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The MySQL Hypergraph Optimizer

What, Why and How

Norvald H. Ryeng
Software Development Director
MySQL Optimizer Team
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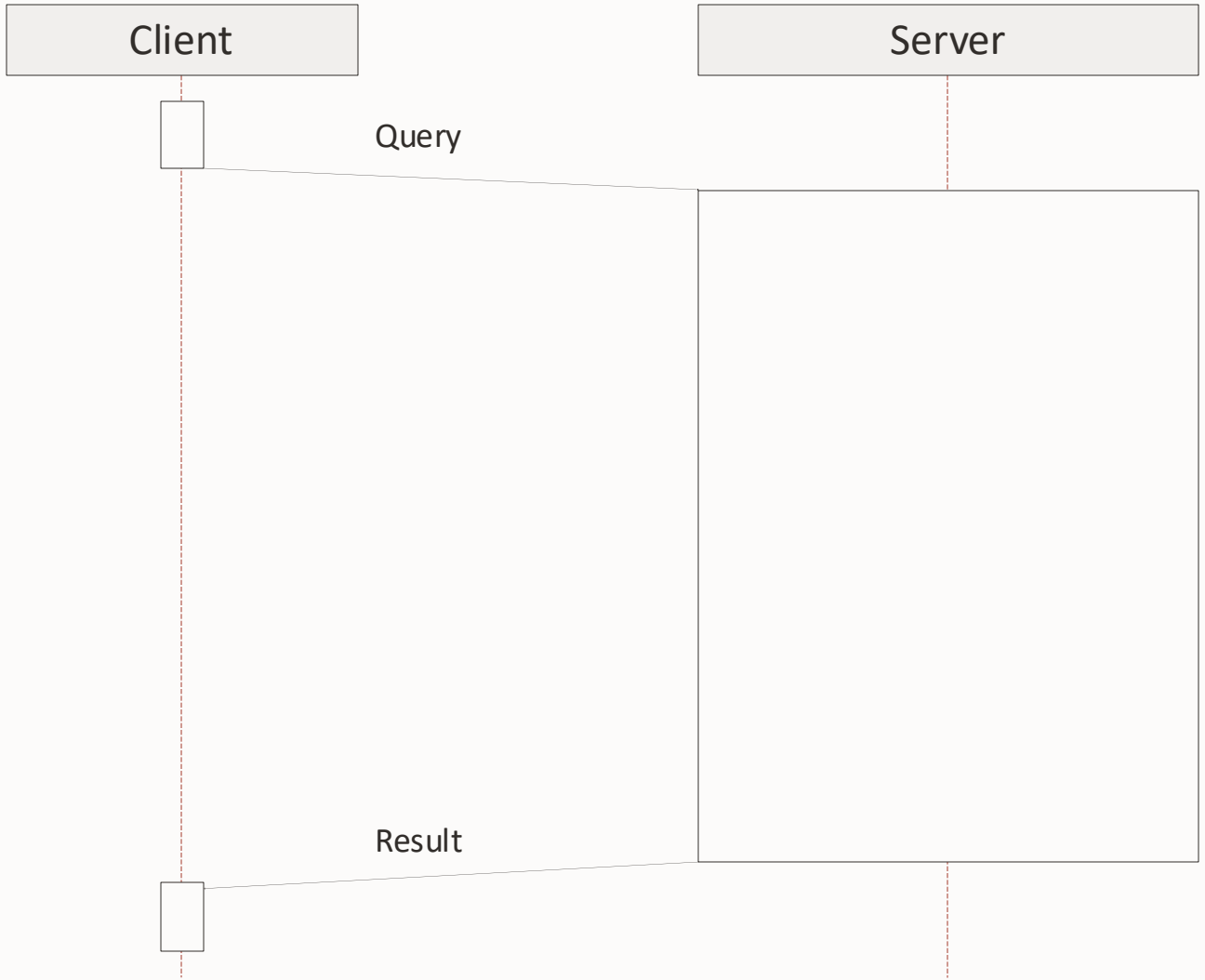
Agenda

1. Query processing 101
2. Why a new optimizer?
3. What is a hypergraph, and what is it doing in my optimizer?
4. How can I start using the hypergraph optimizer?

Query processing 101

Query processing



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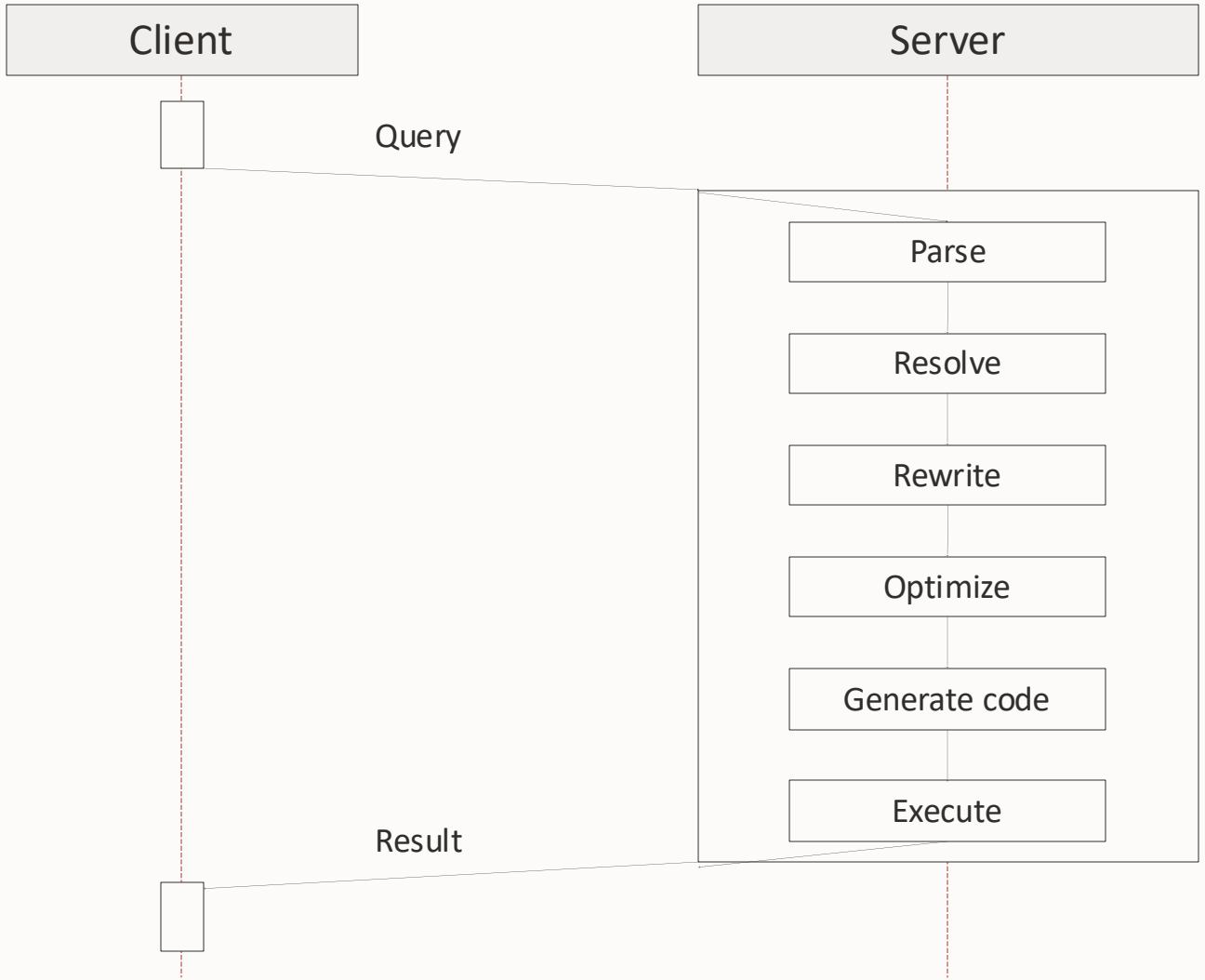

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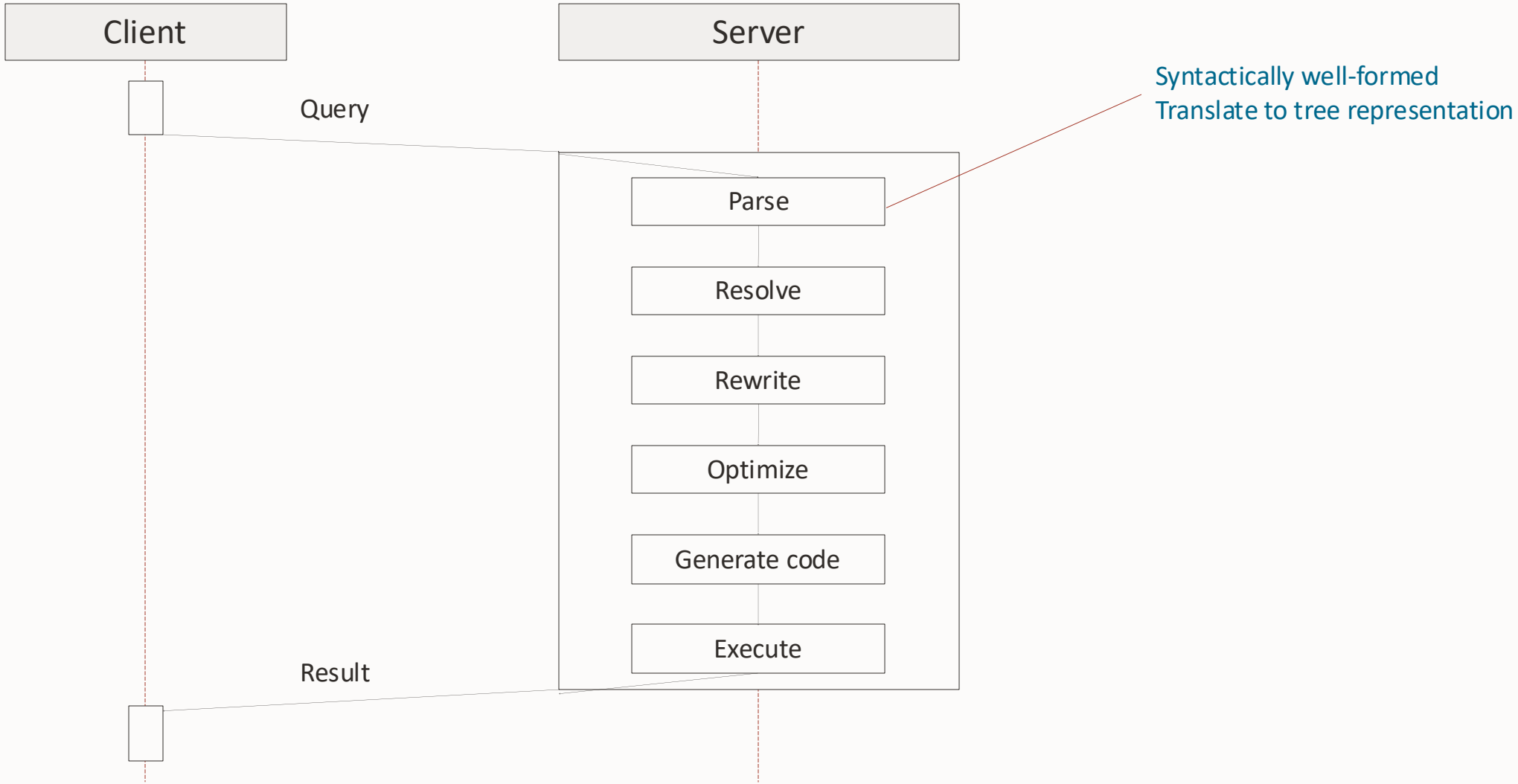

