CPS216: Data-intensive Computing Systems
Query Optimization (Cost-based optimization)

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Query Optimization Problem

Pick the best plan from the space of physical plans

Cost-Based Optimization

- Prune the space of plans using heuristics
- Estimate cost for remaining plans
  - Be smart about how you iterate through plans
- Pick the plan with least cost

Focus on queries with joins

Heuristics for pruning plan space

- Predicates as early as possible
- Avoid plans with cross products
- Only left-deep join trees

Physical Plan Selection

Logical Query Plan

P1 P2 …. Pn

C1 C2 …. Cn

Physical plans

Costs

Pick minimum cost one

Review of Notation

- T (R) : Number of tuples in R
- B (R) : Number of blocks in R

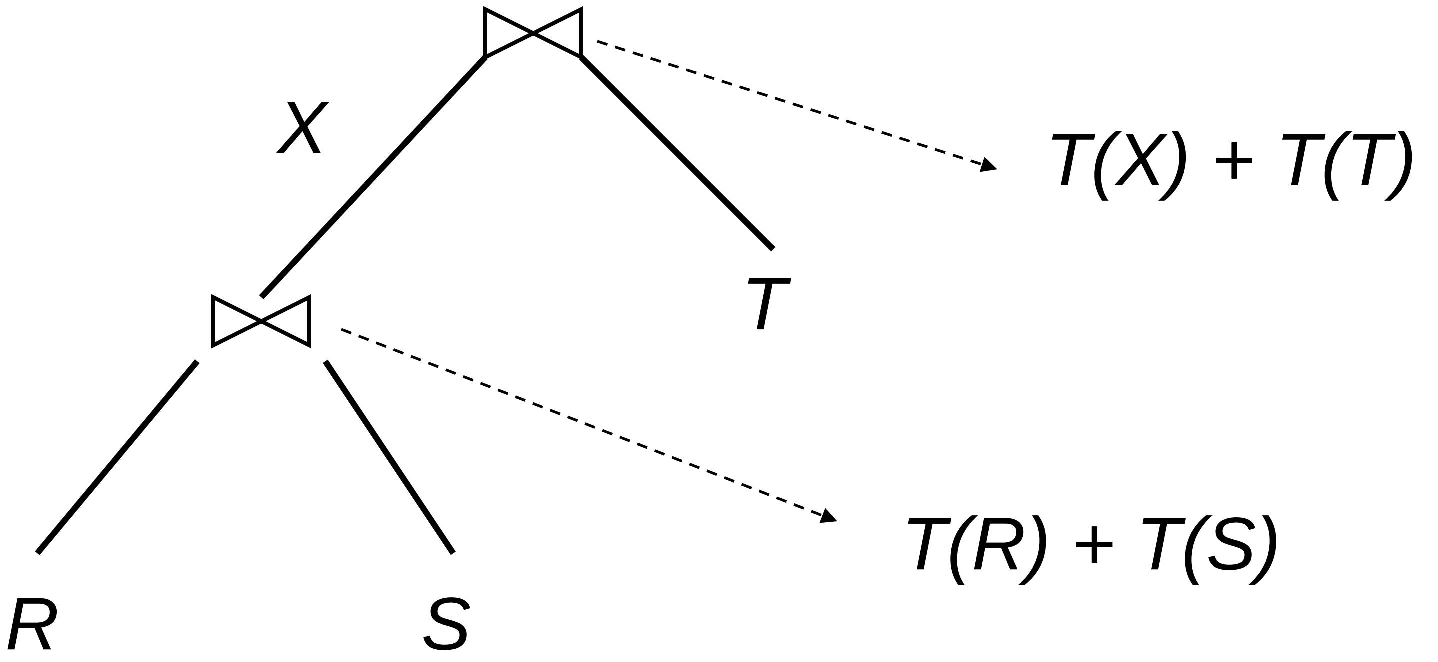
Simple Cost Model

$$\text{Cost}(R \bowtie S) = T(R) + T(S)$$

All other operators have 0 cost

Note: The simple cost model used for illustration only

Cost Model Example



$\boxed{\text{Total Cost: } T(R) + T(S) + T(T) + T(X)}$

Selinger Algorithm

- *Dynamic Programming* based
- Dynamic Programming:
  - General algorithmic paradigm
  - Exploits “principle of optimality”
  - Useful reading:
    - Chapter 16, Introduction to Algorithms, Cormen, Leiserson, Rivest

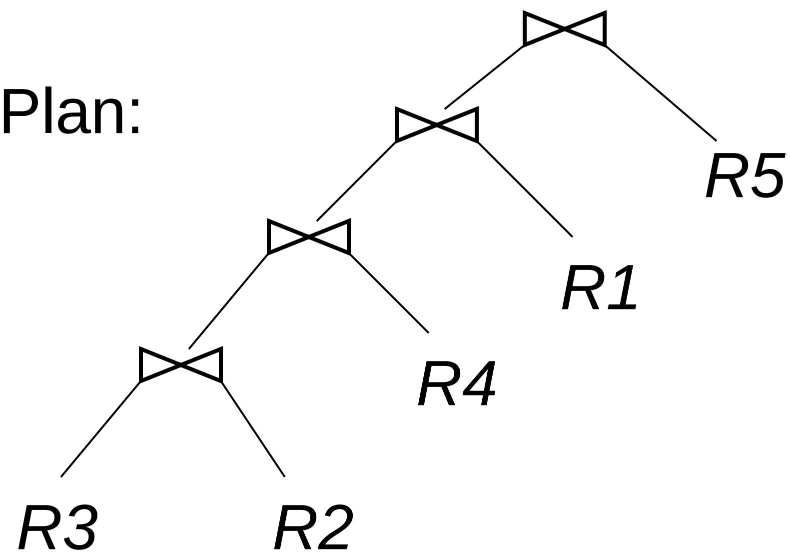
Principle of Optimality

$\boxed{\text{Optimal for “whole” made up from optimal for “parts”}}$

Principle of Optimality

Query: $R1 \bowtie R2 \bowtie R3 \bowtie R4 \bowtie R5$

Optimal Plan:



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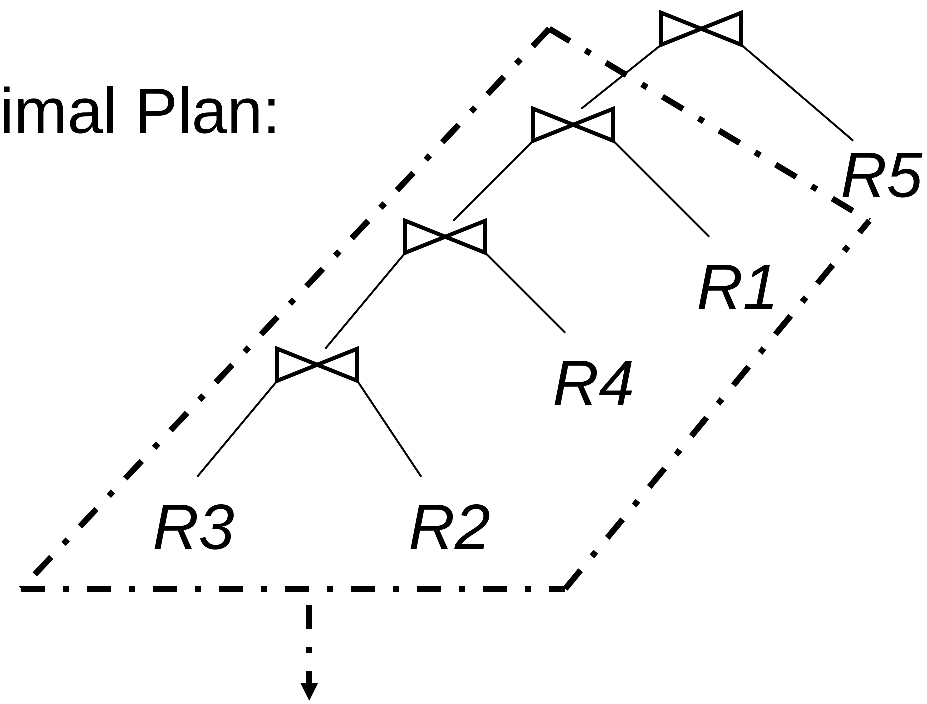
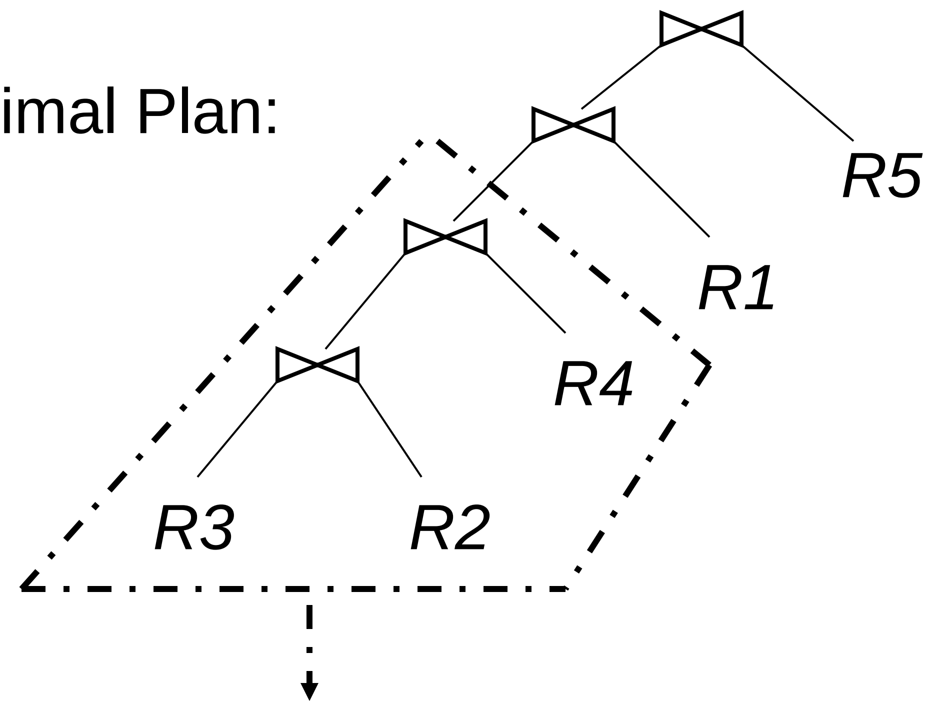


Optimal plan for joining *R3, R2, R4, R1*

Principle of Optimality

Query: $R1 \bowtie R2 \bowtie R3 \bowtie R4 \bowtie R5$

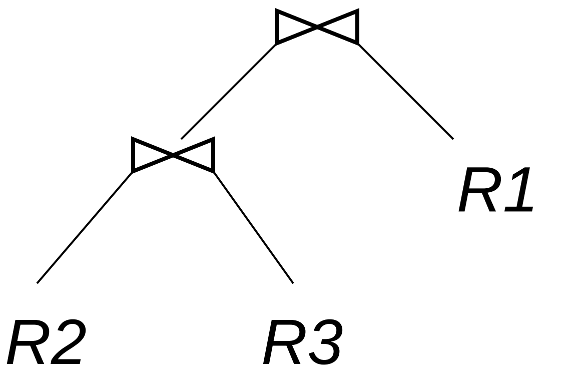
Optimal Plan:



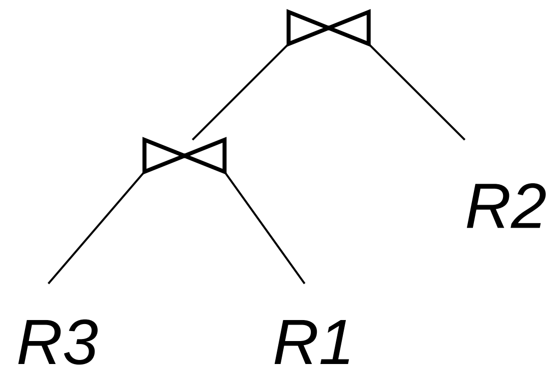
Optimal plan for joining *R3, R2, R4*

Exploiting Principle of Optimality

Query: $R1 \bowtie R2 \bowtie \quad \ldots \quad \bowtie Rn$

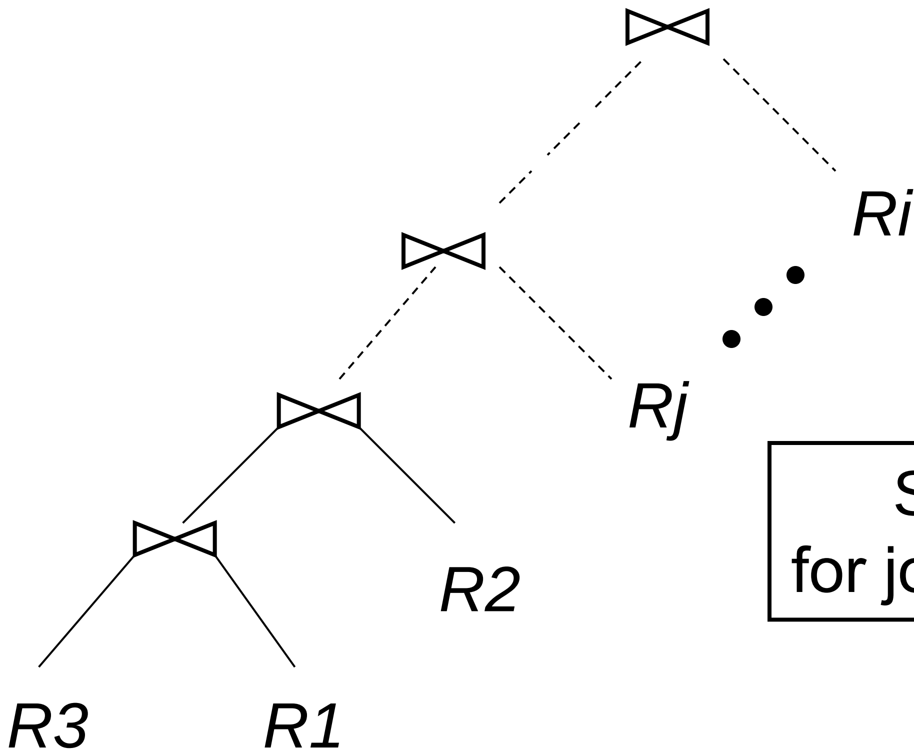


Optimal
for joining *R1, R2, R3*



Sub-Optimal
for joining *R1, R2, R3*

Exploiting Principle of Optimality

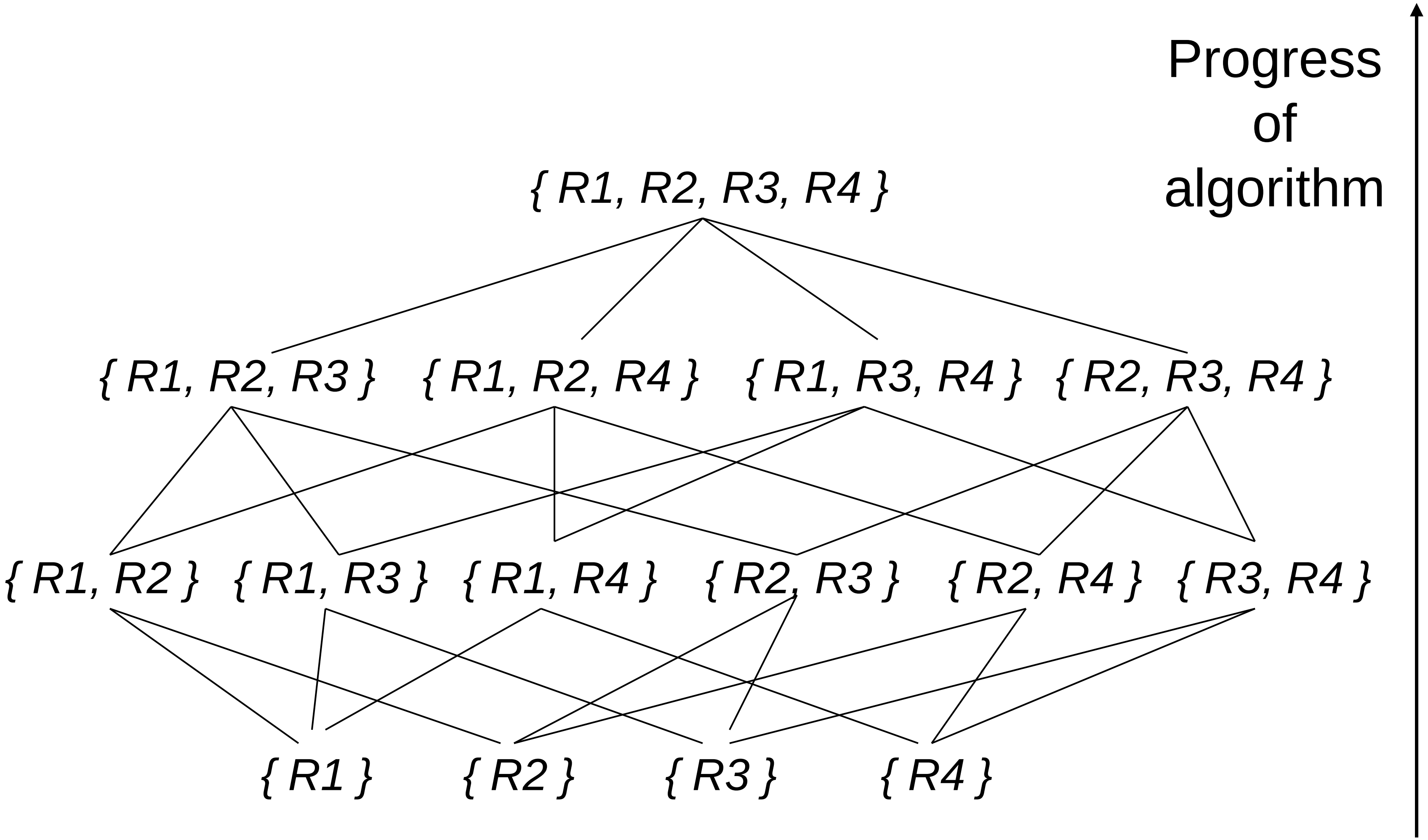


Sub-Optimal
for joining R1,…,Rn

A sub-optimal sub-plan cannot lead to an optimal plan

Selinger Algorithm:

Query: $R1 \bowtie R2 \bowtie R3 \bowtie R4$



Notation

OPT ({ *R1, R2, R3* }):

Cost of optimal plan to join *R1,R2,R3*

T ({ *R1, R2, R3* }):

Number of tuples in $R1 \bowtie R2 \bowtie R3$

Selinger Algorithm:

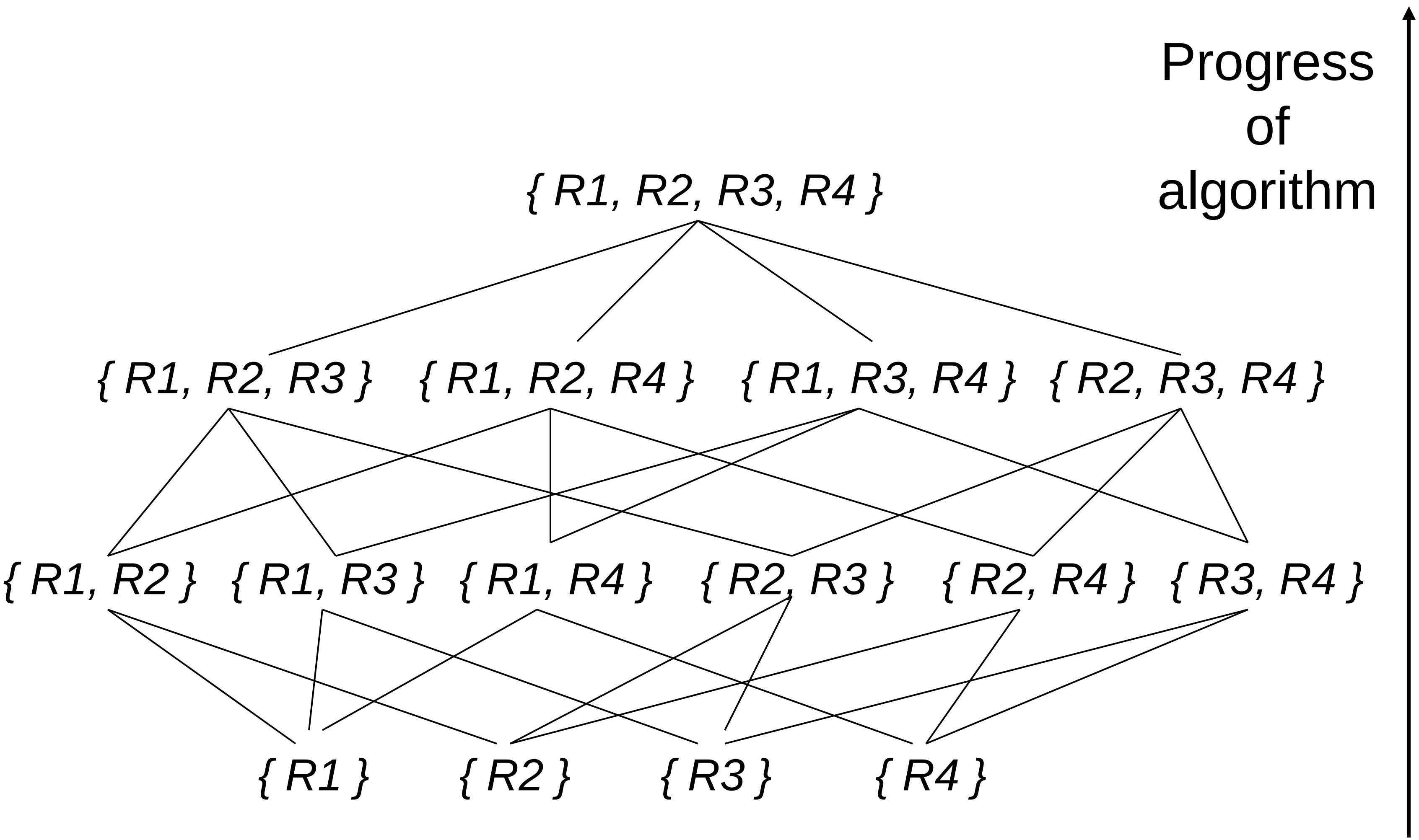
OPT ({ R1, R2, R3 }):

