CS525: Advanced Database Organization

Notes 6: Query Processing
Part I : Overview

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Slides: adapted from courses taught by Hector Garcia-Molina, Stanford, & Shun Yan Cheung, Emory University

Where we are

- How a DBMS processes queries and the methods it uses to optimize their performance.

- Goals: *Understand the basic concepts underlying the steps in query processing and optimization and estimating query processing cost; apply query optimization techniques*

Query Processing

- So far, we have looked
  - hardware features such as disks and memory
  - data structures allowing fast lookup
- Remember that SQL is a declarative language
  - User tells the DBMS what answer they want, not how to get the answer.
  - DBMS needs to translate a SQL statement into an executable query plan
  - This allows for optimization decisions, and for many queries there is a wide range of possible execution strategies, which can differ greatly in their resulting performance
    - i.e., there can be a big difference in performance based on plan is used
- A query processor must find a plan how to execute the query
  - query compilation
  - query execution

Query Processing

- There might be several ways to implement a query - the query compiler should find an appropriate plan
  - parsing: translating the query into a parsing tree
  - query rewrite: the parse tree is transformed into an expression tree of relational algebra (logical query plan[1])
  - physical plan generation: translate the logical plan into a physical plan[2]
    - select algorithms to implement each operator
    - choose order of operations
- *Logical Query Plan the optimal sequence of relational algebra operations to perform the query.*
- *Physical Query Plan the optimal sequence of relational algebra algorithms to perform the query.*

[1] *The logical plan is roughly equivalent to the relational algebra expressions in the query.*

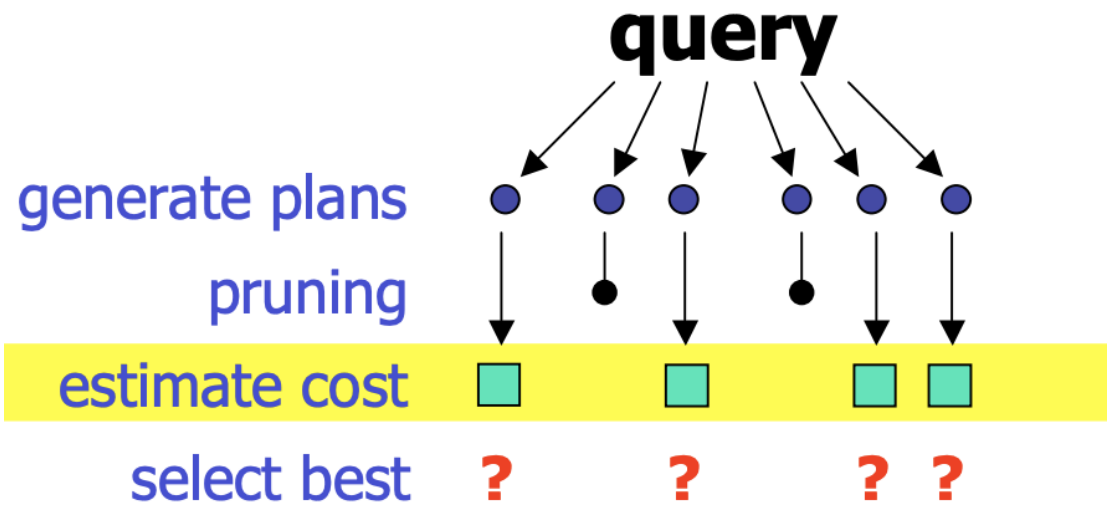
[2] *Physical operators define a specific execution strategy using an access path for the different operators in the query plan.*

Query Plan

- The DBMS converts a SQL statement into a query plan.
- Operators in the query plan are arranged in a tree.
- Data flows from the leaves of this tree towards the root.
- The output of the root node in the tree is the result of the query.
- Typically operators are binary (1-2 children).
- The same query plan can be executed in multiple ways.
- Most DBMSs will want to use an index scan as much as possible