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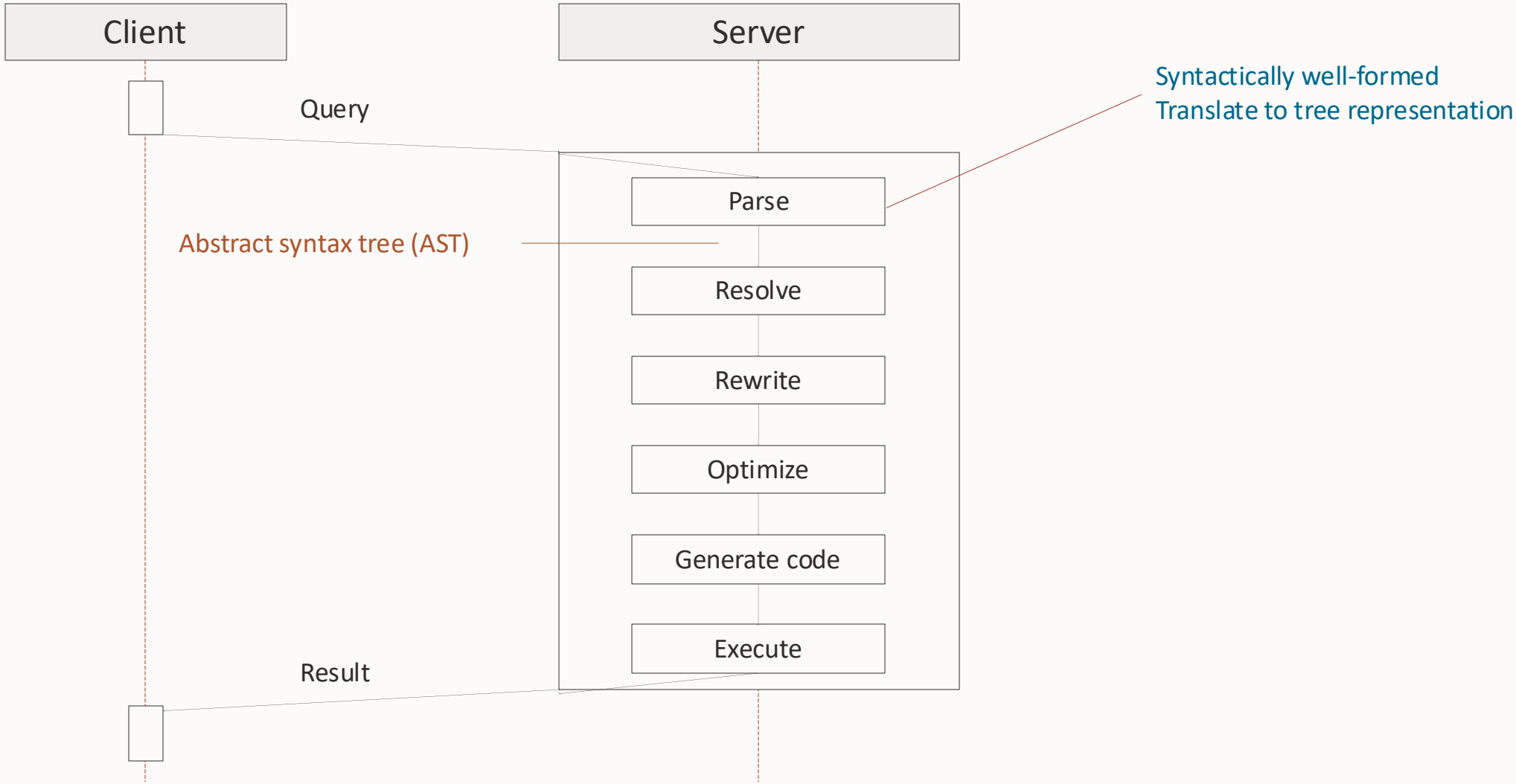

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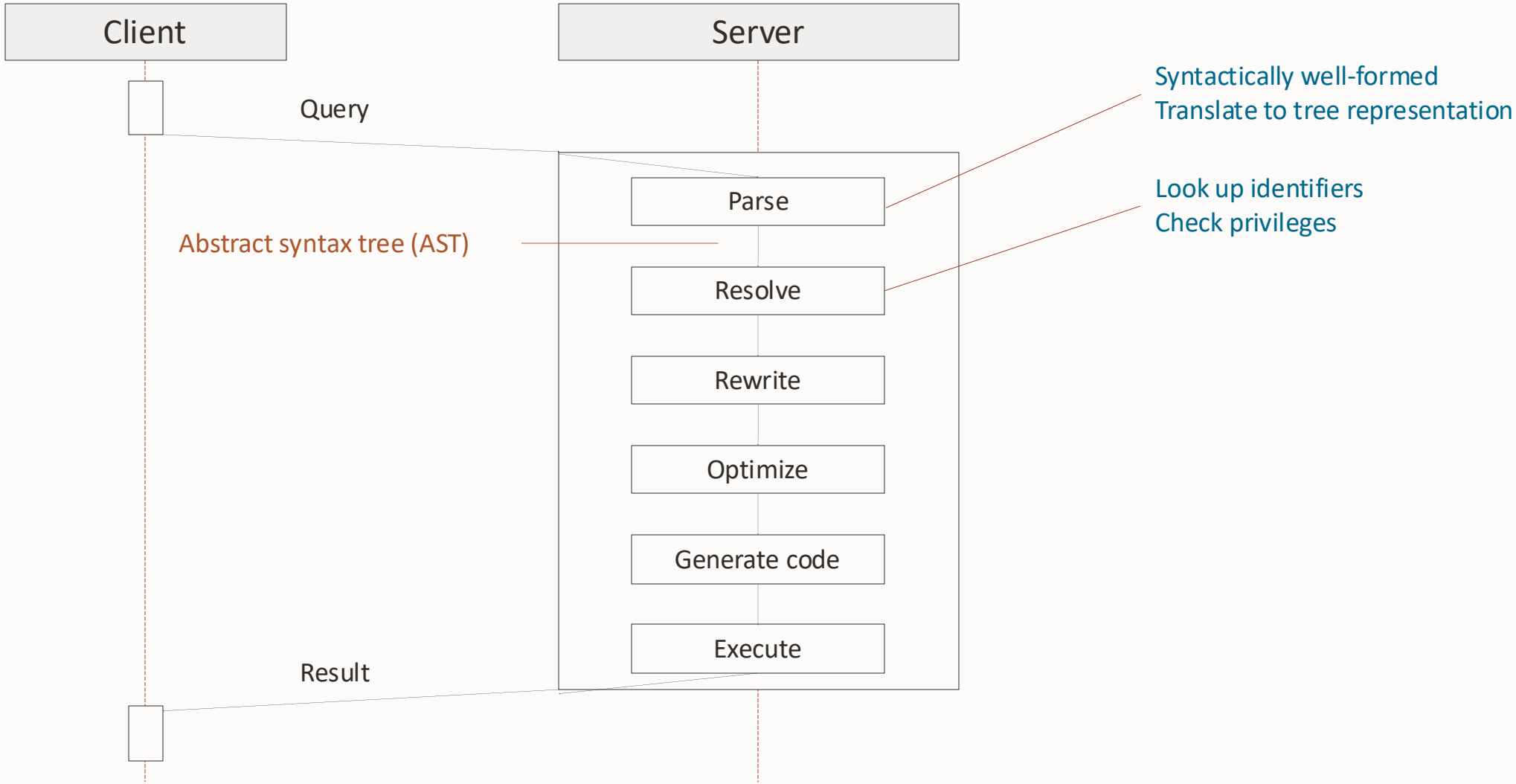

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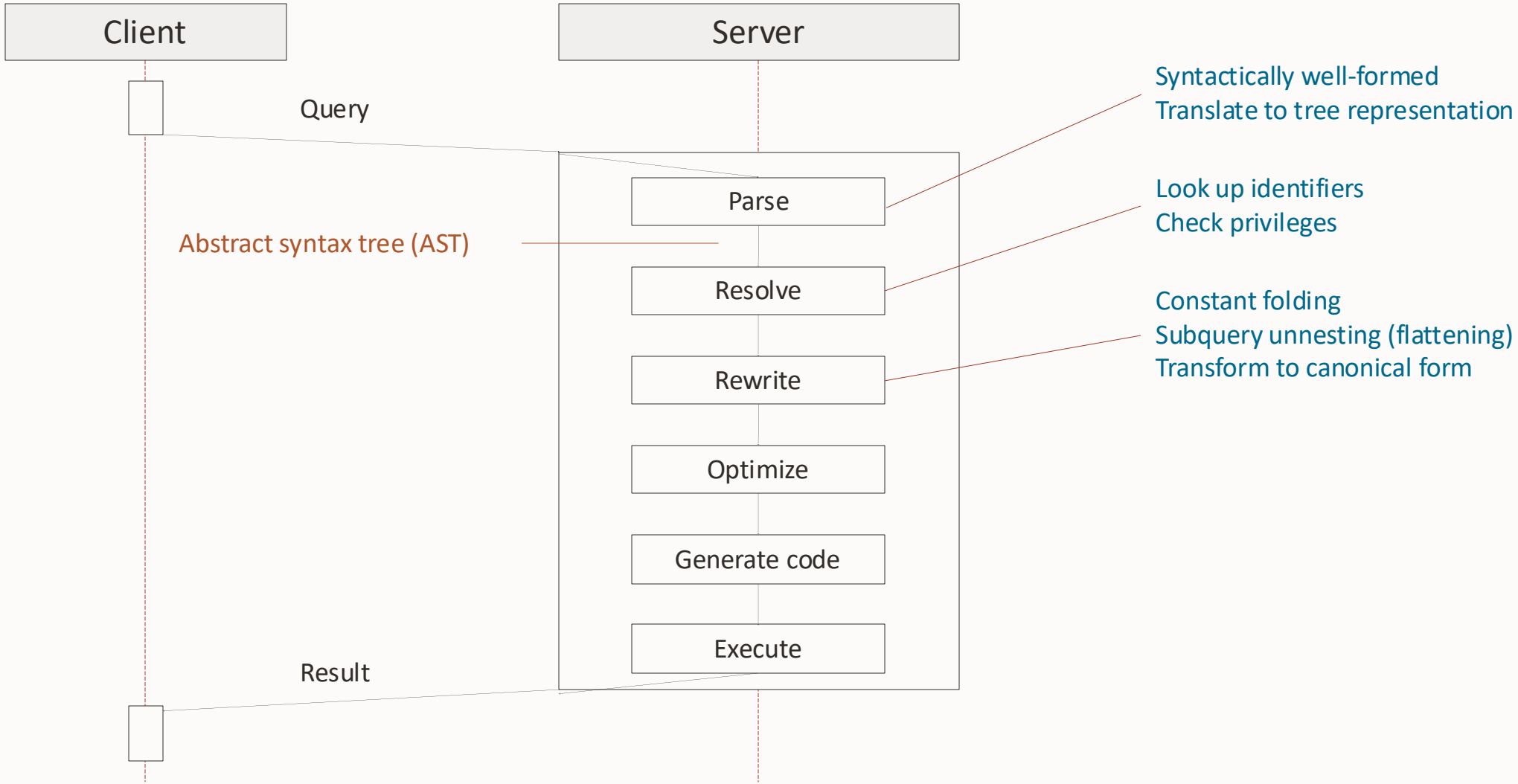

