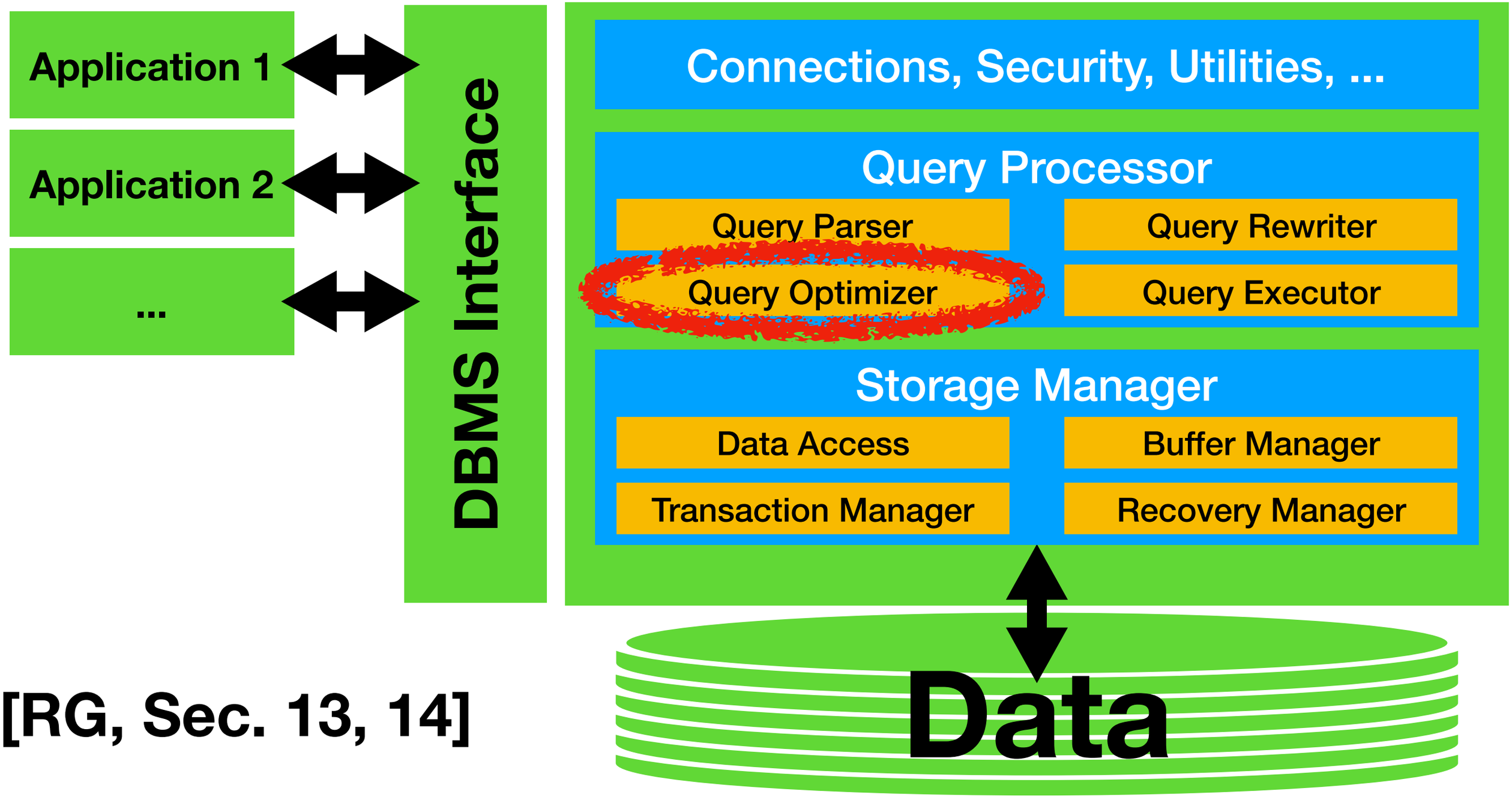
Query Optimization

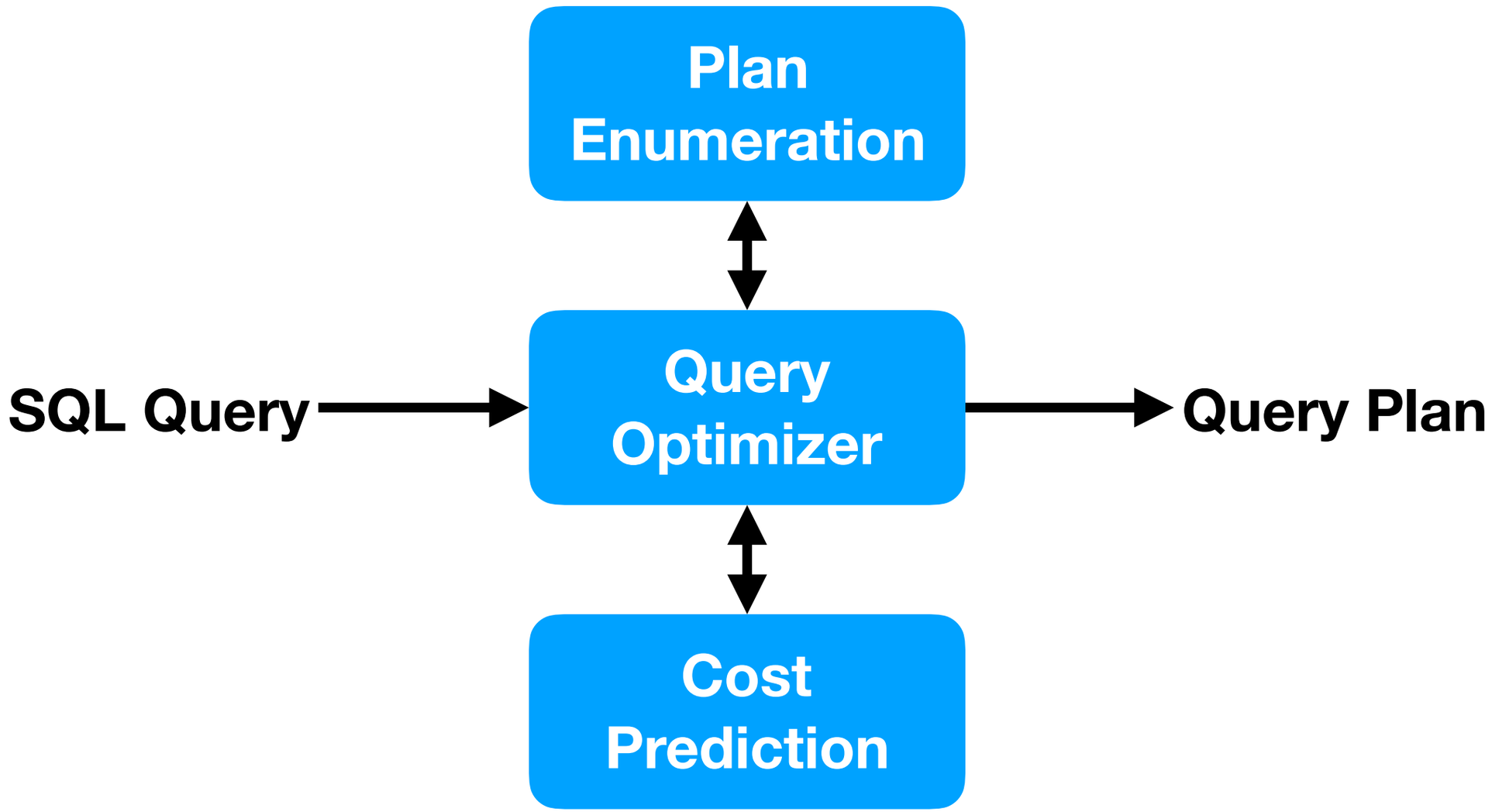
Immanuel Trummer
itrummer@cornell.edu
www.itrummer.org

Database Management Systems (DBMS)

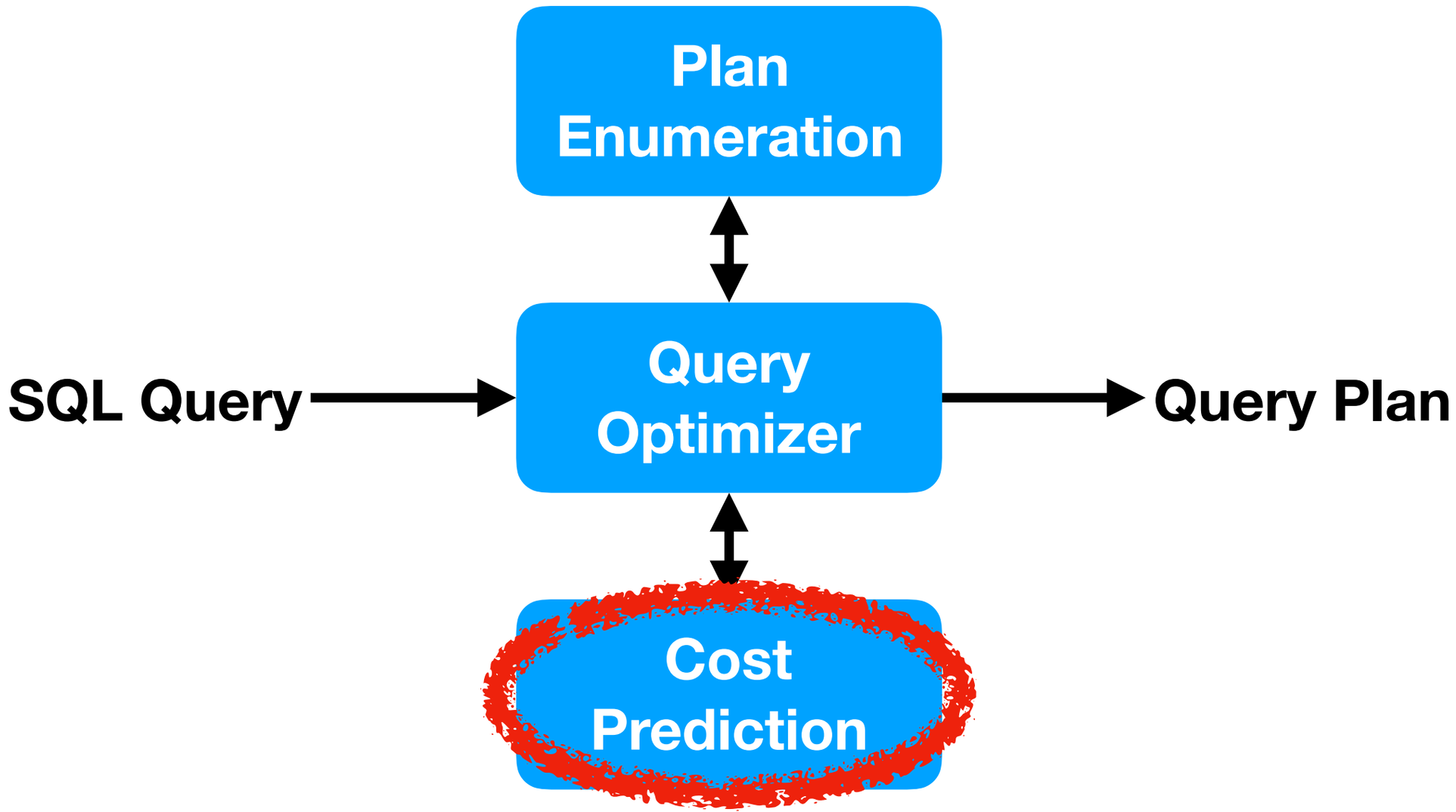


[RG, Sec. 13, 14]

