Implementing Relational Algebra Operators in a DBMS

Relational Algebra

- Operations that can be performed on sets to perform queries in a relational model
- Consist of:
  - Basic set operations (Union, Intersection, Difference, etc)
  - Unary operators
    - Selection – filter a set based on some predicate
    - Projection – Select only specific attributes of a set
      - In a DBMS, by default any duplicate tuples in the result of a Projection operation are not removed
  - Binary operators
    - Cartesian Product – all possible pairings between tuples in two sets
    - Join – Conceptually, a Cartesian Product followed by a Selection operation
      - Many different algorithms exist for more efficient execution of a Join

Relational Algebra and a DBMS

- When a DBMS parses an incoming SQL query, it eventually transforms it into a Relational Algebra query for evaluation – a Query Tree/Query Evaluation Plan (QEP)
- Each Relational Algebra operator is implemented using a common Iterator interface that will return one tuple from the result set at a time
  - Allows for *lazy evaluation*
    - Each Iterator is only accessed when it is required to return the next tuple
  - Allows for *pipelining*
    - Tuples can "flow" through the query one-at-a-time without waiting for any operation to complete, giving immediate results to the query

Iterator Interface

- open()
  - Creates and opens the Iterator
  - In terms of Project 3, this is the Constructor for the Iterator object
- close()
  - Destroys the Iterator, releasing any resources
  - In terms of Project 3, this will recursively close() any input Iterators
- restart()
  - Restarts the Iterator, as if it had just been opened
  - If the Iterator is a subtree in the Query Tree instead of a base scan, this will recursively restart the entire subtree
- hasNext()
  - Returns true if there is another tuple in the result, false otherwise
  - Not always sufficient to simply recursively call hasNext() on the input Iterators to compute this (e.g. Selection, Joins)
- getNext()
  - Returns the next tuple in the result

Relational Algebra Iterators: Minibase

- Basic Scans
  - Iterate through the base relational table (*FileScan*) or through an index defined on the table (*IndexScan* for the entire index, or *KeyScan* for only the tuples matching a given key)
- Operators
  - Projection
  - Selection
  - SimpleJoin (nested loop join – already implemented)
  - HashJoin (use hashing to perform a Hash Join)
- Queries are executed by starting with the root Iterator in the Query Tree and recursively calling hasNext() and getNext()

Example (with Nested Loop Join)

- SELECT R.a, S.x
  FROM R, S
  WHERE R.a = S.x AND S.y > 5;

- Relational Algebra:
  $\pi_{R.a,\,S.x}(\sigma_{S.y>5}(S) \bowtie_{R.a\,=\,S.x} R)$

R.a	R.b
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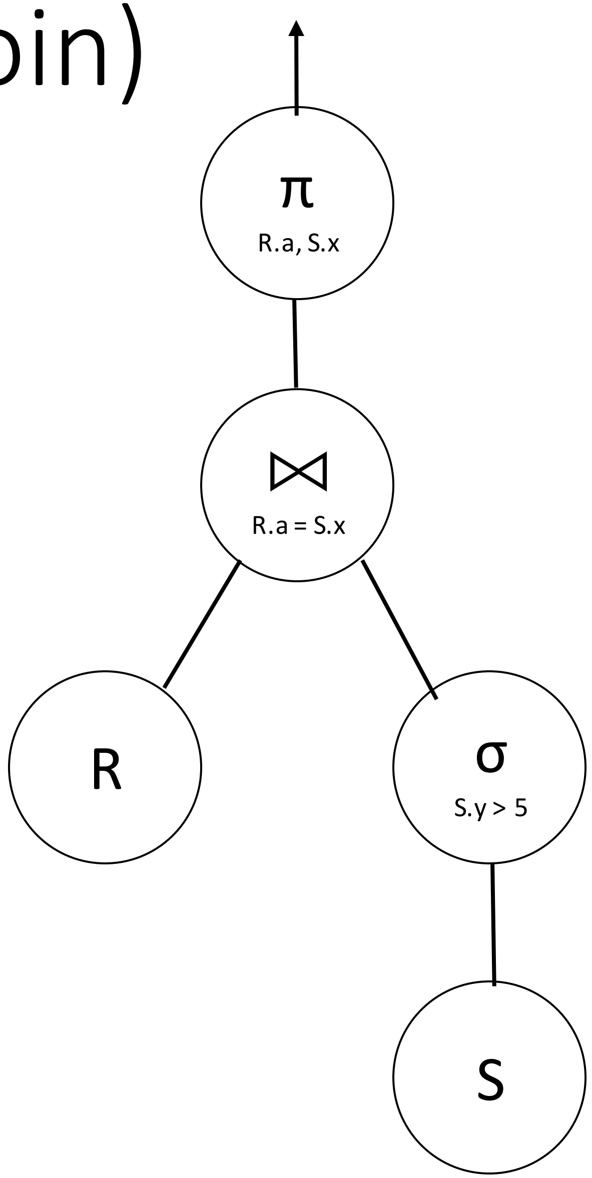