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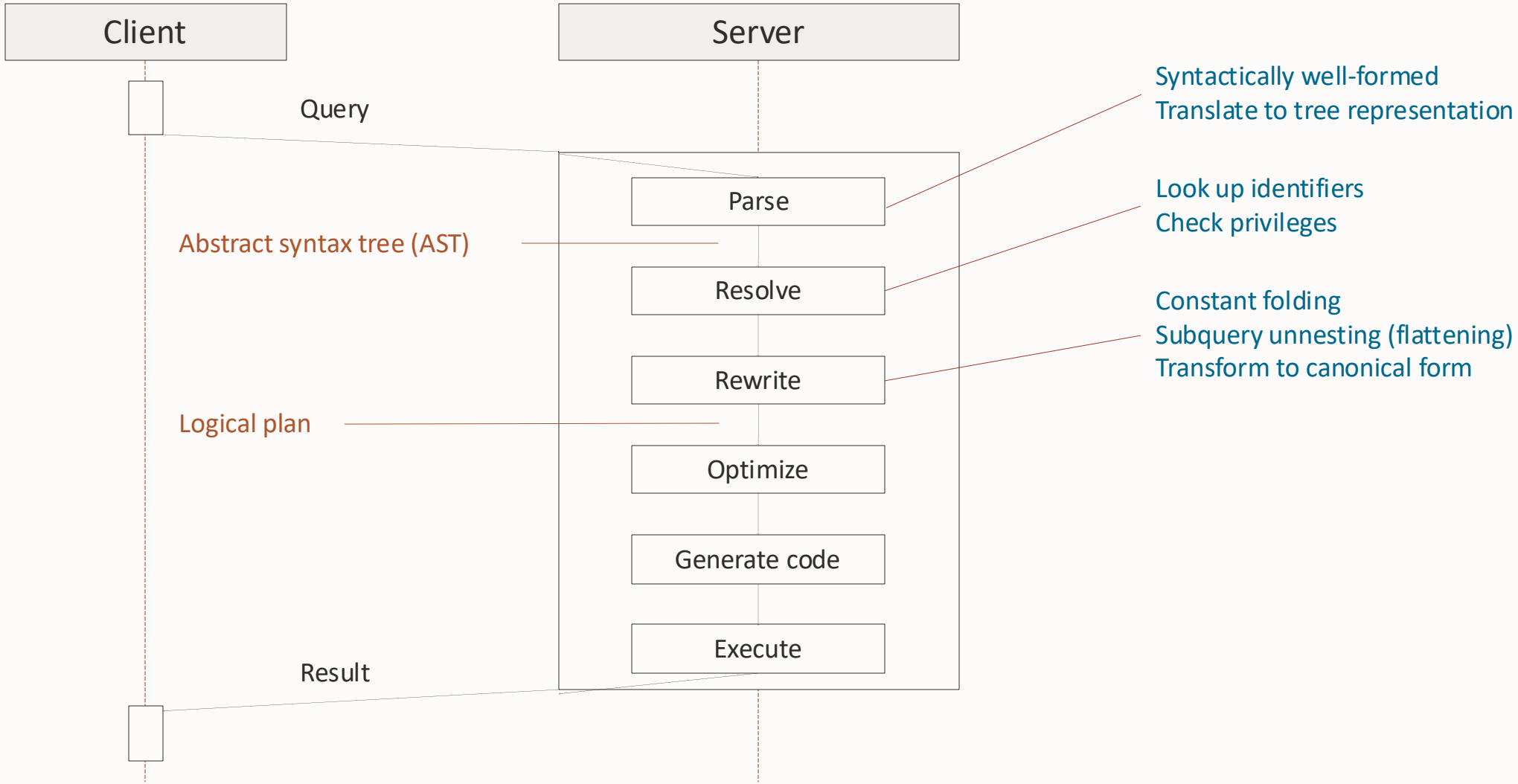

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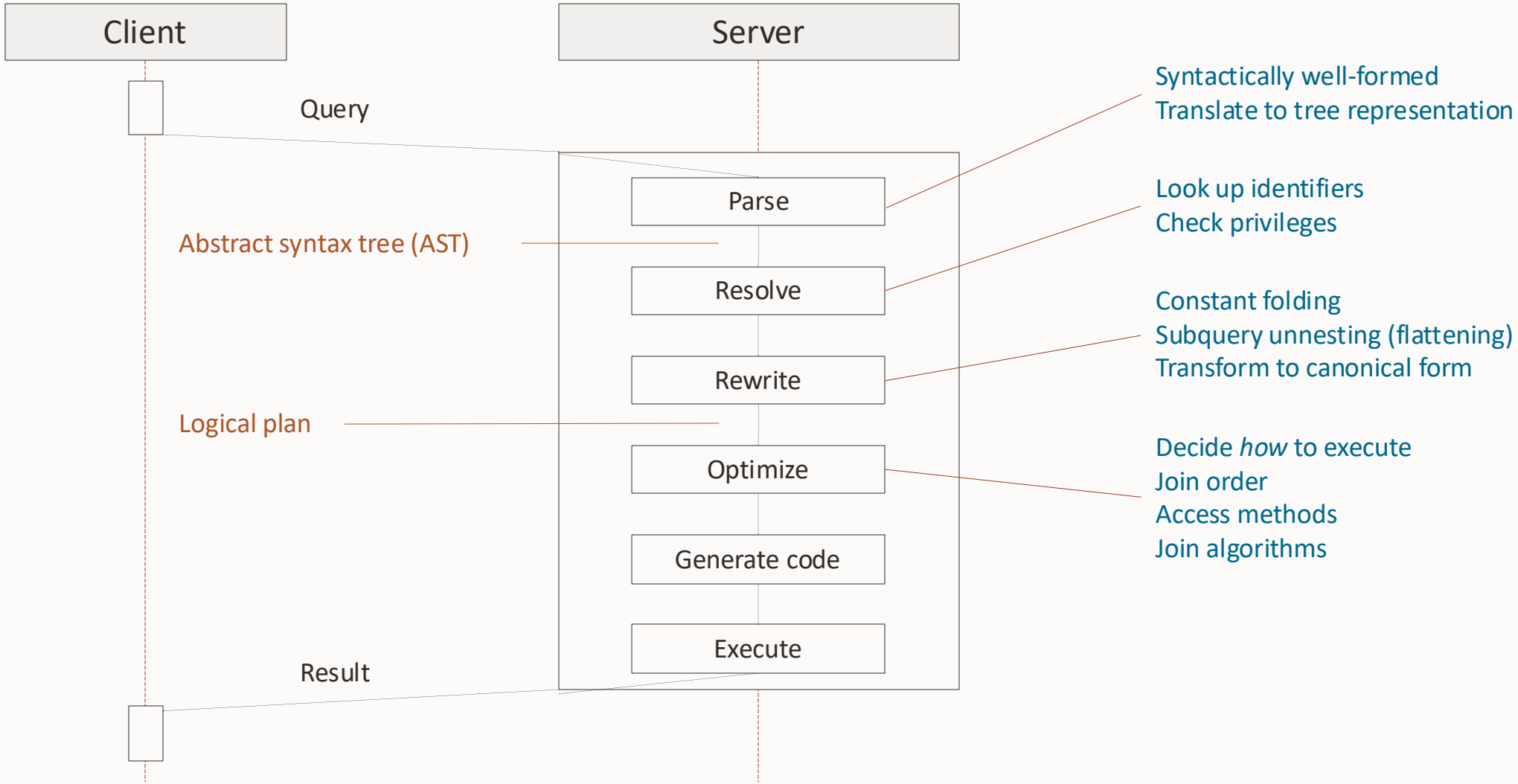