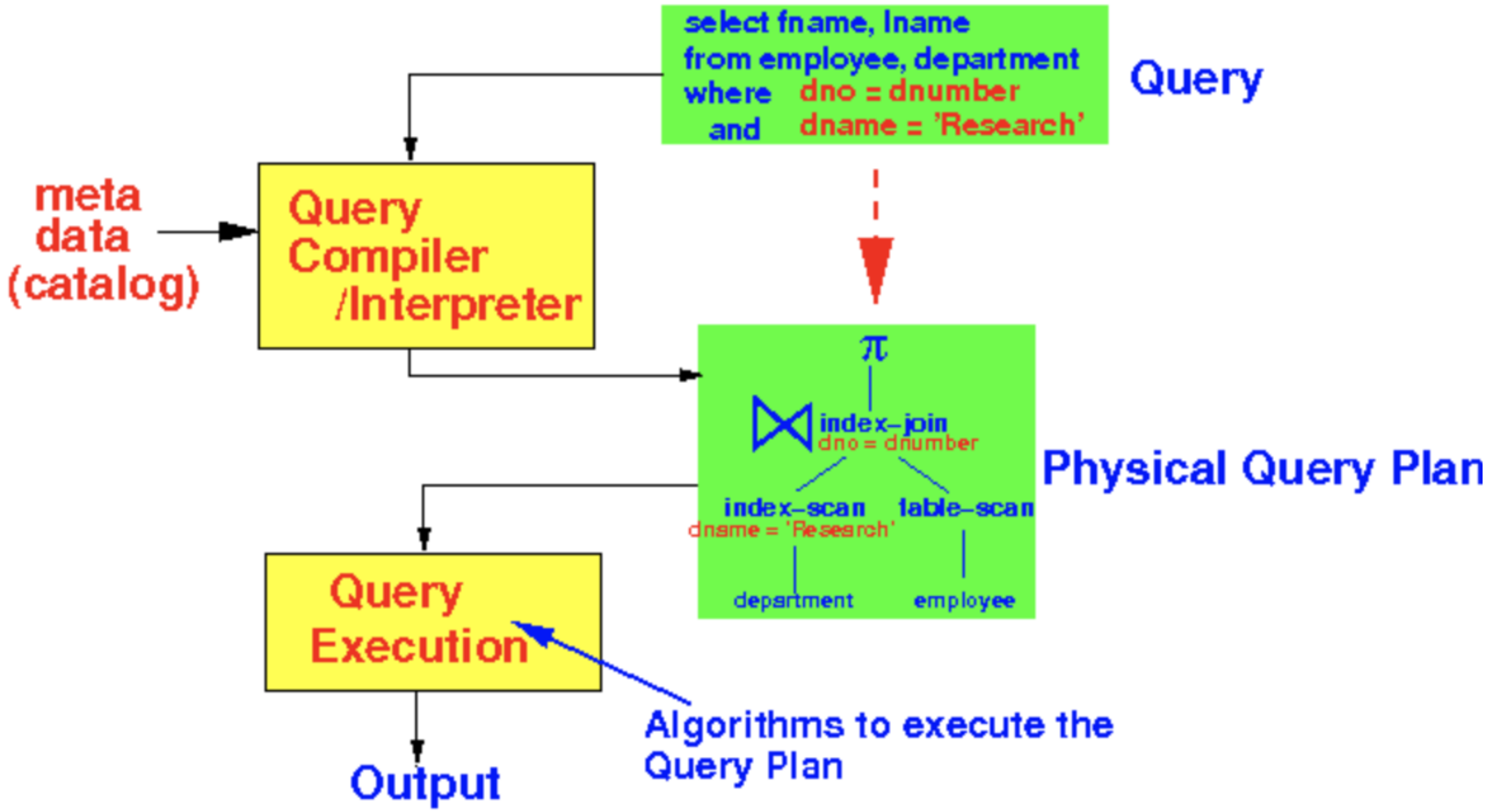
Query Processing

- Making logical and physical query plans are often called query optimizing



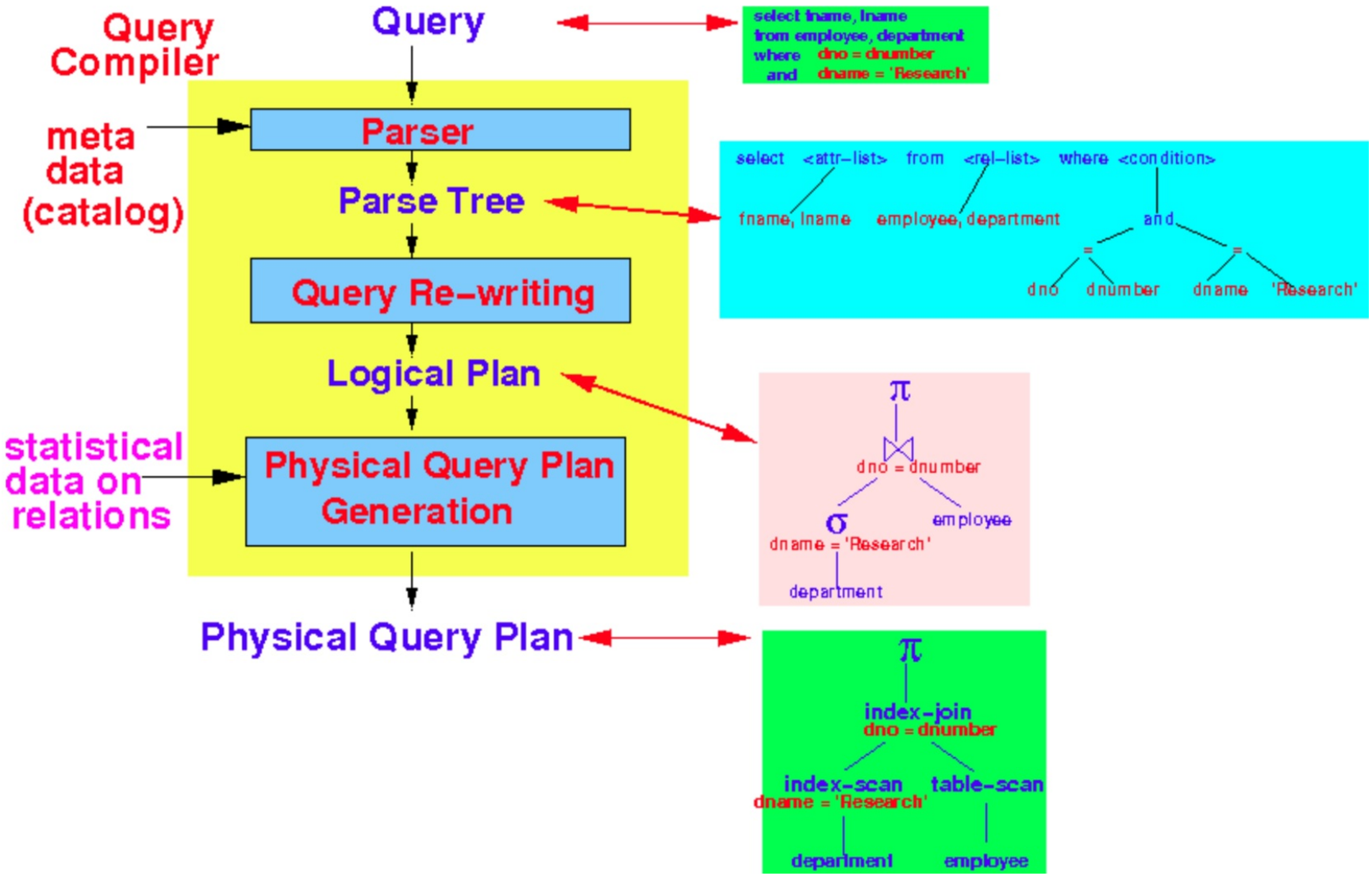
Query Processing: Steps to Process SQL Query

- Steps needed to process a query (SQL command)



Query Processing

- The **Query Compiler** consists of 3 major steps



Query Processing: Example

```
SELECT B,D
FROM R,S
WHERE R.A='c' and S.E=2 and R.c=S.c
```

Query Processing: Example

R

A	B	C
a	1	10
b	1	20
c	2	10
d	2	35
e	3	45

S

C	D	E
10	x	2
20	y	2
30	z	2
40	x	1
50	y	3

Query Processing: Example

R

A	B	C
a	1	10
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S

C	D	E
10	x	2
20	y	2
30	z	2
40	x	1
50	y	3

Answer

B	D
2	x

How do we execute query?

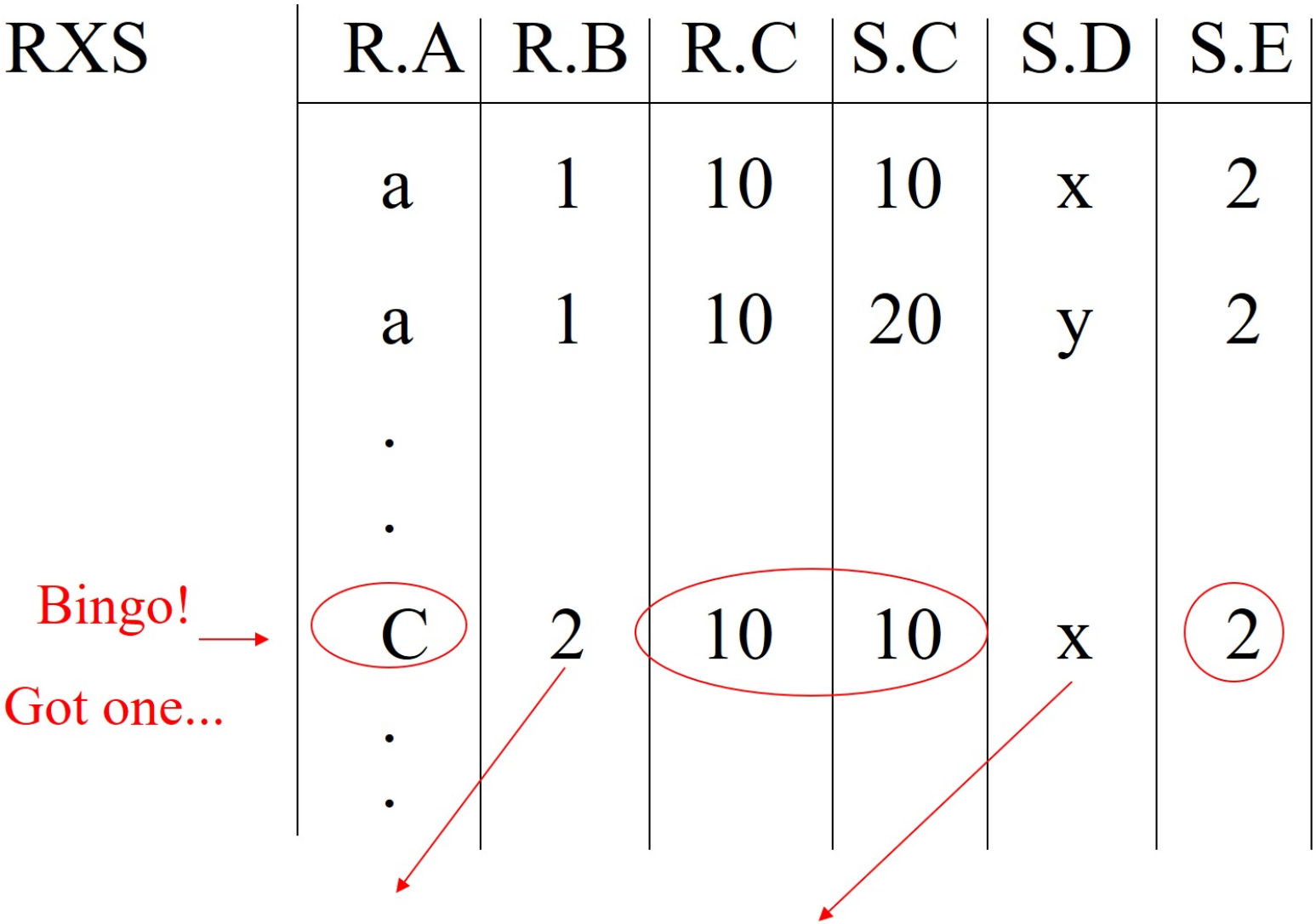
- One idea
  - Scan relations
  - Do Cartesian product
  - Select tuples
  - Do projection

Query Processing: Example

$R \times S$

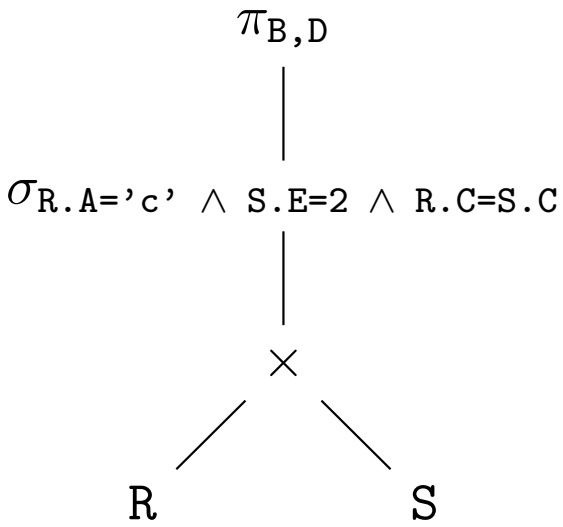
R.A	R.B	R.C	S.C	S.D	S.E
a	1	10	10	x	2
a	1	10	20	y	2
.					
.					
C	2	10	10	x	2
.					
.					