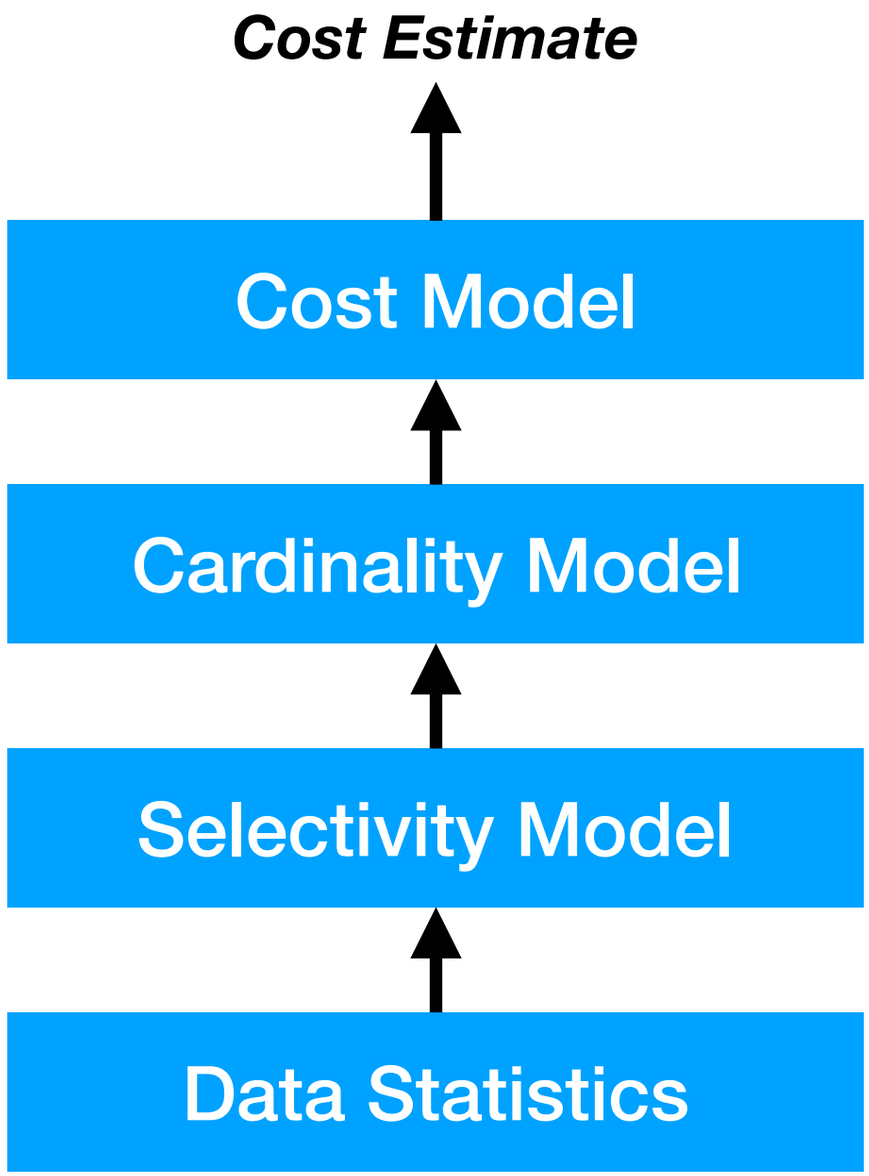
Optimizer Overview



Optimizer Overview



Cost Model Structure



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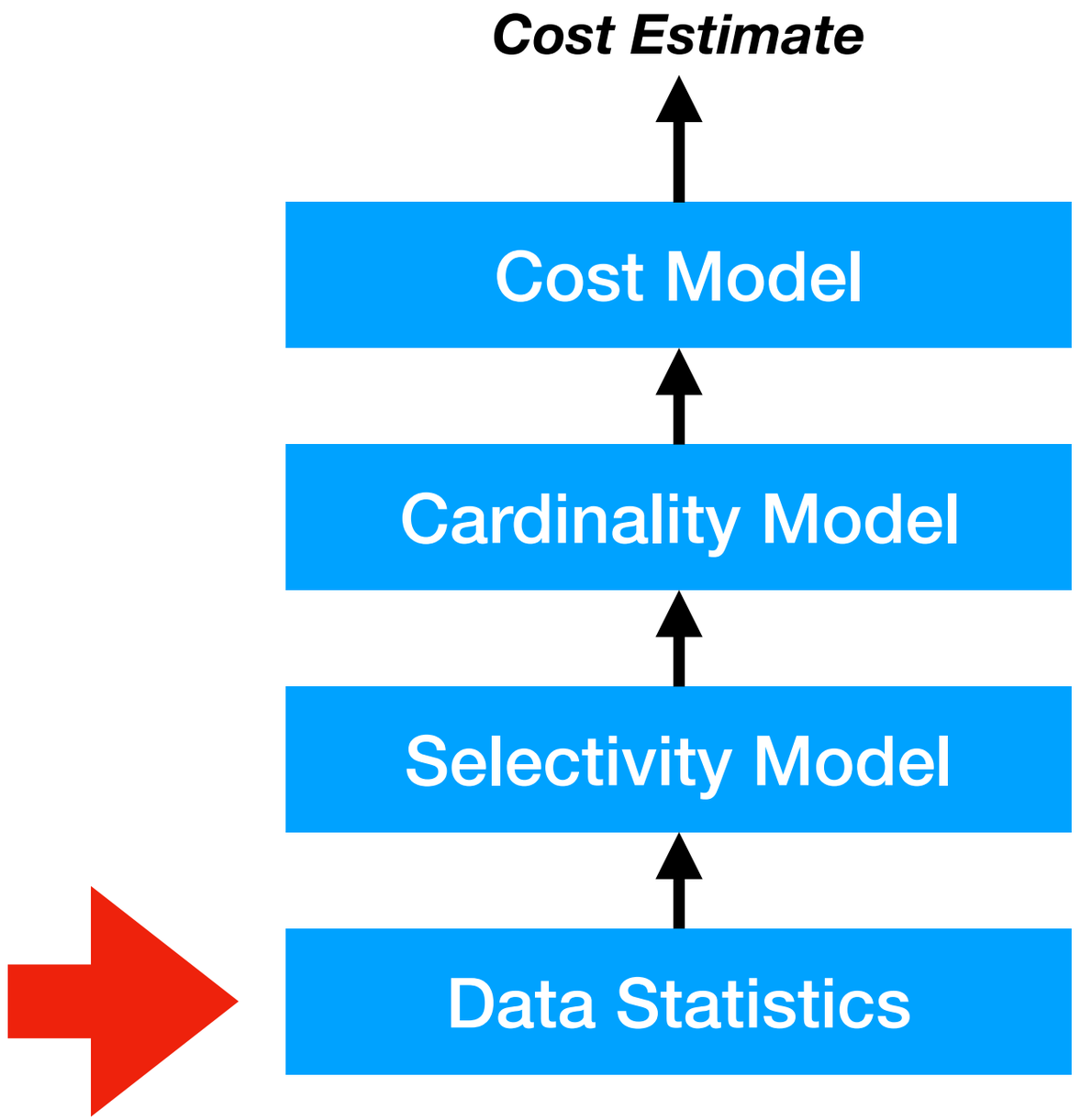


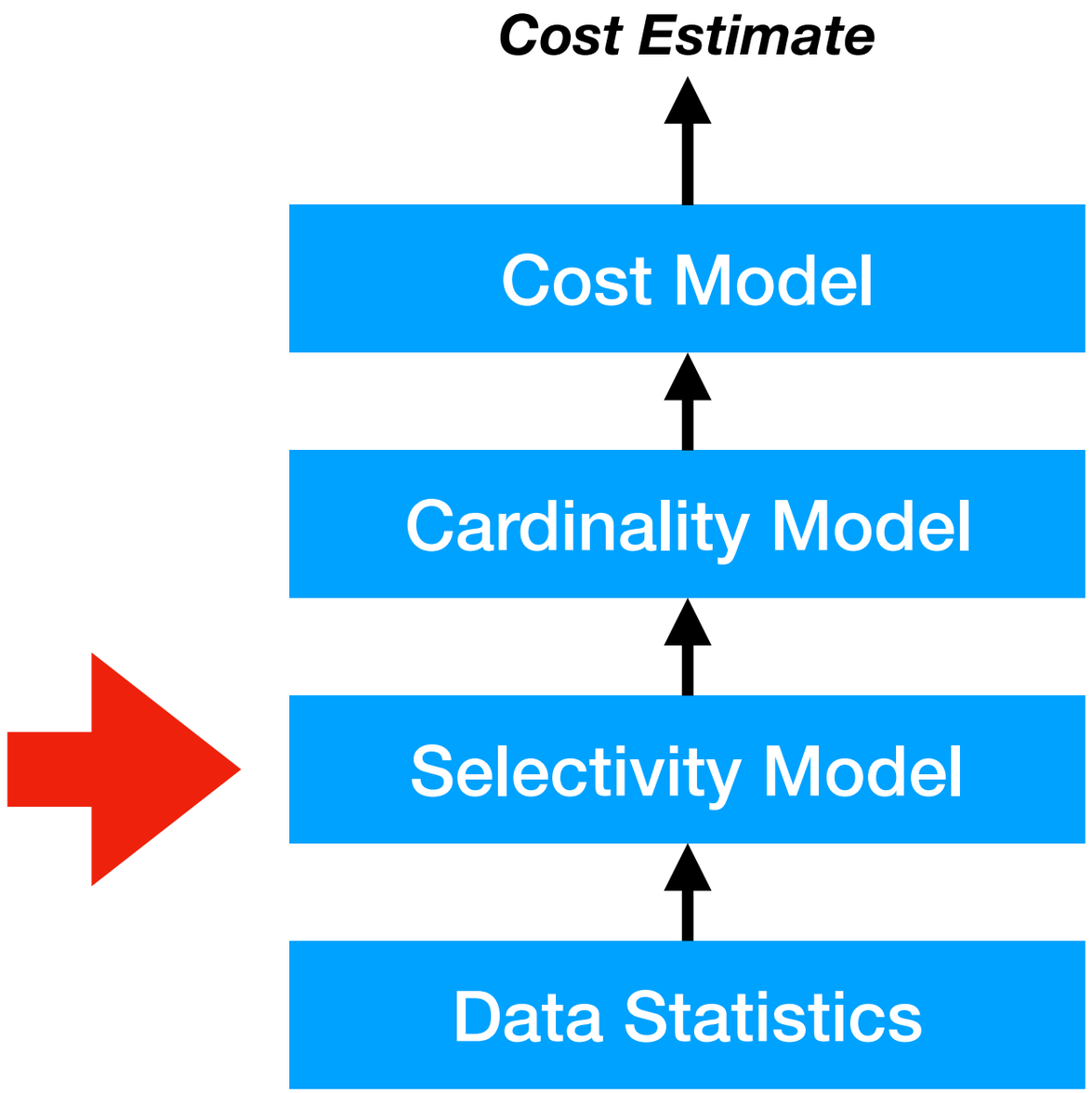
Data Statistics

- Different DBMS collect **different** statistics
- **Example statistics** (collected in Postgres):
  - Number of **distinct values** in column
  - Ratio of SQL **null values** in column
  - Most **frequent values** with associated frequency
  - **Histograms** approximating column data distribution
  - ...

Data Statistics in PG

- Force DBMS to create statistics via **VACUUM ANALYZE**
- Generated **statistics** are exploited by **query optimizer**
  - Inexplicably bad performance? Might **miss statistics**
- Can access column statistics via **pg_stats** view
  - E.g., **tablename**, **attname**, **n_distinct**, **null_frac**, ...

Cost Model Structure



Estimating Selectivity

- **Selectivity**: probability that row satisfies predicate

- Estimate via **constraints** and data **statistics**

- E.g., **Selectivity(Column=Value) = 1/NrValues**

- E.g., **NrRows(Column=Value) ≤ 1 if Key Column**

- **Selectivity(A∧B) = Selectivity(A) * Selectivity(B)**

Which Simplifying Assumptions Do We Make?

Estimating Selectivity

- **Selectivity**: probability that row satisfies predicate

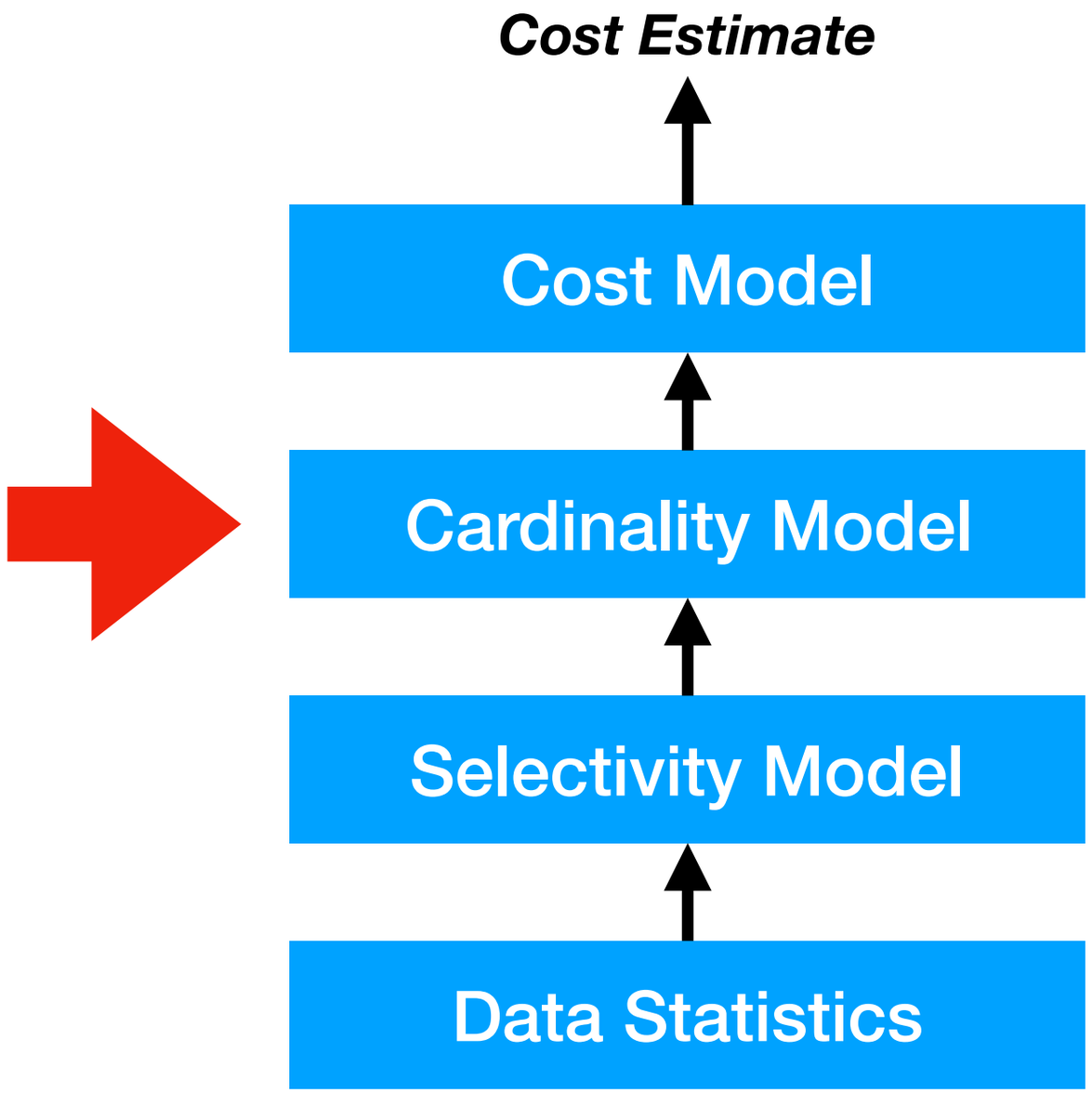
- Estimate via **constraints** and data **statistics**

- E.g., **Selectivity(Column=Value) = 1/NrValues**
  Assumes Uniform Data

- E.g., **NrRows(Column=Value) ≤ 1 if Key Column**

- **Selectivity(A∧B) = Selectivity(A) * Selectivity(B)**
  Assumes Independent Predicates

Cost Model Structure



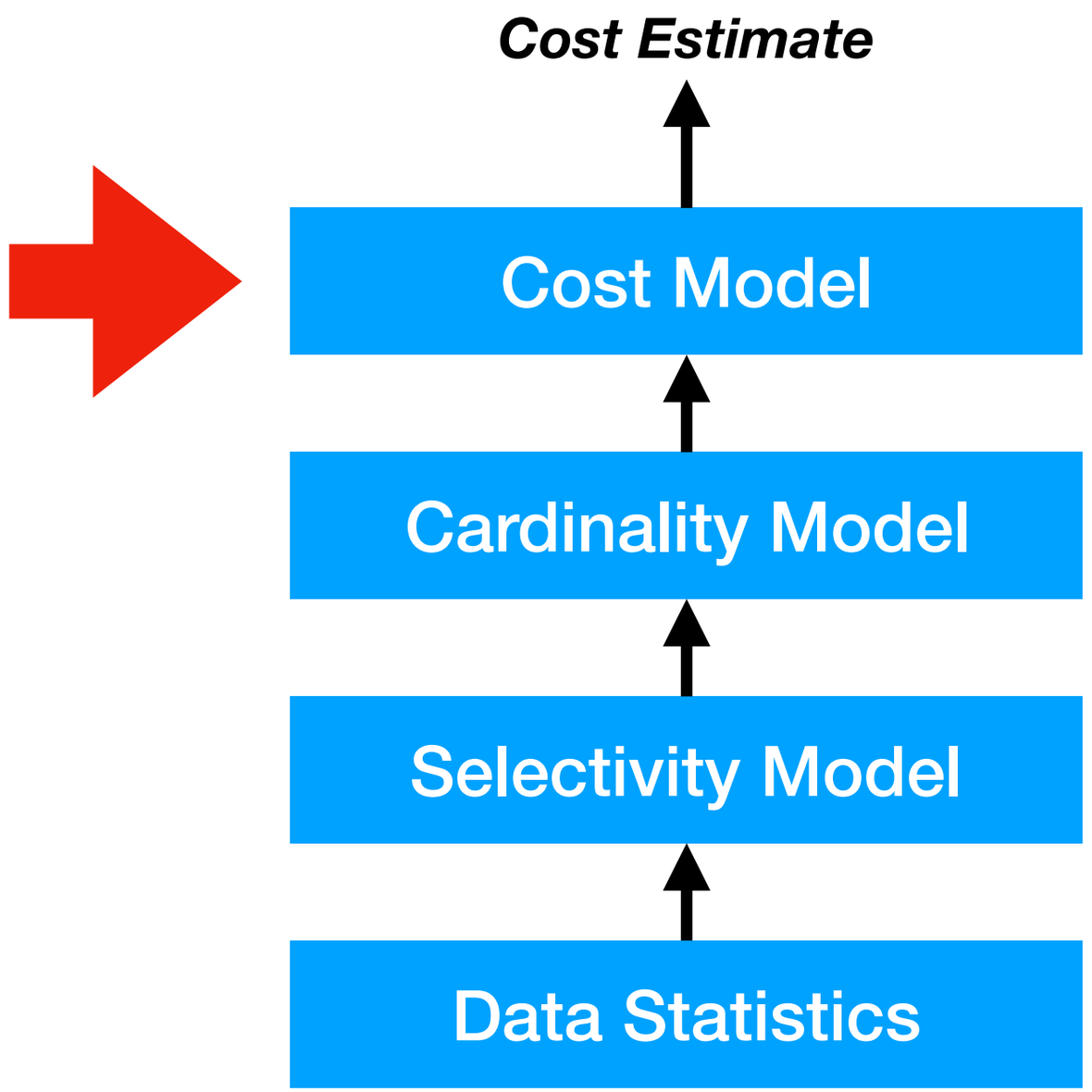
Estimating Cardinality

- Assume that **cardinality of single tables** is given
  - DBMS **store that information** for each base table
- Calculate **cardinality product** for tables in from clause
  - = Number of **result rows** if predicates are always true
- Now **multiply with selectivity** estimates for all predicates
  - Estimate how many rows **pass** predicate filter

Estimating Page Size

- Cost functions are based on number of data **pages**
- Calculate average byte **size per record** for each result
- Calculate how many records **fit** on one data page
  - Pages cannot store fractional records → **round down**
- **Divide** number of rows by number of records per page
  - Result is size, measured in **pages**

Cost Model Structure



Estimating Cost

- Generally only count cost of **page reads and writes**
- **Sum up cost** over all operators in the plan
- For each operator consider the following:
  - For **each input**, how often is it read from disk?
  - For **each output**, is it written to disk? Is it final result?
  - Does the operator read/write **intermediate results**?