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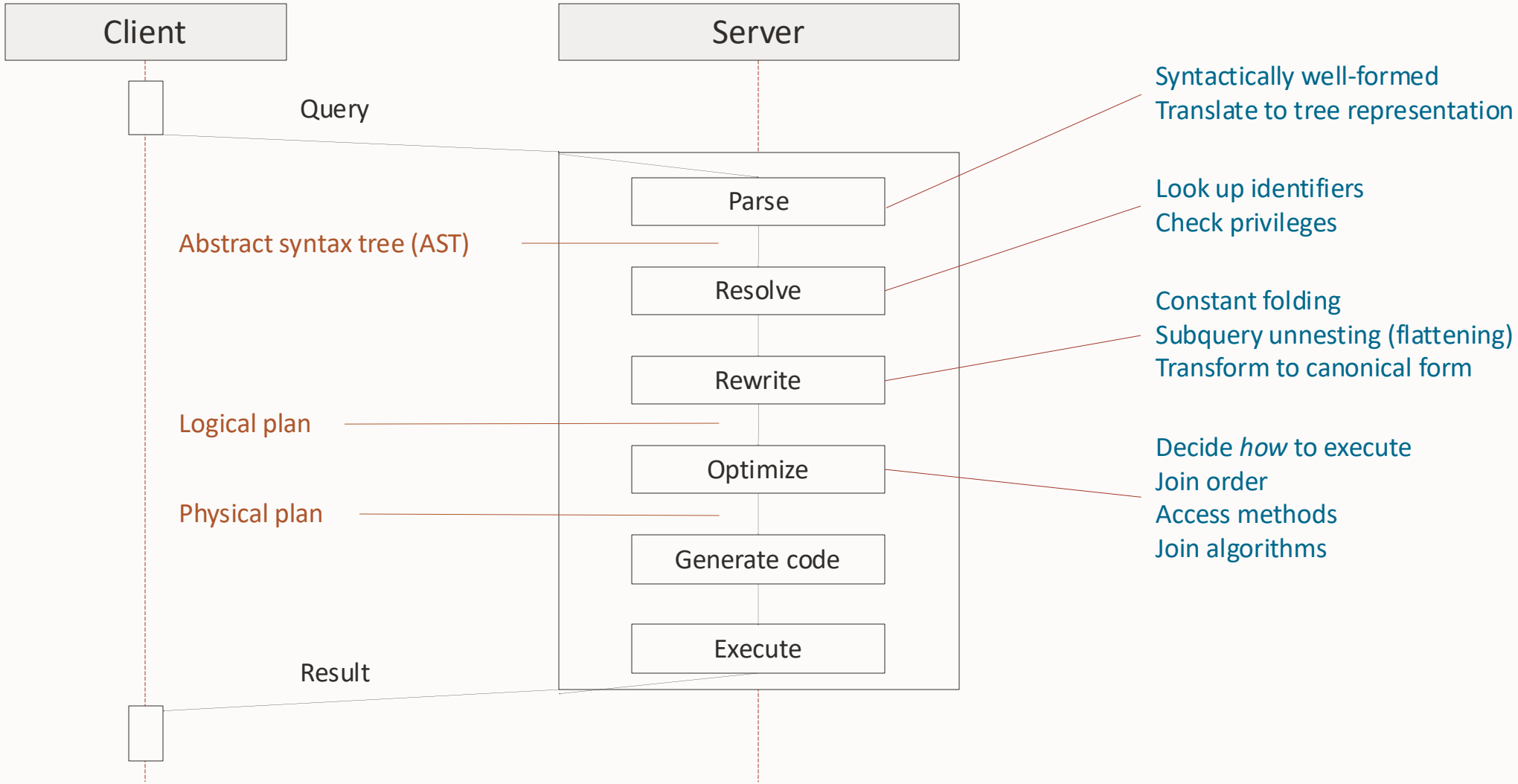

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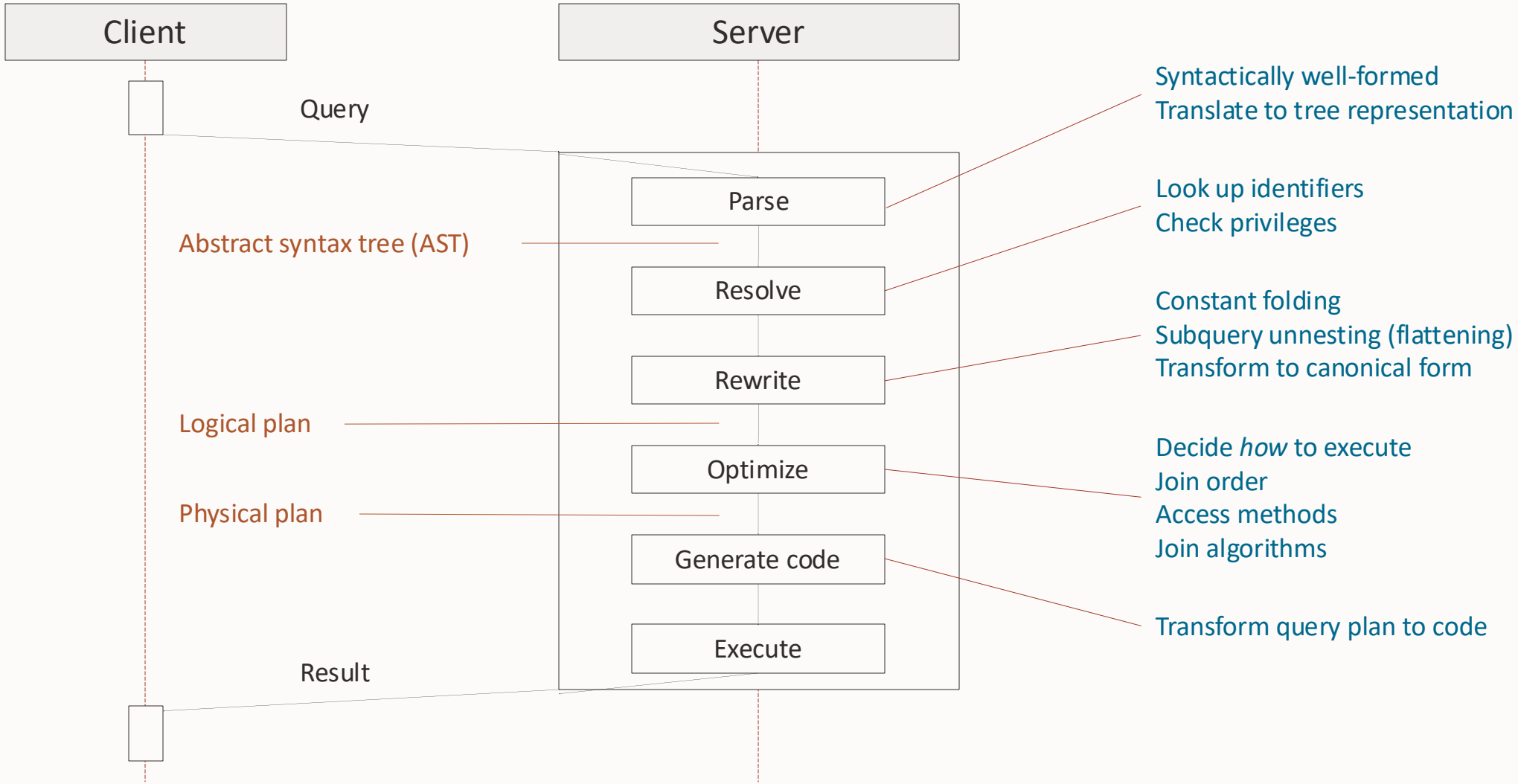

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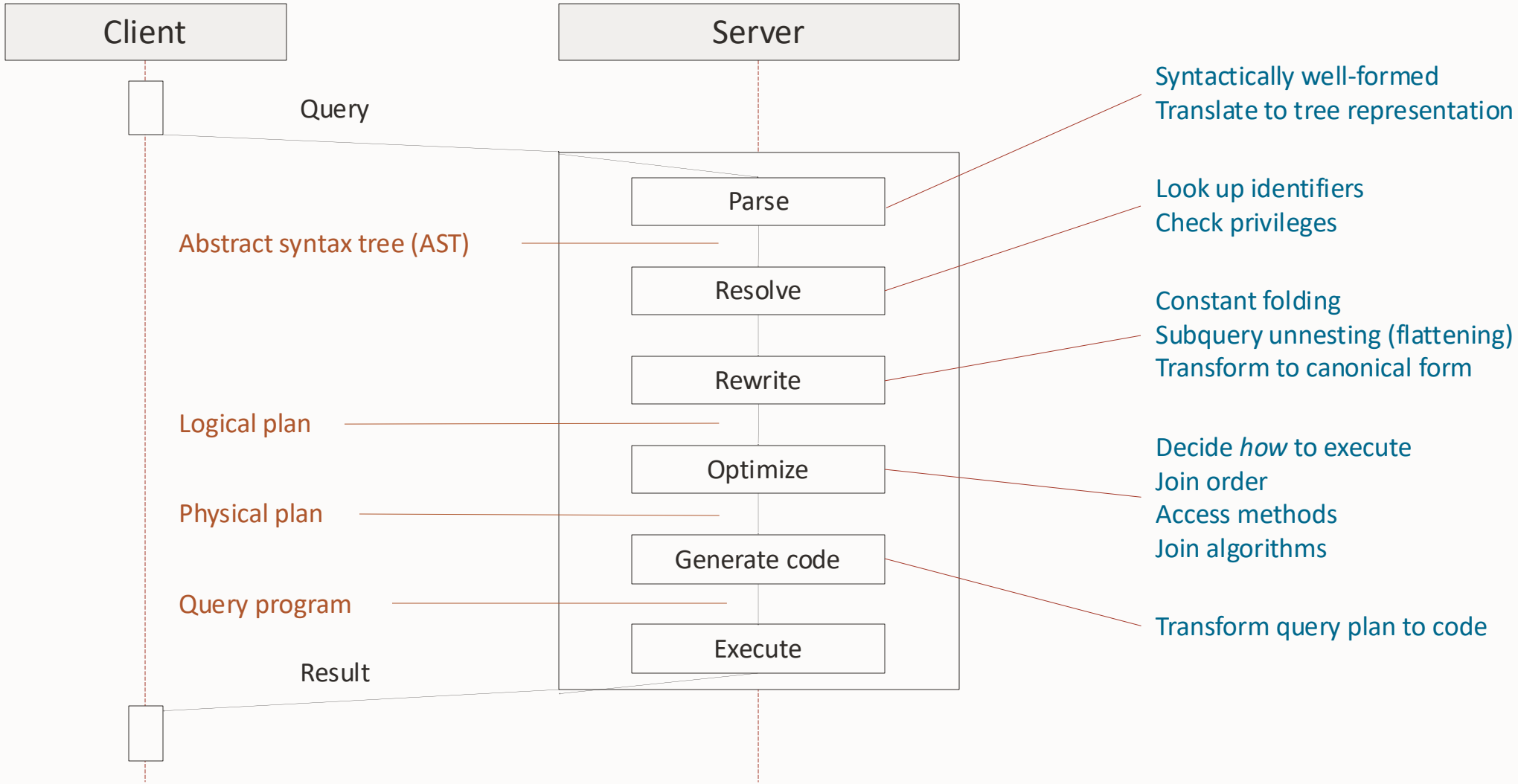