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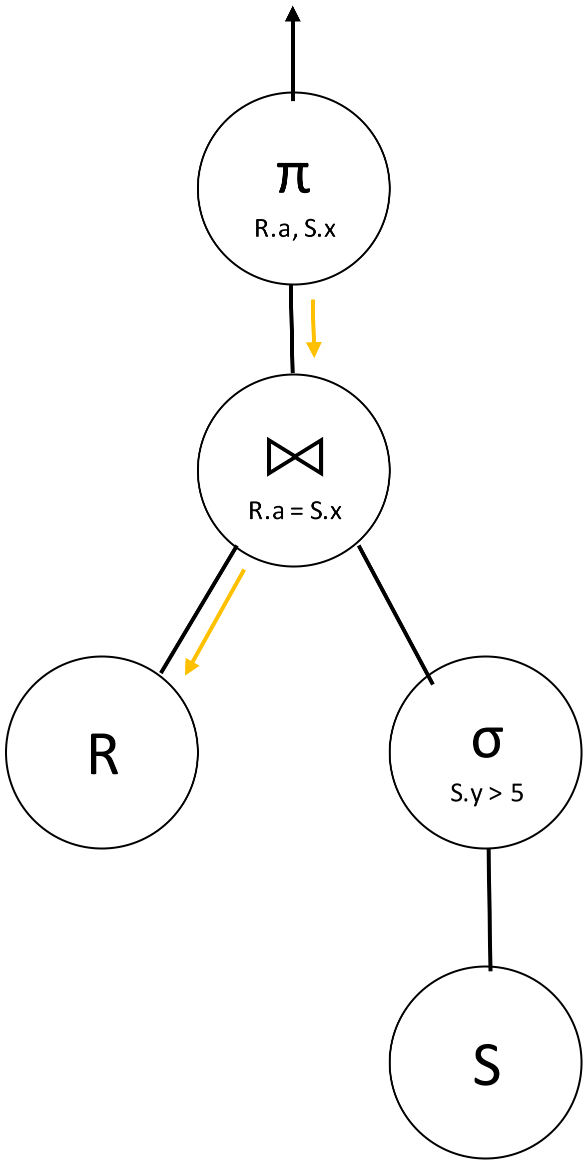

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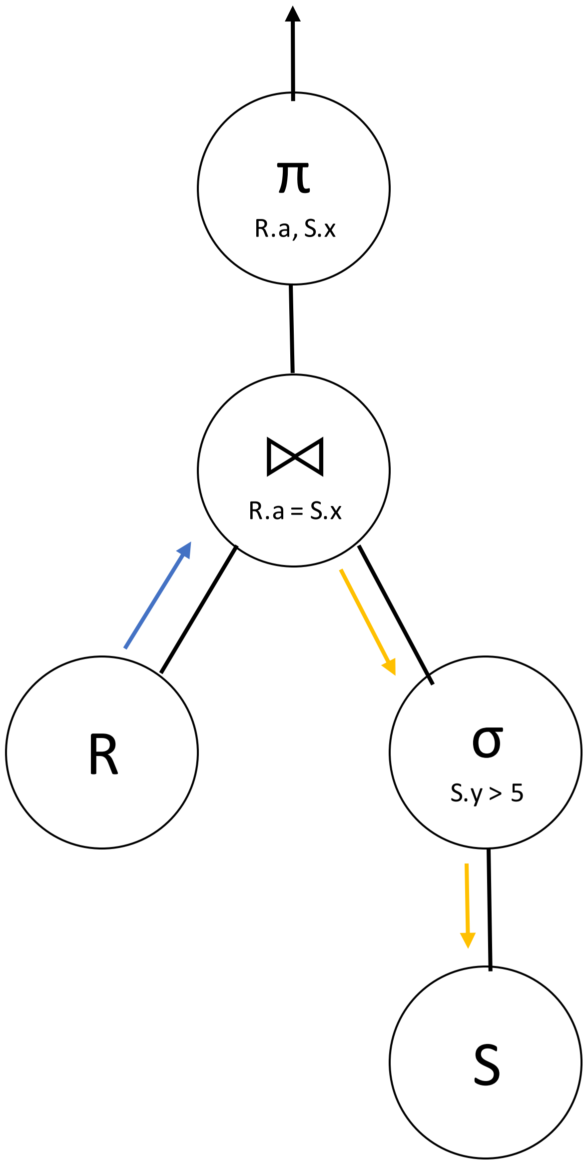

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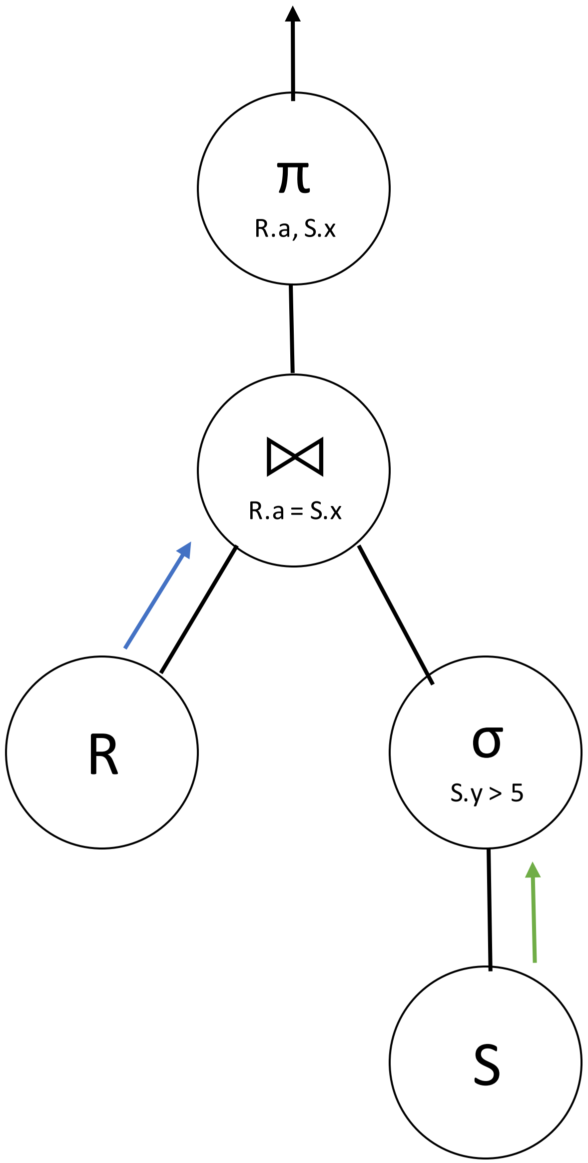

