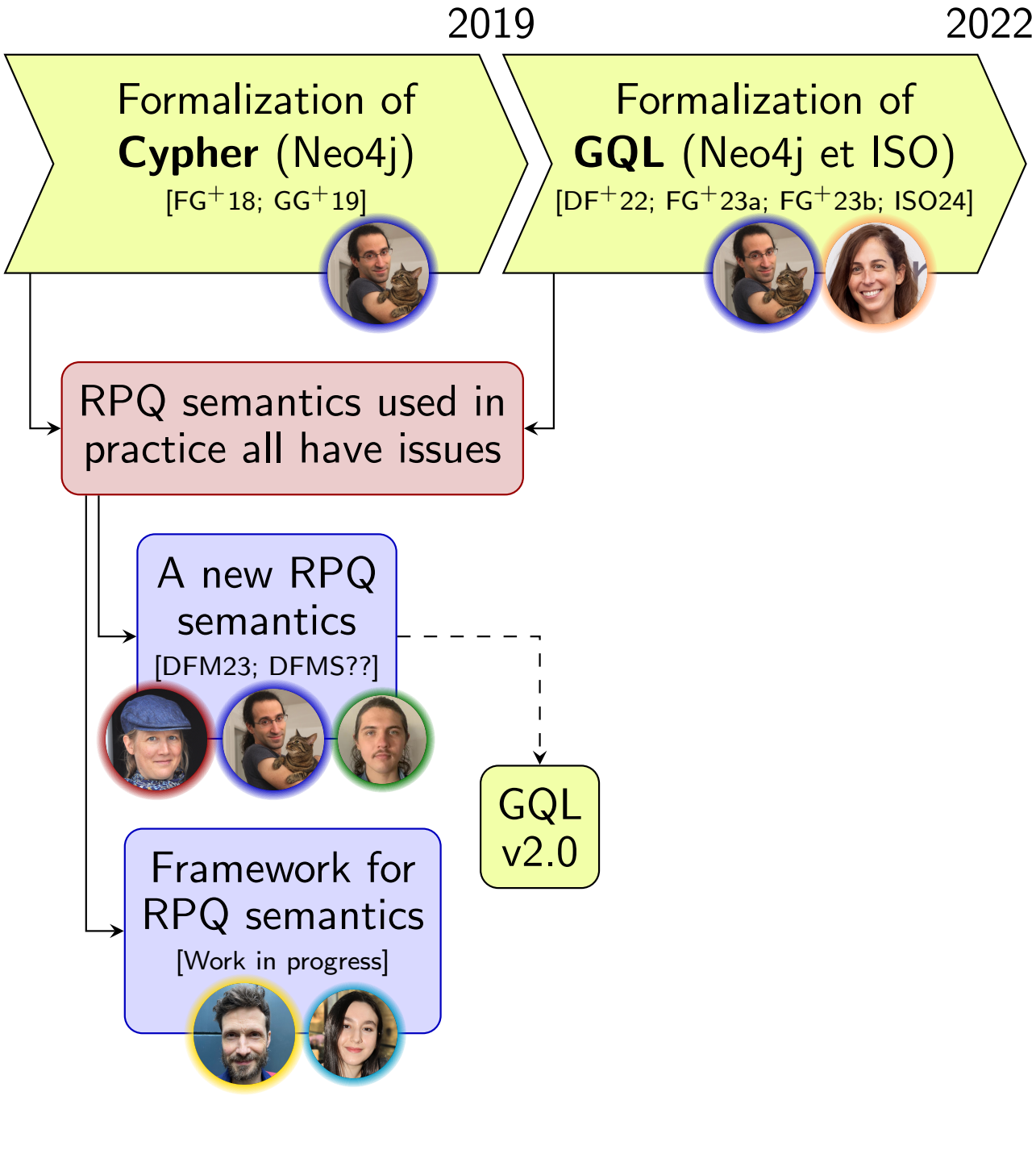
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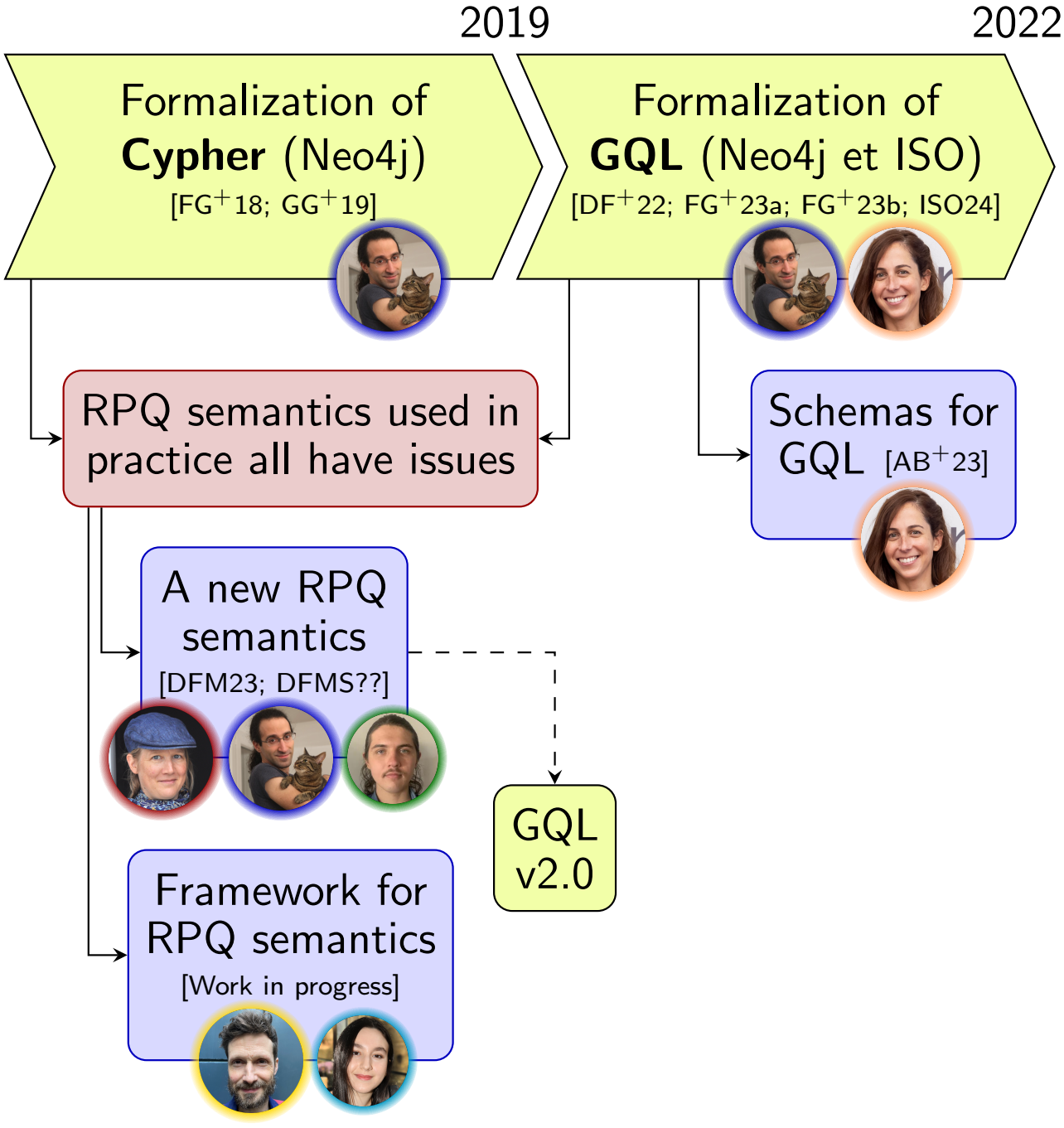
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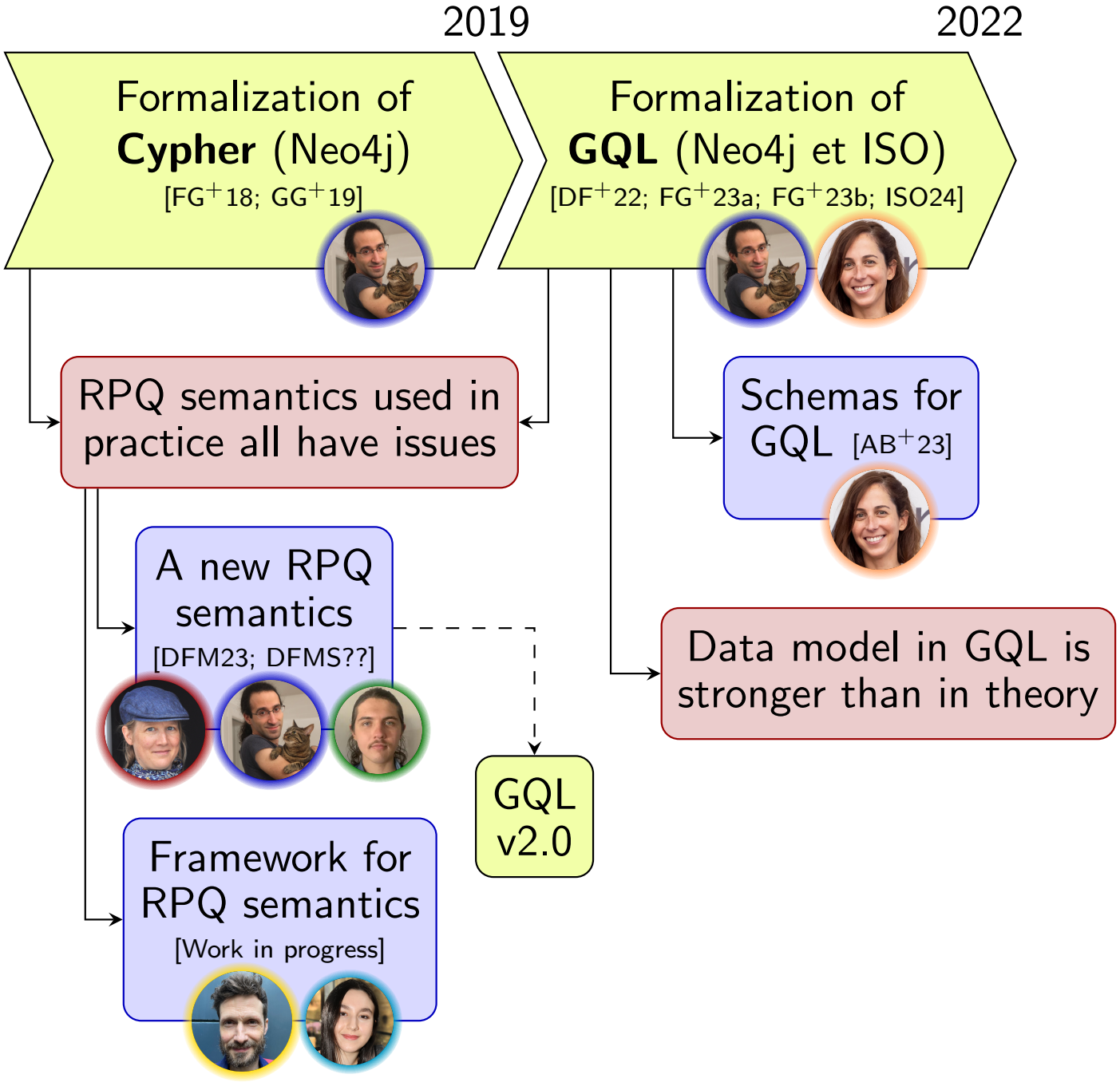
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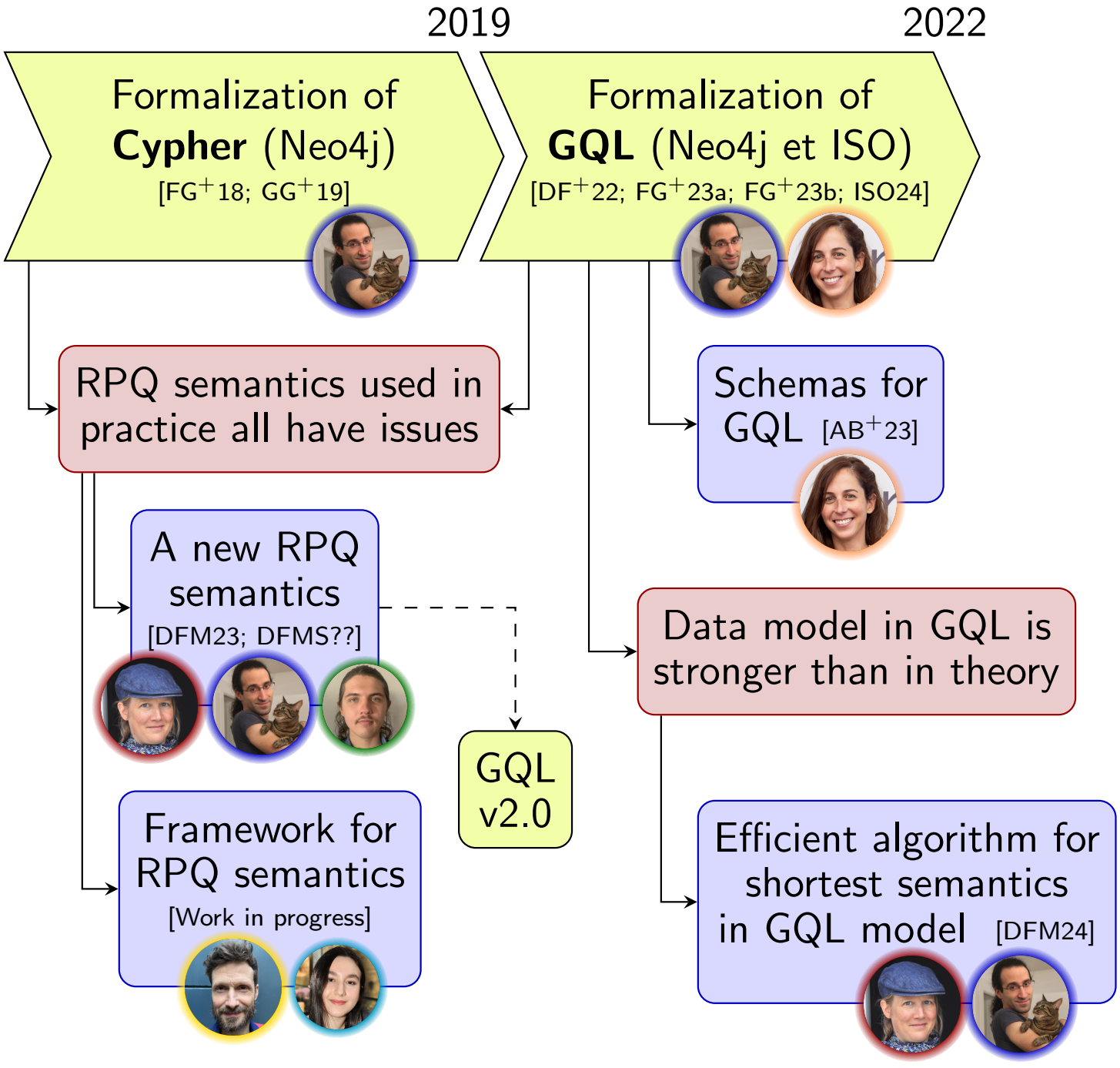
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Efficient algorithm for shortest semantics in GQL model [DFM24]