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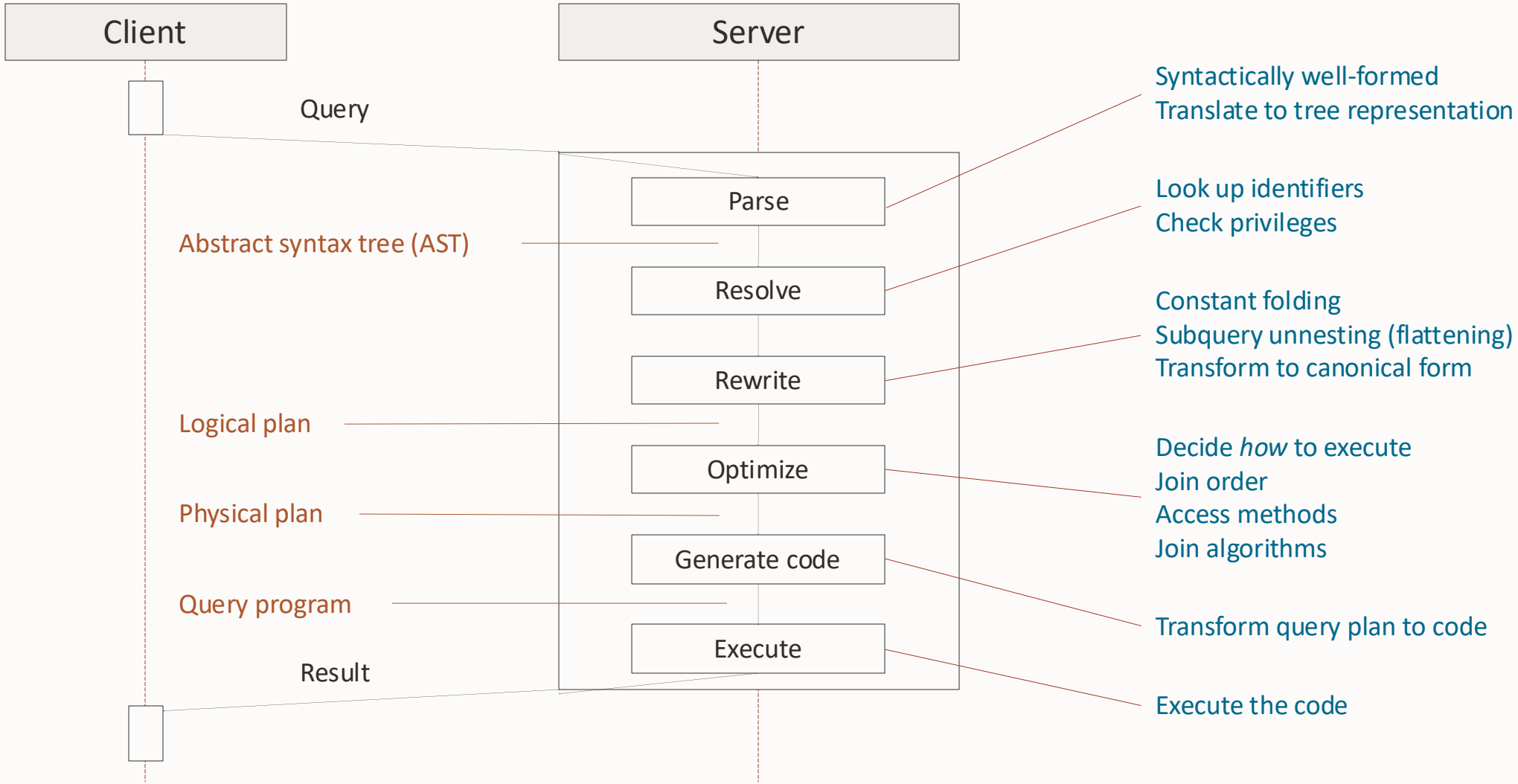

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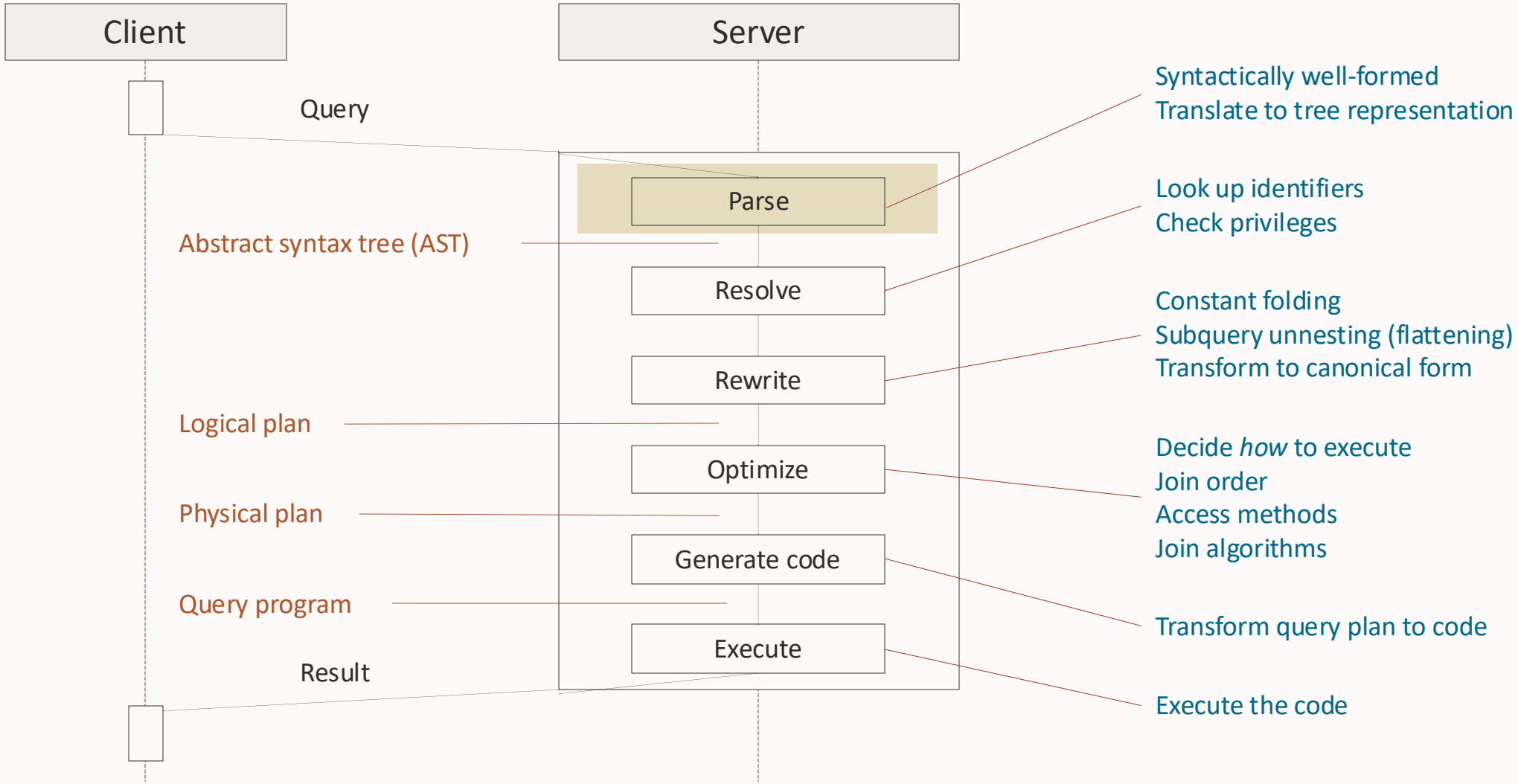

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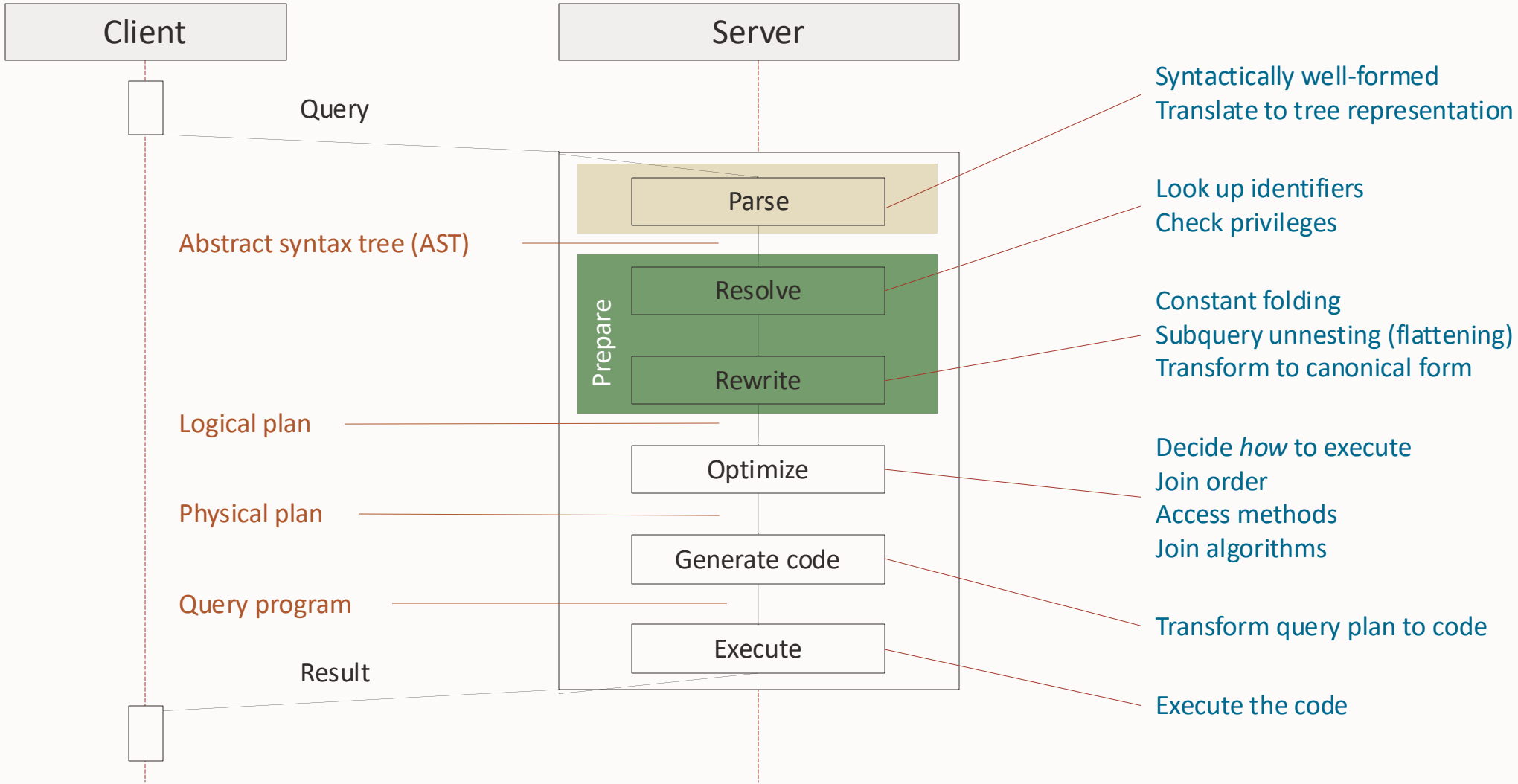