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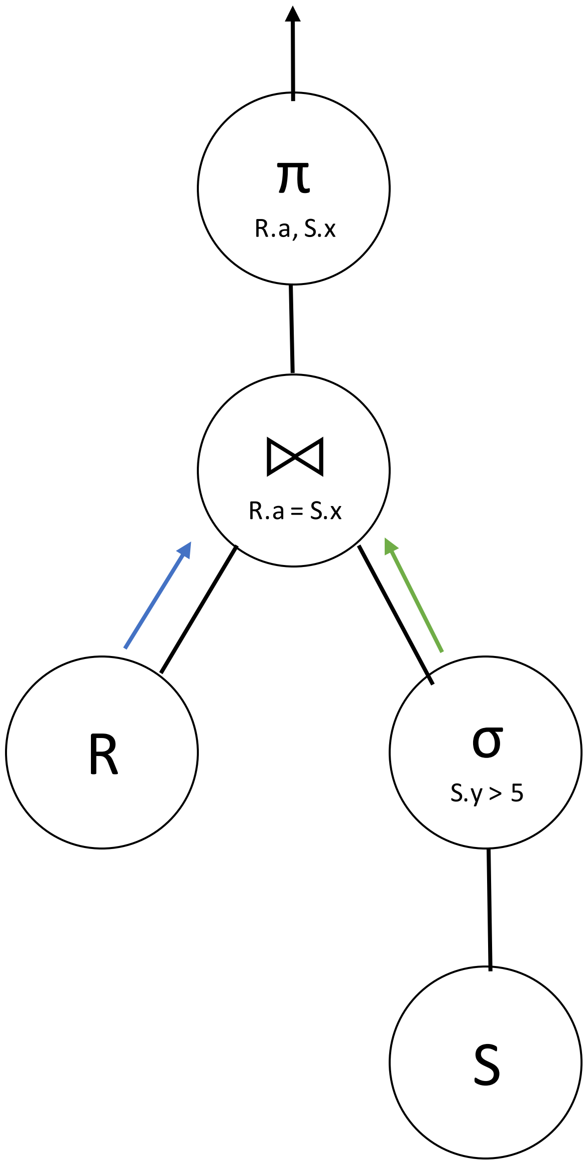

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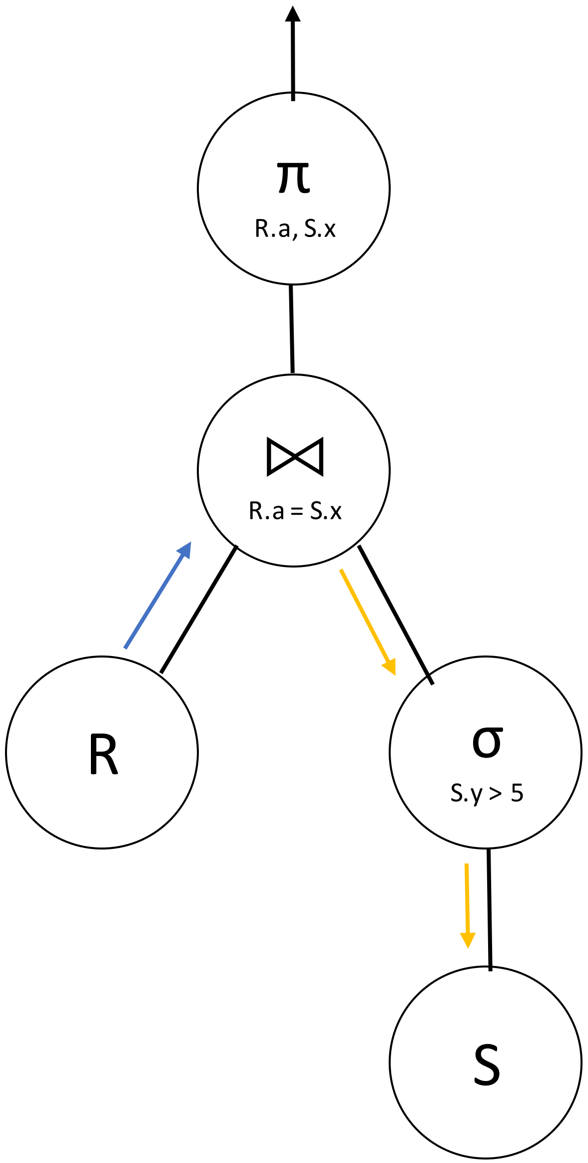