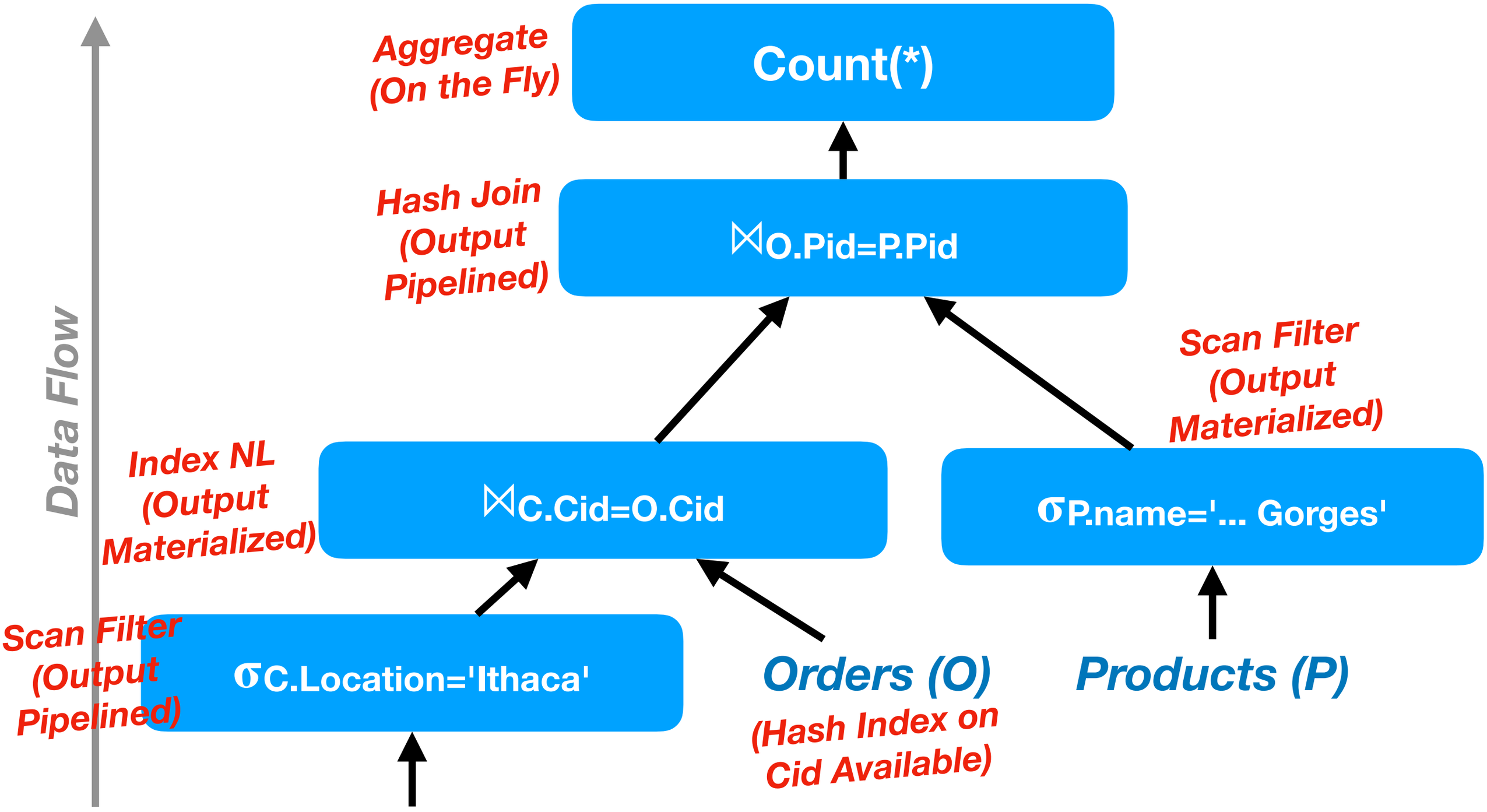
Cost Estimation Example

Input Query and Database

```
SELECT Count(*)
FROM Customers C JOIN Orders O USING (cid)
  JOIN Products P USING (pid)
WHERE C.location = 'Ithaca' AND
  P.name = 'Book Ithaca is Gorges'
```

Customers(Cid, name, location)
Orders(Cid, Pid, date)
Products(Pid, name, price)

Query Plan Candidate



Selectivity Estimation

Element	Property	Value
Customers	Cardinality	10,000
Orders	Cardinality	100,000
Products	Cardinality	5,000
Customers.Location	# Values	100
Products.Name	# Values	2,500

Foreign Key: Orders.Cid to Customers.Cid
Foreign Key: Orders.Pid to Products.Pid

Predicate	Selectivity
σC.Location='Ithaca'	?
C.Cid=O.Cid	?
σP.name='... Gorges'	?
O.Pid=P.Pid	?

Selectivity Estimation

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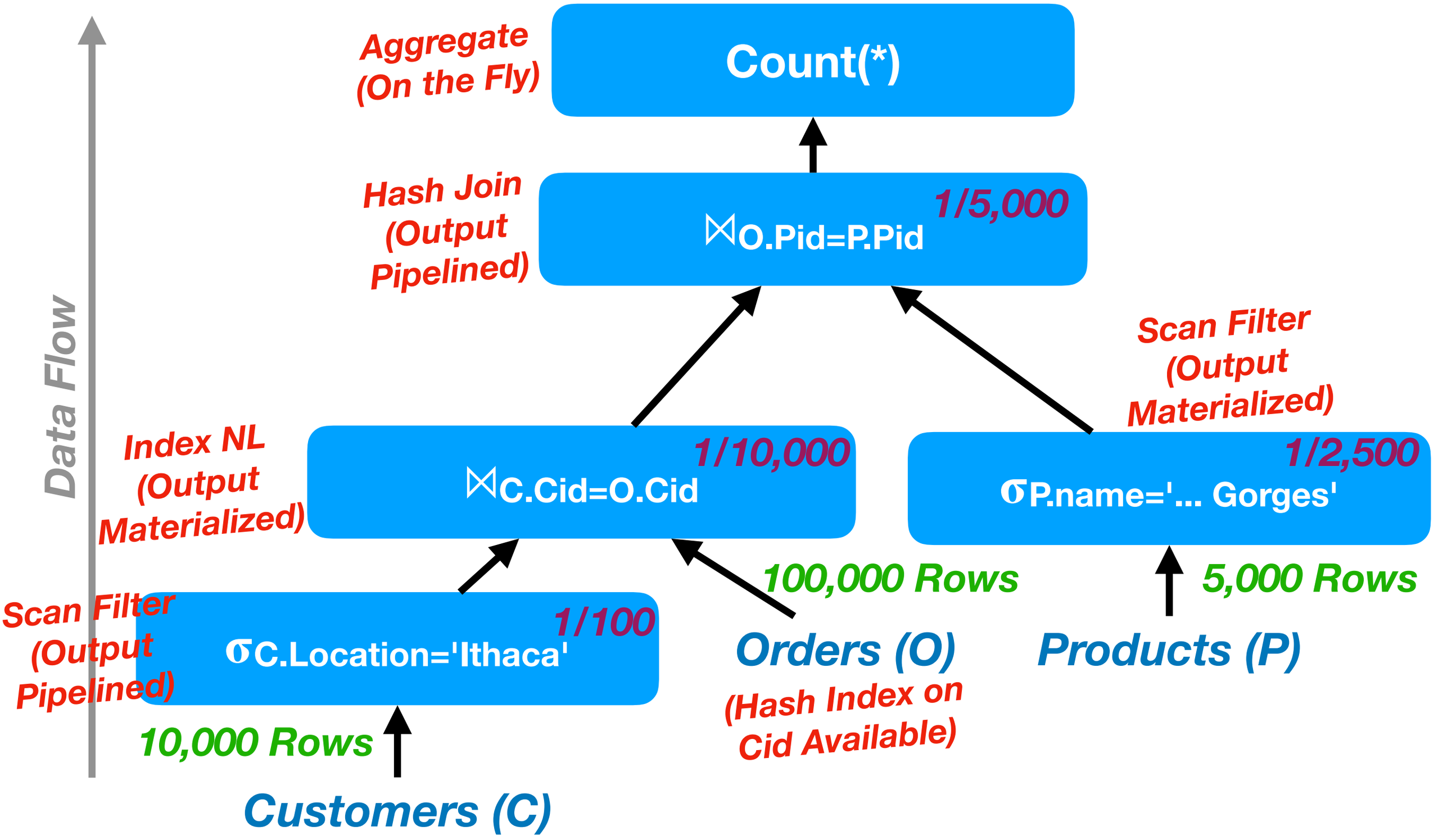
Customers	Cardinality	10,000
Orders	Cardinality	100,000
Products	Cardinality	5,000
Customers.Location	# Values	100
Products.Name	# Values	2,500

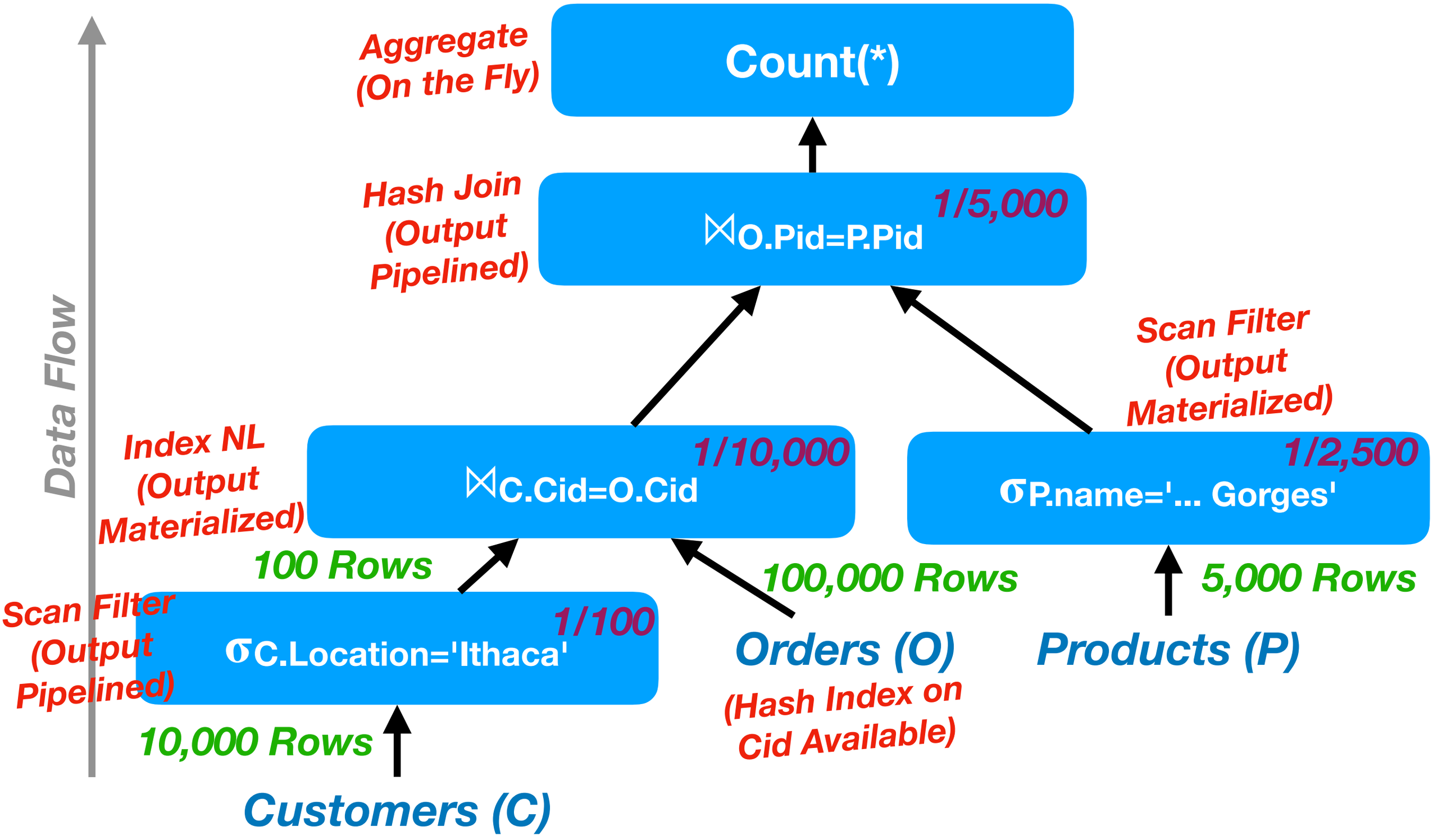
Foreign Key: Orders.Cid to Customers.Cid
Foreign Key: Orders.Pid to Products.Pid

Predicate	Selectivity
σC.Location='Ithaca'	1/100
C.Cid=O.Cid	1/10,000
σP.name='... Gorges'	1/2,500
O.Pid=P.Pid	1/5,000