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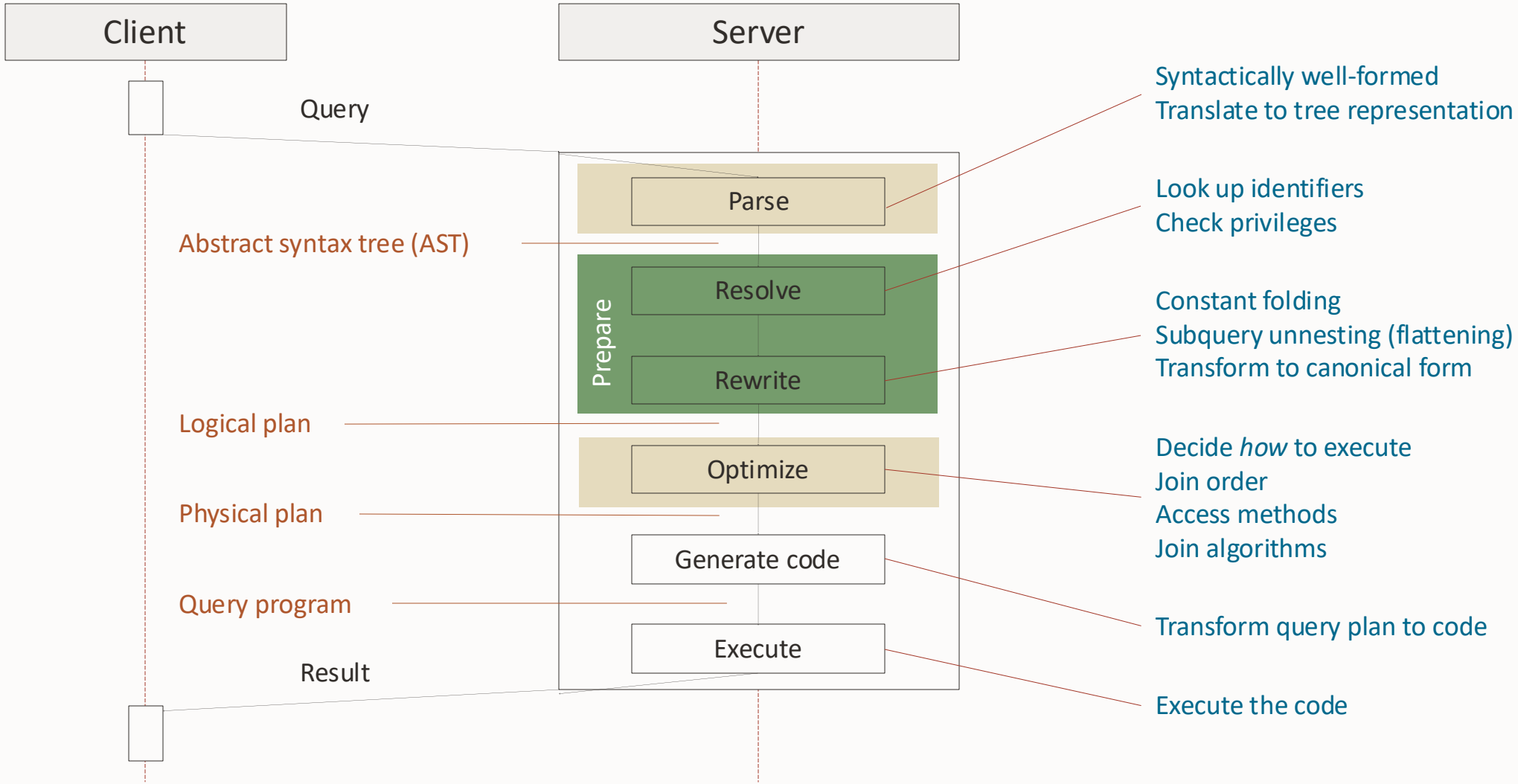

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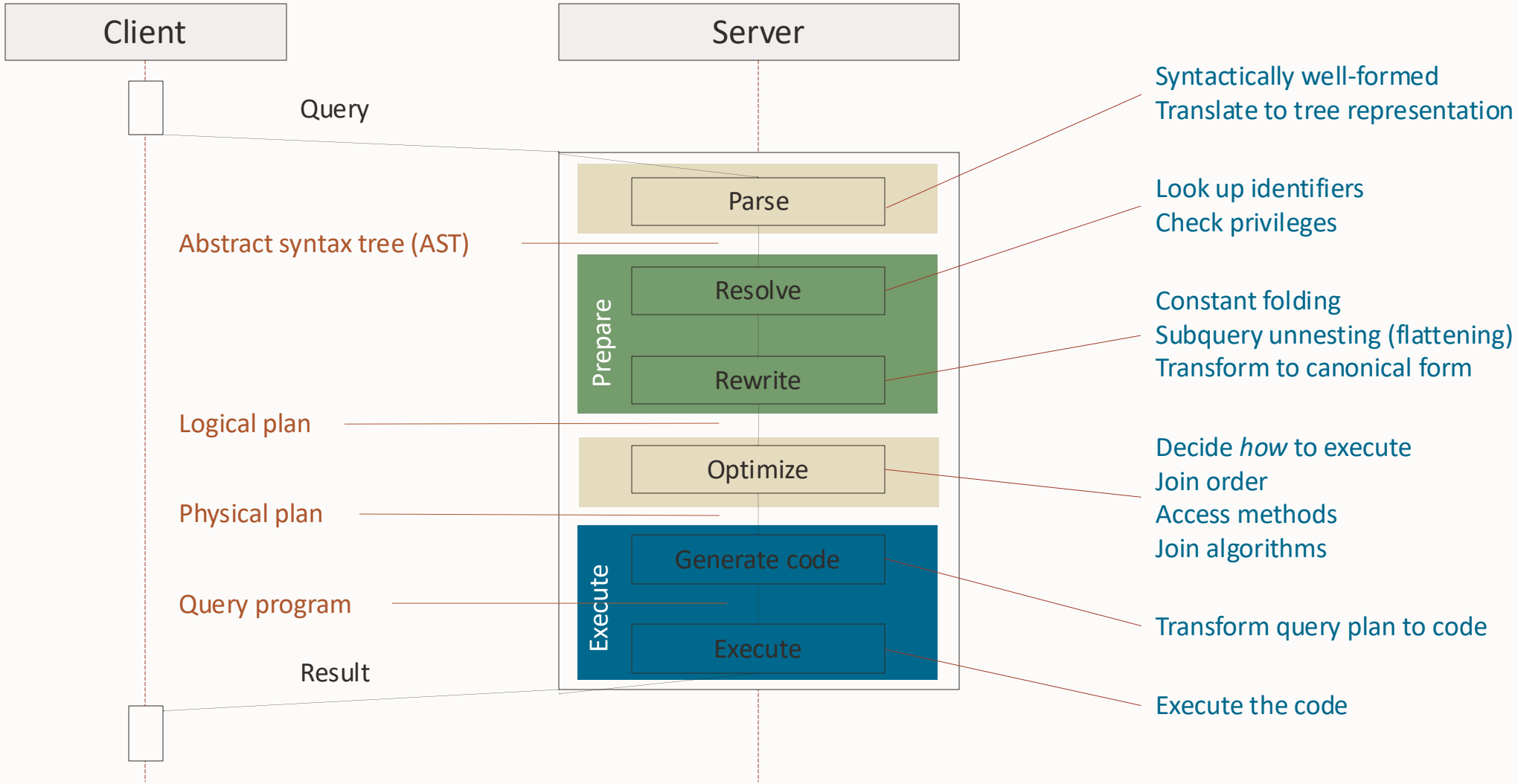
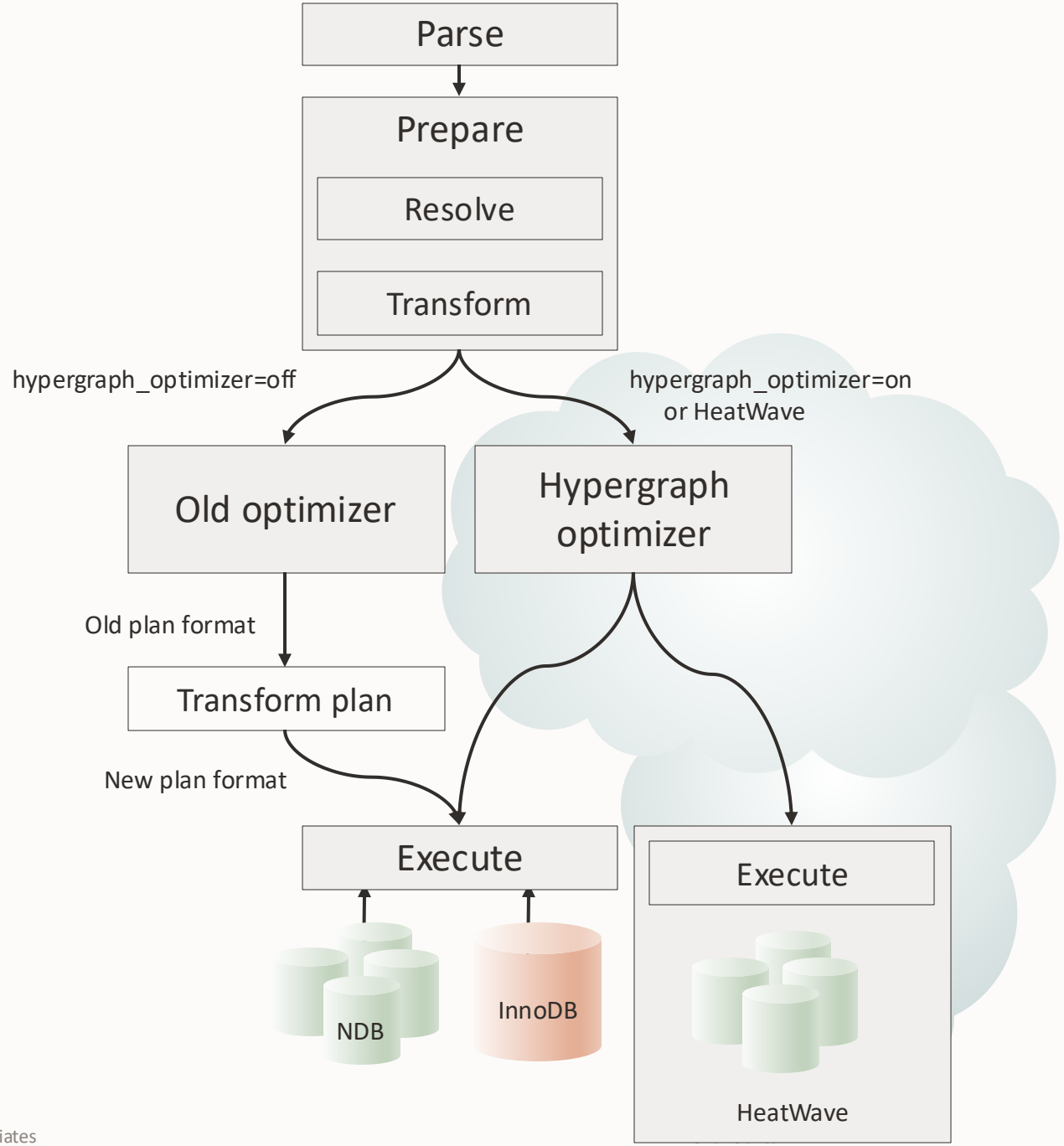


MySQL 9.0+



Why a new optimizer?