Focus on [DFM23]:
Run-based semantics for RPQs

Setting of [DFM23]

User

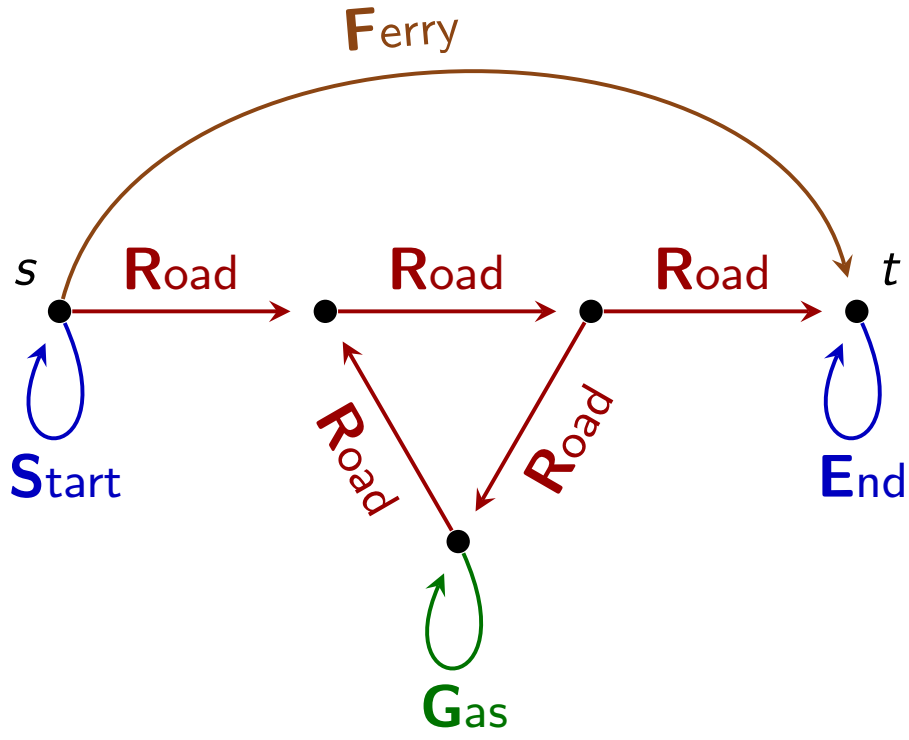
Query is an RPQ = Regular Expression

Answer

Graph Database

Our database is a labeled graph

- Finite label alphabet: $\Sigma = \{\mathbf{S}, \mathbf{R}, \mathbf{F}, \mathbf{G}, \mathbf{E}\}$
- Vertices
- Edges labelled over Σ