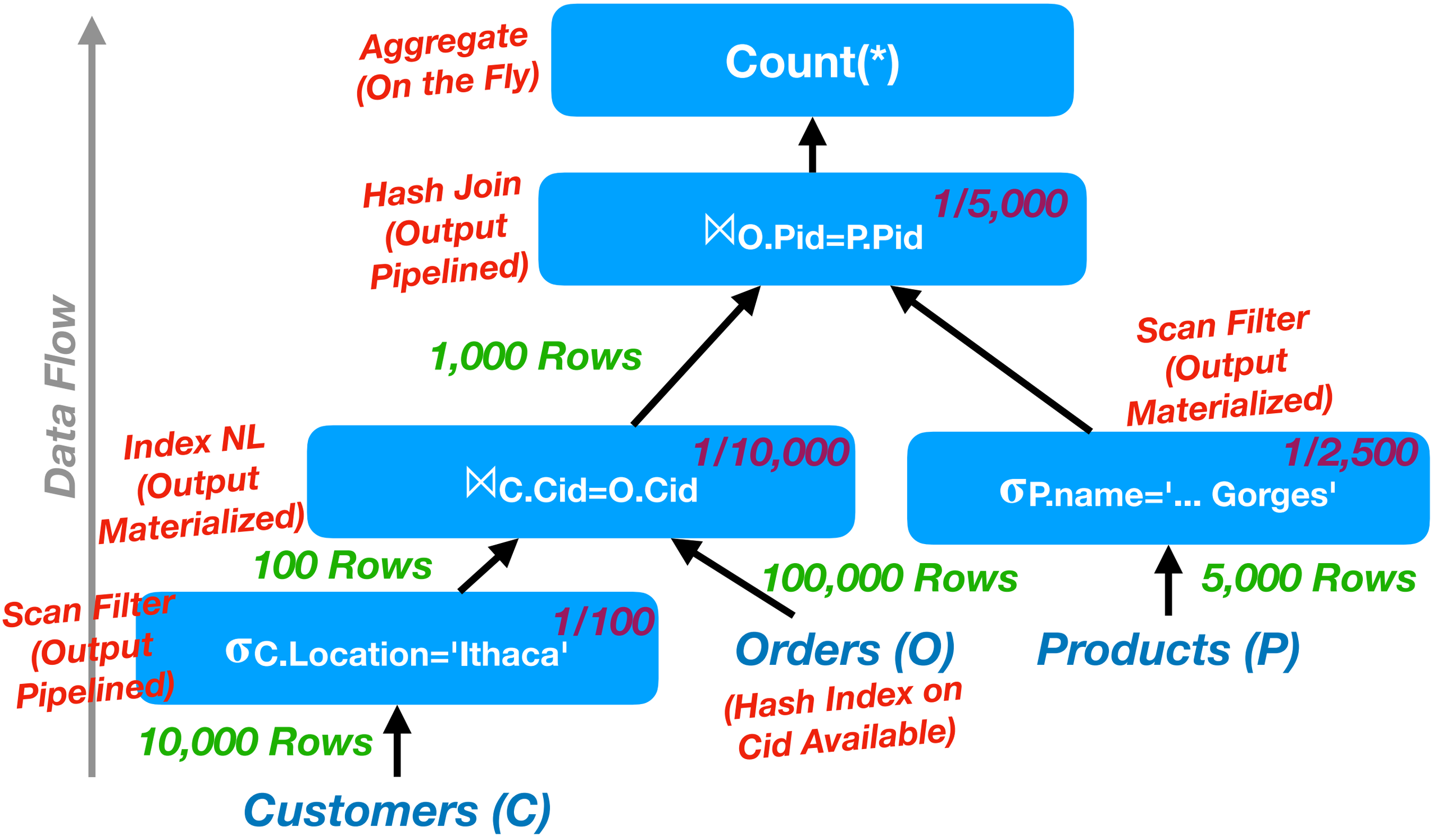
Cardinality Estimation



Cardinality Estimation



Cardinality Estimation



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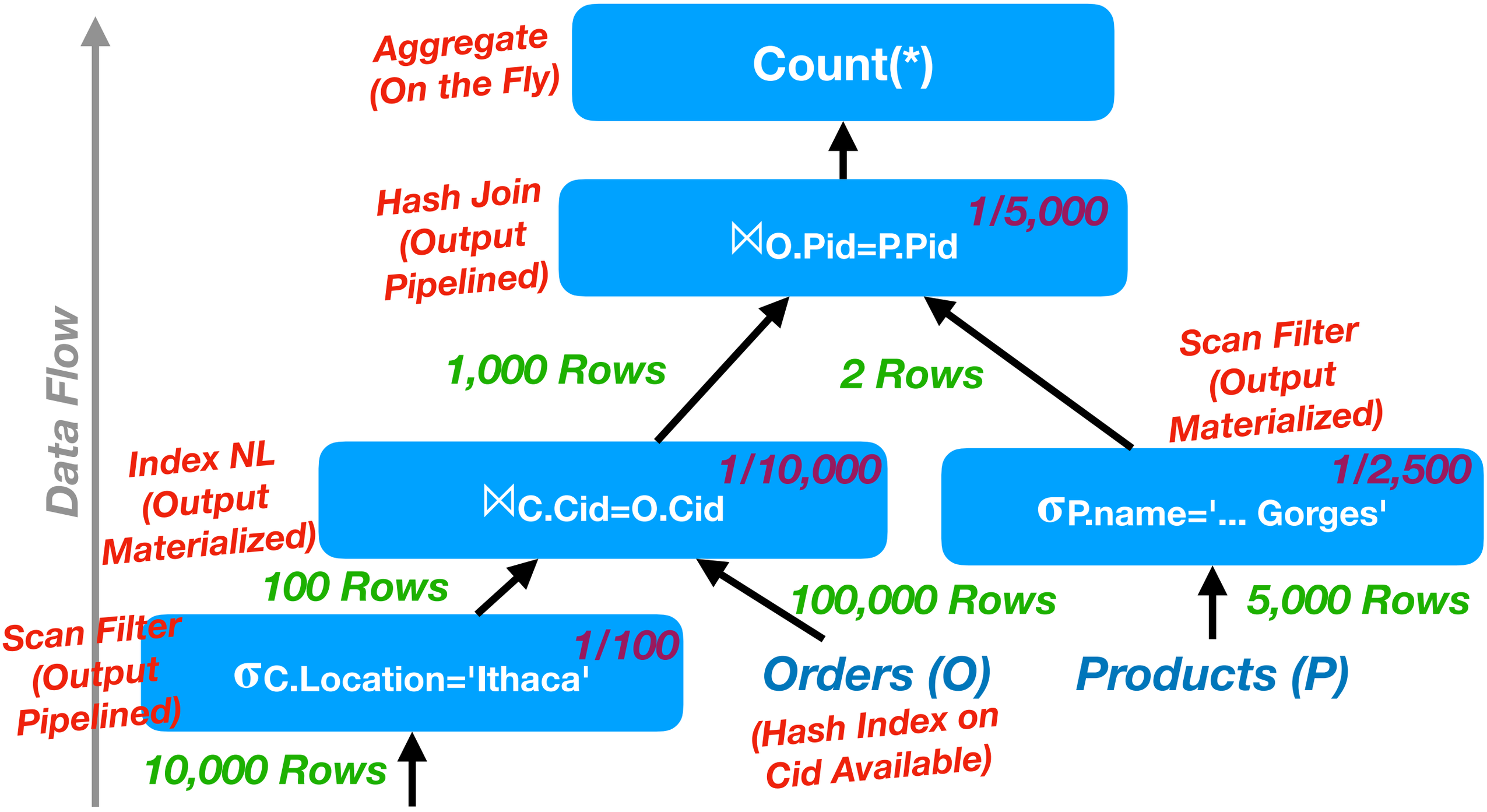
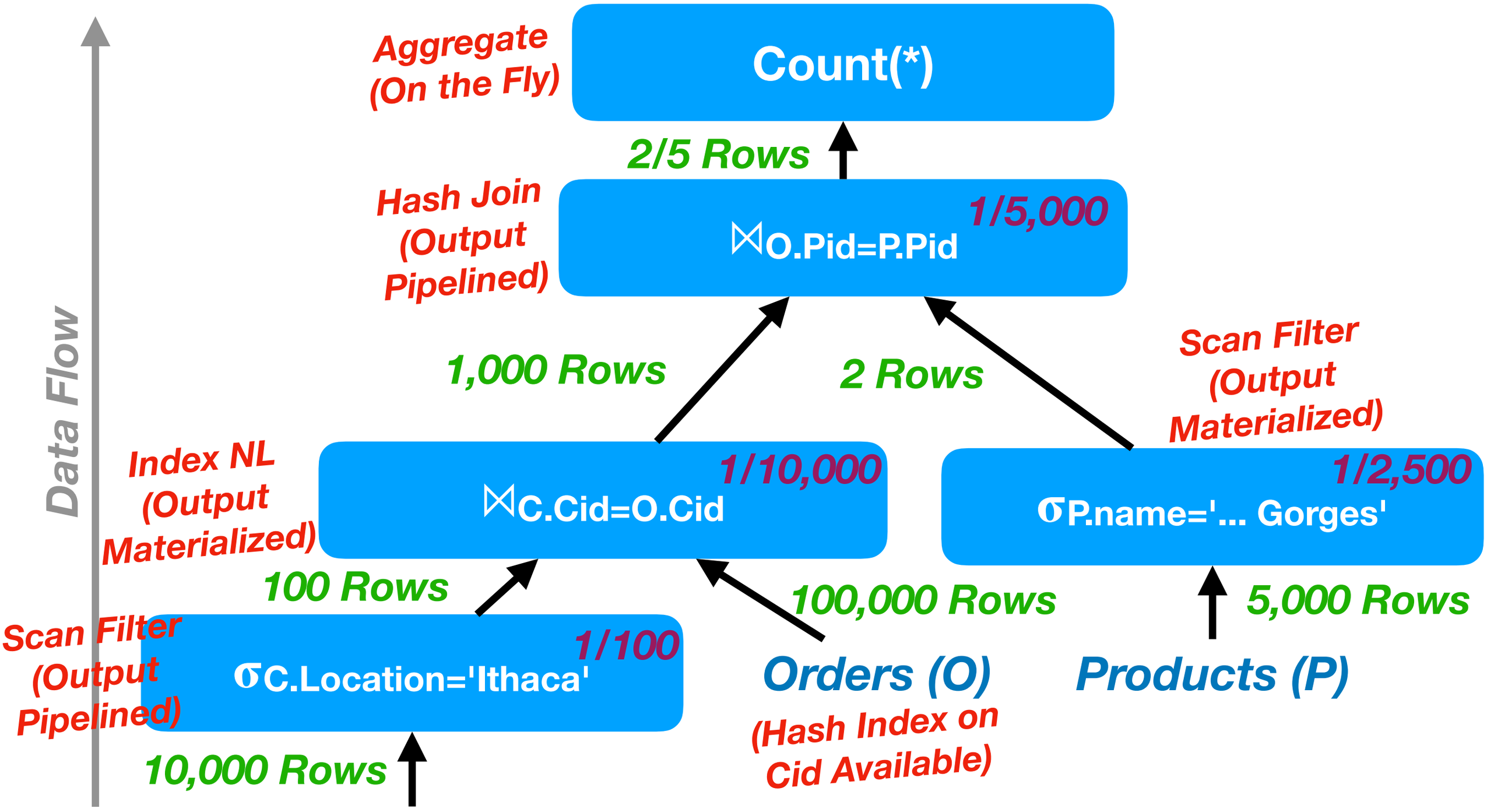


Cardinality Estimation



Is That Realistic ... ?

Size Estimation (Preparation)

Table	Columns	Size/Entry	Rows/Page
Customers	Cid, name, location	?	?
Orders	Cid, Pid, date	?	?
Products	Pid, name, price	?	?
C⋈O	Cid, name, location, pid, date	?	?
C⋈O⋈P	Cid, C.name, location, pid, date, P.name, price	?	?

Assume page size of 8,000 bytes,
4 bytes for ints and dates, 10 bytes for strings

Size Estimation (Preparation)

Table	Columns	Size/Entry	Rows/Page
Customers	Cid, name, location	24	?
Orders	Cid, Pid, date	?	?
Products	Pid, name, price	?	?
C⋈O	Cid, name, location, pid, date	?	?
C⋈O⋈P	Cid, C.name, location, pid, date, P.name, price	?	?

Assume page size of 8,000 bytes,
4 bytes for ints and dates, 10 bytes for strings

Size Estimation (Preparation)

Table	Columns	Size/Entry	Rows/Page
Customers	**Cid, name, location**	**24**	**333**
Orders	**Cid, Pid, date**	**?**	**?**
Products	**Pid, name, price**	**?**	**?**
C⋈O	**Cid, name, location, pid, date**	**?**	**?**
C⋈O⋈P	**Cid, C.name, location, pid, date, P.name, price**	**?**	**?**

Assume page size of 8,000 bytes,
4 bytes for ints and dates, 10 bytes for strings

Size Estimation (Preparation)

Table	Columns	Size/Entry	Rows/Page
Customers	Cid, name, location	24	333
Orders	Cid, Pid, date	12	666
Products	Pid, name, price	18	444
C⋈O	Cid, name, location, pid, date	32	250
C⋈O⋈P	Cid, C.name, location, pid, date, P.name, price	46	173

Assume page size of 8,000 bytes,
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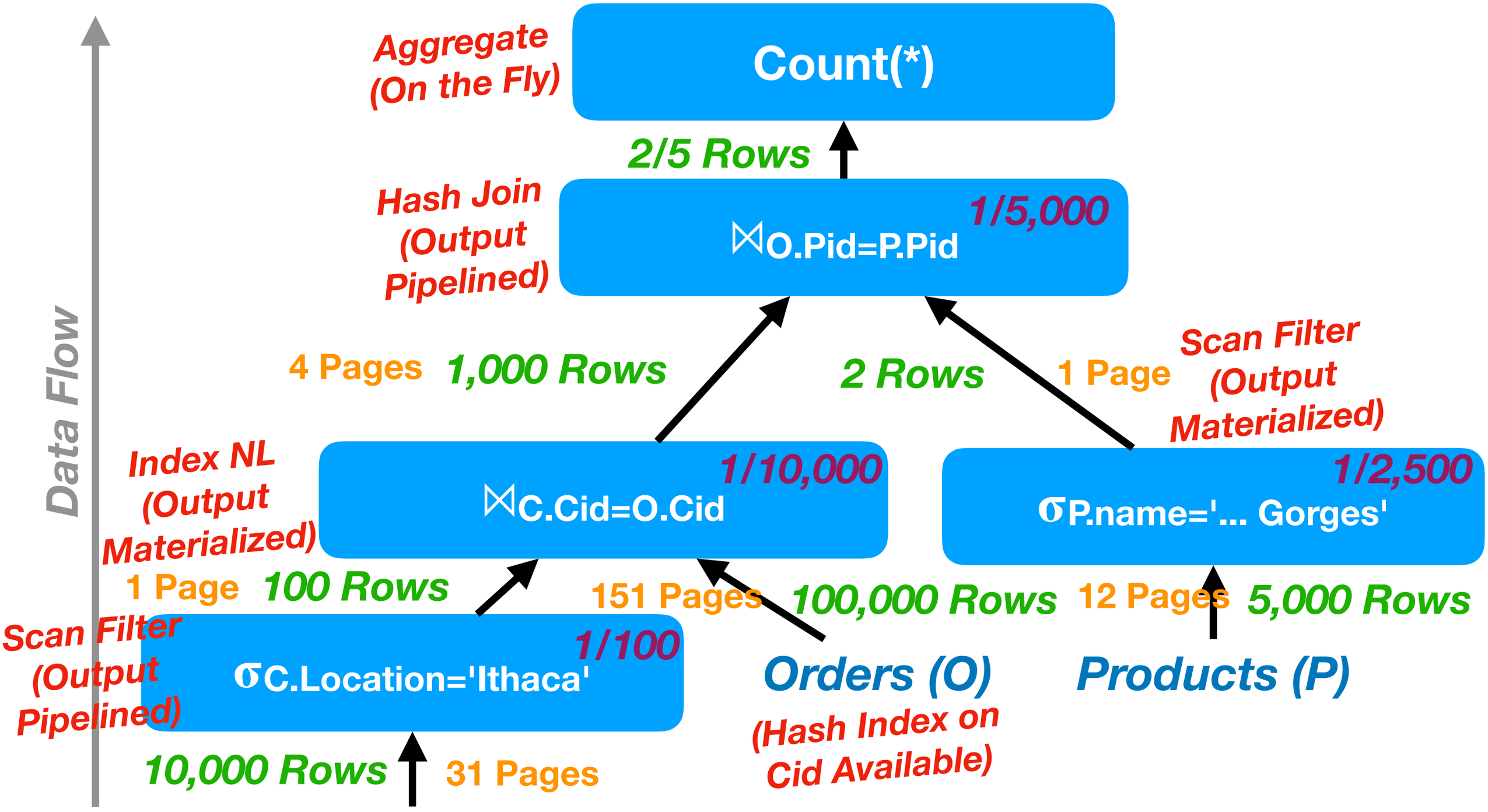
Size Estimation