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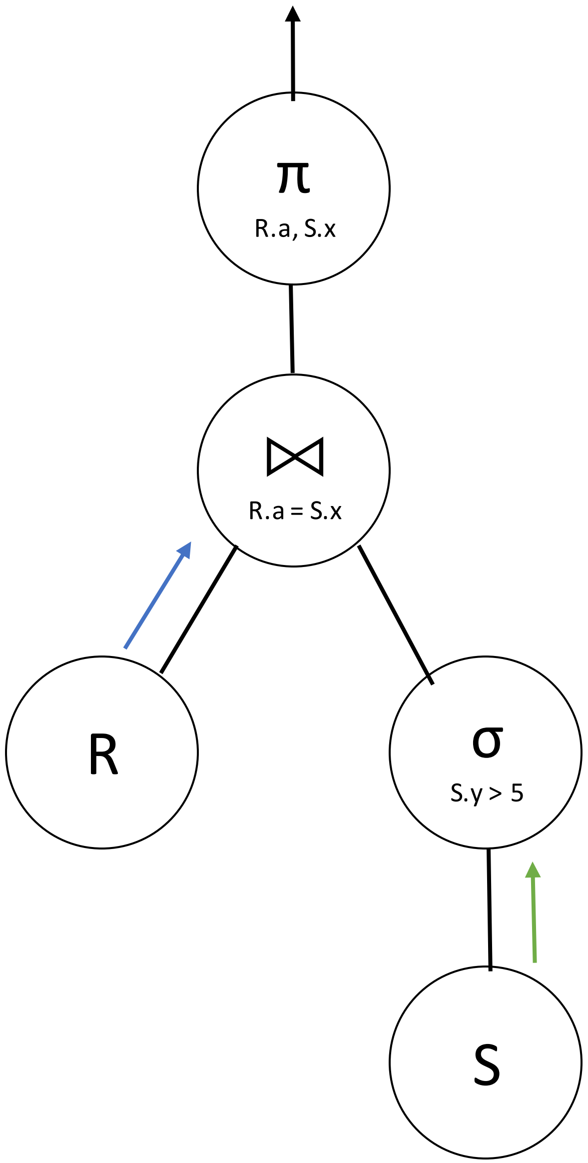

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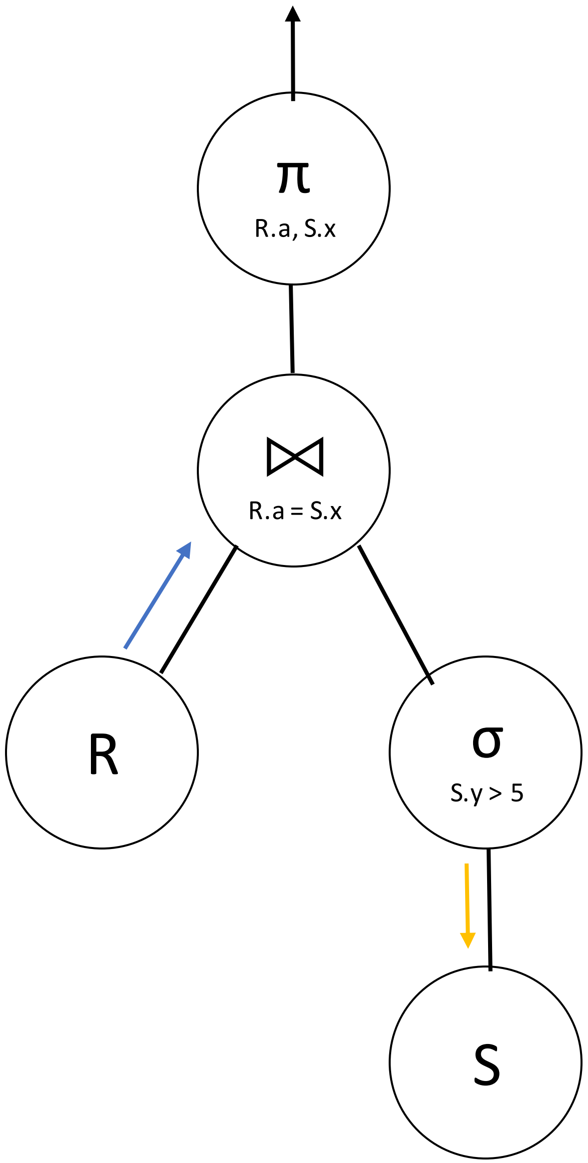

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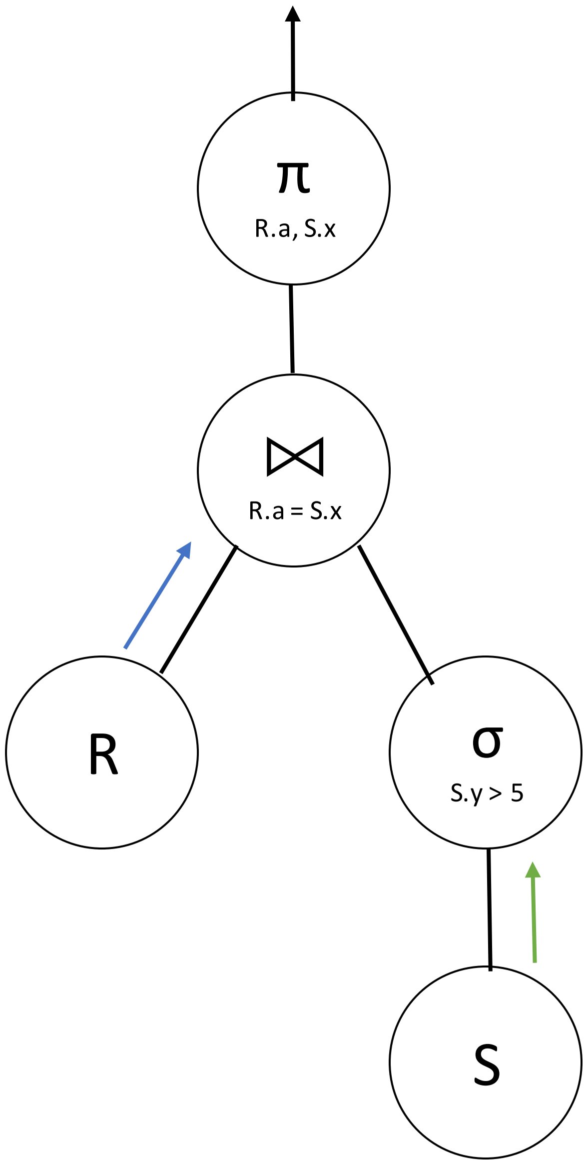