Query Processing: Example



Relational Algebra

- Can be used to describe plans
- Example: Plan I: Initial query plan constructed directly from the query.



- FROM expressed by a `product`, WHERE by a `selection` above it, Select by a `projection`

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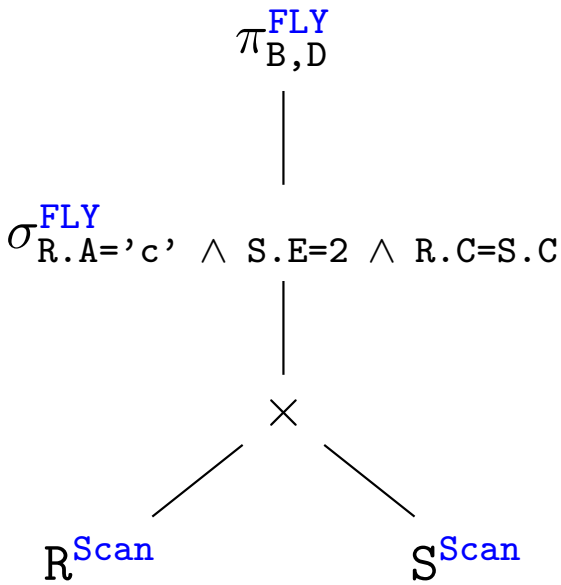
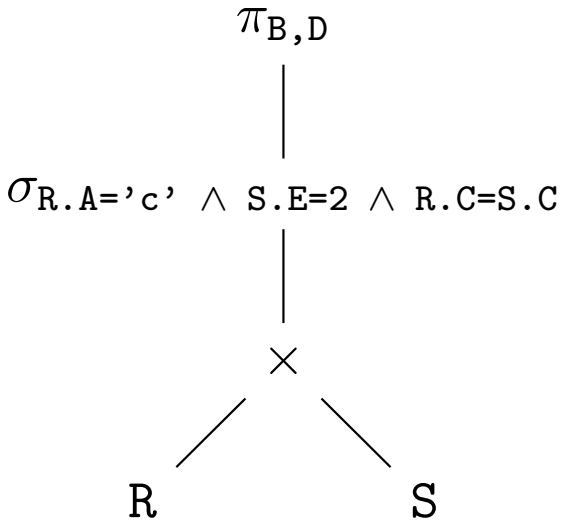


1. Scan `R`
2. For each tuple `r` of `R` scan `S`
3. For each tuple `r,s`, where `s` in `S`, select and project on the fly

- OR: $\pi^{\texttt{FLY}}_{\texttt{B,D}}\left[\sigma^{\texttt{FLY}}_{\texttt{R.A='c'} \wedge \texttt{S.E=2} \wedge \texttt{R.C=S.C}}(\texttt{R}^{\texttt{Scan}} \times \texttt{S}^{\texttt{Scan}})\right]$

“FLY” and “SCAN” are the defaults

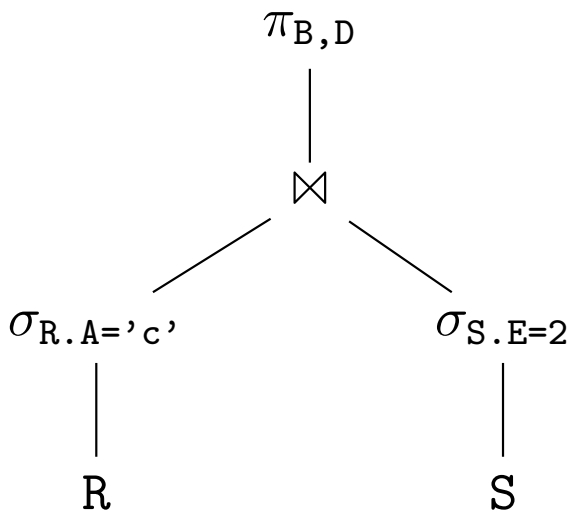
- Example: Plan I: Initial query plan constructed directly from the query.



- OR: $\pi_{\texttt{B,D}}\left[\sigma_{\texttt{R.A='c'} \wedge \texttt{S.E=2} \wedge \texttt{R.C=S.C}}(\texttt{R} \times \texttt{S})\right]$

Another idea

- Example: Plan II: Scan `R` and `S`, perform on the fly selections, do natural join, project



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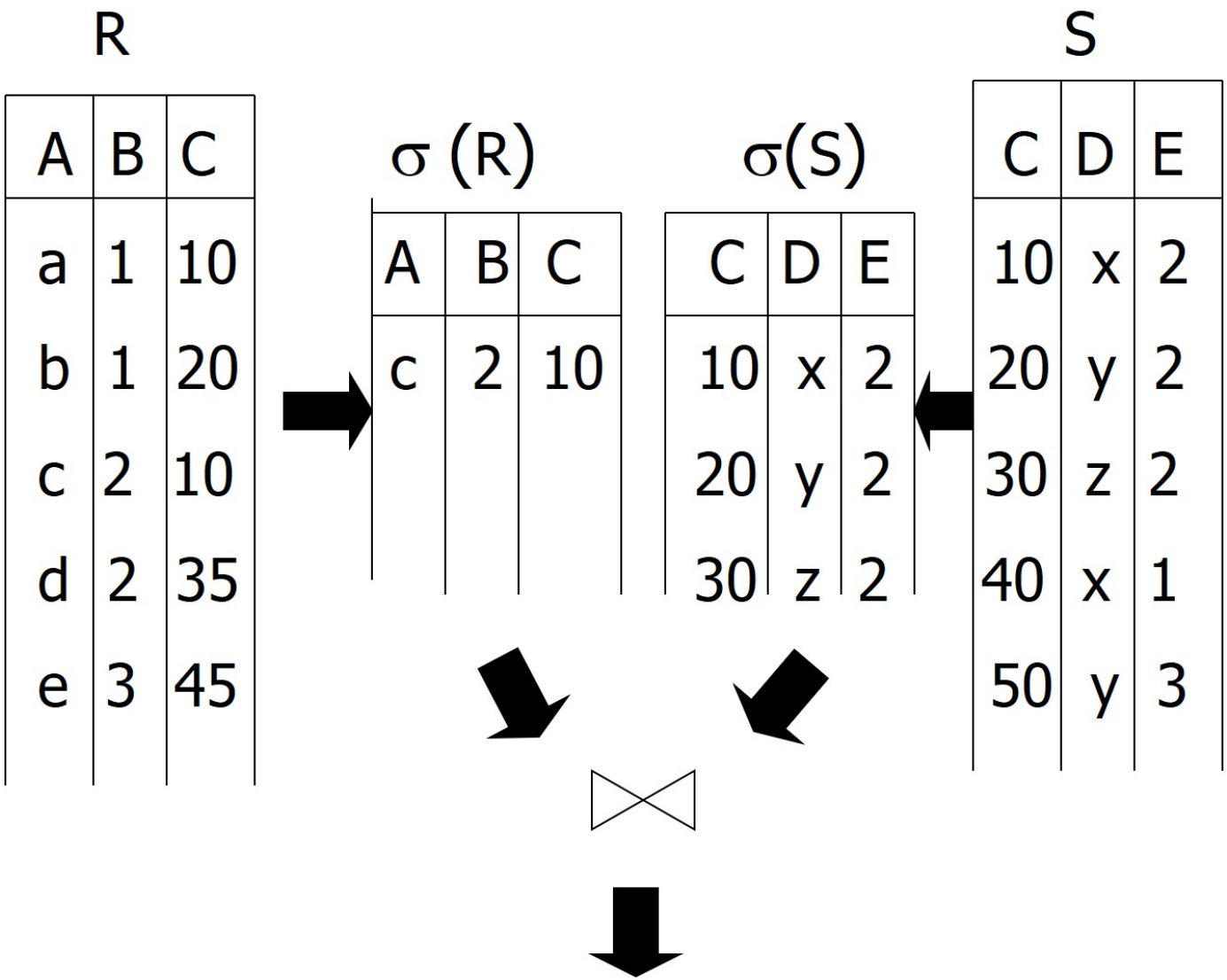
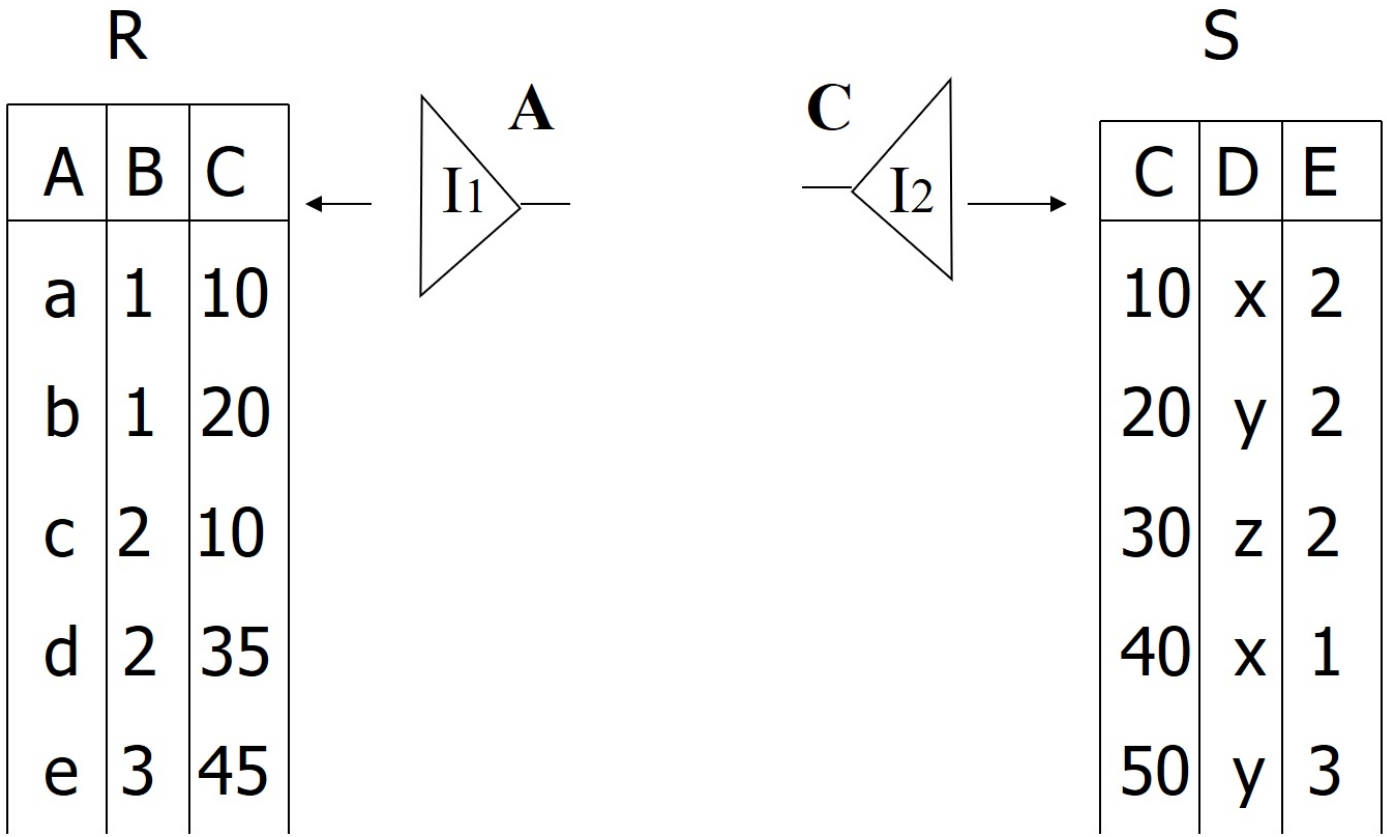