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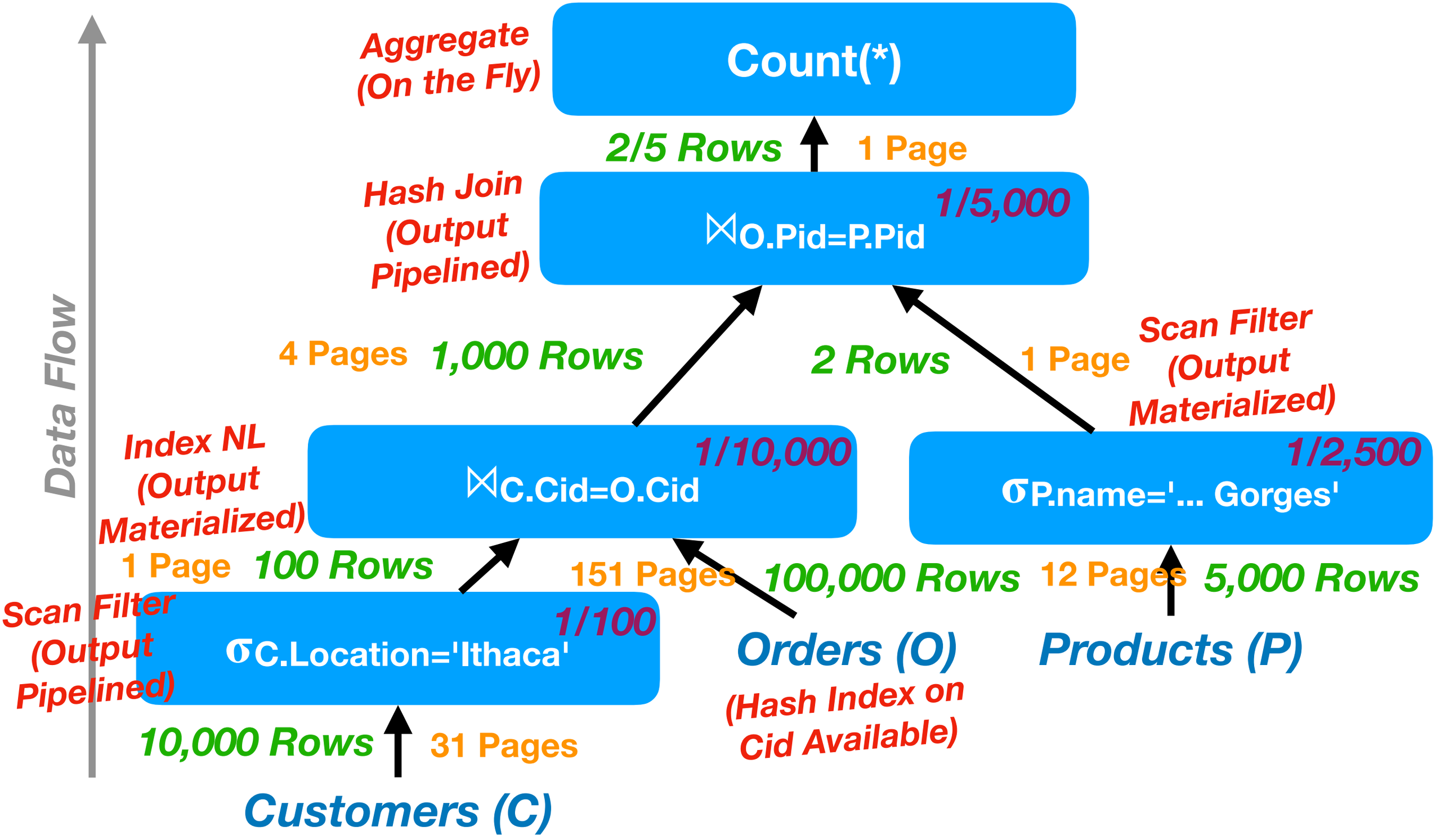
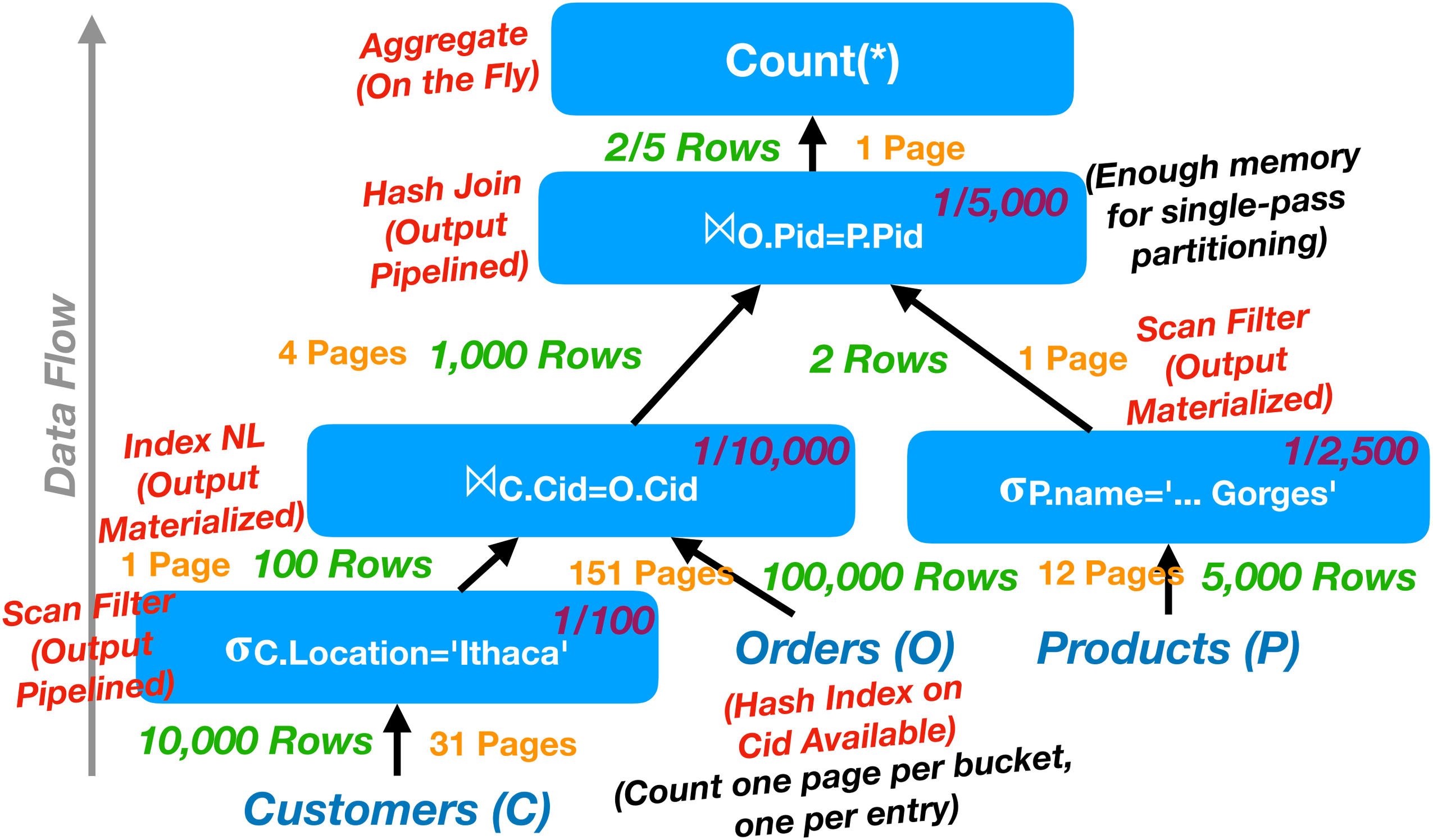


Cost Estimation



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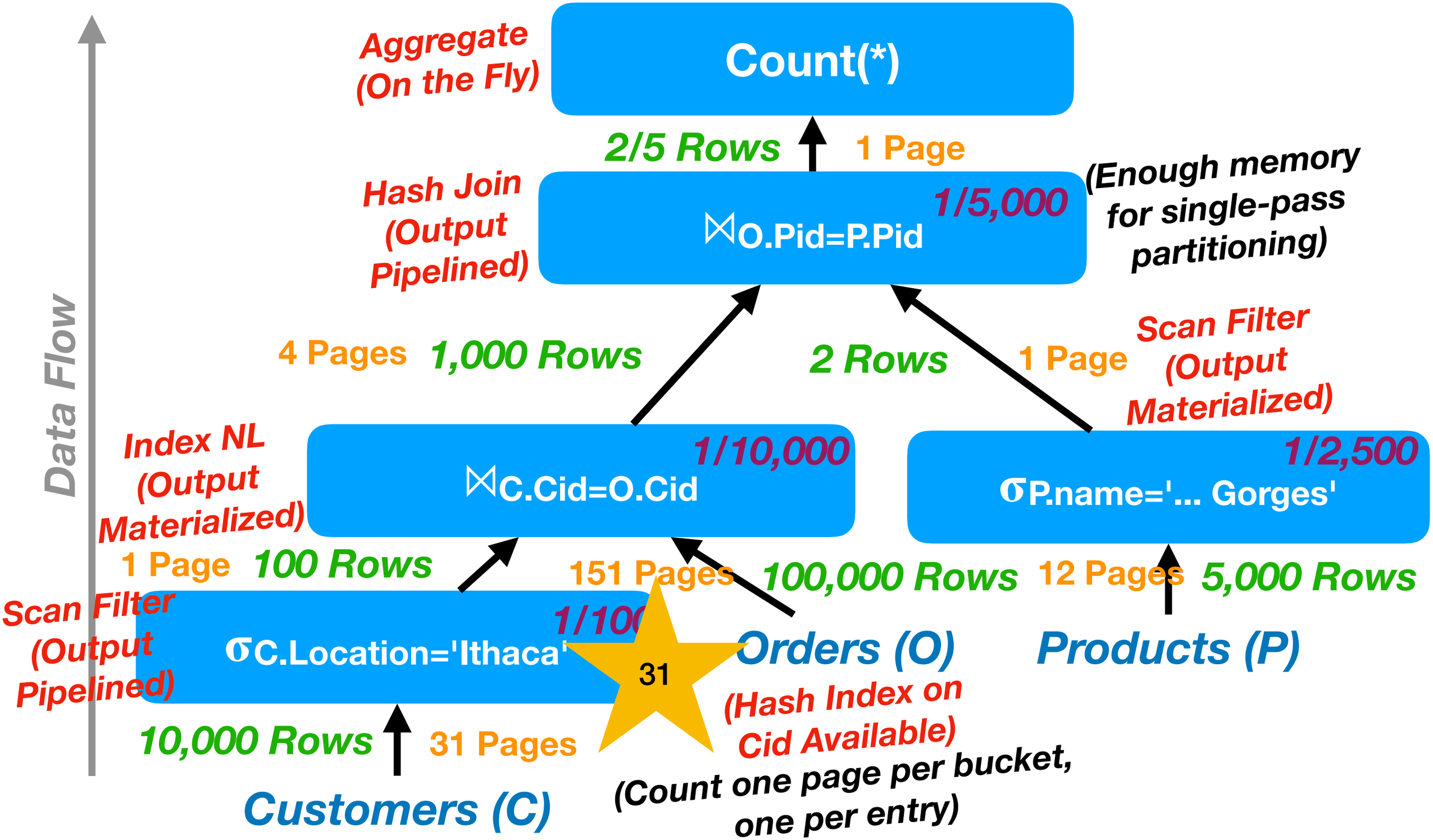

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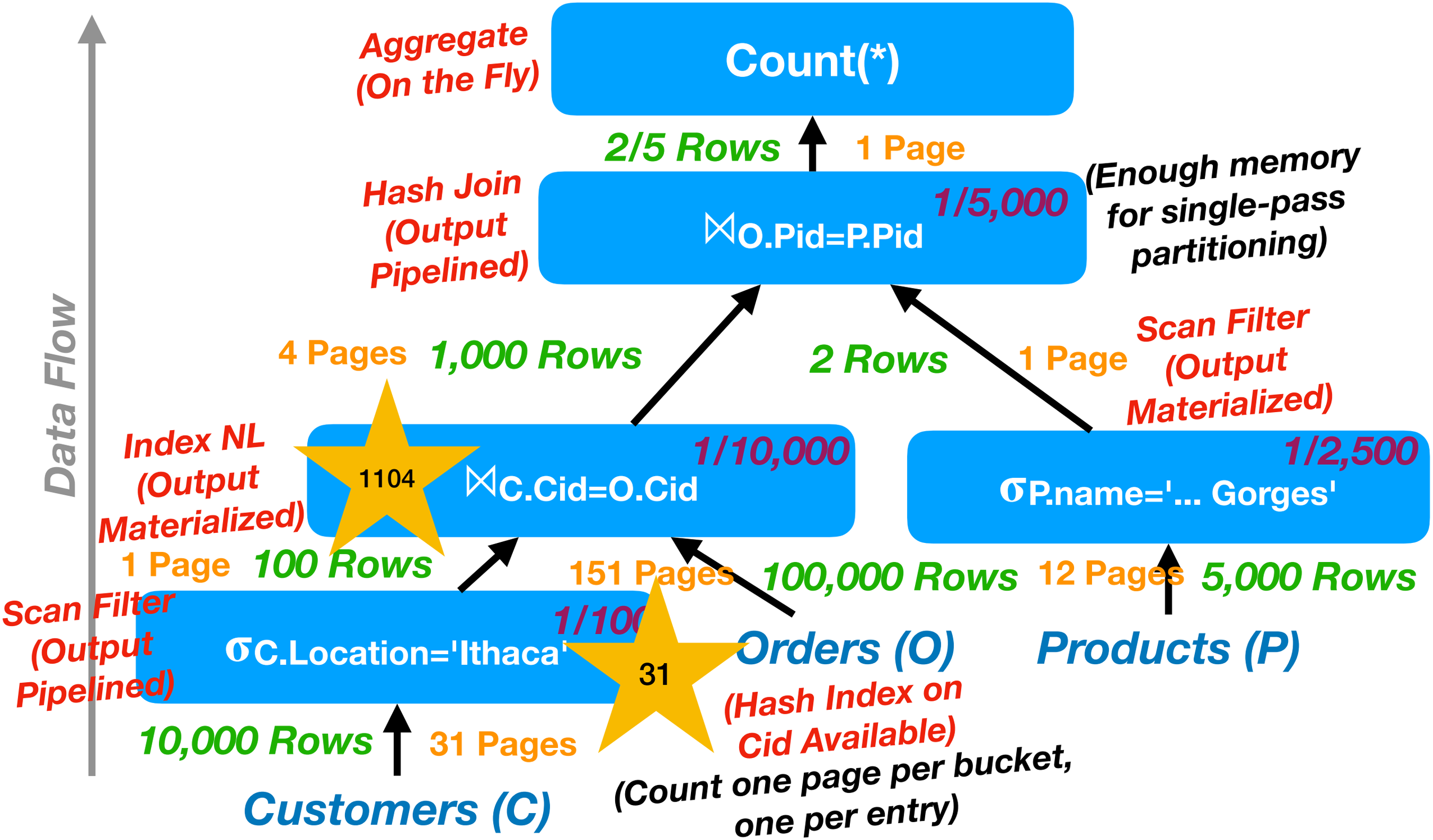

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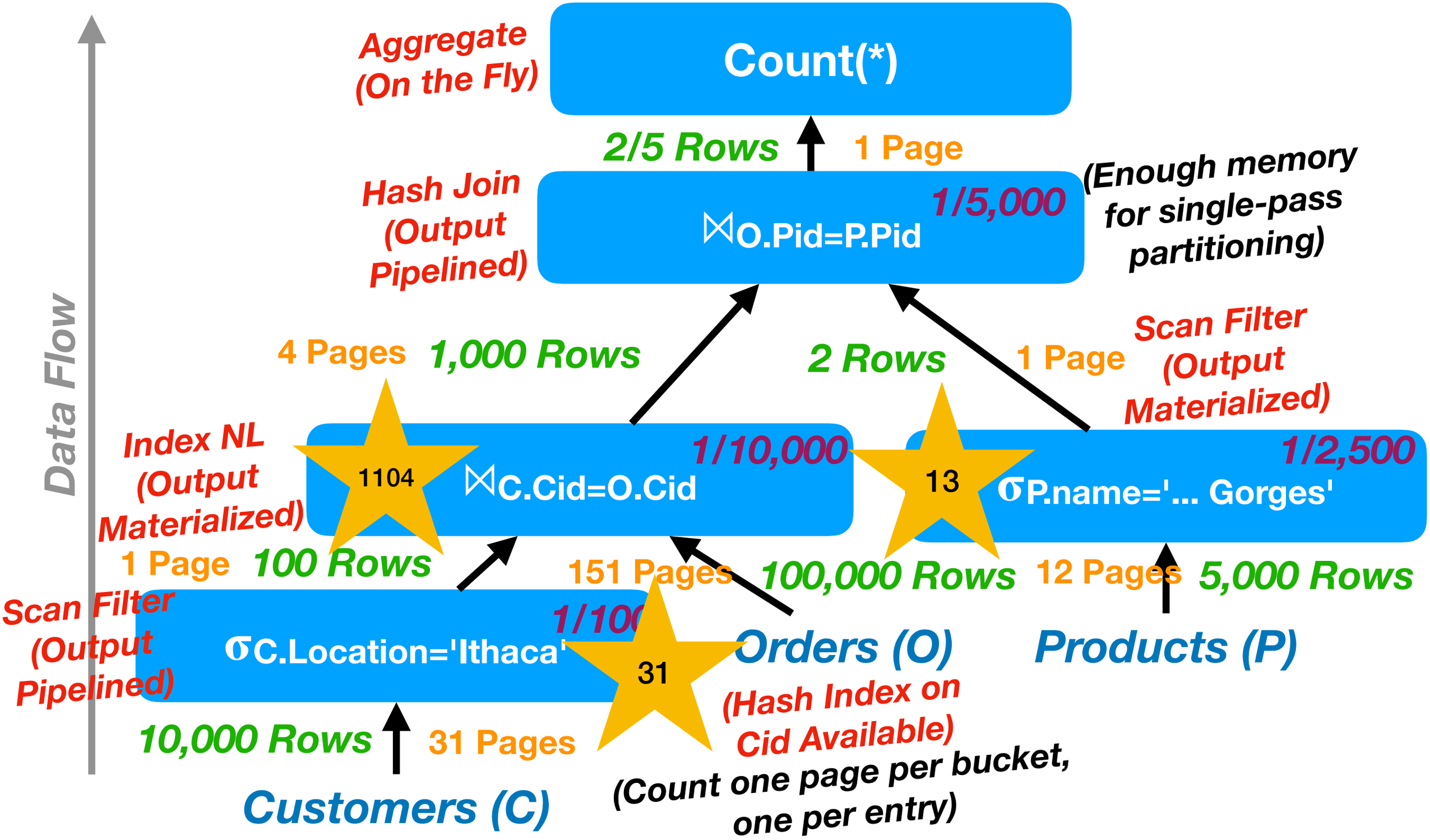