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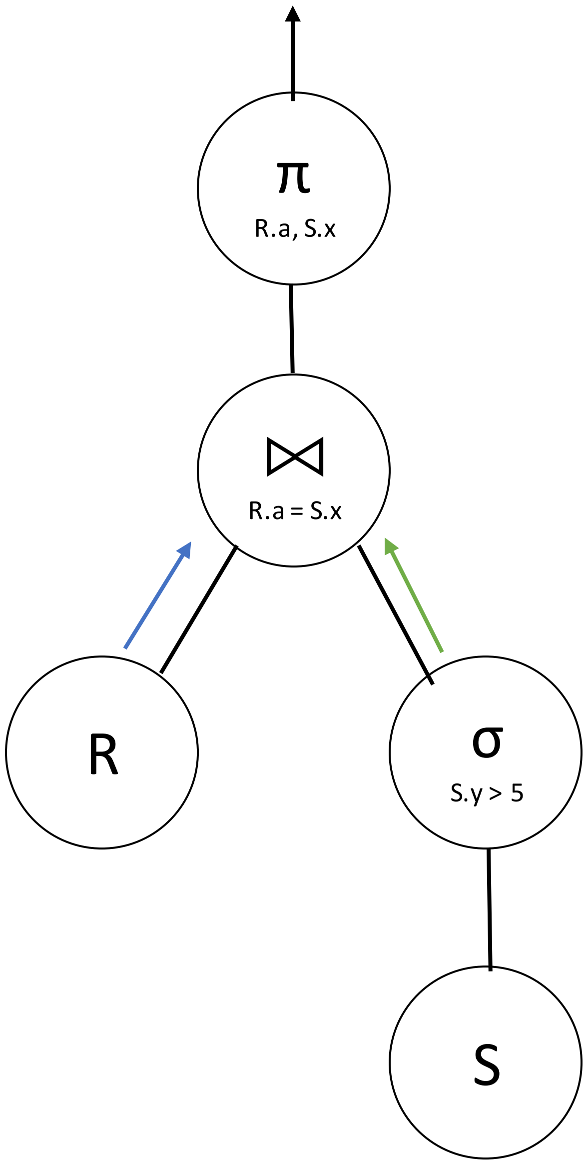

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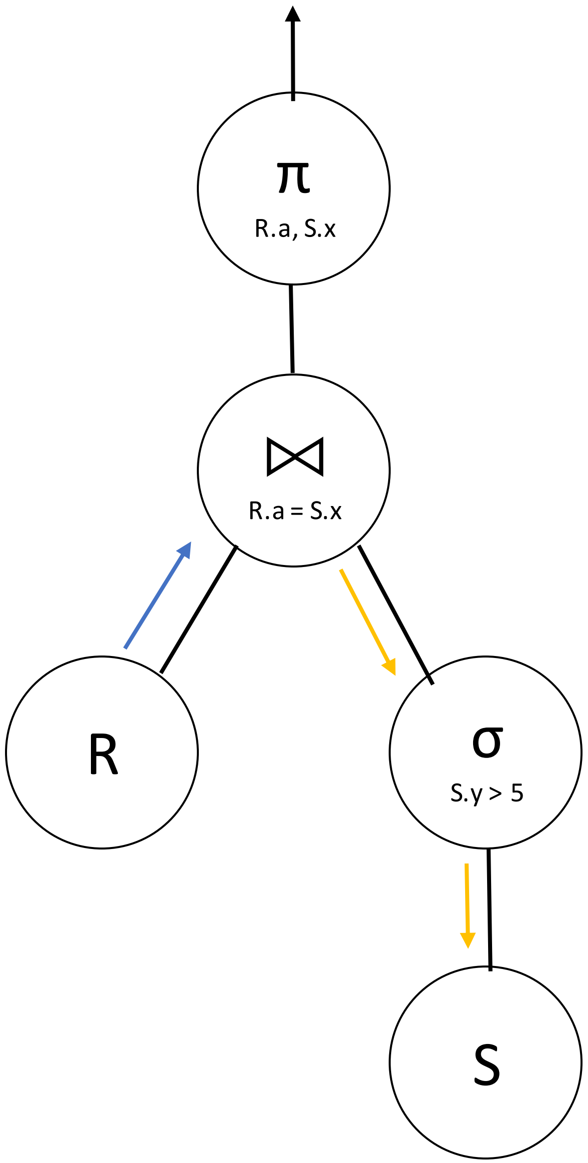