Plan III: Use R.A and S.C Indexes

1. Use `R.A index` to select `R` tuples with `R.A = 'c'`
2. For each `R.C` value found, use `S.C index` to find matching tuples
3. Eliminate `S` tuples `S.E` $\neq$ `2`
4. Join matching `R,S` tuples, project `B,D` attributes and place in result

Plan III: Use R.A and S.C Indexes



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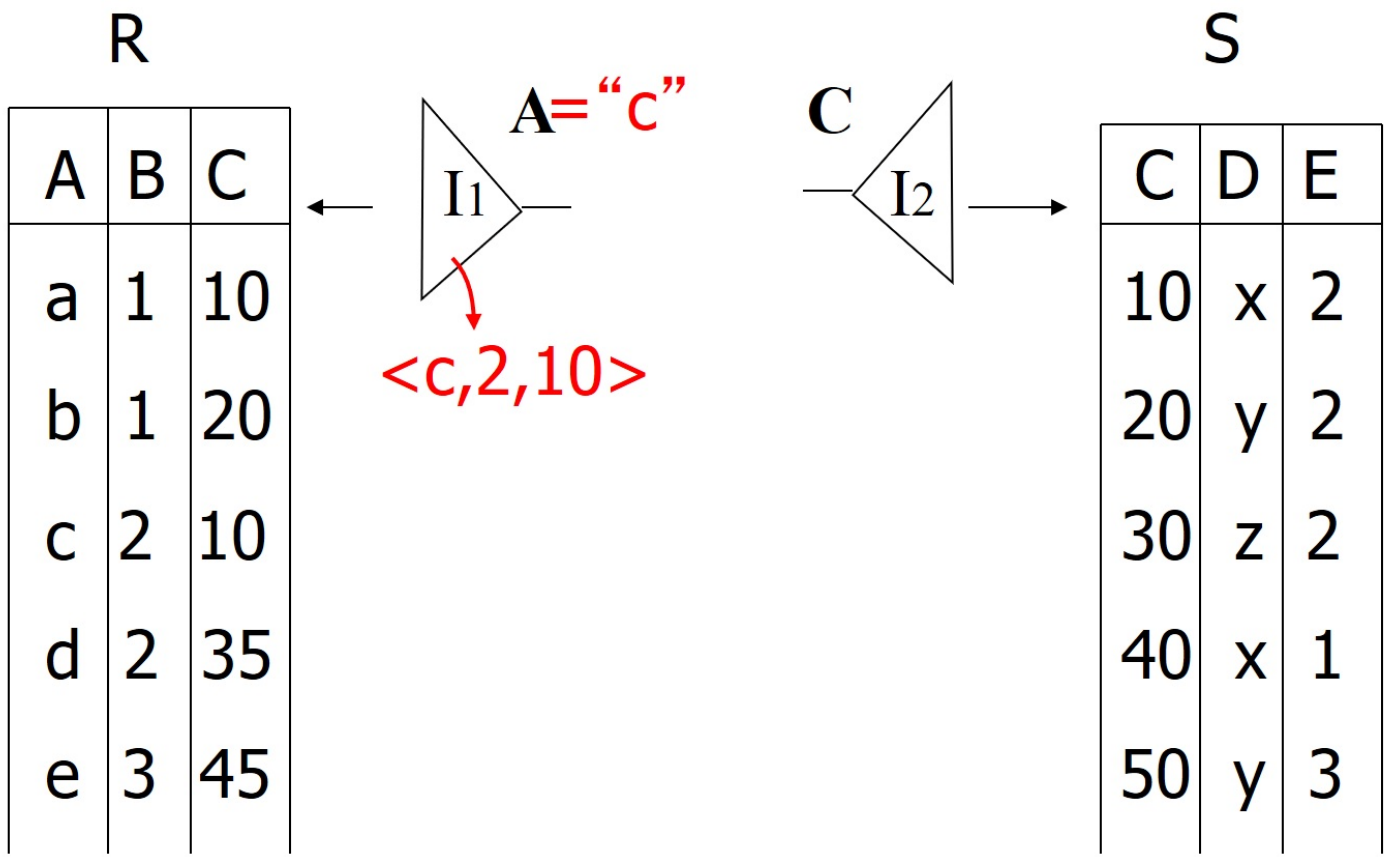