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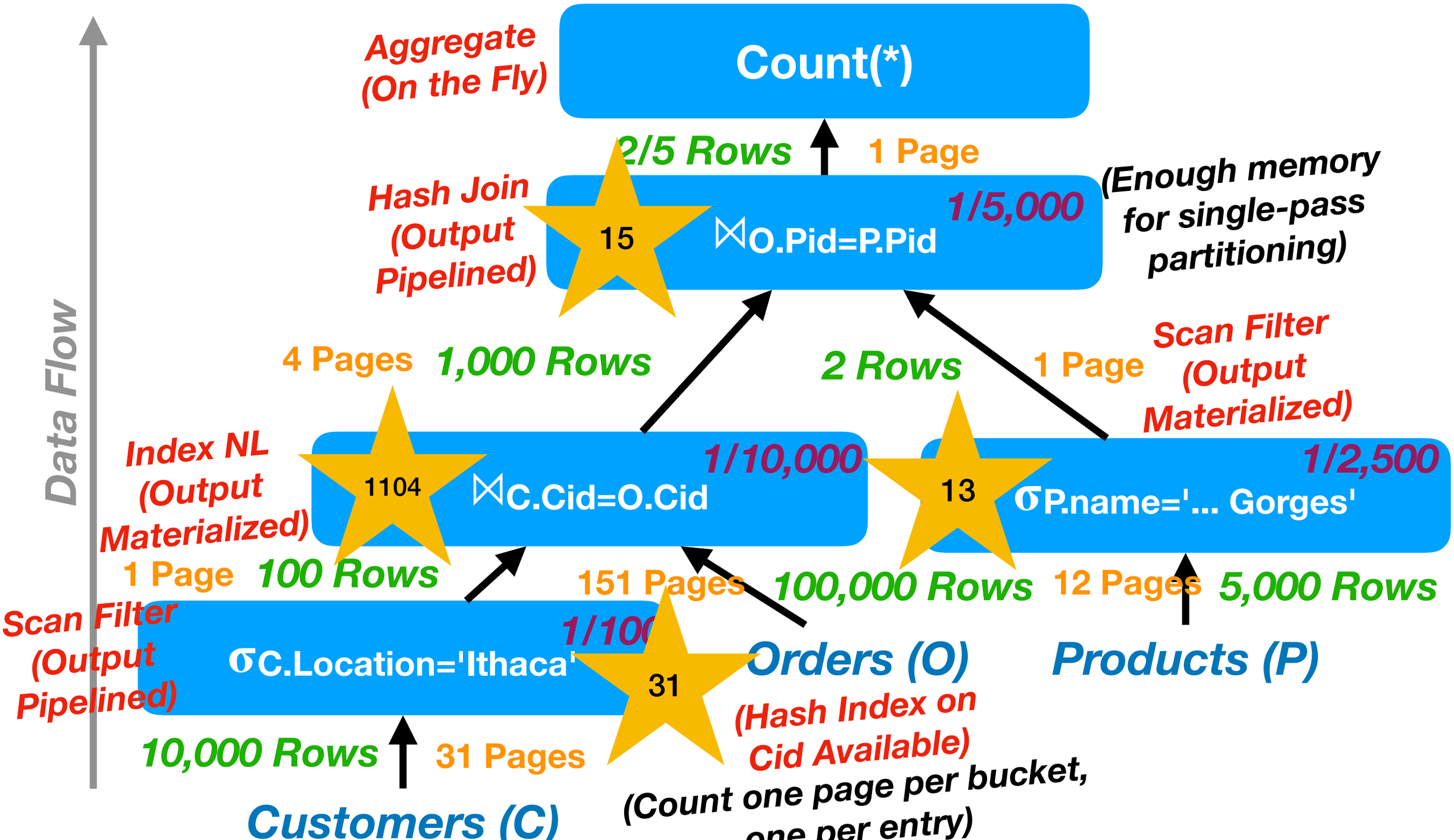

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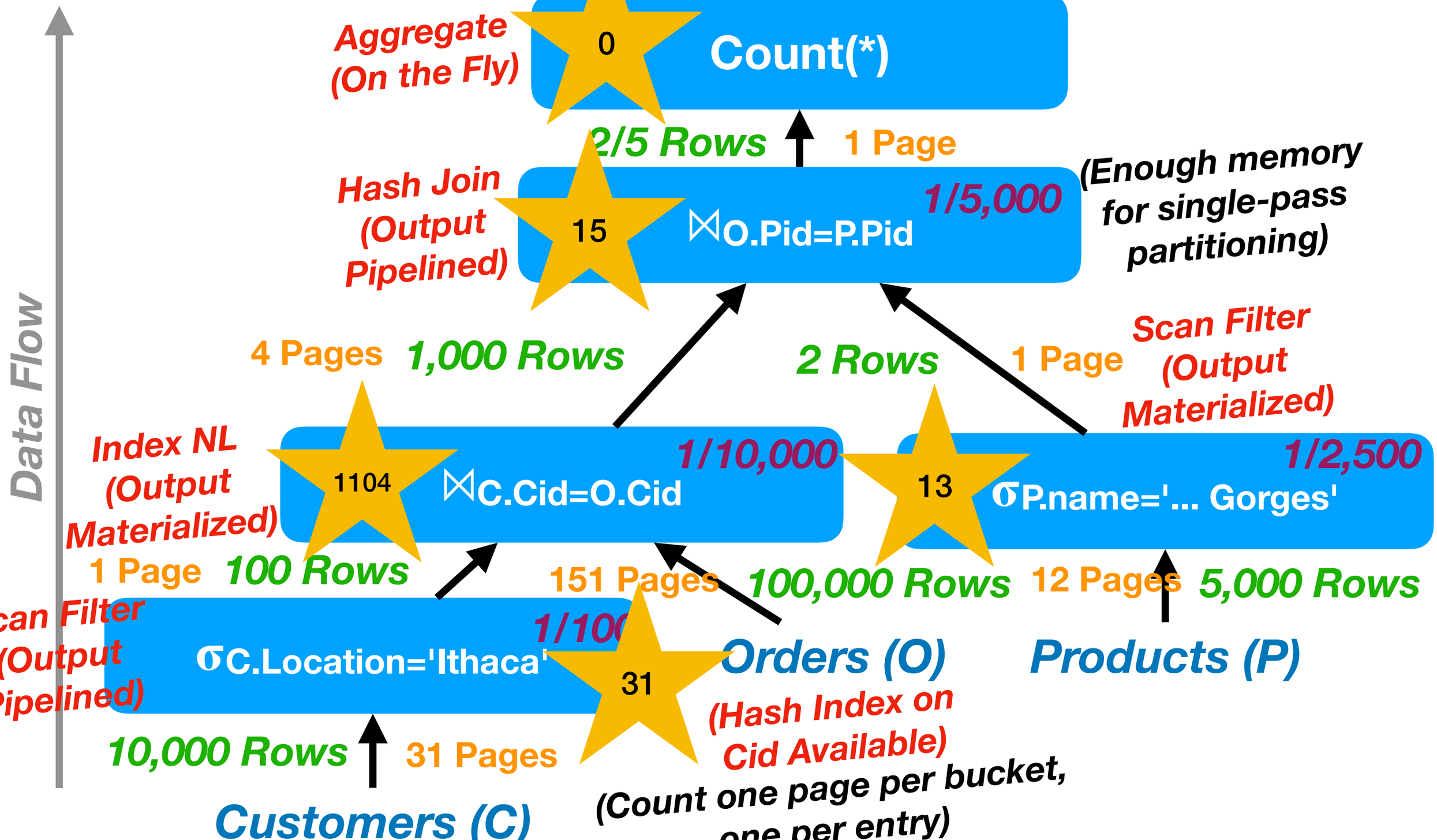

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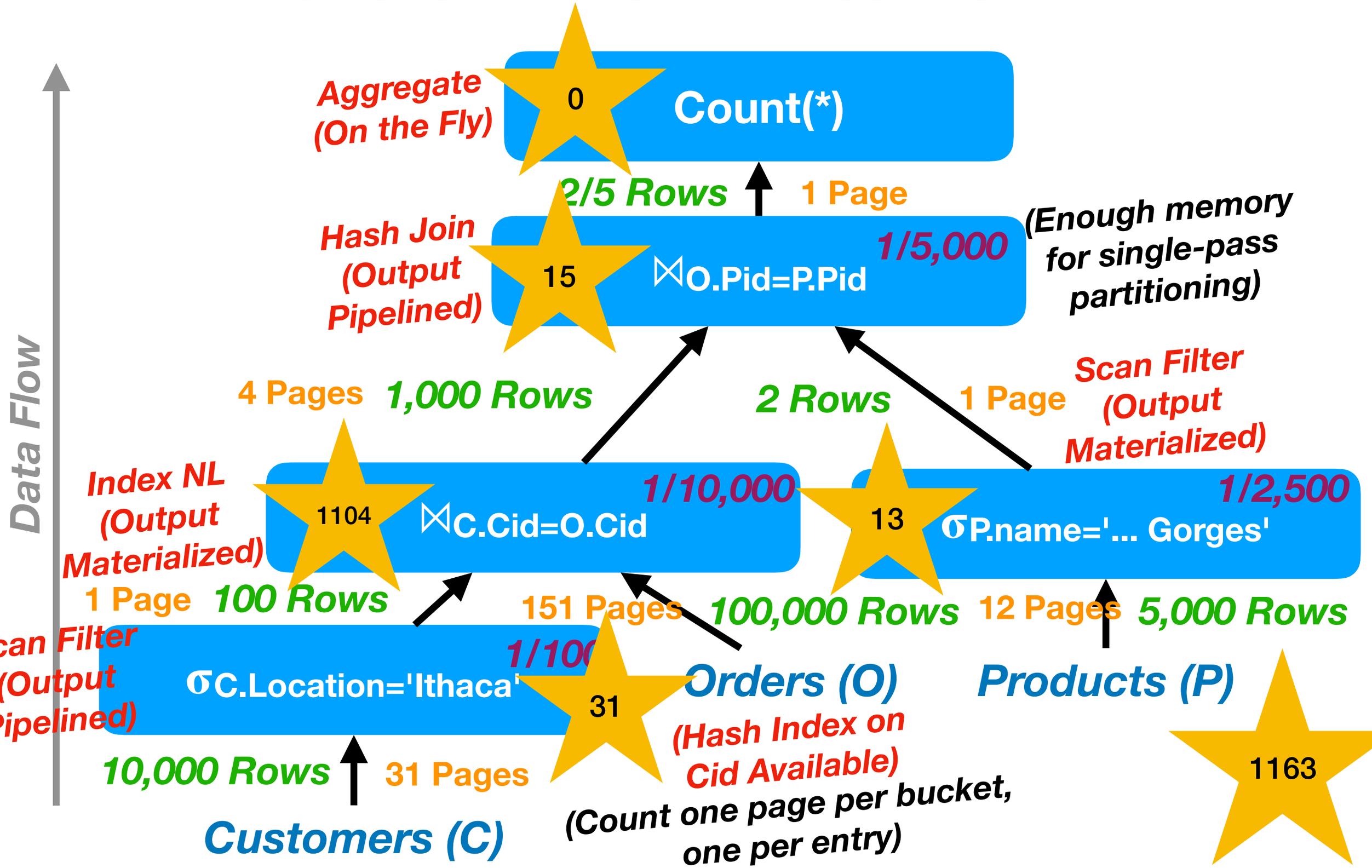
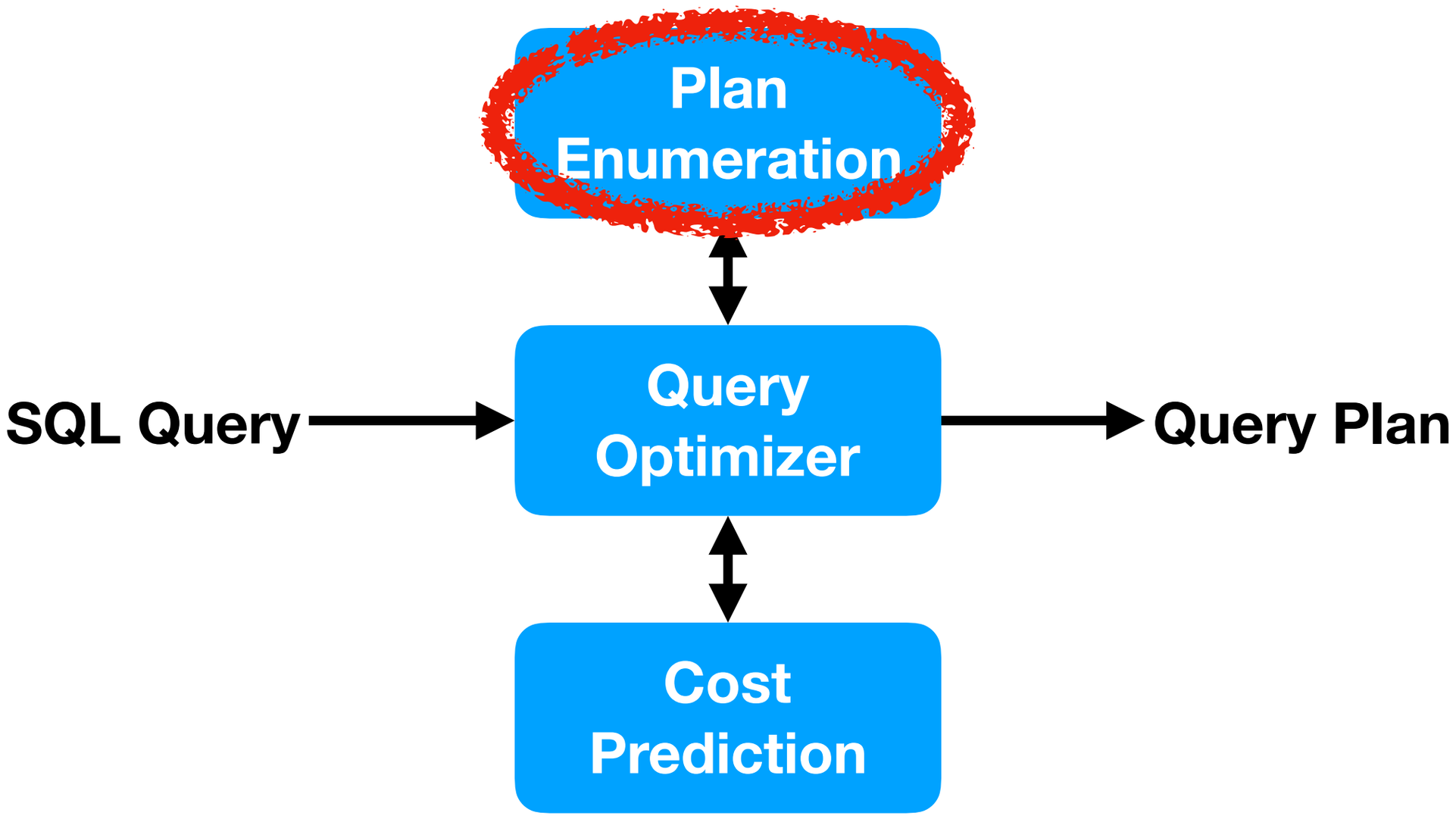