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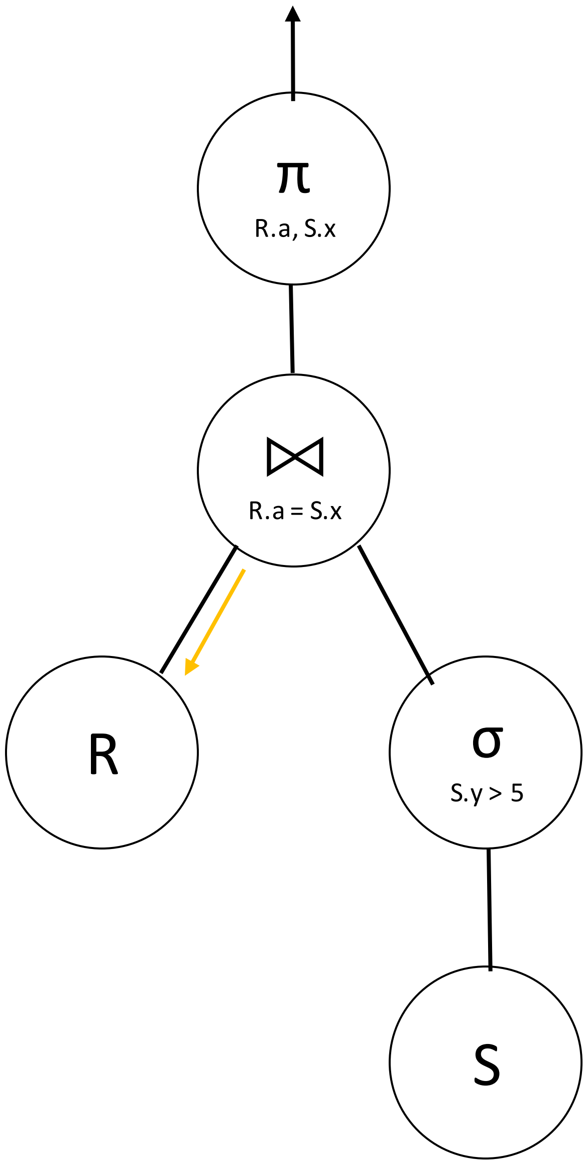

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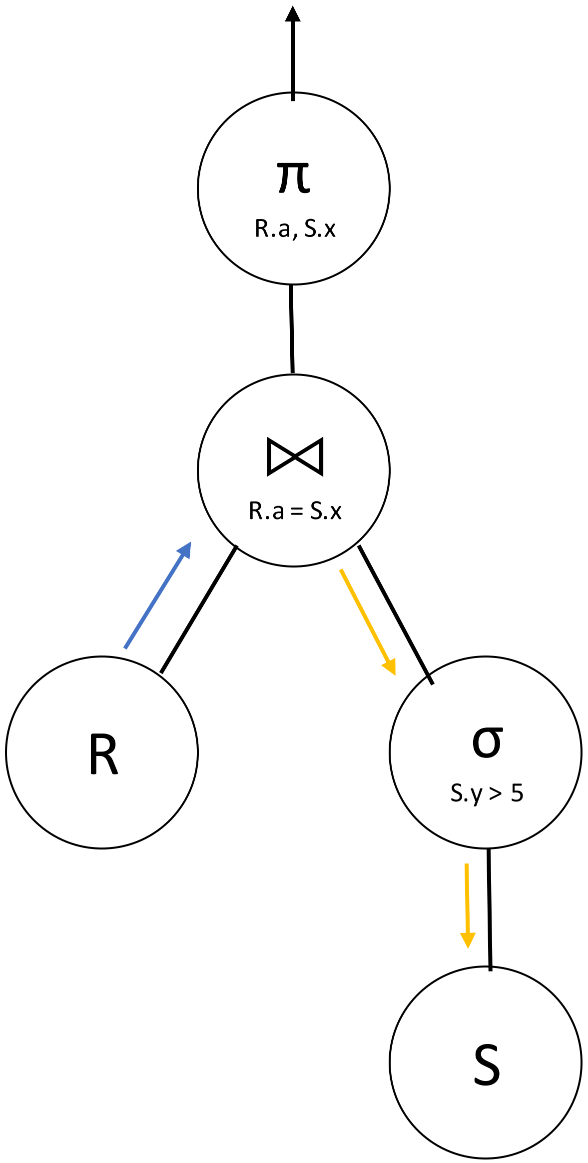

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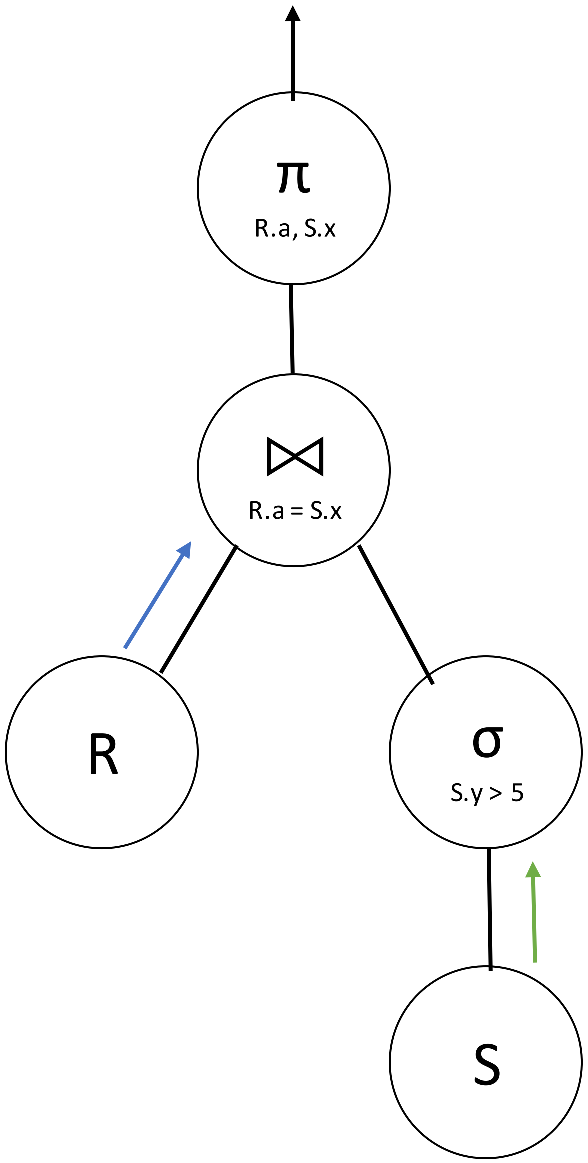