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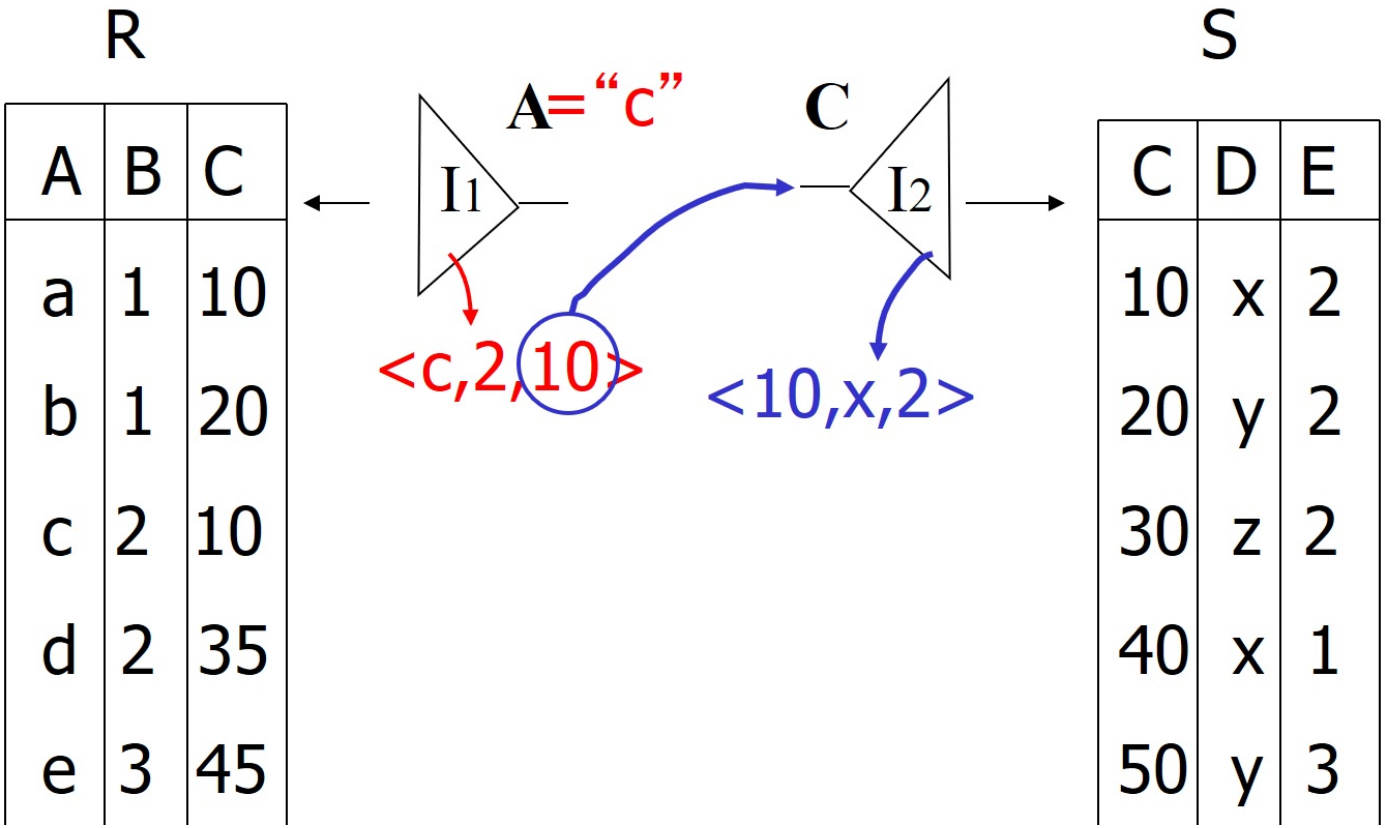

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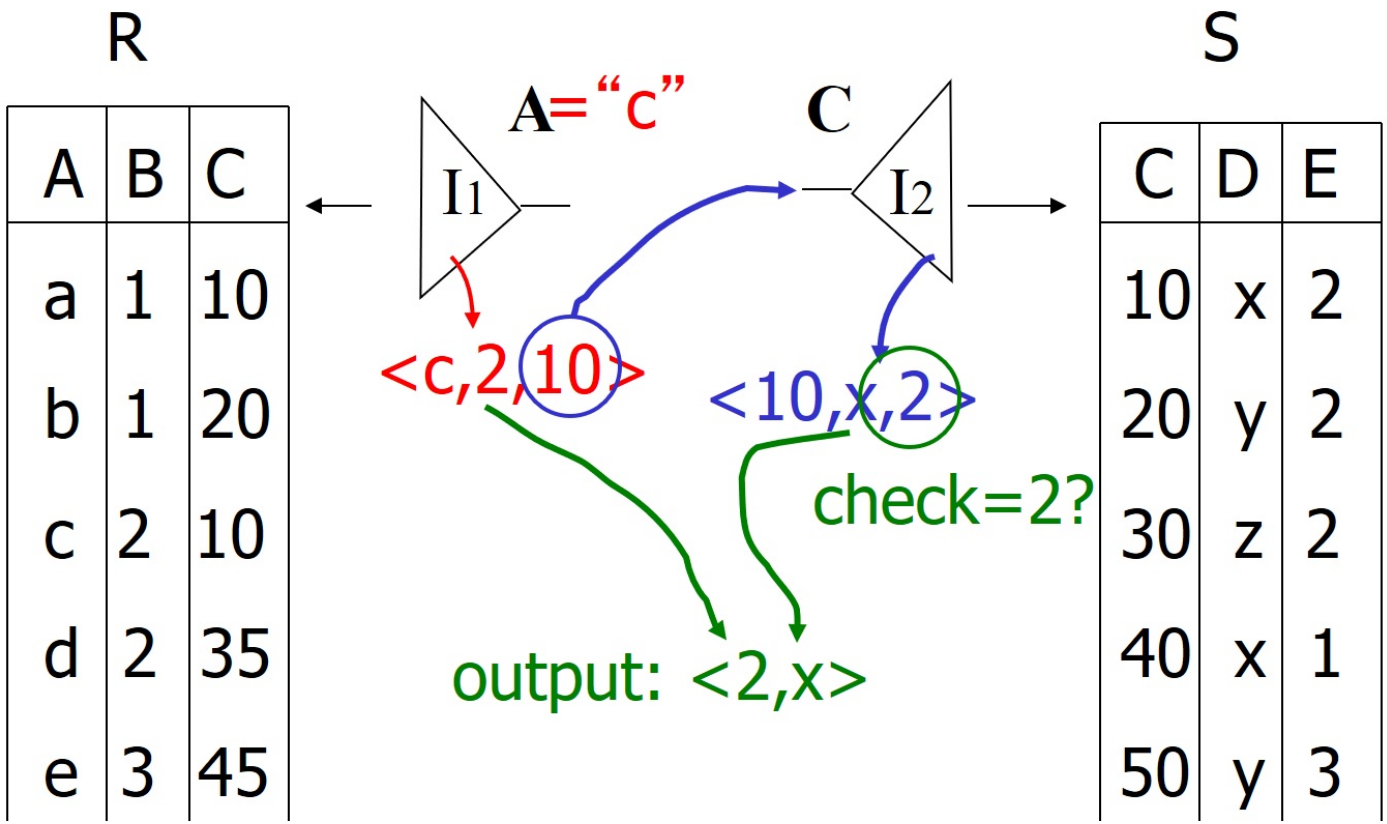