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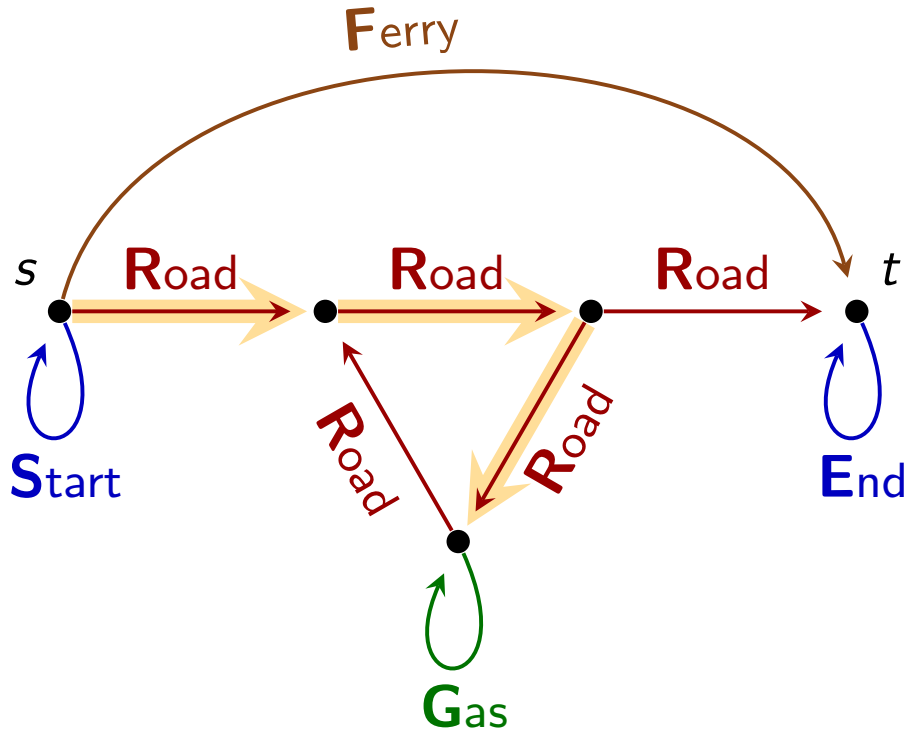

Terminogy: Walk

- Consistent sequence of edges
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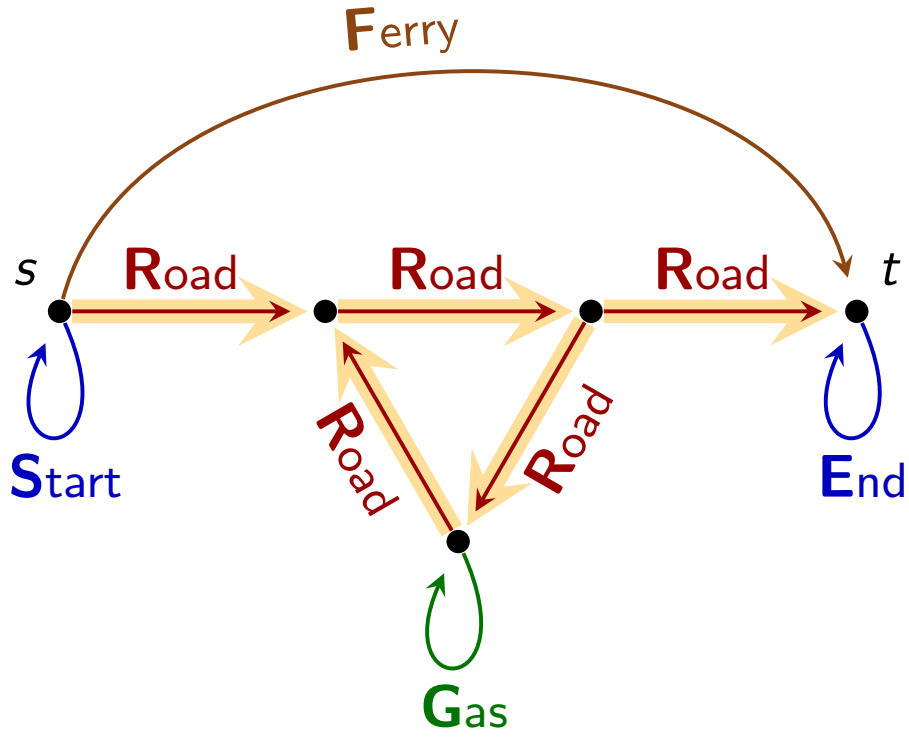

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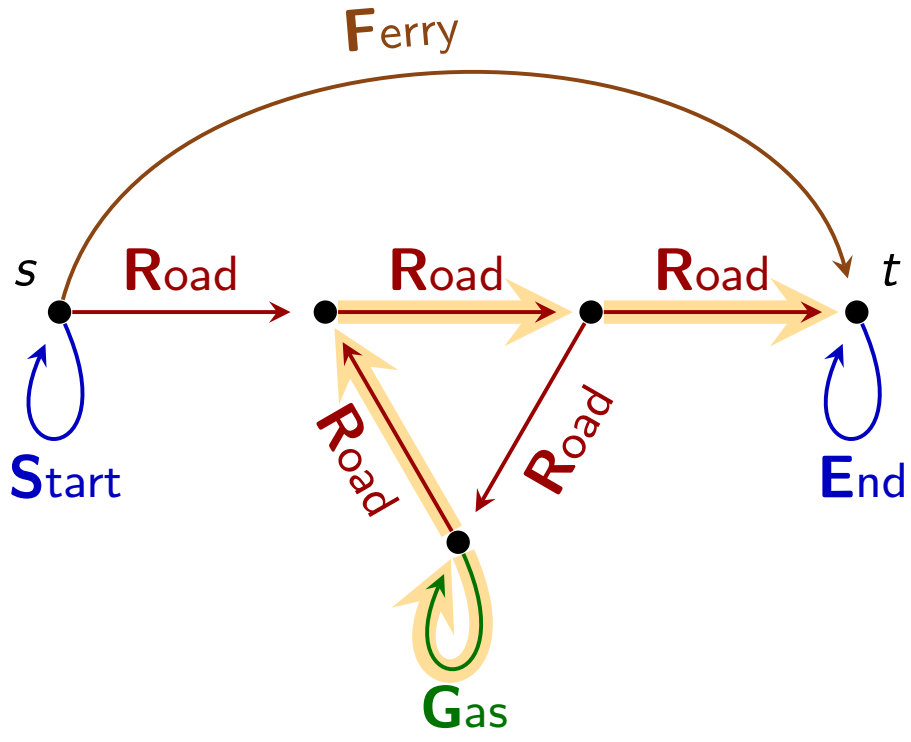
RPQ : pattern matching of walks

$Q ::=$	**A**	Atoms
	QQ	Concatenation
	$Q + Q$	Disjunction
	Q^*	Kleene star

where **A** is a label in the graph.

Ex: **GR***

"One **G** *then any number of* **R***"*



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A walk matches Q
$\iff$ its label matches Q.