Shortcomings of the old optimizer

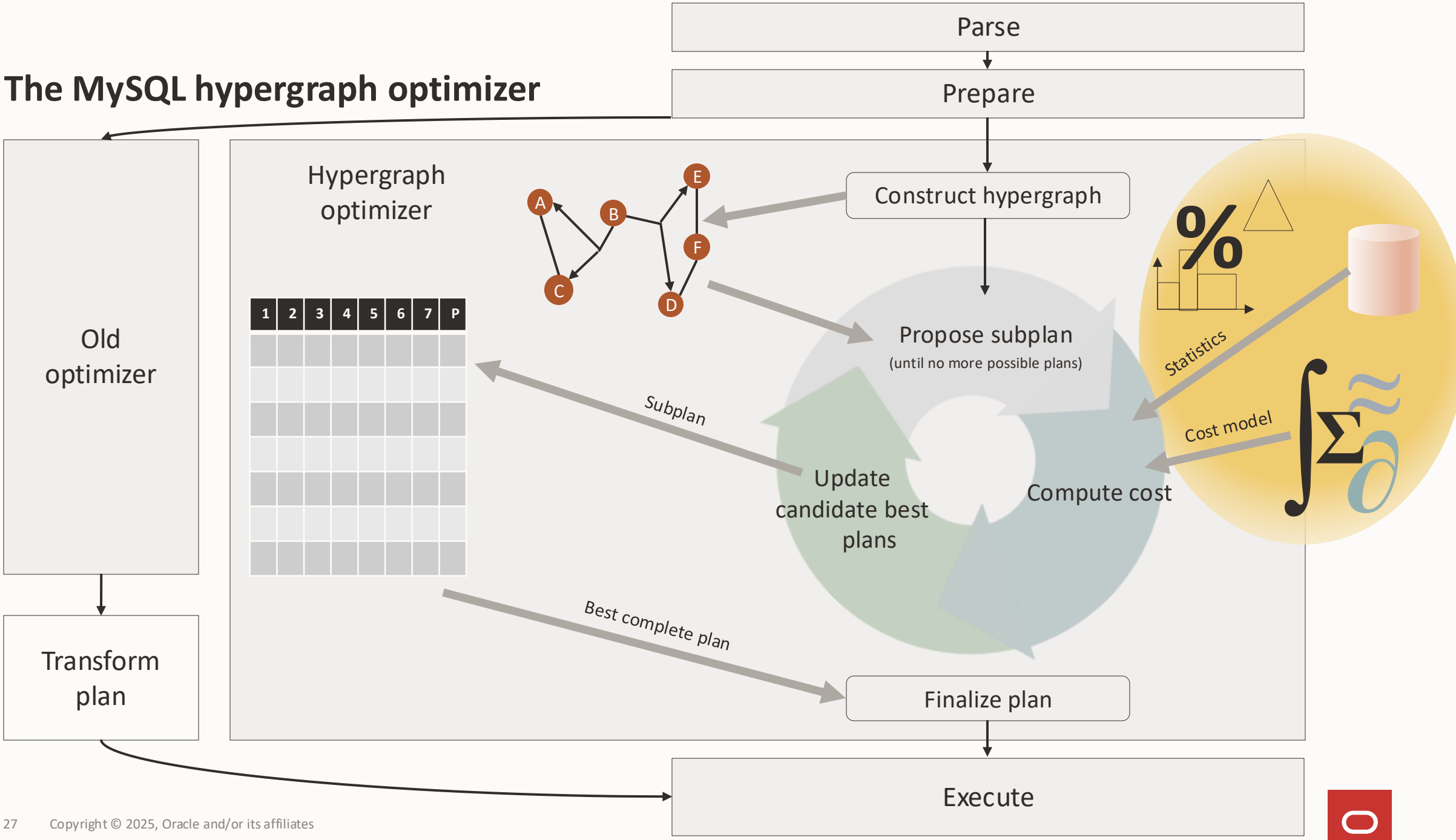
- Too much based on heuristic instead of cost
- Inefficient join ordering algorithm
  - Try all combinations up to a certain number of tables
    - Switches to greedy search when there are too many tables
  - No caching of costs — computes the same numbers several times
- Left deep plans only
- Doesn’t track interesting orders
  - Poor at making the choice between explicit sort and reading in sorted order from an index
- Bad at choosing between join algorithms
  - Inherently nested loop join based
- Presents HeatWave and NDB with only a complete plan
  - No way for HeatWave or NDB to guide the optimizer in plan selection

Design goals

- Modern, based on research
  - But not experimental!
- Cost based
- Interesting order tracking
- Cost based join algorithm selection
- Same optimizer for all storage engines
  - Local row store (InnoDB)
  - Distributed row store (MySQL Cluster/NDB)
  - Distributed column store (HeatWave)
- Bushy plans

What is a hypergraph, and what is it doing in my optimizer?

The MySQL hypergraph optimizer

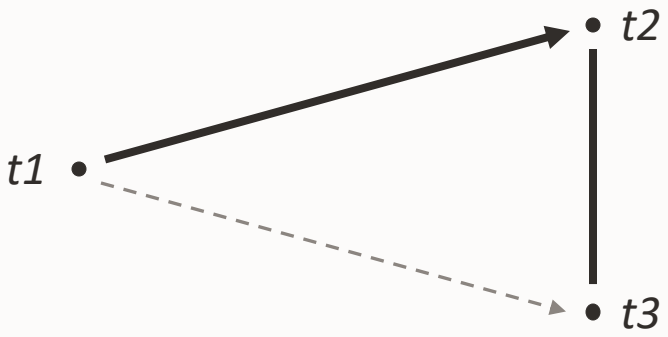


What is a hypergraph?

A hypergraph is a generalization of a graph where **hyperedges** connect two *sets* of vertices

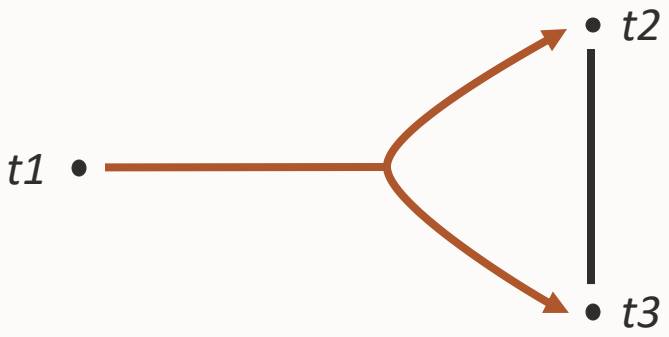
SELECT * FROM *t1* LEFT JOIN (*t2* JOIN *t3* ON *t2.b* = *t3.b*) ON *t1.a* = *t2.a*)

Join graph



There is no edge (*t1*, *t3*) in the graph since there is no join condition connecting *t1* and *t3*.

Join hypergraph



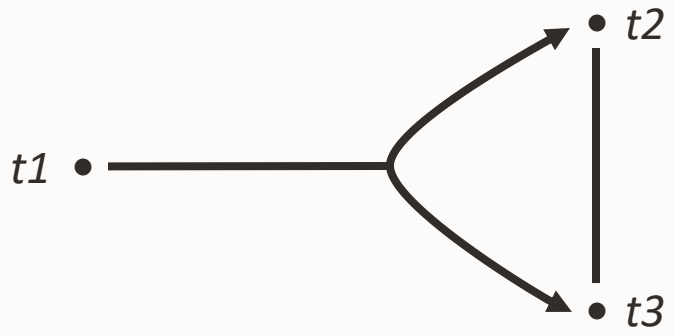
The hypergraph captures the (*t1*, *t3*) connection through the ({*t1*}, {*t2*, *t3*}) hyperedge.

Proposing subplans

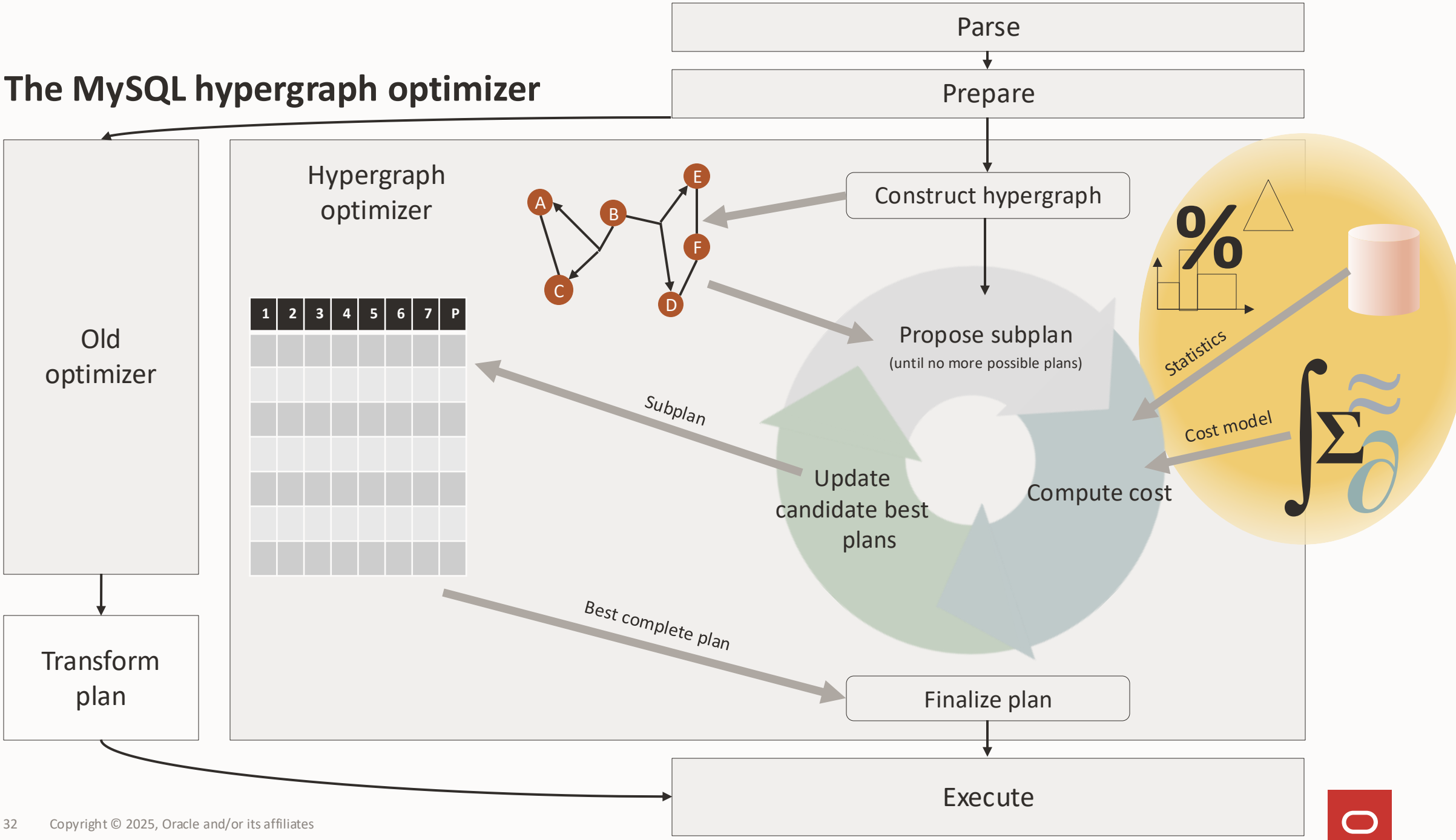
- Start by proposing all the ways we can access a single table
  - Table scan, index scan, index lookup, index range scan, etc.
- Propose all the ways to access another table
- Propose all the ways to join the two tables
  - All join orderings
- Build larger and larger plans
  - Always propose both sides of a join before proposing the join itself