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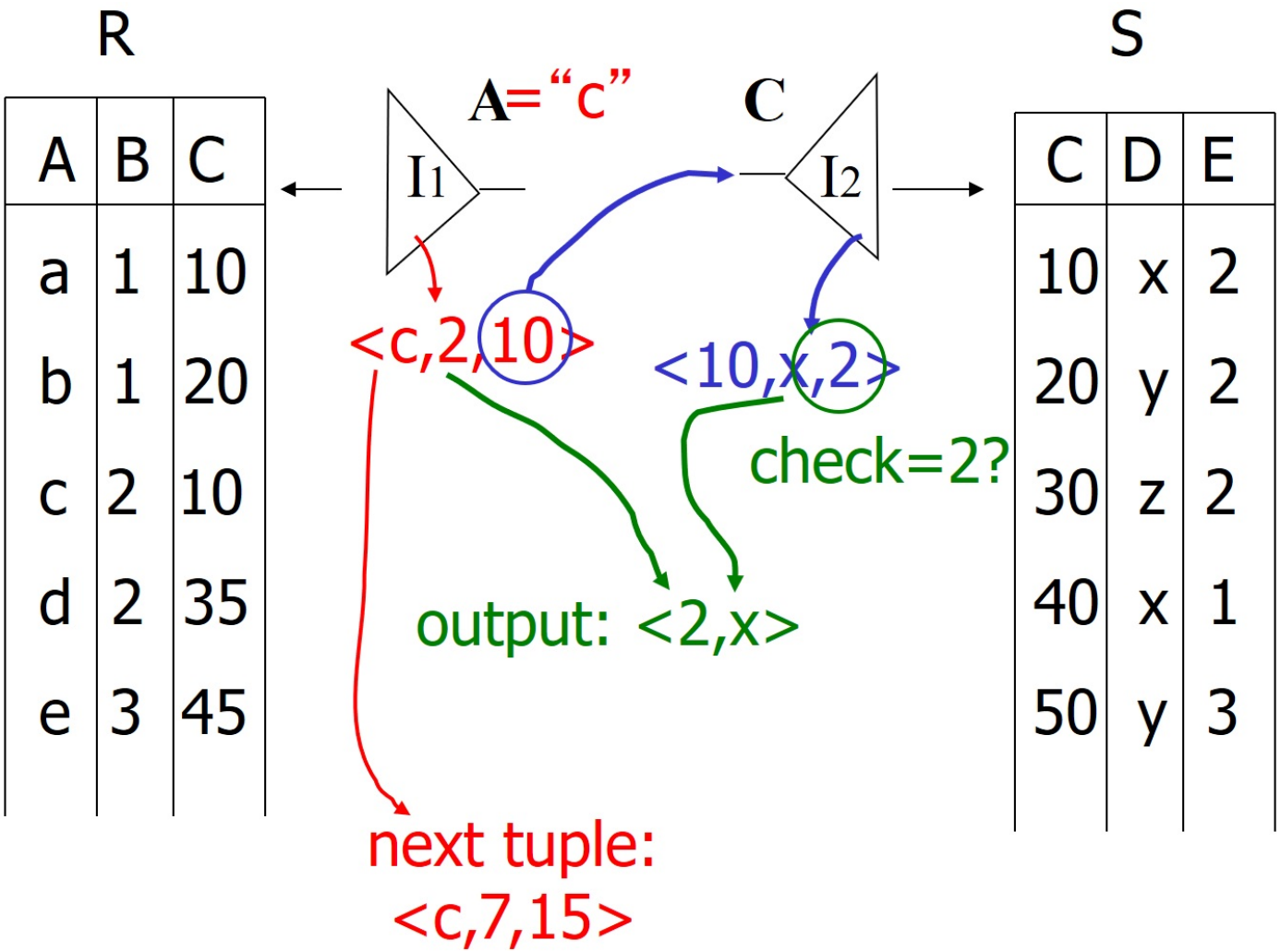
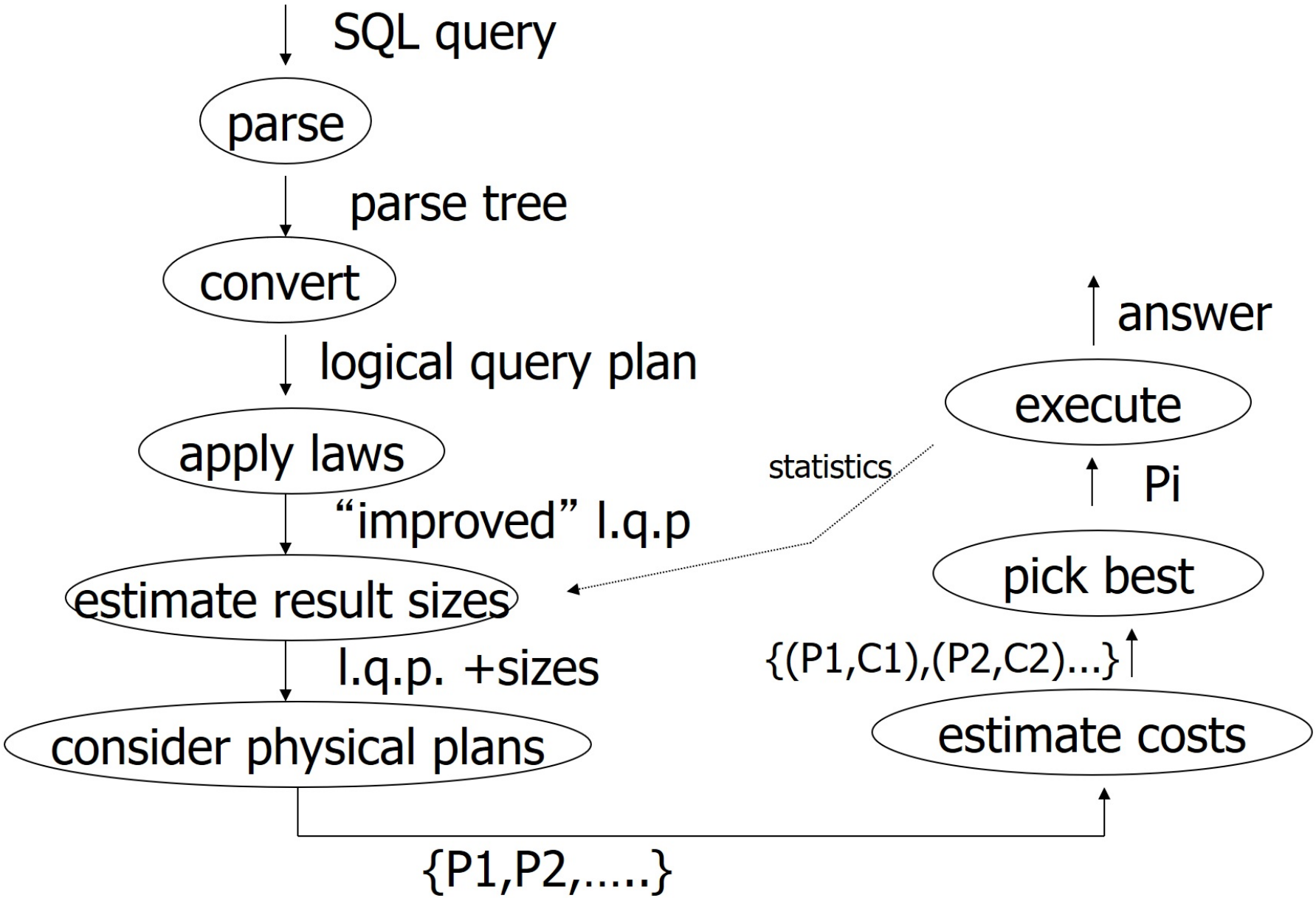