$$
\text{Min} \begin{cases} \text{OPT}(\{R1, R2\}) + T(\{R1, R2\}) + T(R3) \\ \text{OPT}(\{R2, R3\}) + T(\{R2, R3\}) + T(R1) \\ \text{OPT}(\{R1, R3\}) + T(\{R1, R3\}) + T(R2) \end{cases}
$$

Note: Valid only for the simple cost model

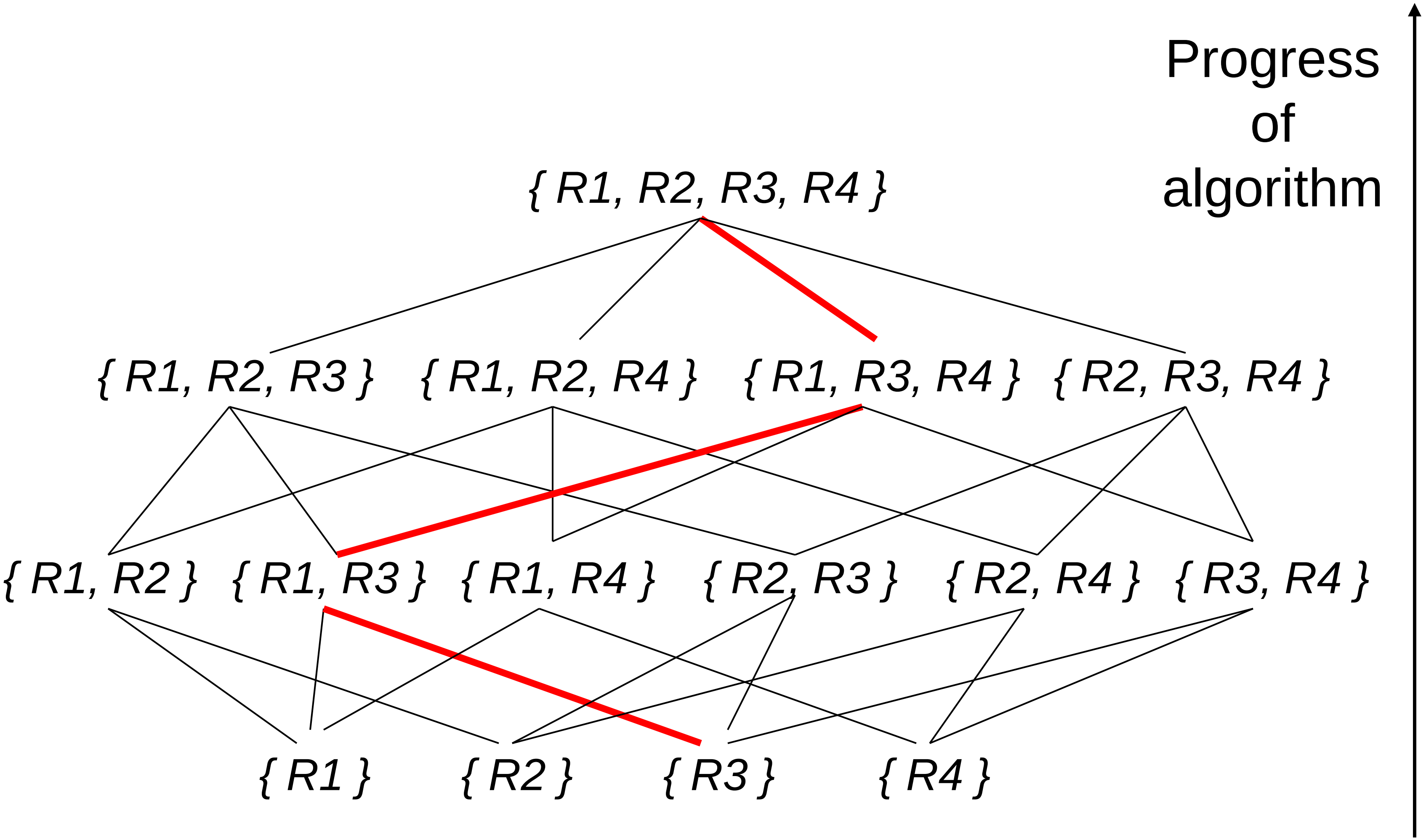
Selinger Algorithm:

Query: $R1 \bowtie R2 \bowtie R3 \bowtie R4$



Selinger Algorithm:

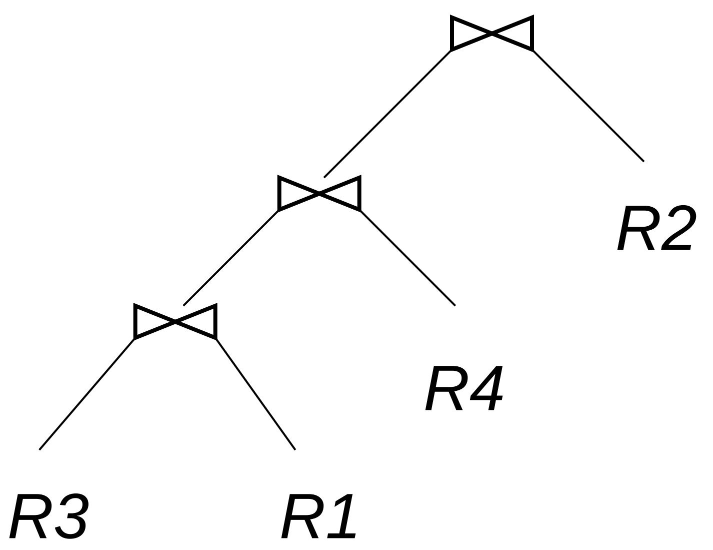
Query: $R1 \bowtie R2 \bowtie R3 \bowtie R4$



Selinger Algorithm:

Query: $R1 \bowtie R2 \bowtie R3 \bowtie R4$

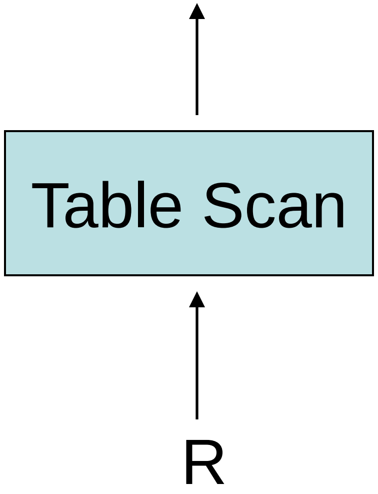
Optimal plan:



More Complex Cost Model

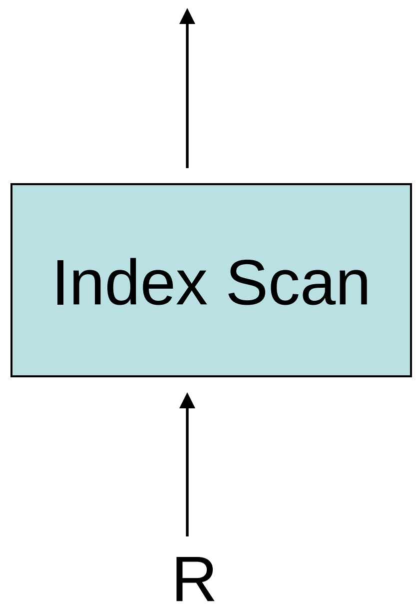
- DB System:
  - Two join algorithms:
    - Tuple-based nested loop join
    - Sort-Merge join
  - Two access methods
    - Table Scan
    - Index Scan (all indexes are in memory)
  - Plans pipelined as much as possible
- Cost: Number of disk I/O s

Cost of Table Scan



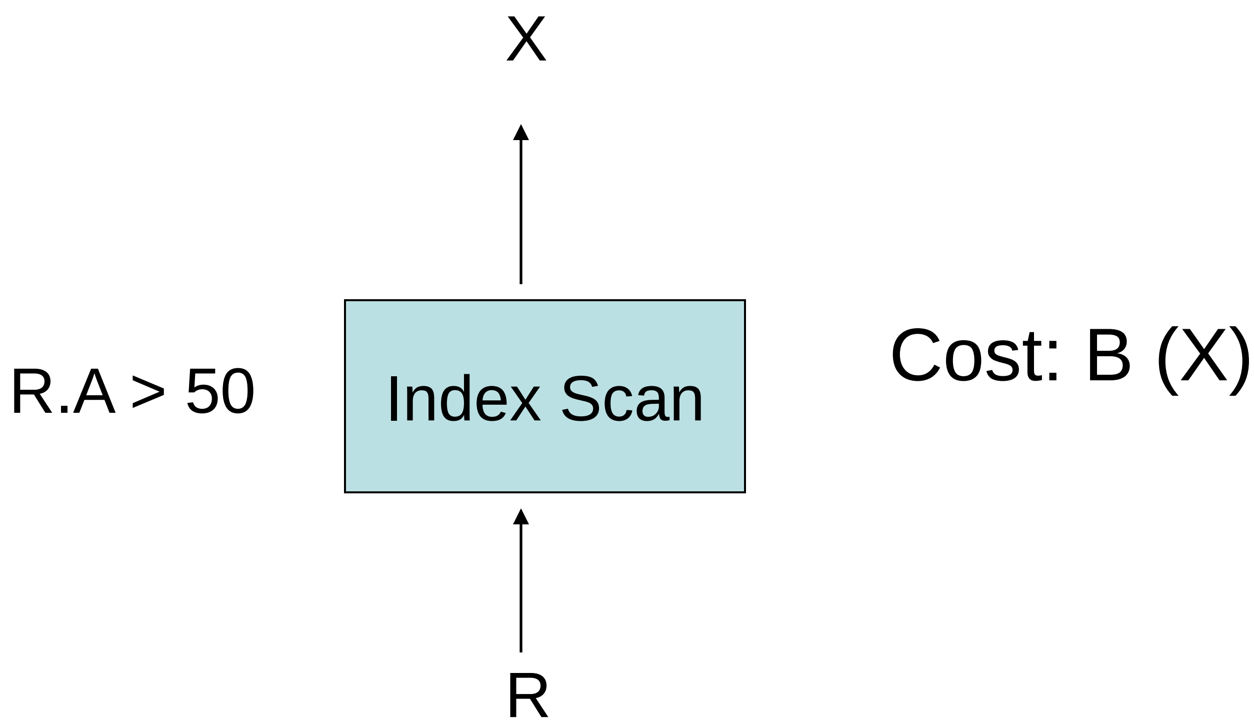
Cost: B (R)

Cost of Clustered Index Scan

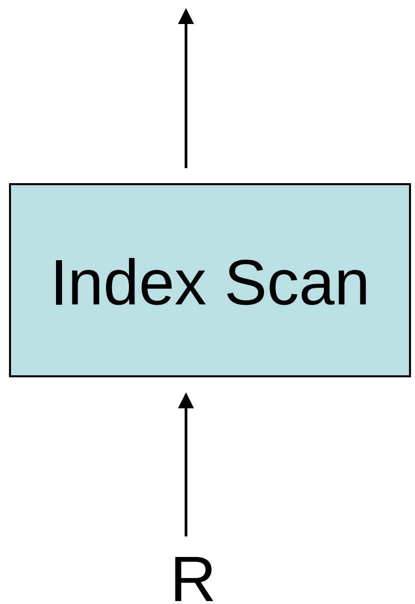


Cost: B (R)