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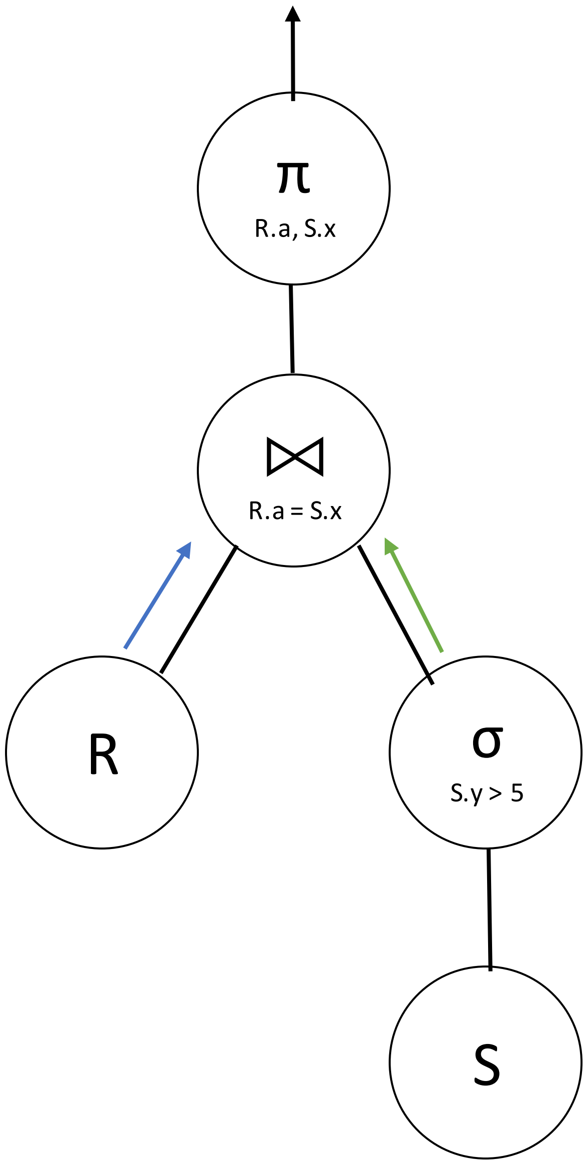

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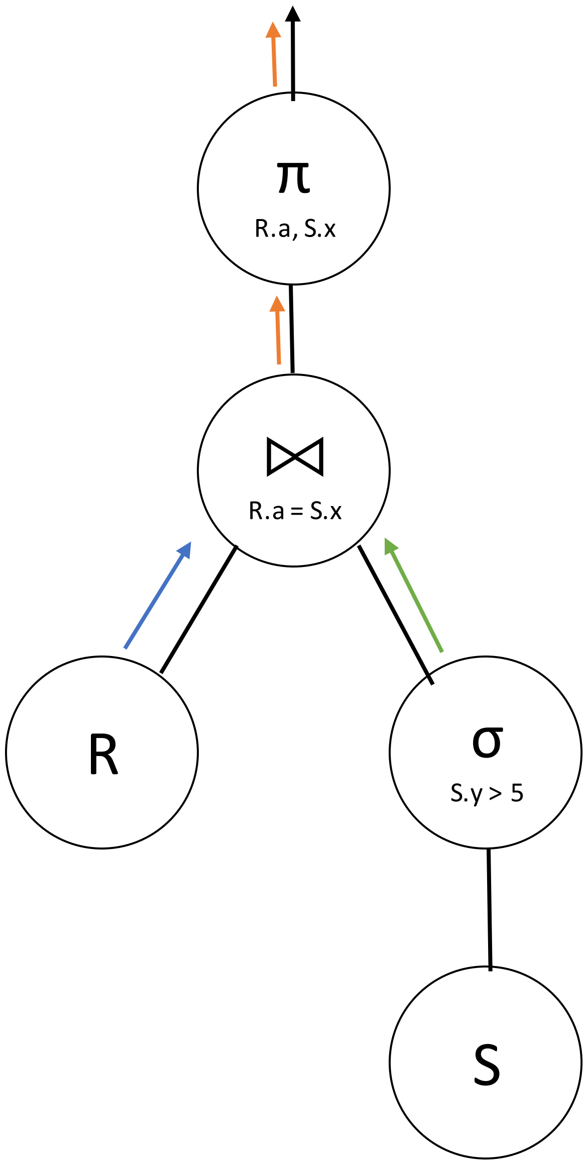