Optimizer Overview



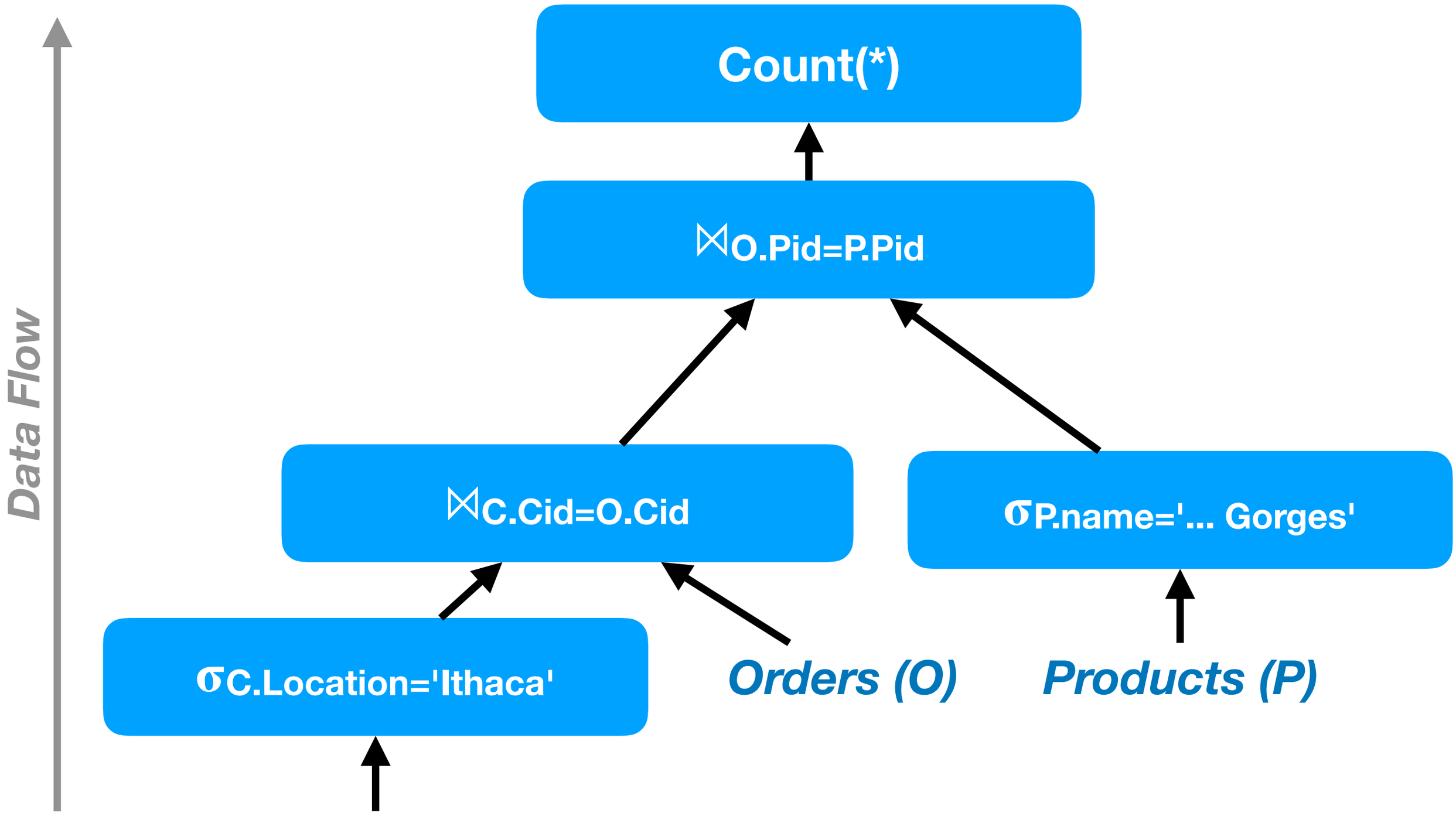
Query Plan Space

- Decide **order** of operations and **implementation**
- Apply **heuristic** restrictions
  - H1: Apply predicates/projections **early**
  - H2: Avoid **predicate-less** joins
  - H3: Focus on **left-deep plans**

H1: Early Predicates and Projections

- Processing **more** data is more expensive
- Want to **reduce** data size as quickly as possible
- Can do that by adding **predicates** (discarding rows)
- Can also do that by adding **projections** (discard columns)

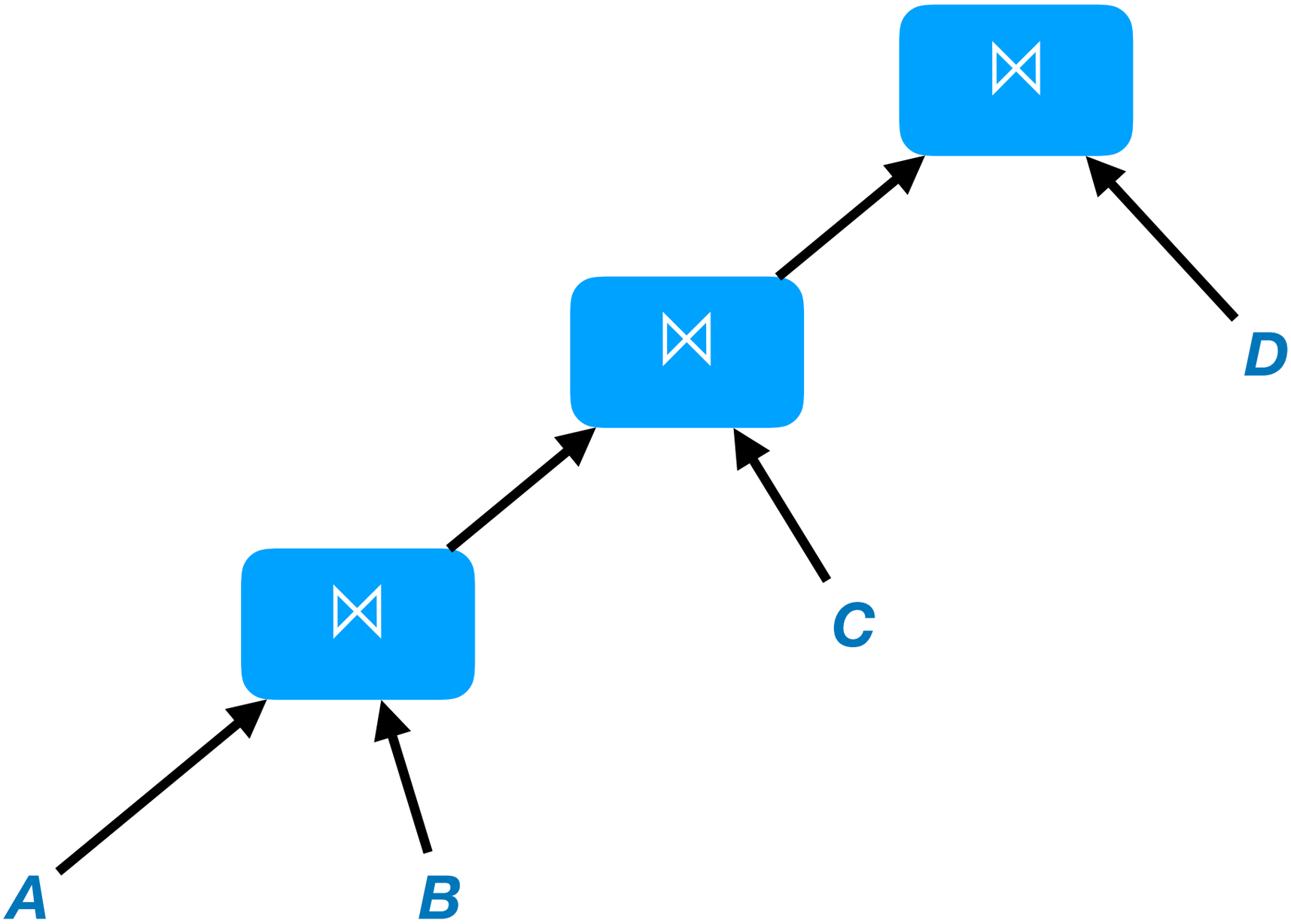
Can We Improve This?



H2: Avoid Joins without Predicates

- Join result **size**: product of input cardinality * selectivity
- Selectivity is **one** when joining tables without predicates
- Often means very **large** join results, probably sub-optimal
- (Heuristic may **discard** optimal order in special cases)

H3: Use "Left-Deep Plans"

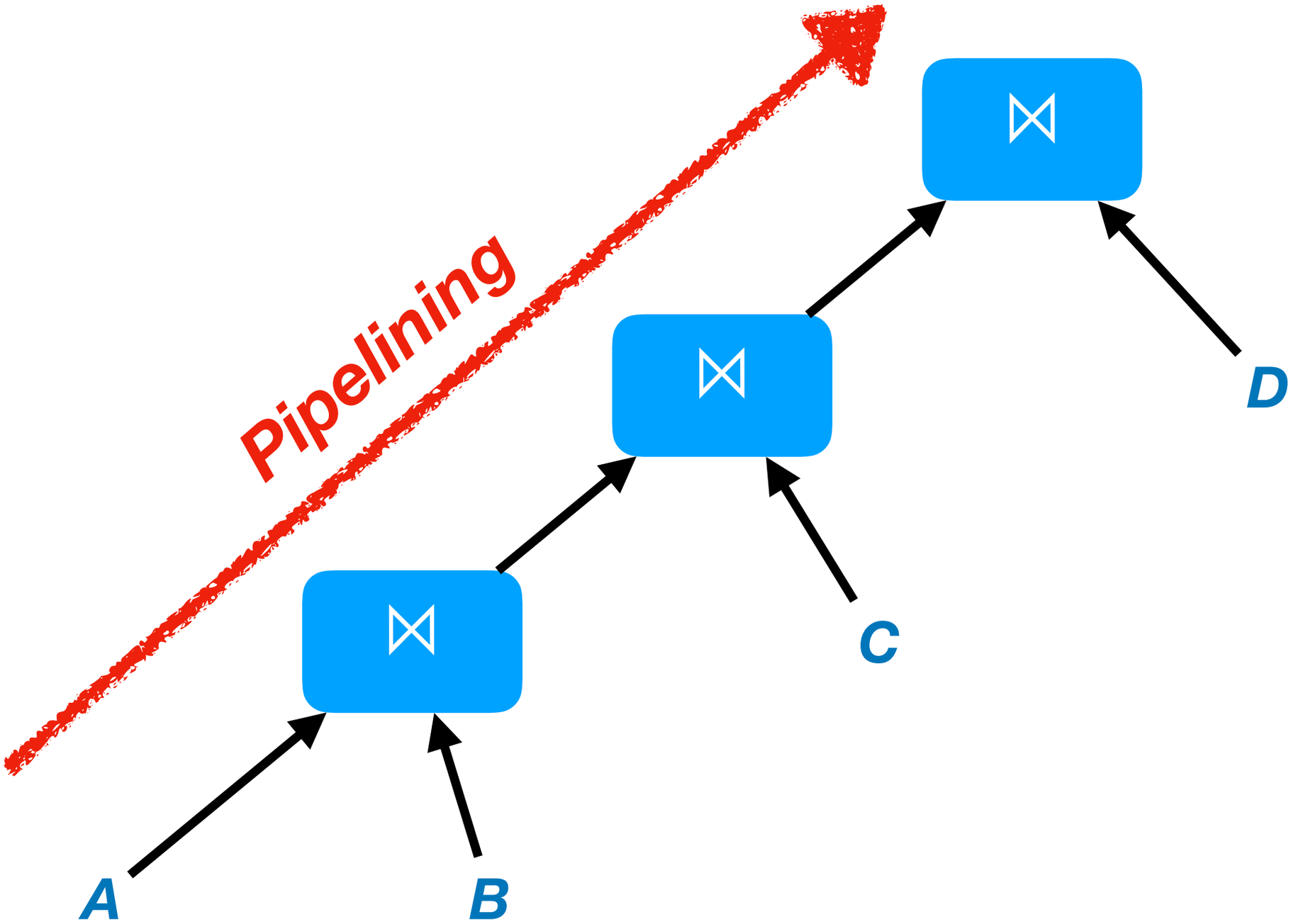


Why Left-Deep Plans?

- Allows **pipelining**: joins pass on result parts in-memory

- Allows to use **indices** on join columns (of base tables)

Focus on "Left-Deep Plans"



Naive Plan Enumeration

- **Generate** every possible plan
- **Estimate** cost for each plan
- **Select** plan with minimal cost

Asymptotic Analysis

- Number of join orders can grow quickly **O(nrTables!)**.
- Number of join orders **lower-bounds** number of plans
- Enumerating plans is considered **impractical**

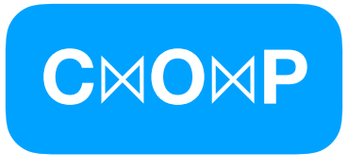
Principle of Optimality

- Want **cheapest** plan to join set of tables
- This plan joins **table subsets** "on the way"
- Assume we use **sub-optimal** plan for joining table subset
- Replacing by a **better** plan can only improve overall cost
- This is generally called the **principle of optimality**

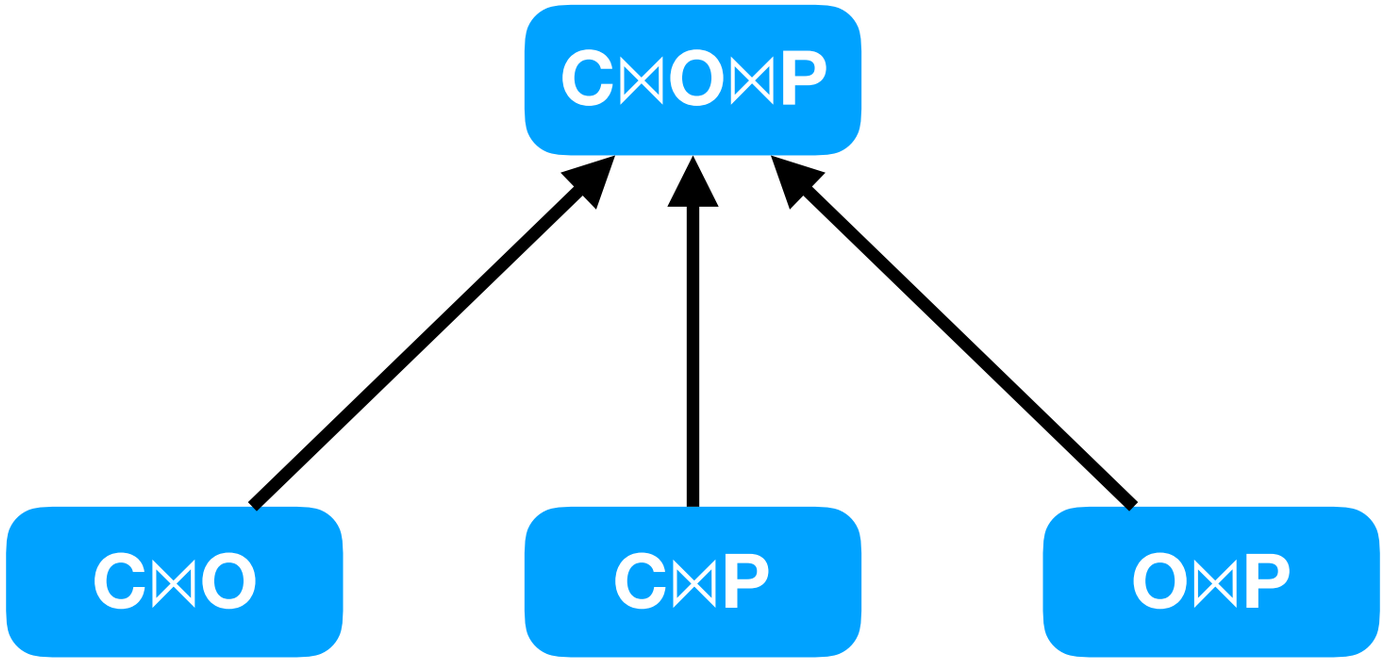
Efficient Optimization

- Find optimal plans for (smaller) sub-queries **first**
  - **Sub-query**: joins subsets of tables
- Compose optimal plans **from optimal sub-query plans**