Ex: *Orange walk is labelled* **GRRR**
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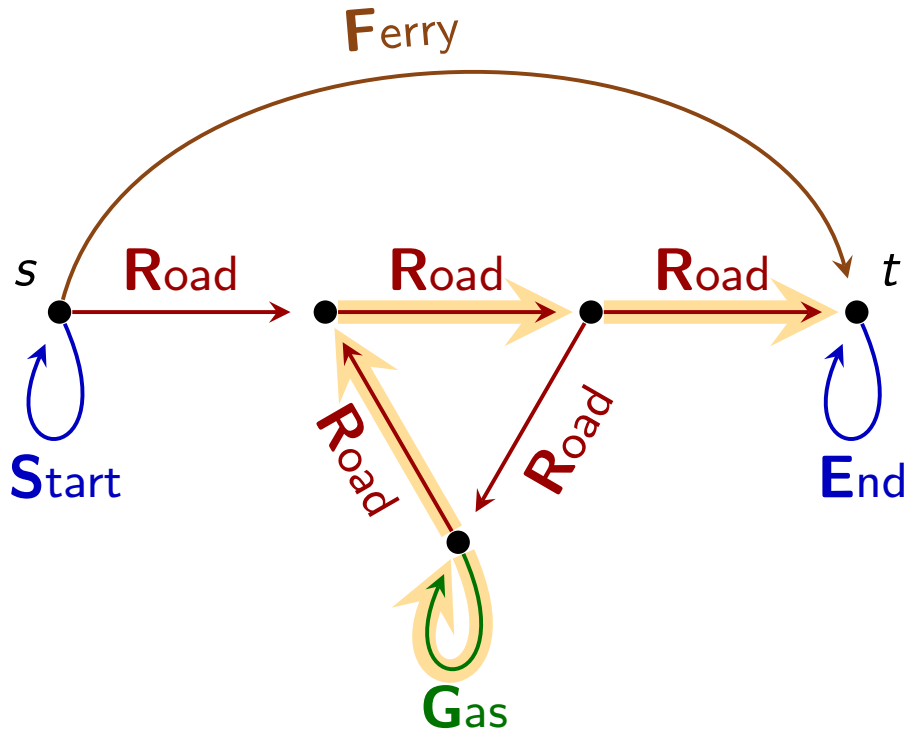

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RPQ Semantics

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- Main semantics in theory
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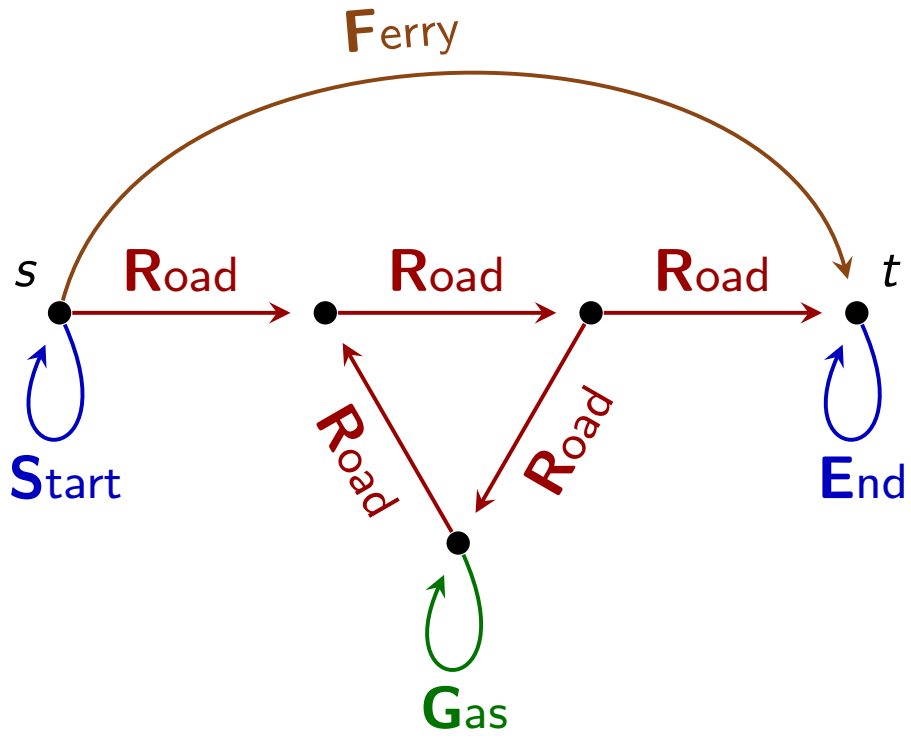
Binding-trail semantics

- Our proposal
- Edges may be repeated when using different atoms

Finding a way from s to t

$$Q_1 = \quad \mathbf{S}\ (\mathbf{R}+\mathbf{F})^*\ \mathbf{E}$$



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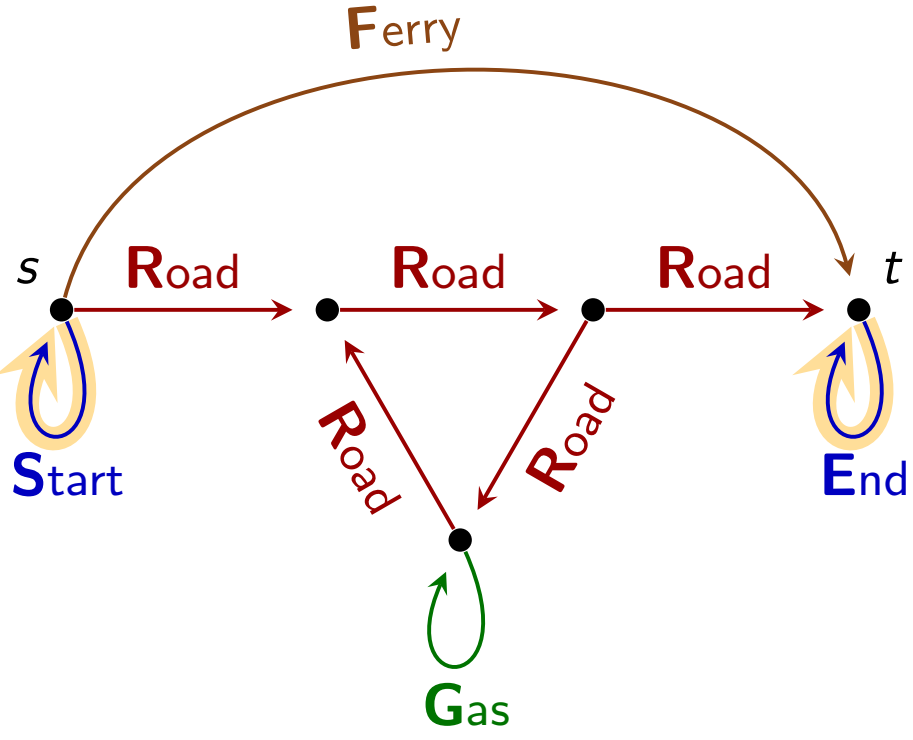

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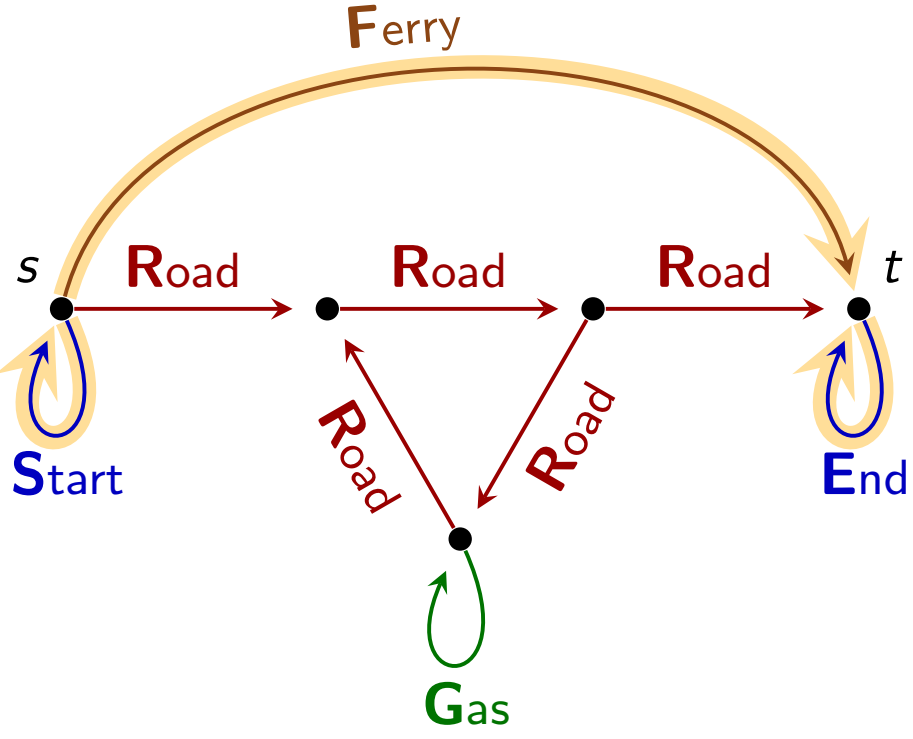