Overview of Query Optimization

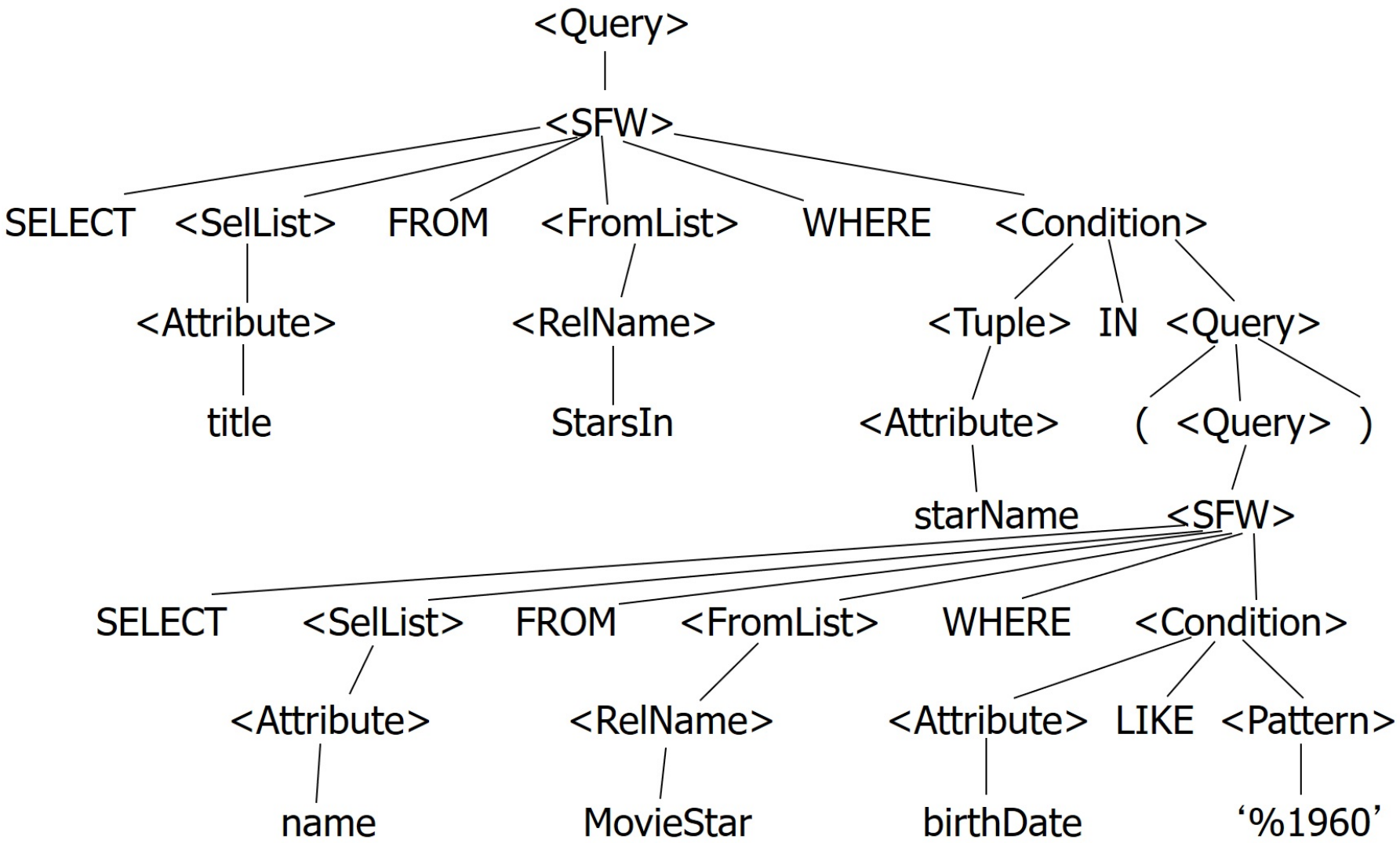


Example: SQL query

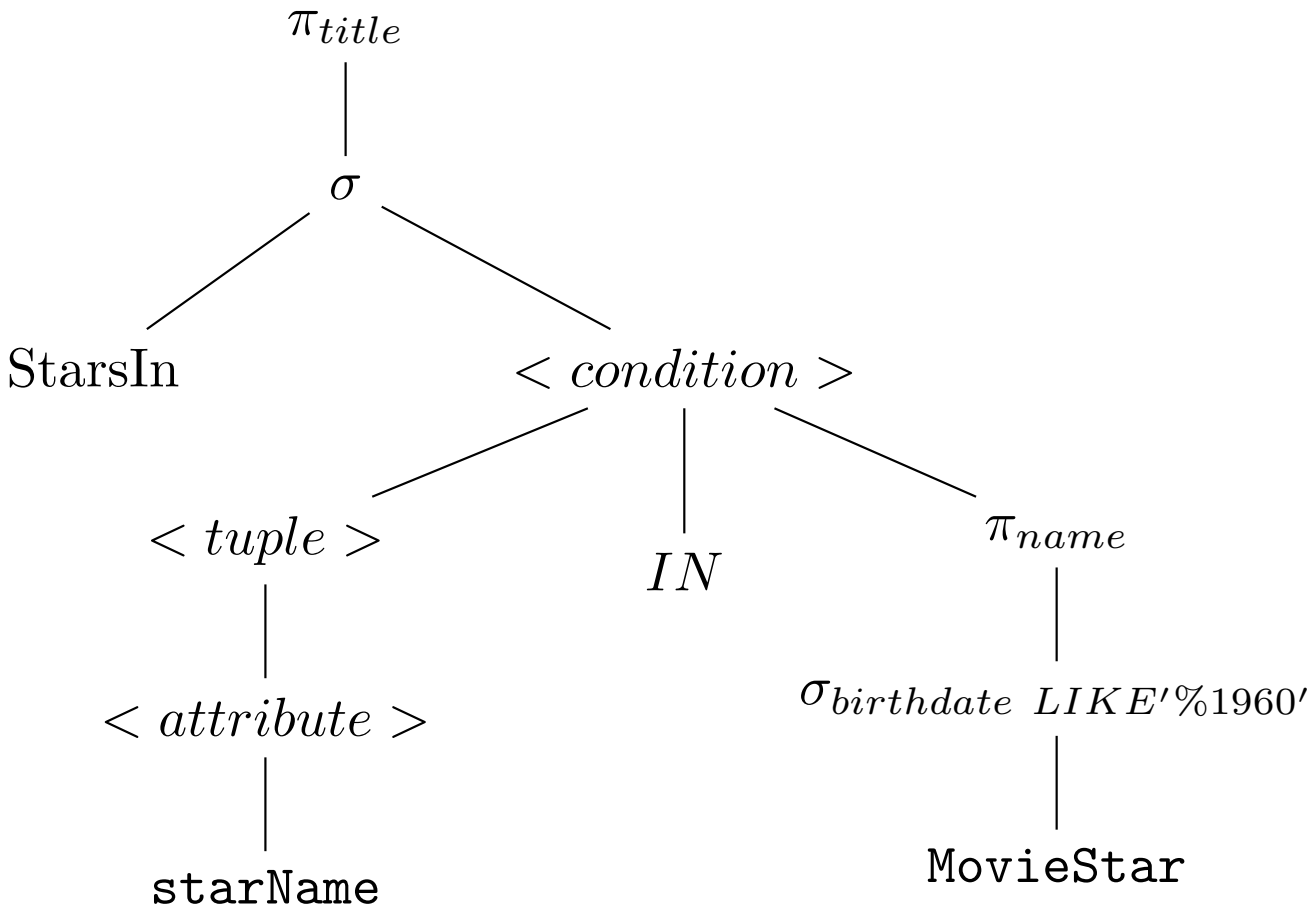
```
SELECT title
FROM   StarsIn
WHERE  starName IN (SELECT name
                    FROM MovieStar
                    WHERE birthdate LIKE '%1960');
```