Cost of Clustered Index Scan

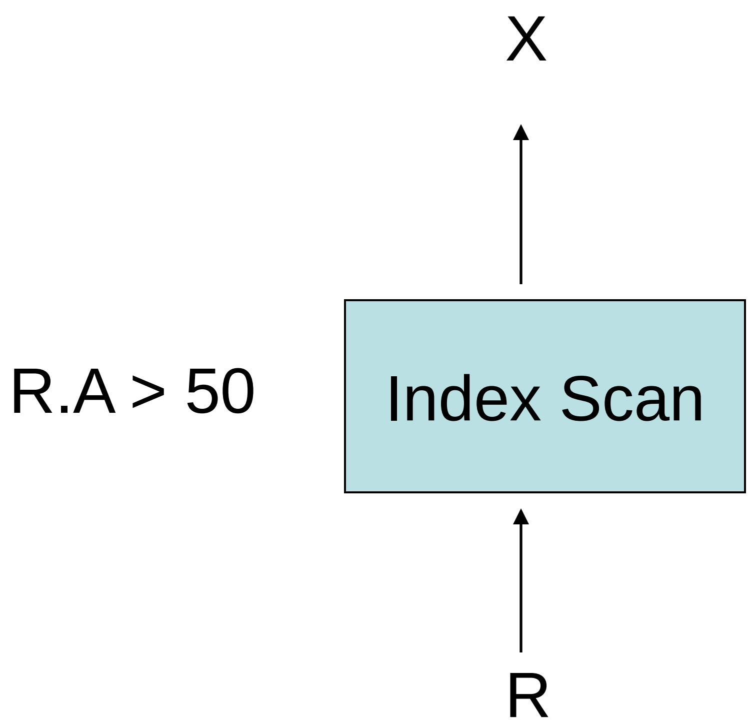


Cost of Non-Clustered Index Scan



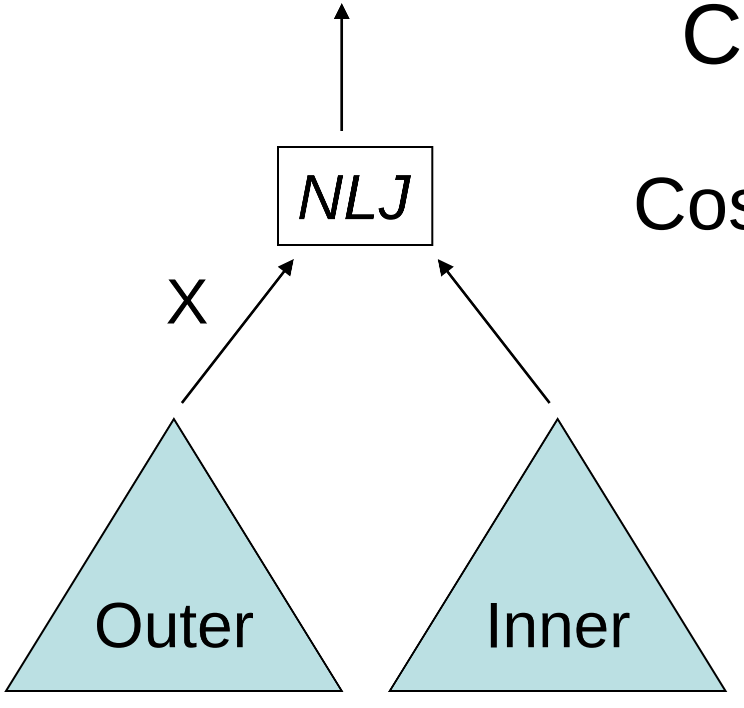
Cost: T (R)

Cost of Non-Clustered Index Scan



Cost: T (X)

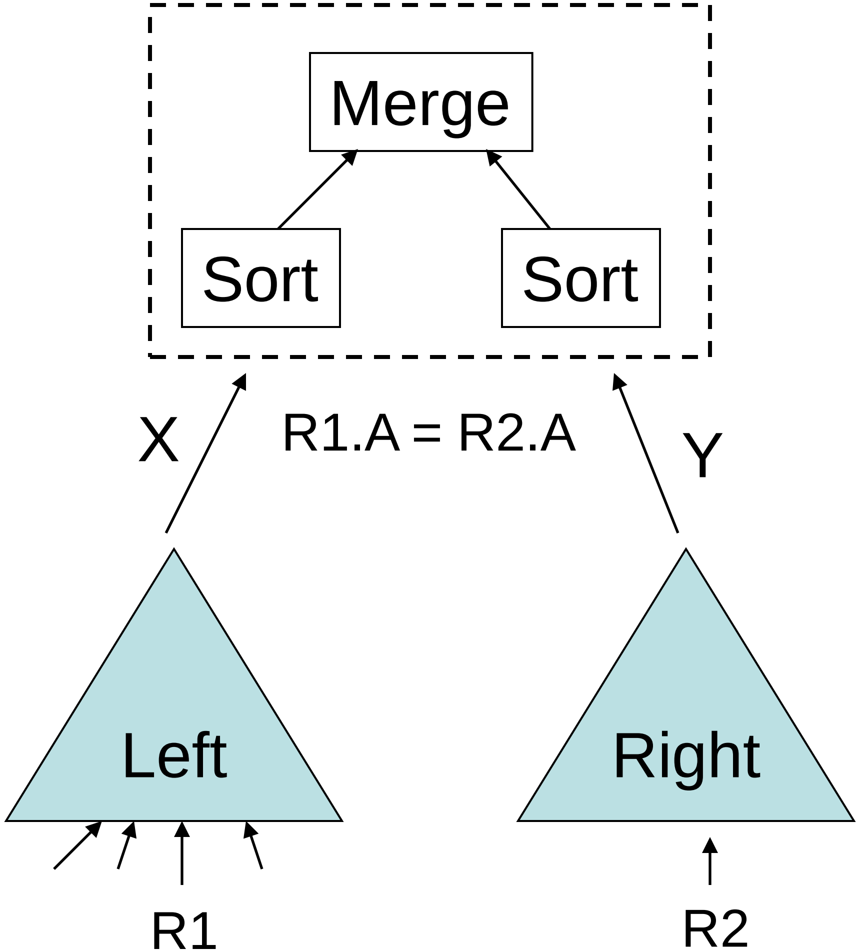
Cost of Tuple-Based NLJ



Cost for **entire** plan:

Cost (Outer) + T(X) x Cost (Inner)

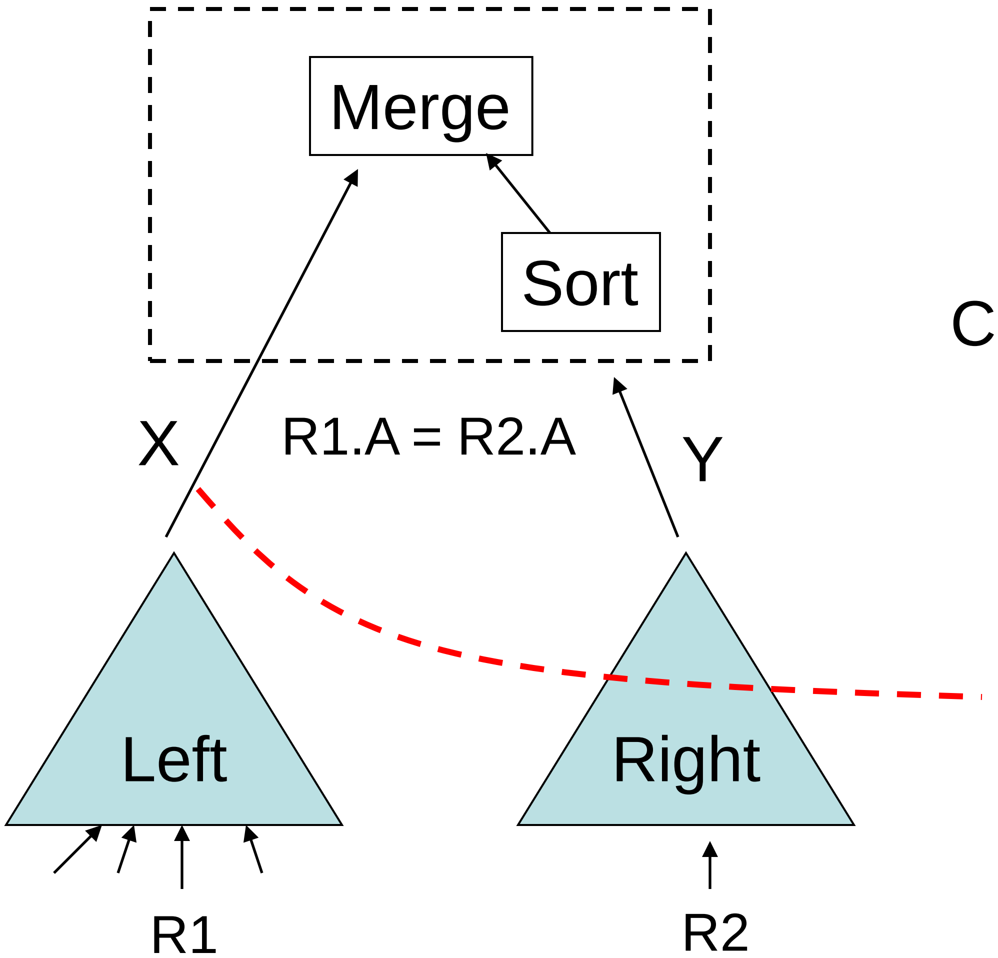
Cost of Sort-Merge Join



Cost for **entire** plan:

Cost (Right) + Cost (Left) +
2 (B (X) + B (Y))

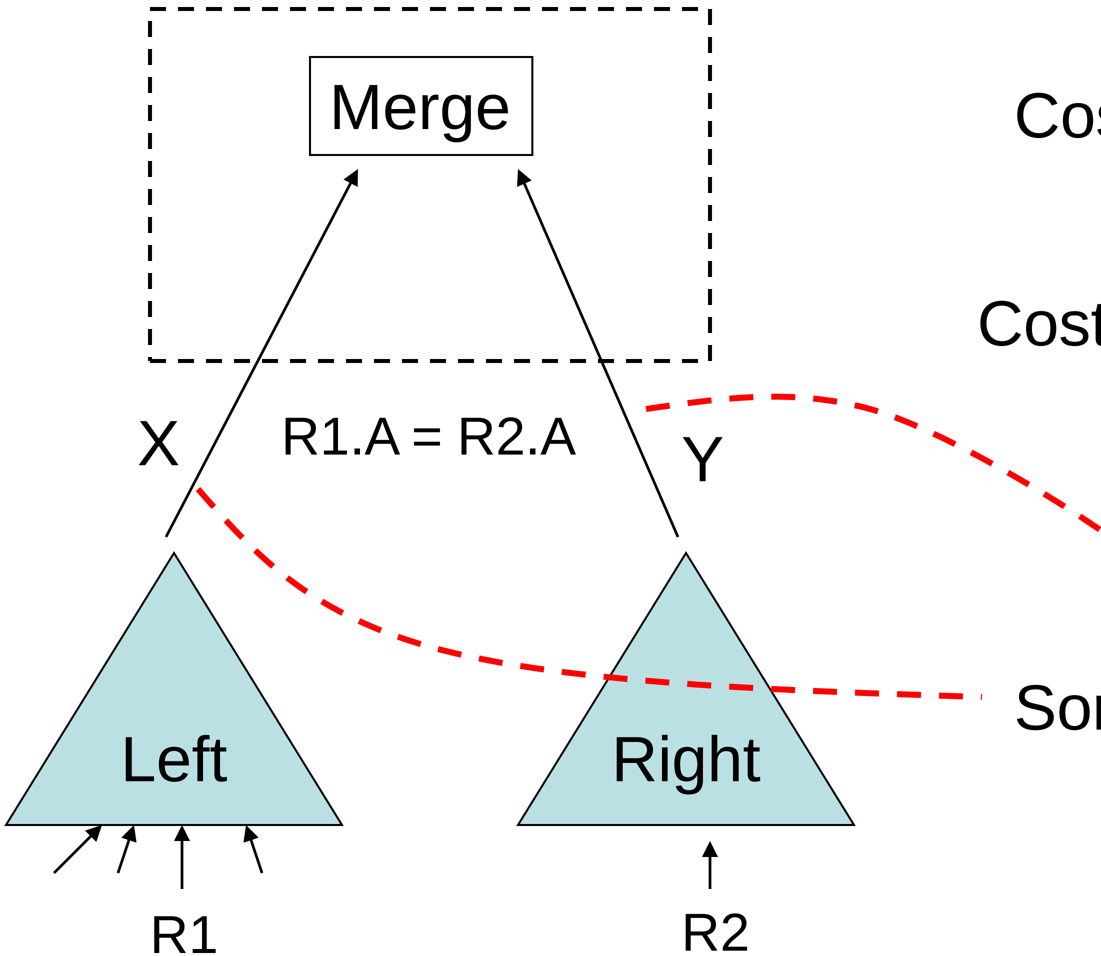
Cost of Sort-Merge Join



Cost for **entire** plan:

Cost (Right) + Cost (Left) +
2 B (Y)

Cost of Sort-Merge Join



Cost for **entire** plan:

Cost (Right) + Cost (Left)

Sorted on R2.A

Sorted on R1.A

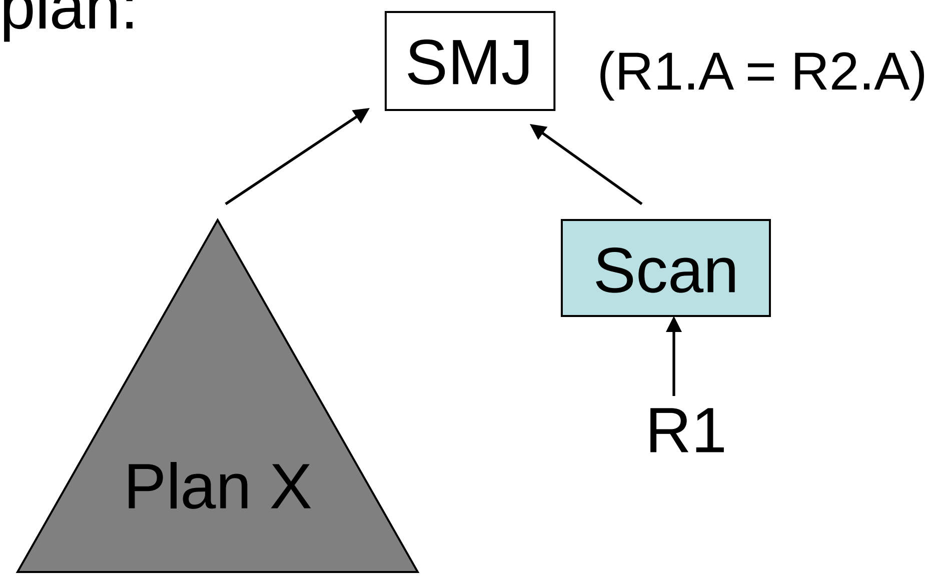
Cost of Sort-Merge Join

Bottom Line: Cost depends on sorted-ness of inputs

Principle of Optimality?

Query: $R1 \bowtie R2 \bowtie R3 \bowtie R4 \bowtie R5$

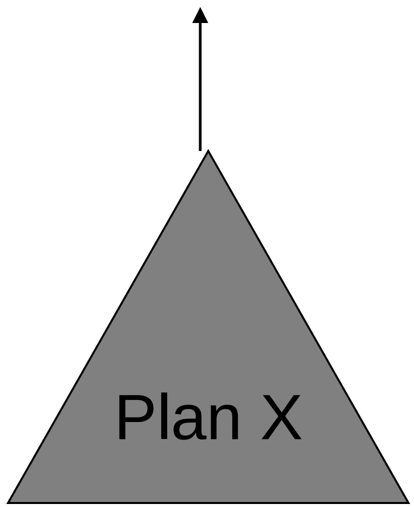
Optimal plan:



Is Plan X the optimal plan for joining R2,R3,R4,R5?