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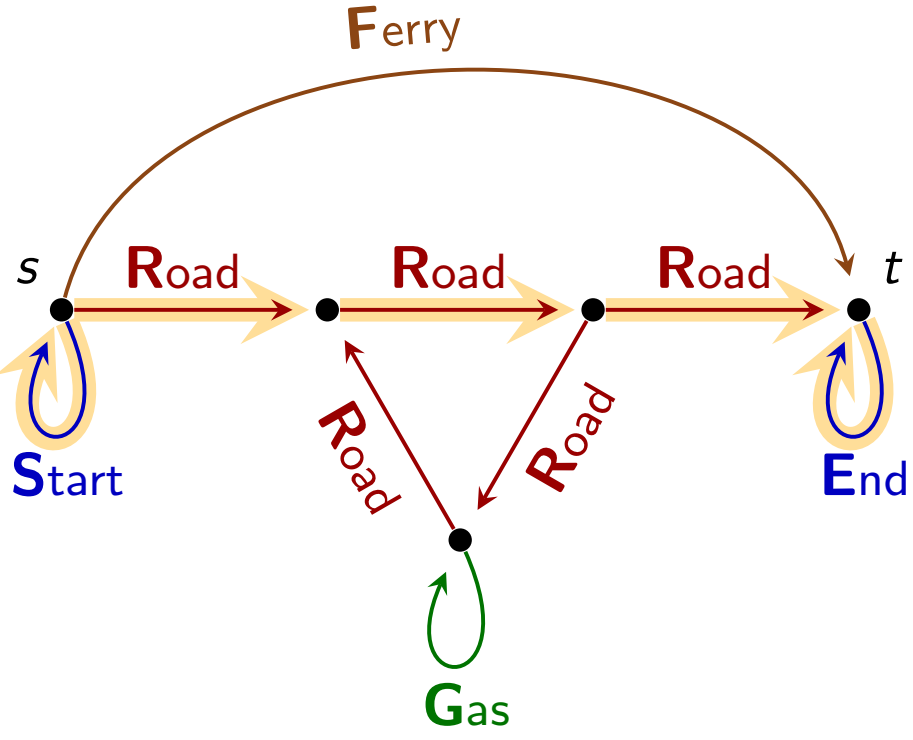

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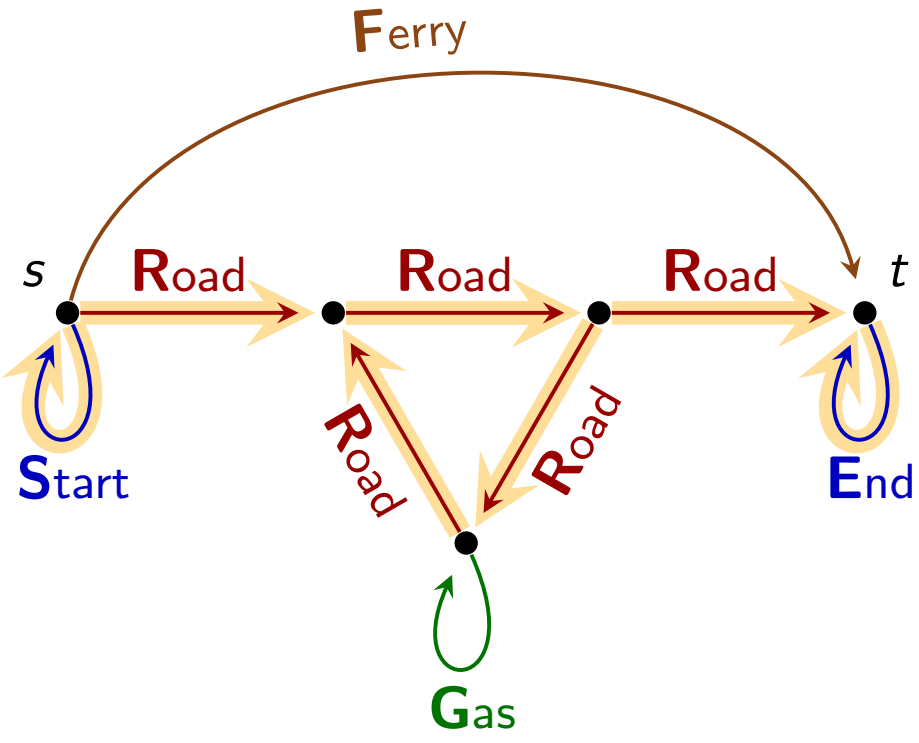

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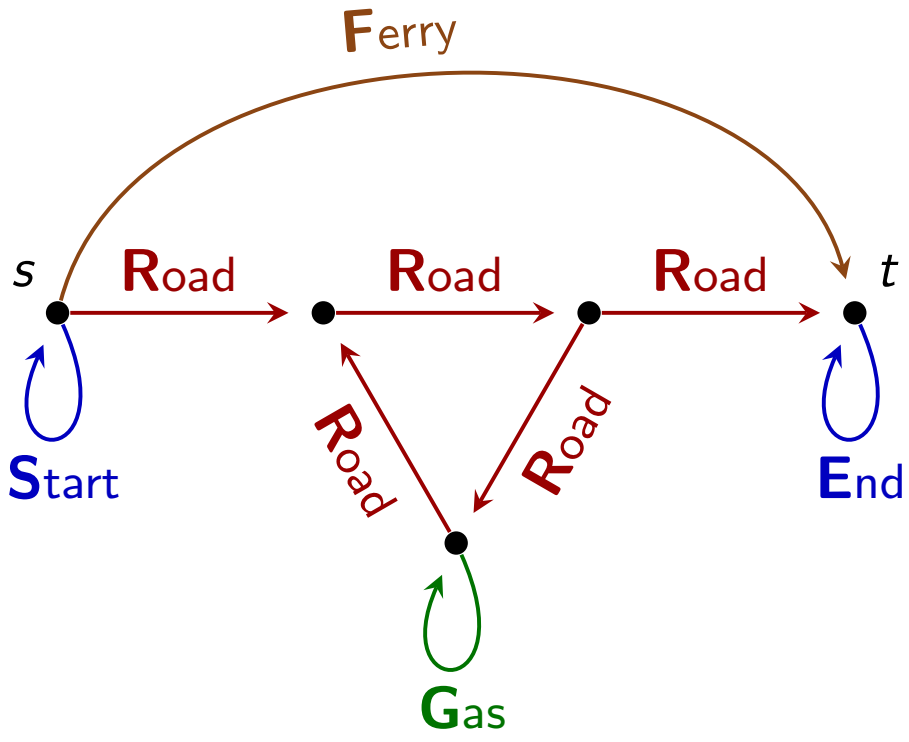

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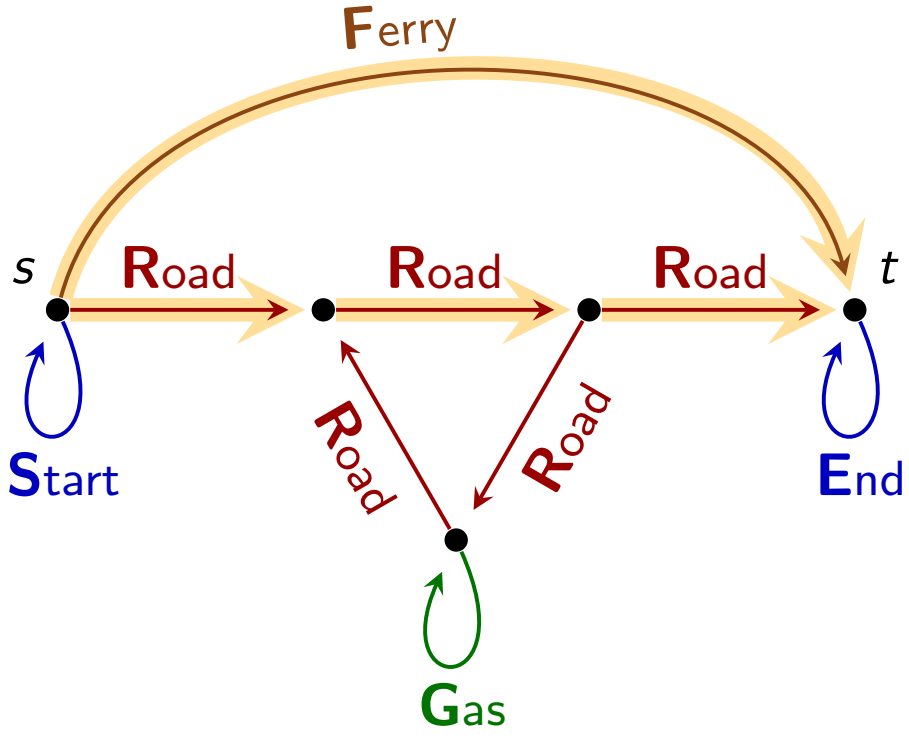