Example:

1. *t2*
2. *t3*
3. *t2* ⋈ *t3*
4. *t1*
5. *t1* ⋈ (*t2* ⋈ *t3*)



The MySQL hypergraph optimizer



Multidimensional cost model

- A more expensive subplan may turn out to be a better choice in the end
  - E.g., it produces a sorted order, and an ordered result is beneficial in the final plan
- Several cost dimensions
  1. Total cost of producing this result once
  2. Initialization cost (e.g., materialize a subquery)
  3. Rescan cost (e.g., read a materialized table the second time)
  4. Dependency on other tables (subplan is a candidate only when those tables are present)
  5. Ordering
  6. Does provide row IDs (sorting may be faster if it does)
  7. Can update/delete while scanning the table (allows UPDATE/DELETE without materialization)
- A plan candidate is kept if it is not dominated by any other plan
  - I.e, there is at least one dimension where this plan is better than the current set of best plans

When will the optimizer finish processing?

- Theoretical ideal: Finish when the time spent to find a better plan is more than the potential savings
  - I.e., minimize the total query processing time (optimization + execution)
  - Impossible to know up front
- Bottom-up planner
  - No complete plan until (almost) all orderings have been tried
- MySQL hypergraph optimizer: Finish when there are no more plans to propose
- Planning time depends on query properties
  - Number of tables
  - Join conditions
  - Number of relevant indexes
  - ...

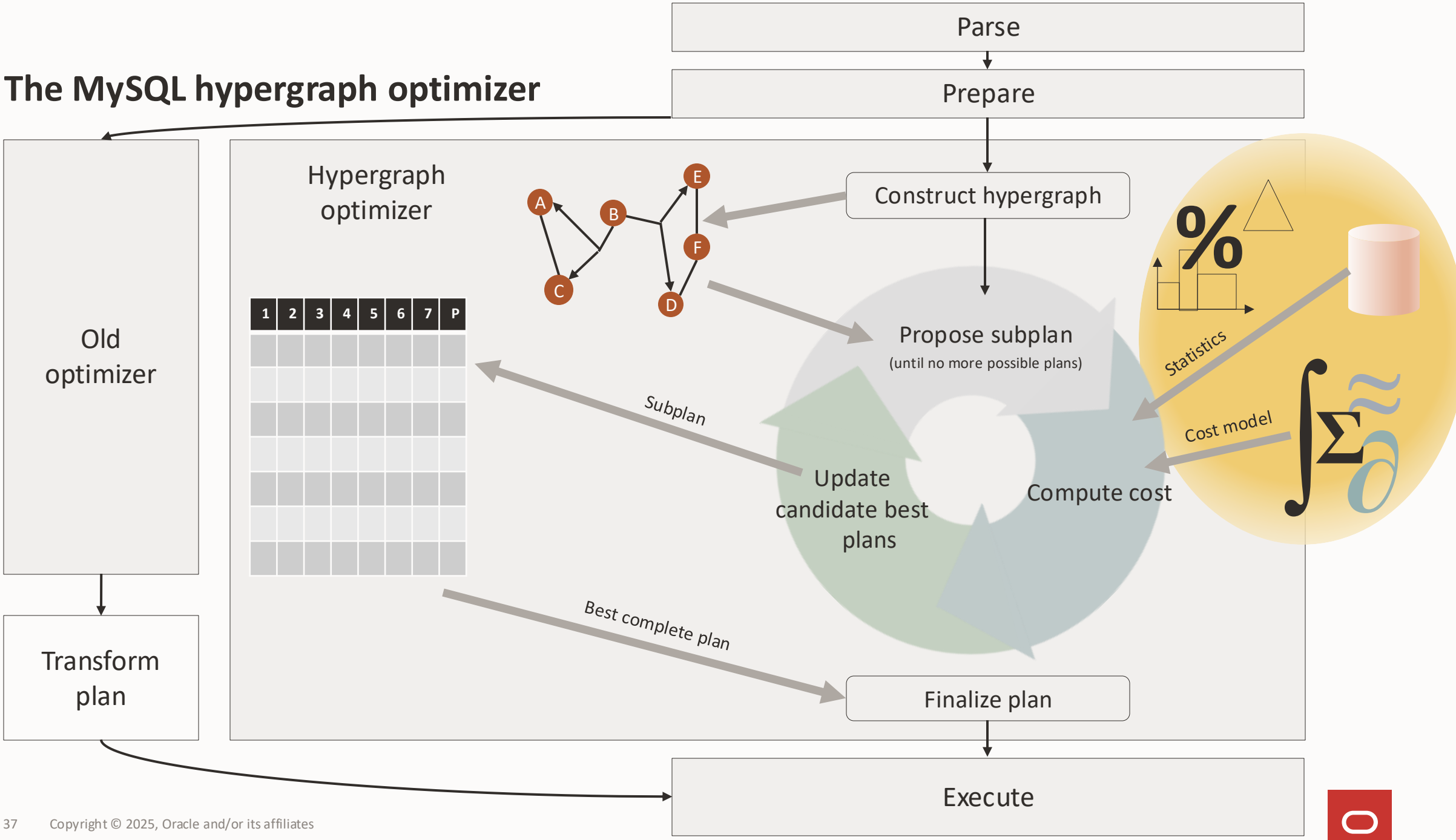
Back to heuristics

- Resort to heuristics if computing all possible join orderings takes too long
  - Currently limited by number of possible join orderings (not time)
- Use heuristics to add new hyperedges to the join hypergraph
  - Encodes a locked join ordering
    - The full set of tables at each end must be computed before computing the hyperedge

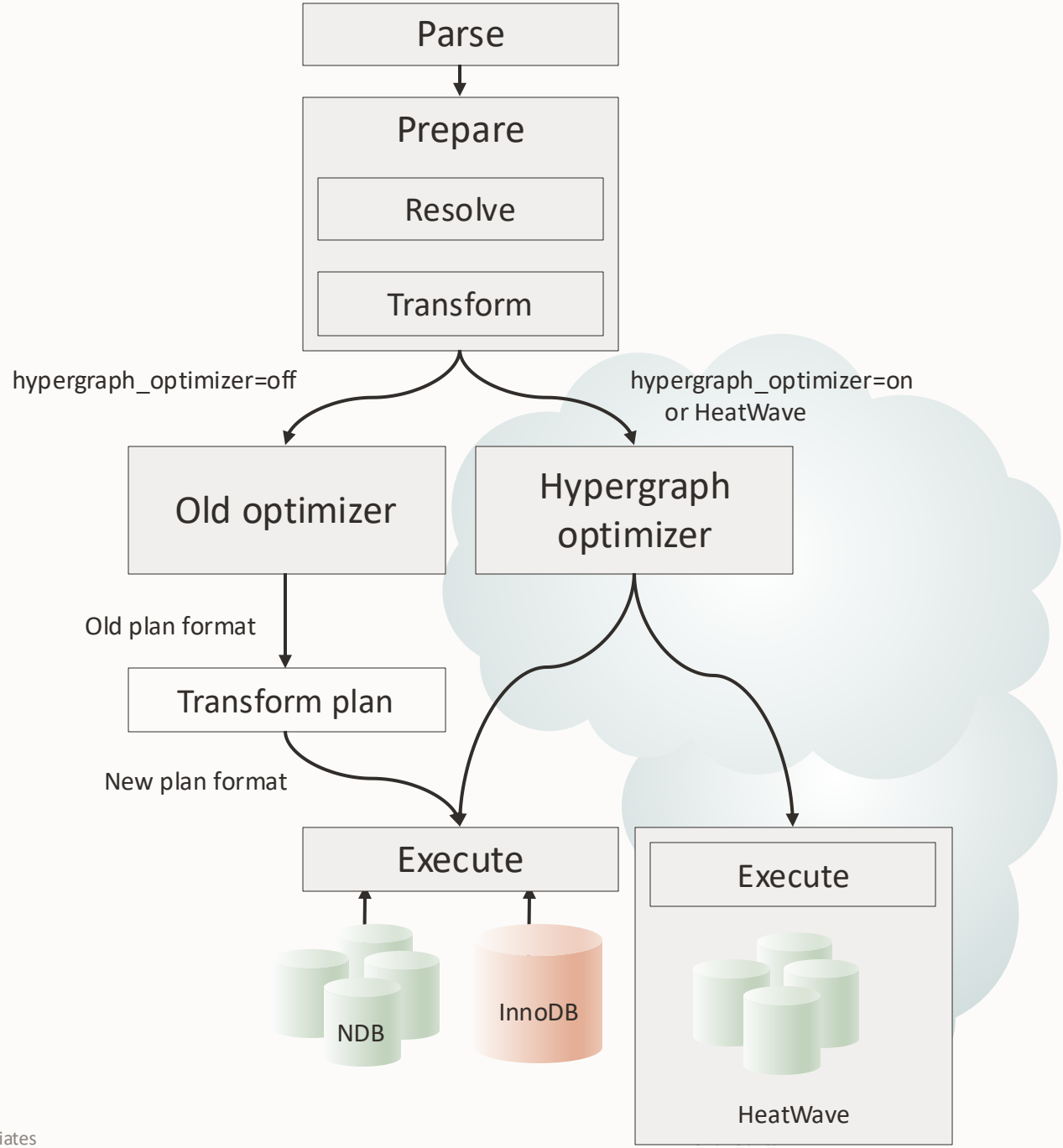
Current algorithm:

1. Set n=1
2. Add n artificial hyperedge(s)
3. Compute number of possible join orderings (skip cost evaluation to make it fast)
4. If there are still too many possible join orderings, set n=2n and go to (2)
5. Bisect between n/2 and n to find minimum number of hyperedges to add without generating too many plans
6. Re-run the optimizer and find best plan

The MySQL hypergraph optimizer



How can I start using the hypergraph optimizer?



Start using the hypergraph optimizer

- Conly available in HeatWave MySQL cloud services (OCI or AWS)
  - Available since 9.0.0
- Switch optimizers by setting an optimizer switch:

SET optimizer_switch='hypergraph_optimizer=on';

Thank you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