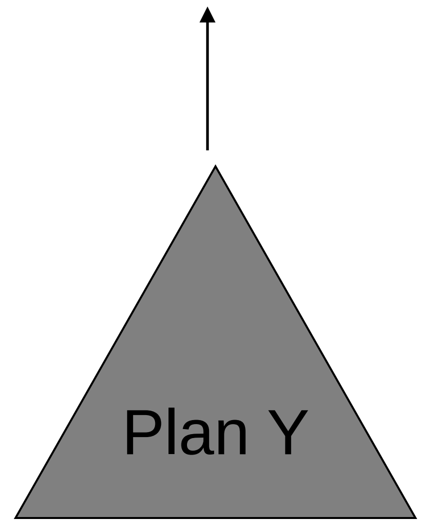
Violation of Principle of Optimality

(sorted on R2.A)



Suboptimal plan for joining
R2,R3,R4,R5

(unsorted on R2.A)

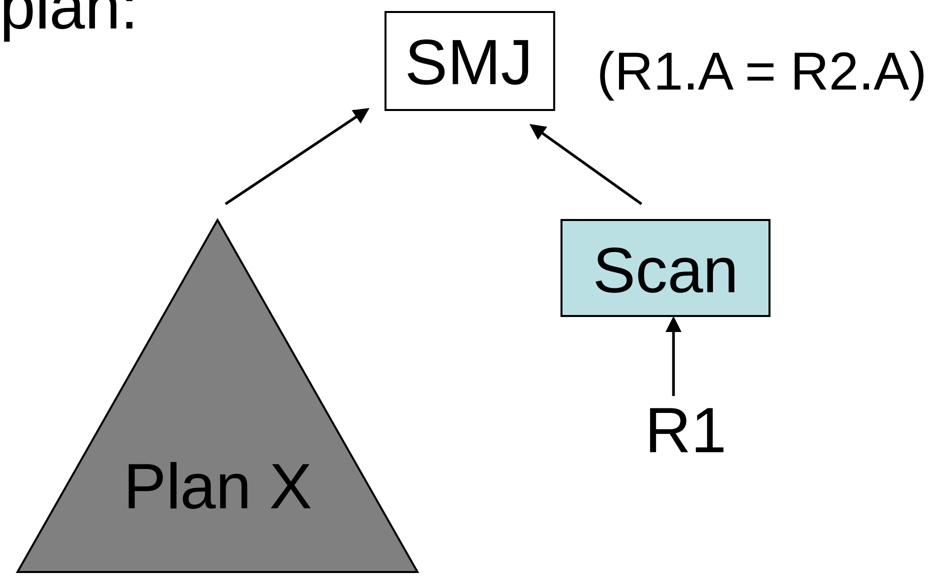


Optimal plan for joining
R2,R3,R4,R4

Principle of Optimality?

Query: $R1 \bowtie R2 \bowtie R3 \bowtie R4 \bowtie R5$

Optimal plan:



Can we assert anything about plan X?

Weaker Principle of Optimality

If plan X produces output sorted on R2.A then plan X is the **optimal plan** for joining R2,R3,R4,R5 that produces output sorted on R2.A

If plan X produces output unsorted on R2.A then plan X is the **optimal plan** for joining R2, R3, R4, R5

Interesting Order

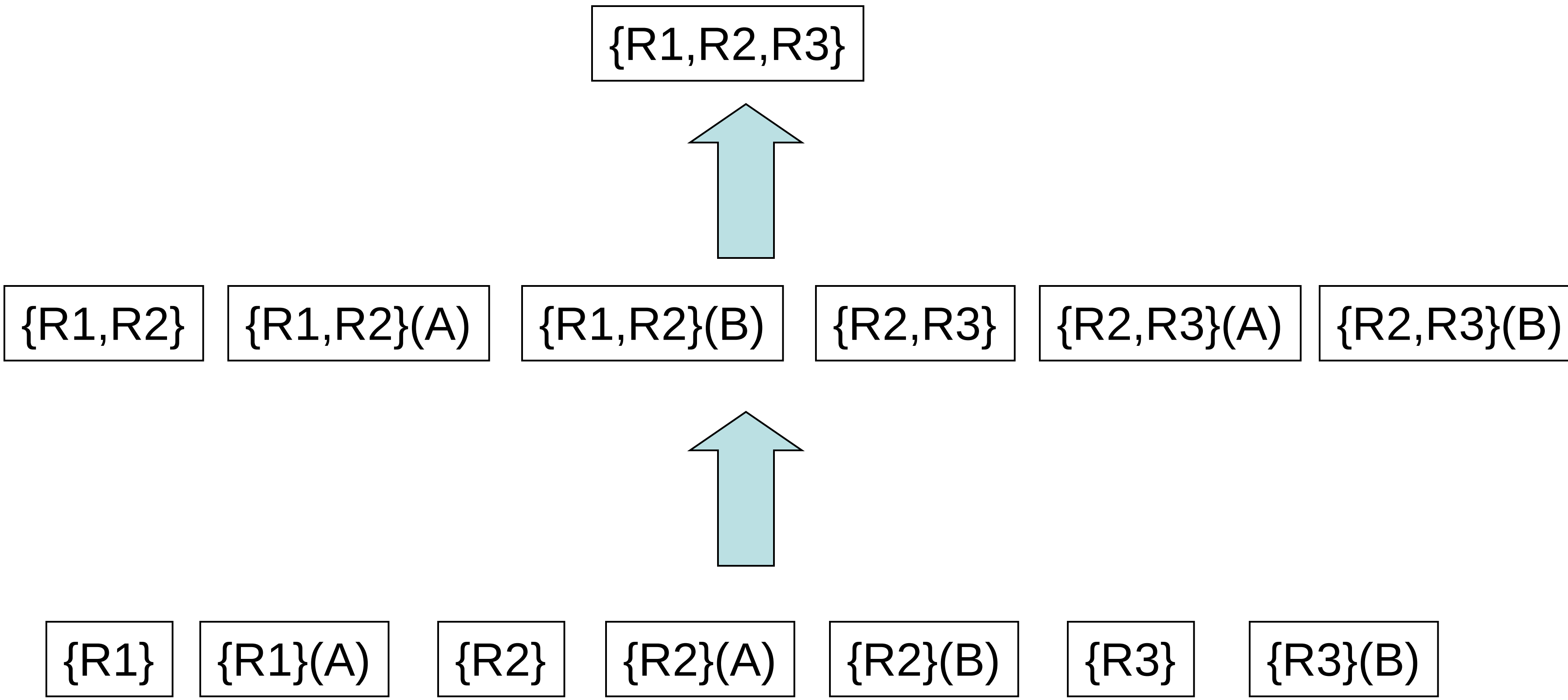
- An attribute is an **interesting order** if:
  - participates in a join predicate
  - Occurs in the Group By clause
  - Occurs in the Order By clause

Interesting Order: Example

```
Select   *
From     R1(A,B), R2(A,B), R3(B,C)
Where    R1.A = R2.A and R2.B = R3.B
```

Interesting Orders: R1.A, R2.A, R2.B, R3.B

Modified Selinger Algorithm



Notation

$\boxed{\{R1,R2\}\ (C)}$

Optimal way of joining R1, R2 so that output is sorted on attribute R2.C

Modified Selinger Algorithm