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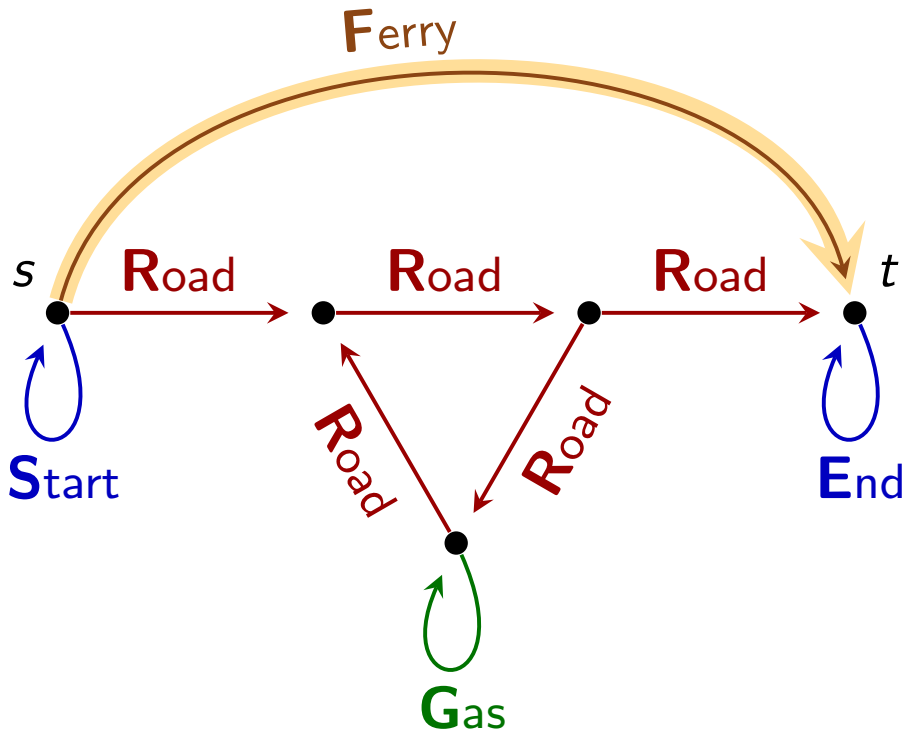

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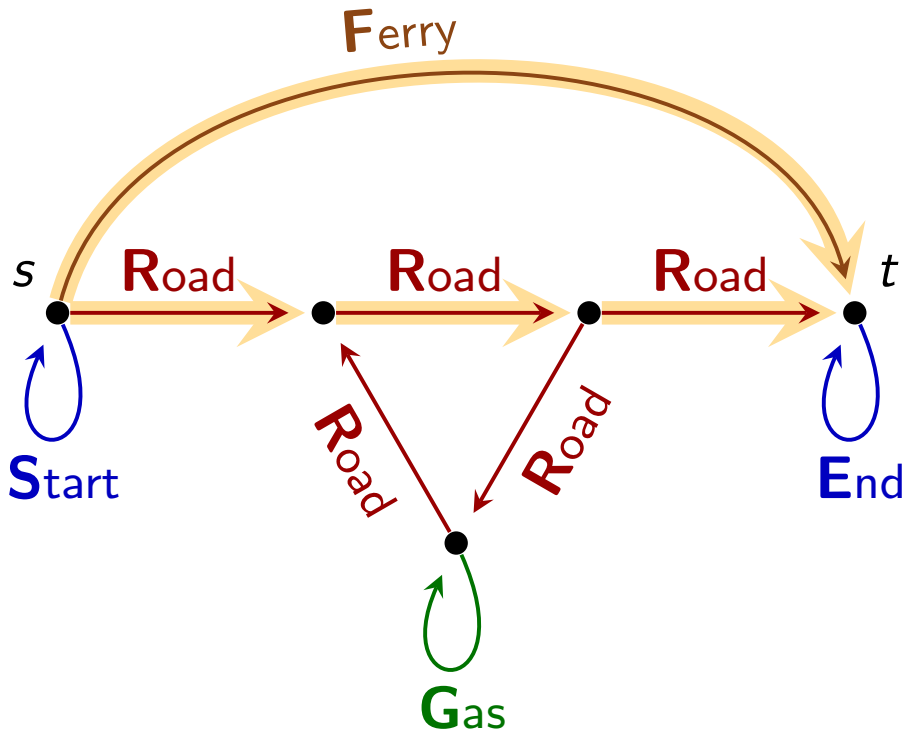

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Binding-trail returns the ferry and the straight road

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Which walks match Q_2?

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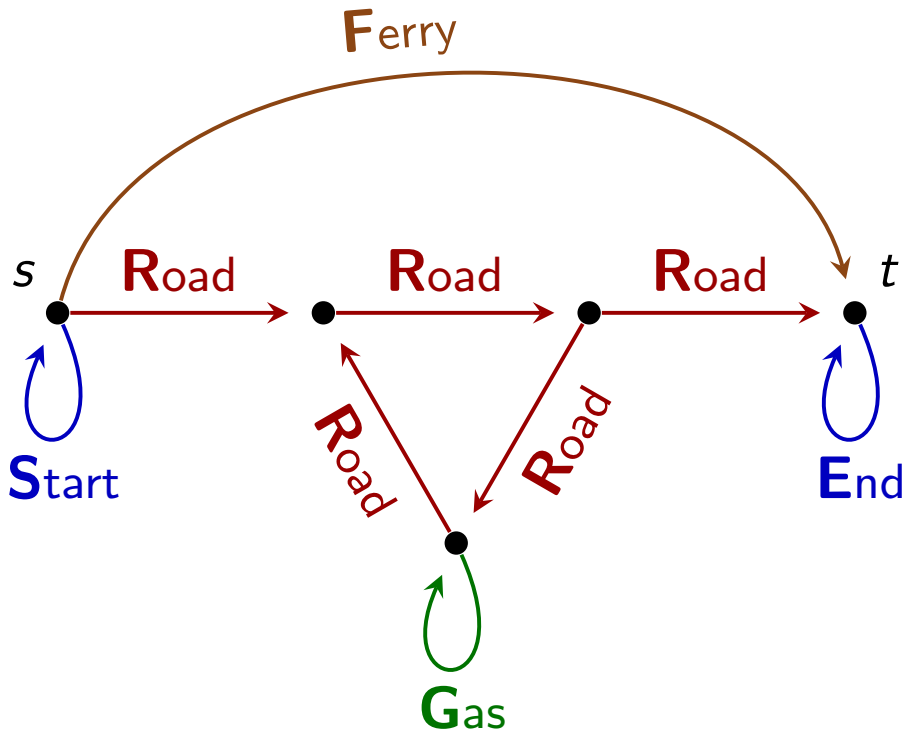