Dynamic Programming



Dynamic Programming



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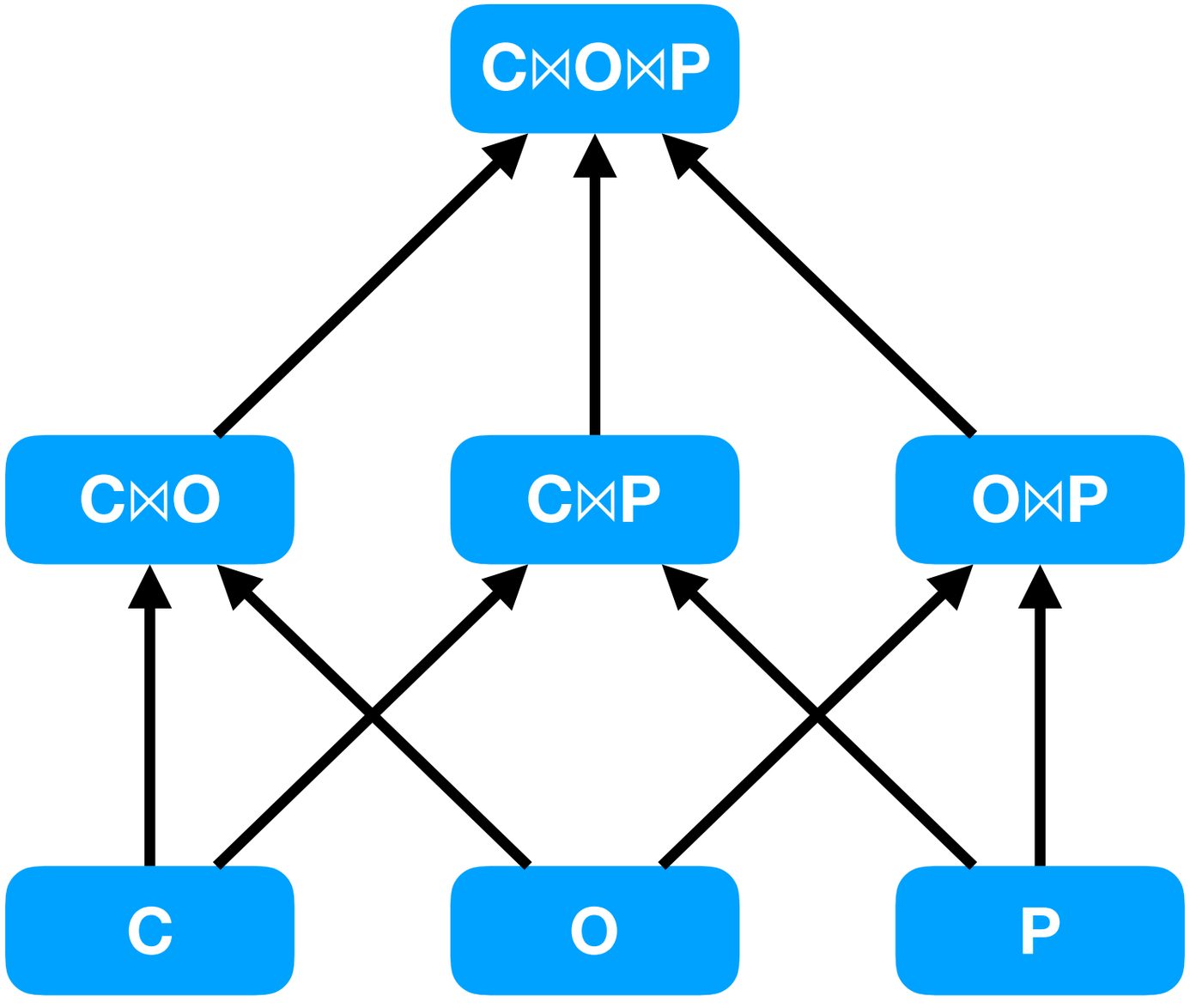

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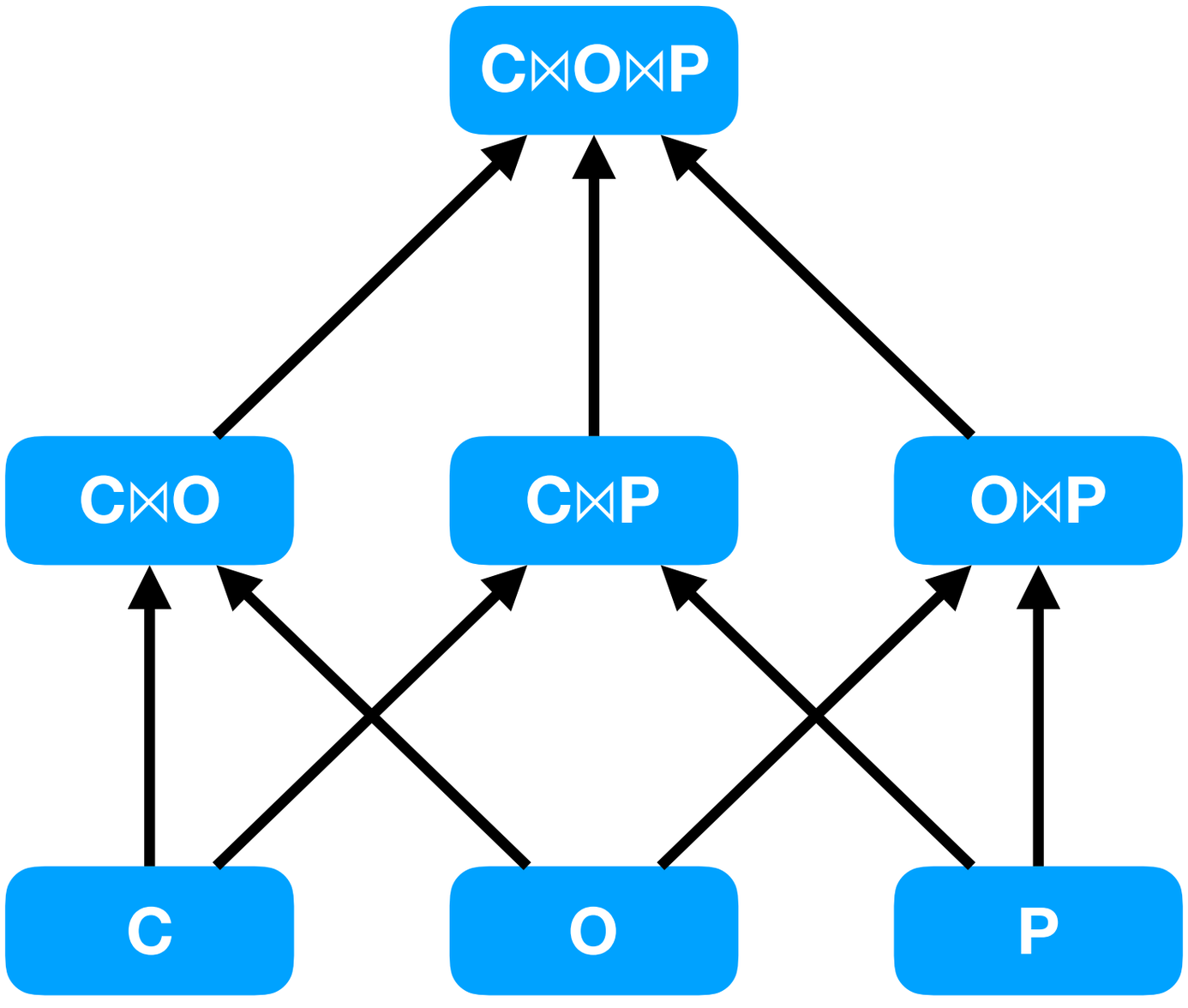
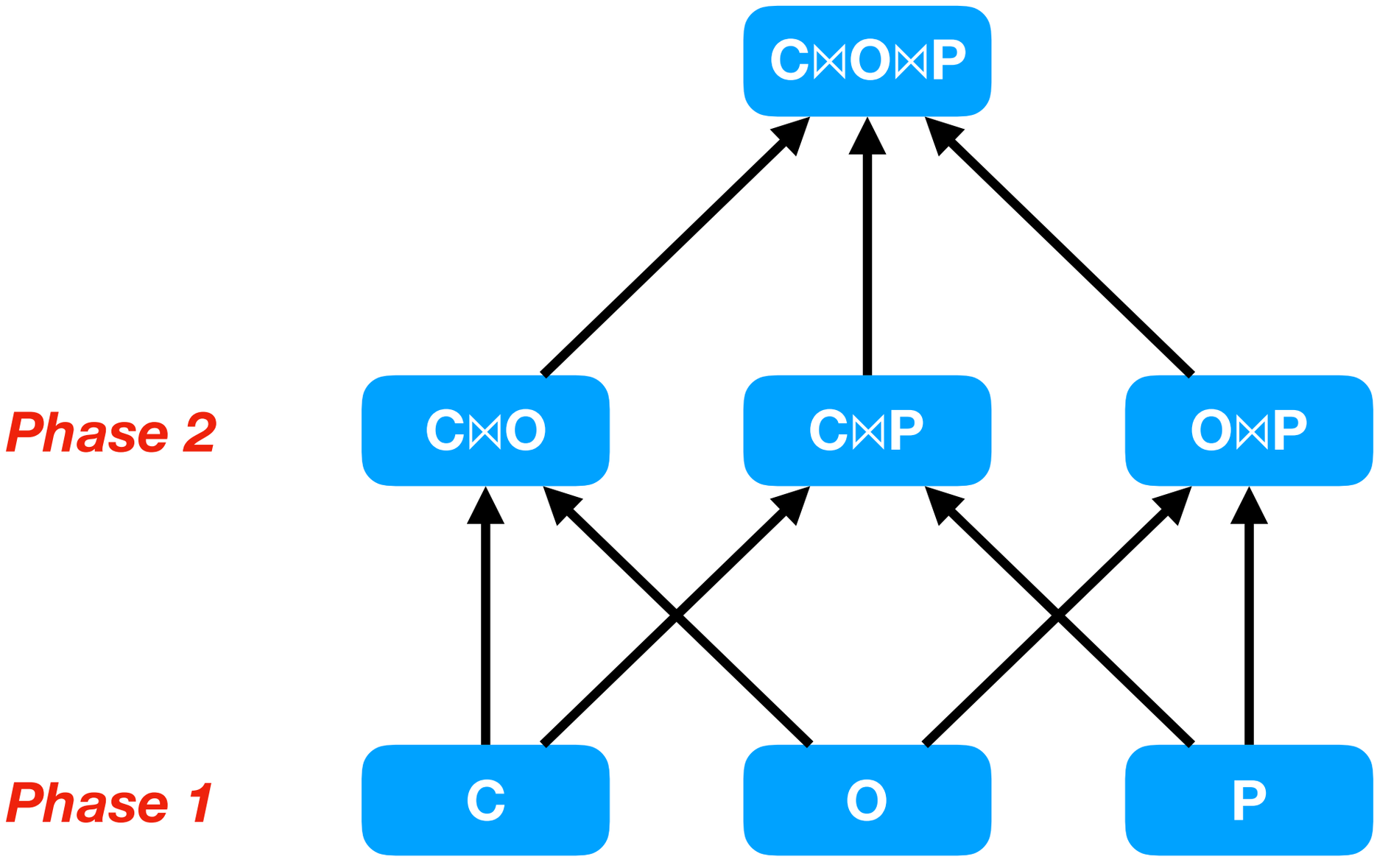


Phase 1

Dynamic Programming

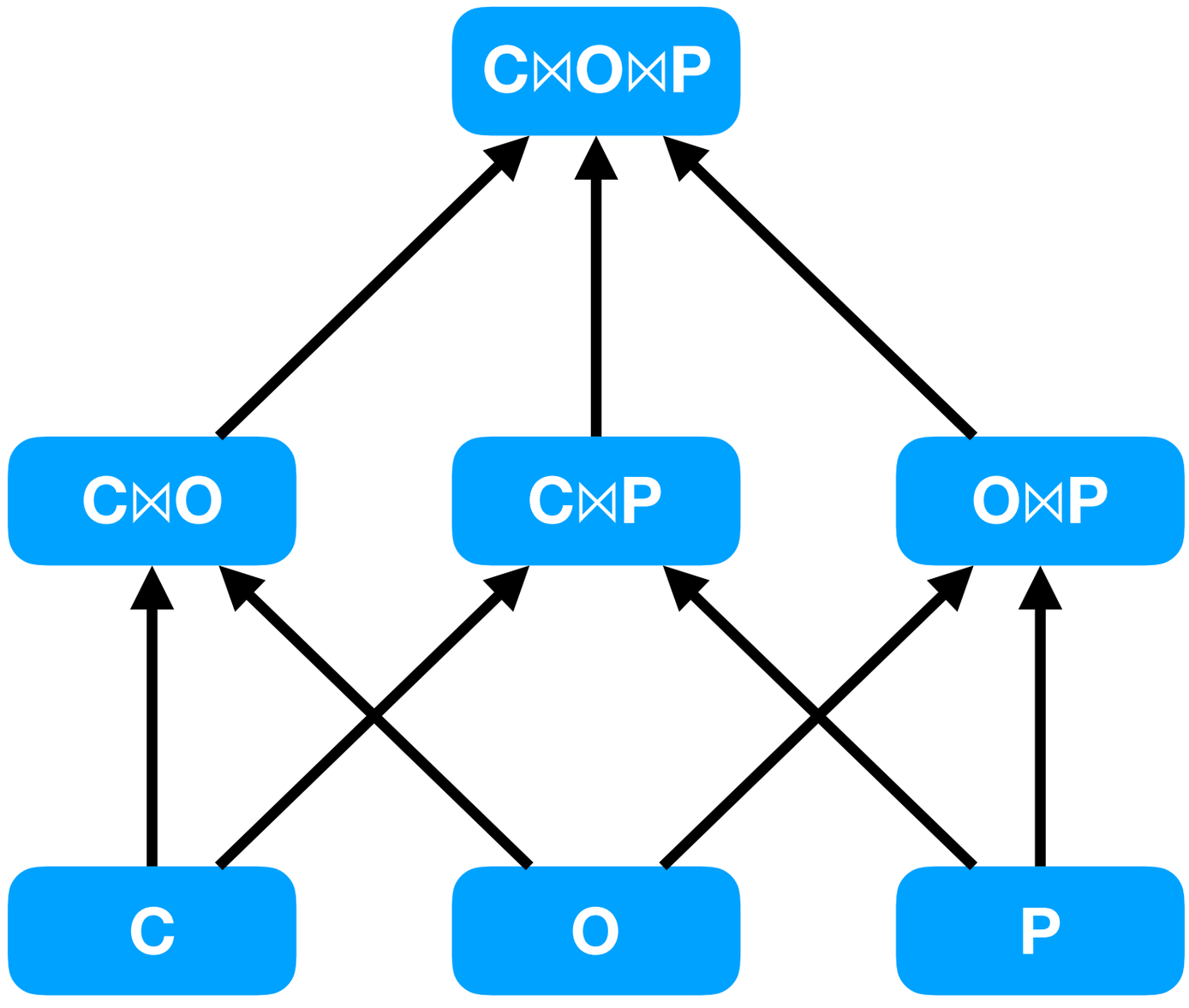


Dynamic Programming

Phase 3

Phase 2

Phase 1



Dynamic Programming