- Find the movies with stars born in 1960

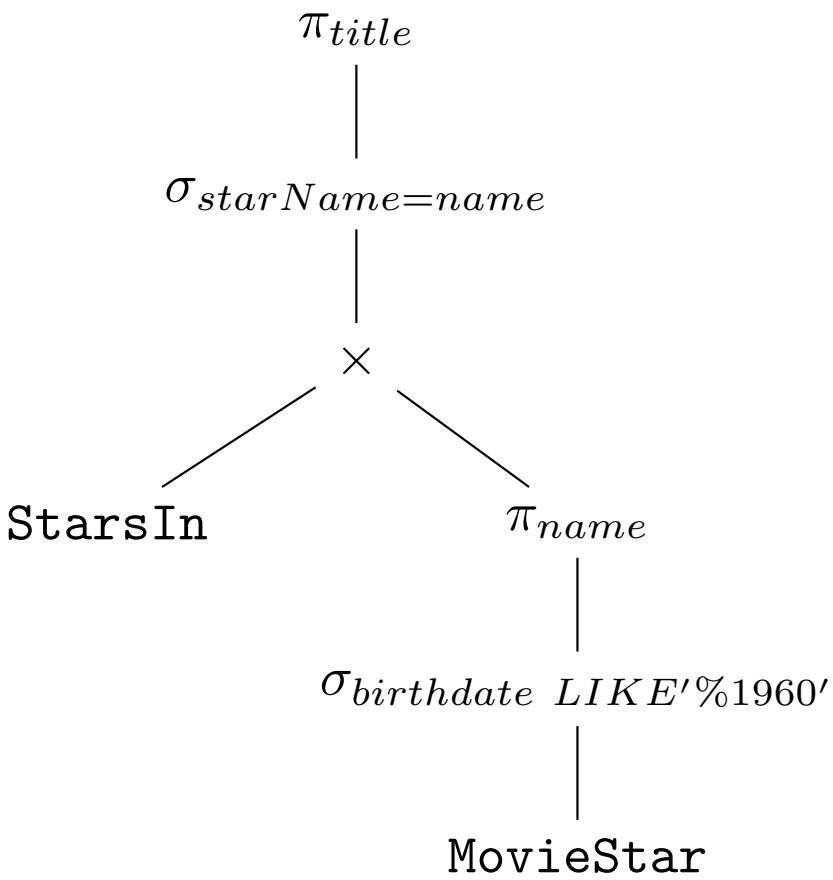
Example: Parse Tree



Example: Generating Relational Algebra

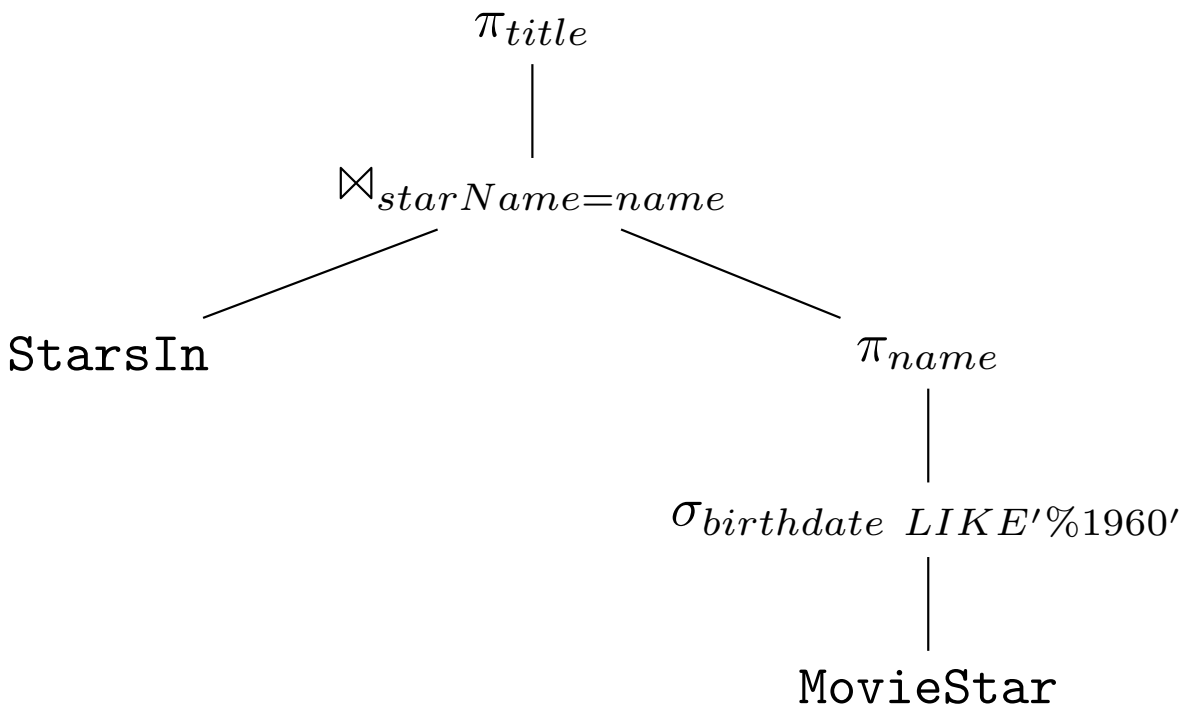


Example: Logical Query Plan



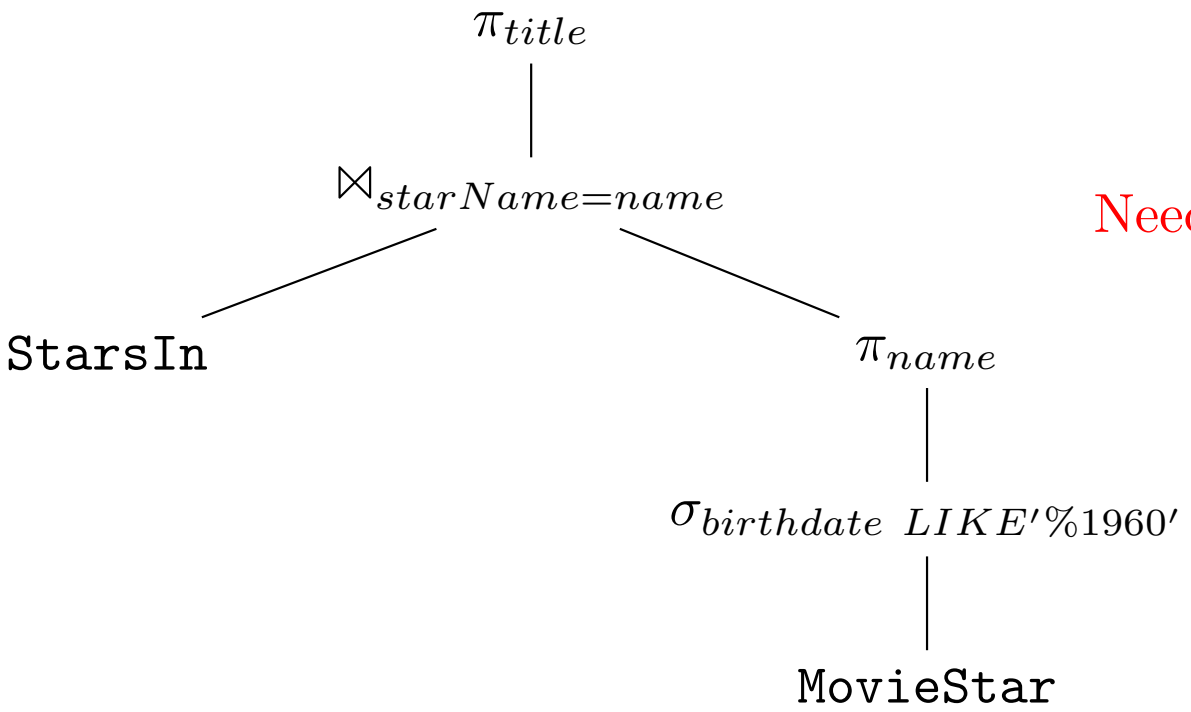
- May consider "IN" elimination as a rewriting in the logical plan generator or may consider it a task of the converter

Example: Improved Logical Query Plan



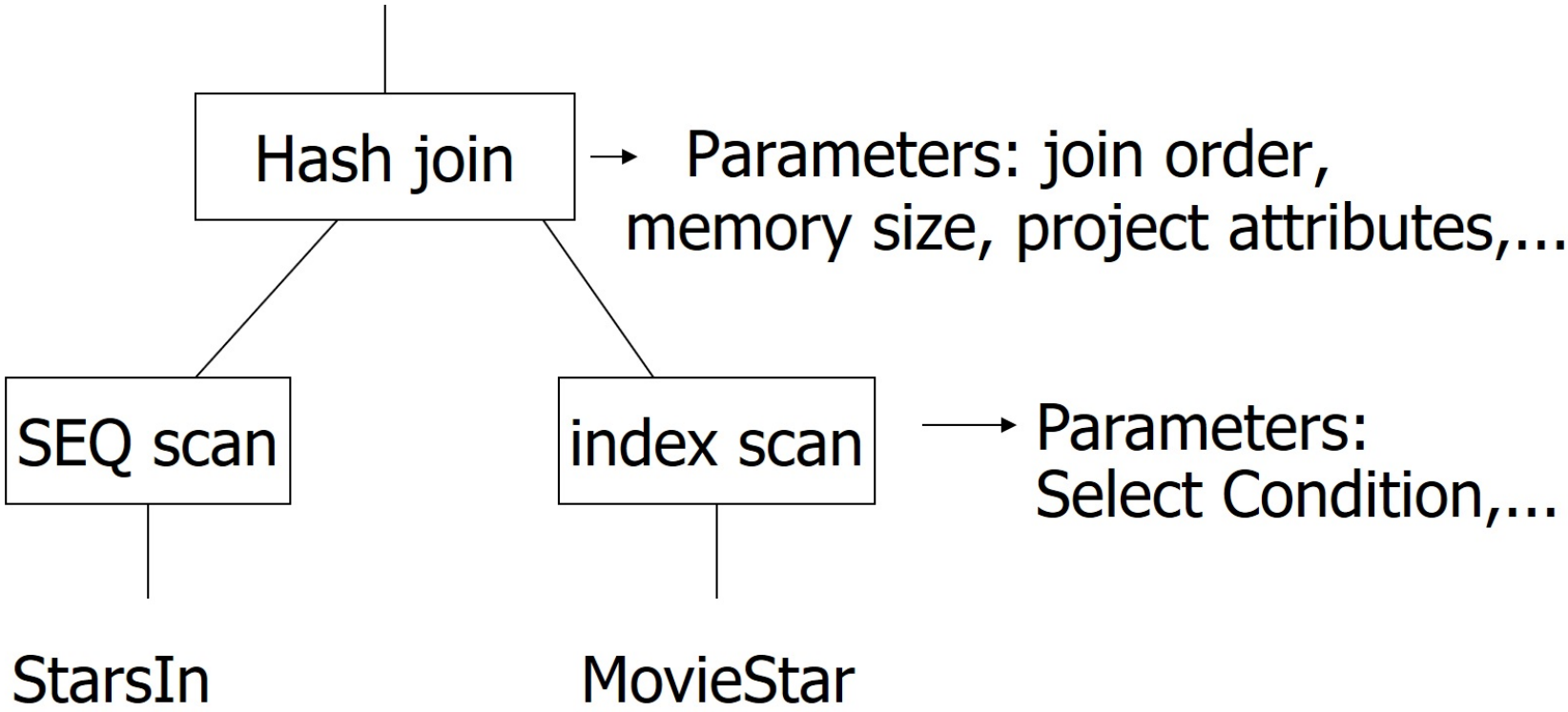
Result sizes are important for selecting physical plans

Estimate Result Sizes



Need expected size

Example: One Physical Plan



Example: Estimate costs