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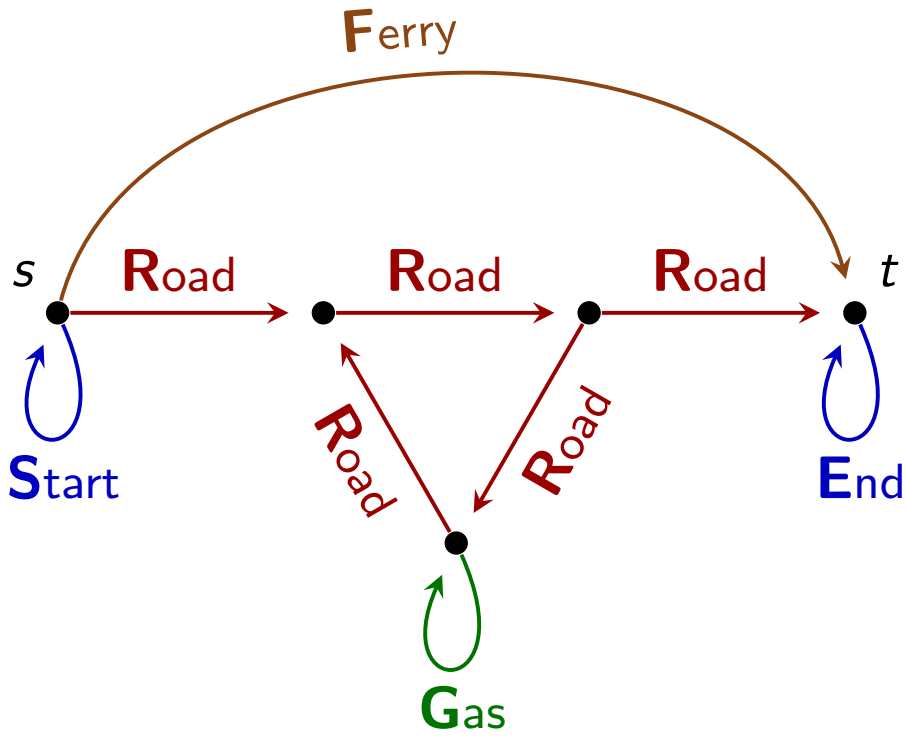

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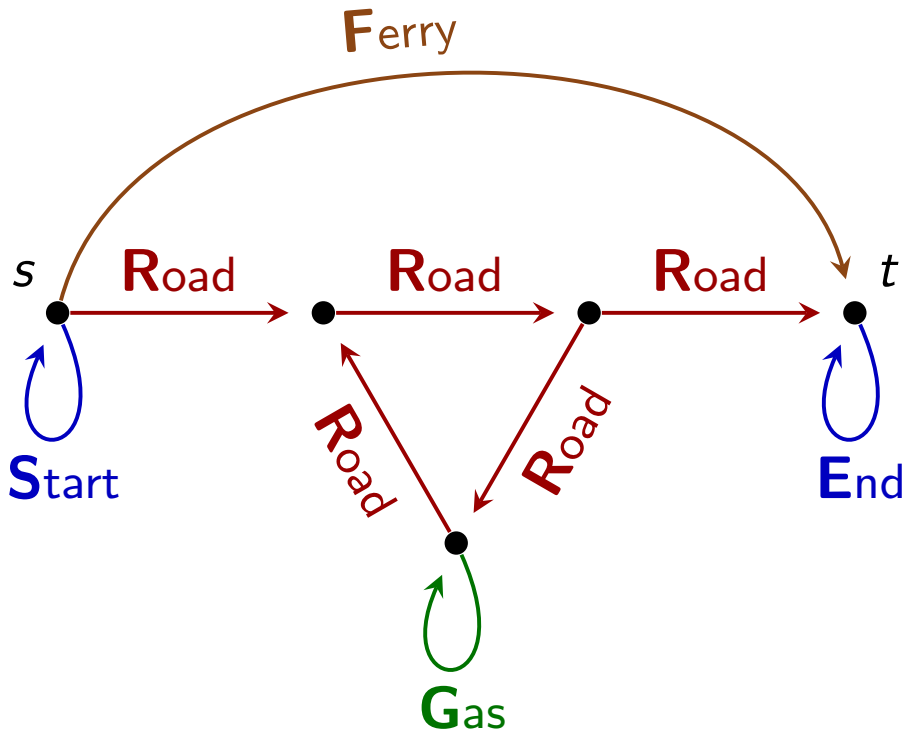

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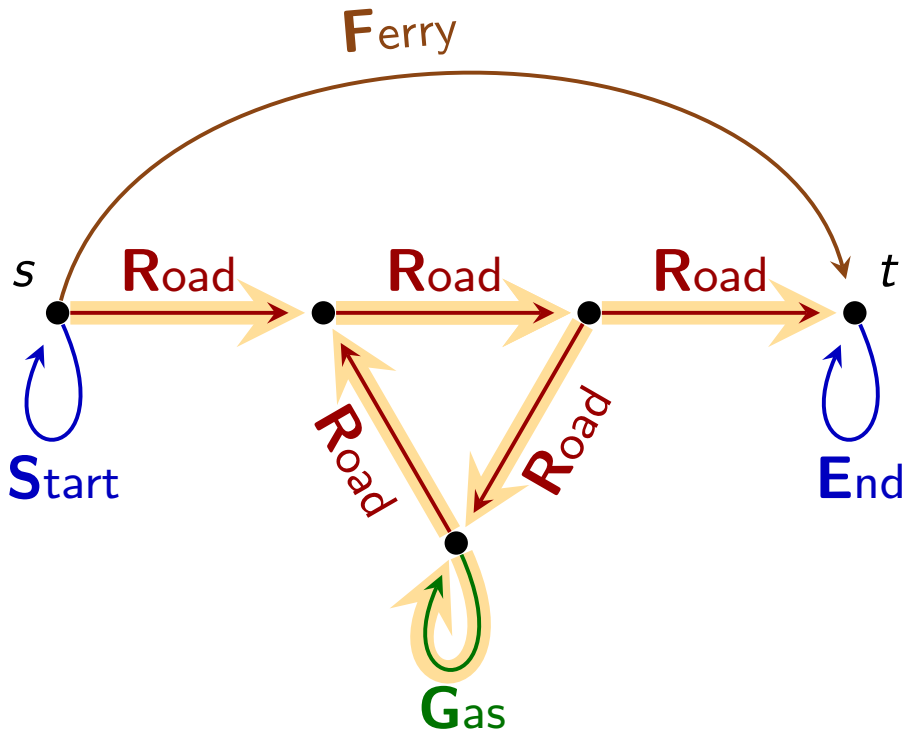

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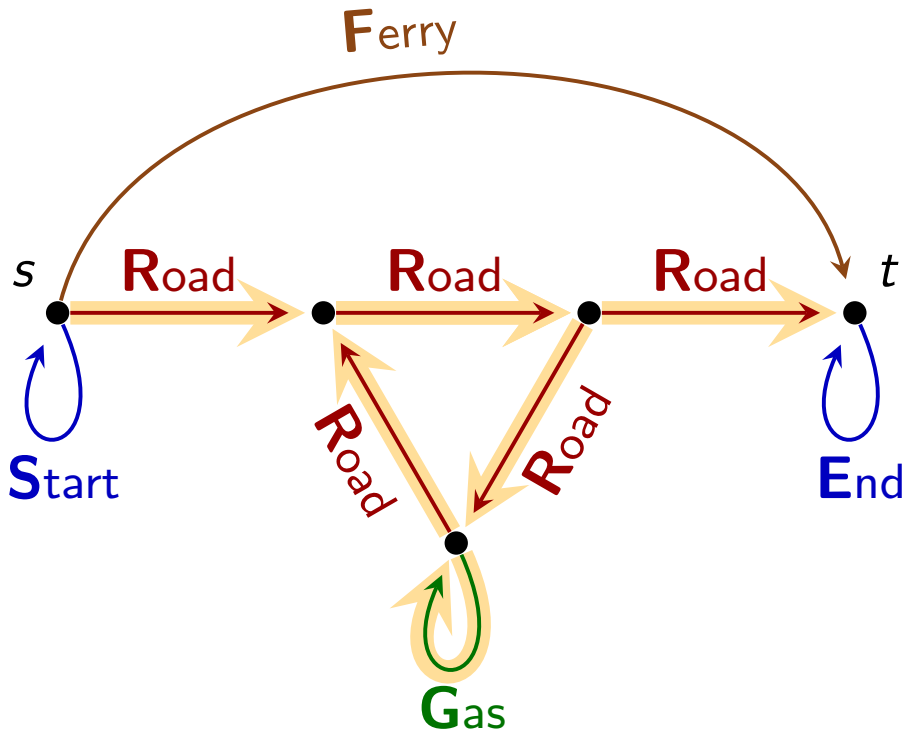

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Recap of [DFM23]

User

Query is an RPQ = Regular Expression

Graph Database

Possibly infinite answer

Question: How to ensure finiteness?

In theory

Endpoint semantics

- Little information is returned

Our proposal

Binding-trail semantics

- A good compromise?

In practice

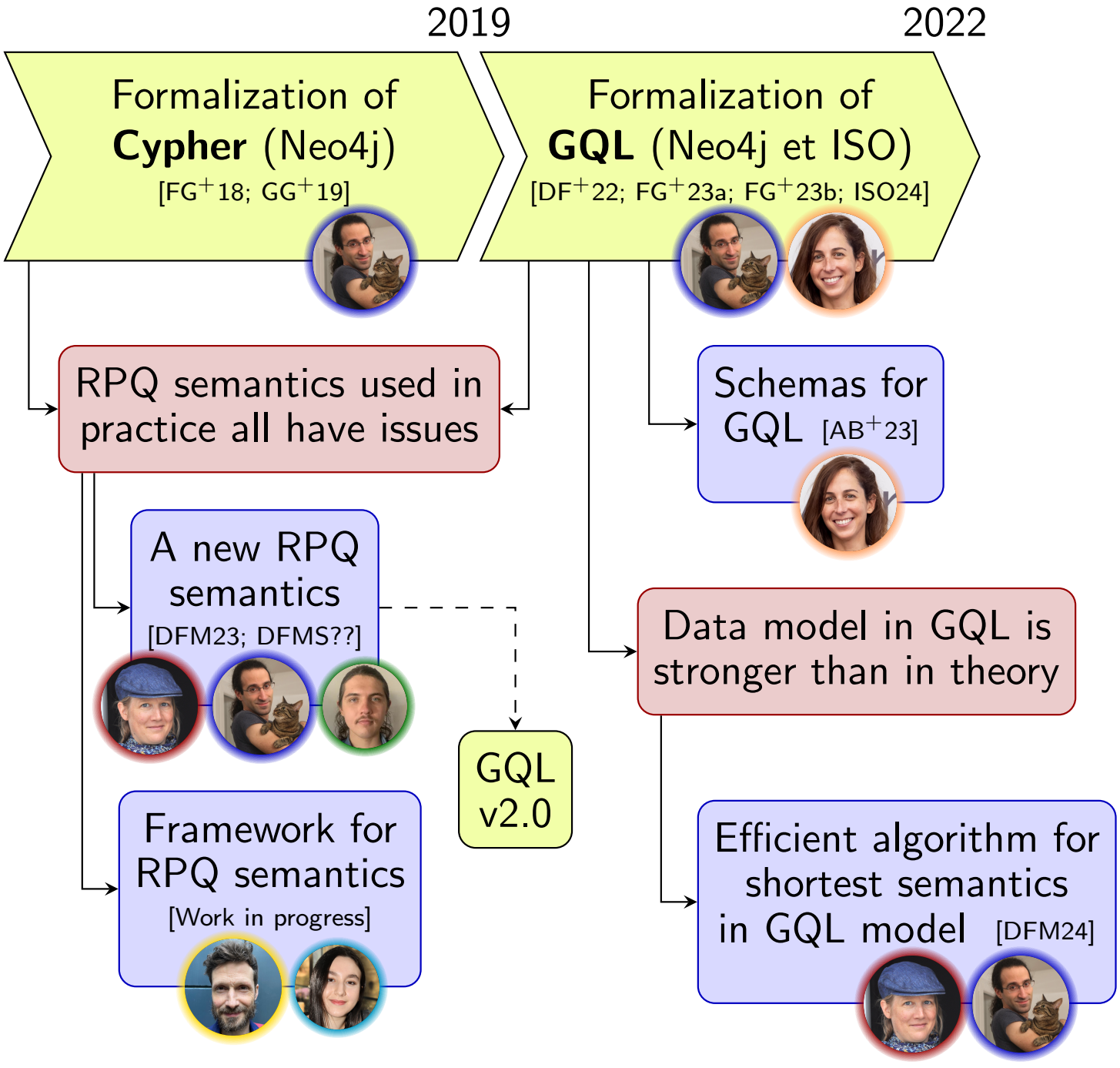
Trail semantics

- Untractable

Shortest sem.

- Arbitrary

Ongoing/Future work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Efficient algorithm for shortest semantics in GQL model [DFM24]

2019 2022

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[FG+18; GG+19]

Formalization of **GQL** (Neo4j et ISO)
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Formalization/Design of **Rel** (RelationalAi)
[Work in progress]

RPQ semantics used in practice all have issues

Schemas for GQL [AB+23]

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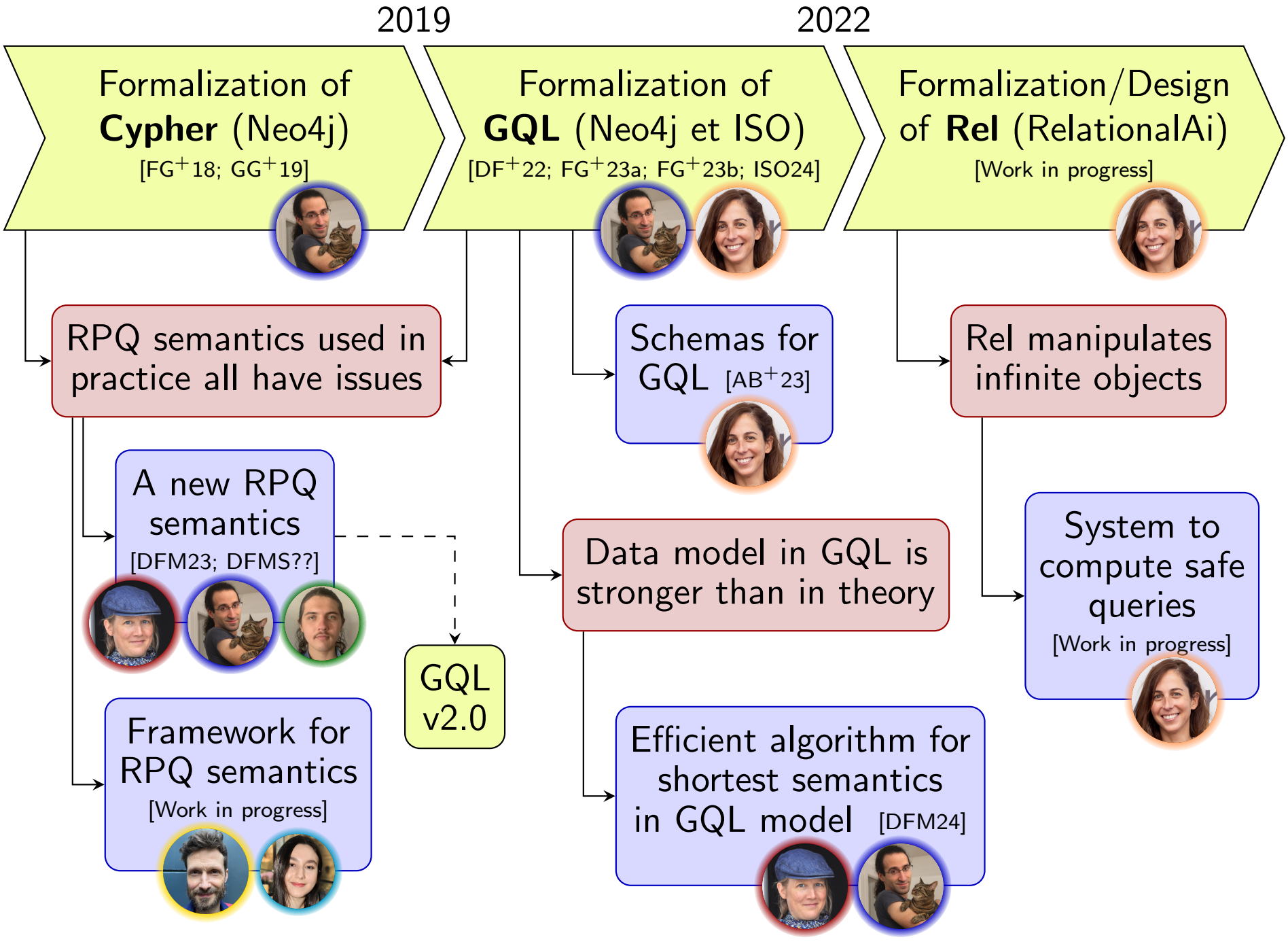
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Framework for RPQ semantics [Work in progress]
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Example Queries in Cypher and GQL

Q_1 in Cypher

```
MATCH ({id:"Paris"}) -[:Road|Ferry*]-> ({id:"Lyon"})
```

Q_2 in GQL

```
MATCH(s WHERE s.id="Paris")
     -[IS Road|Ferry]->* (m WHERE m.hasGas=true)
     -[IS Road|Ferry]->* (t WHERE t.id="Lyon")
```