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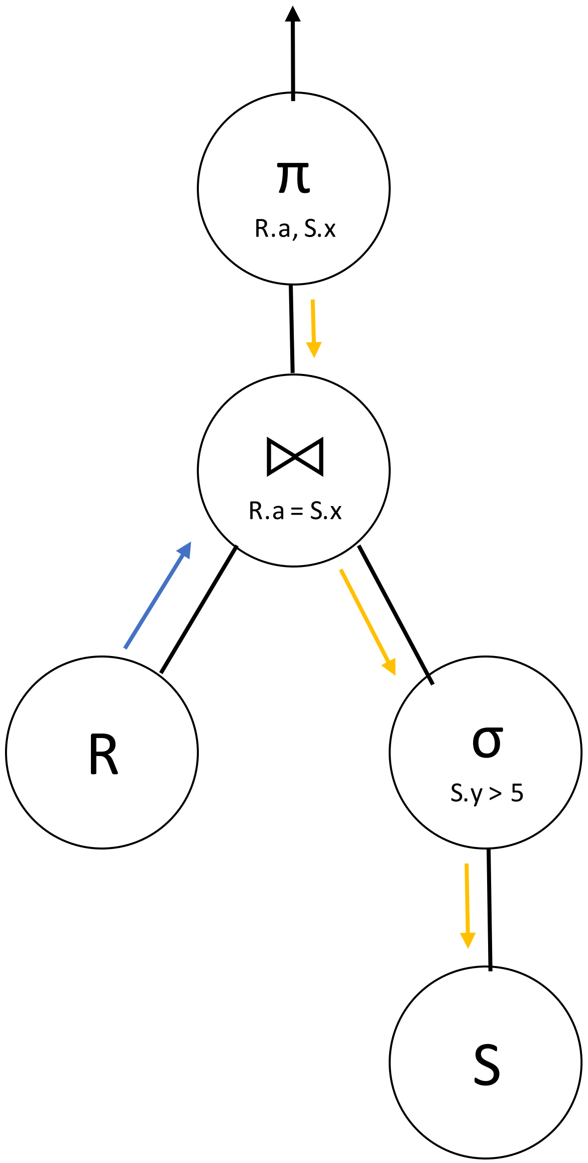

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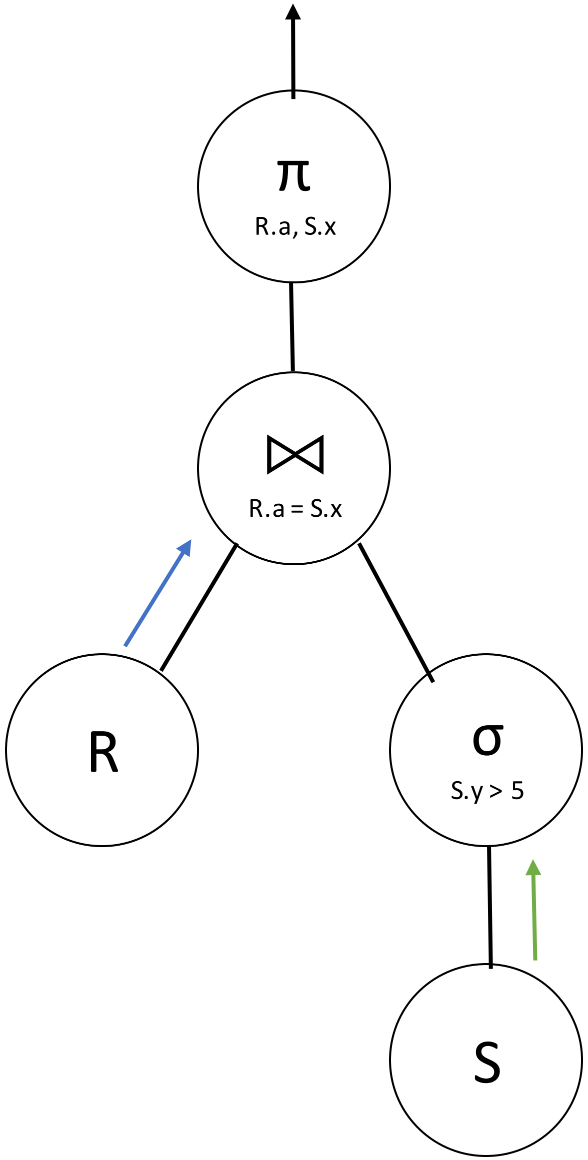

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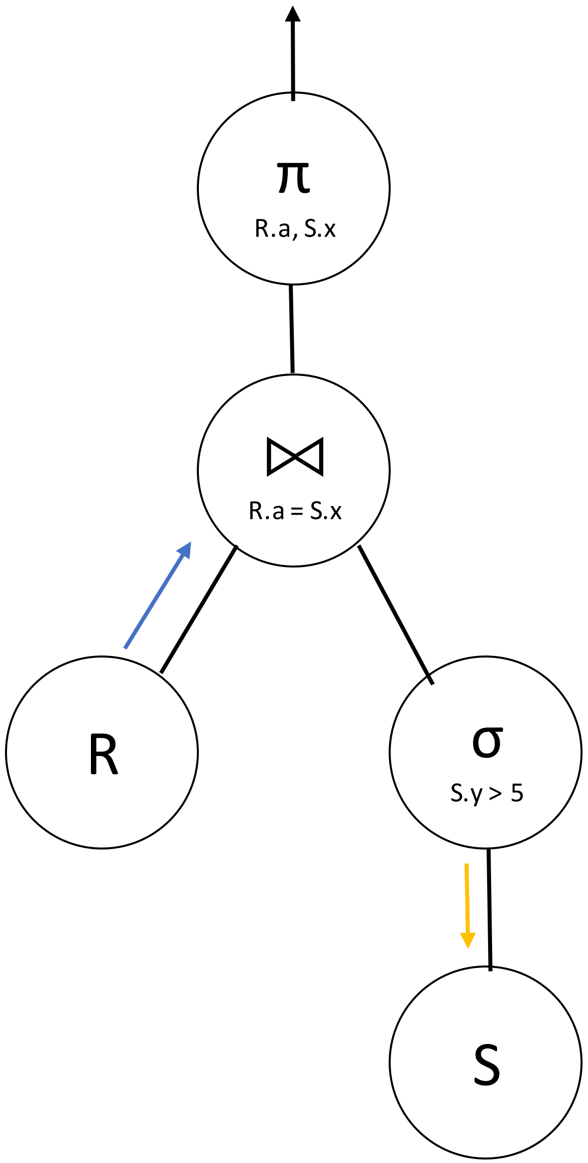

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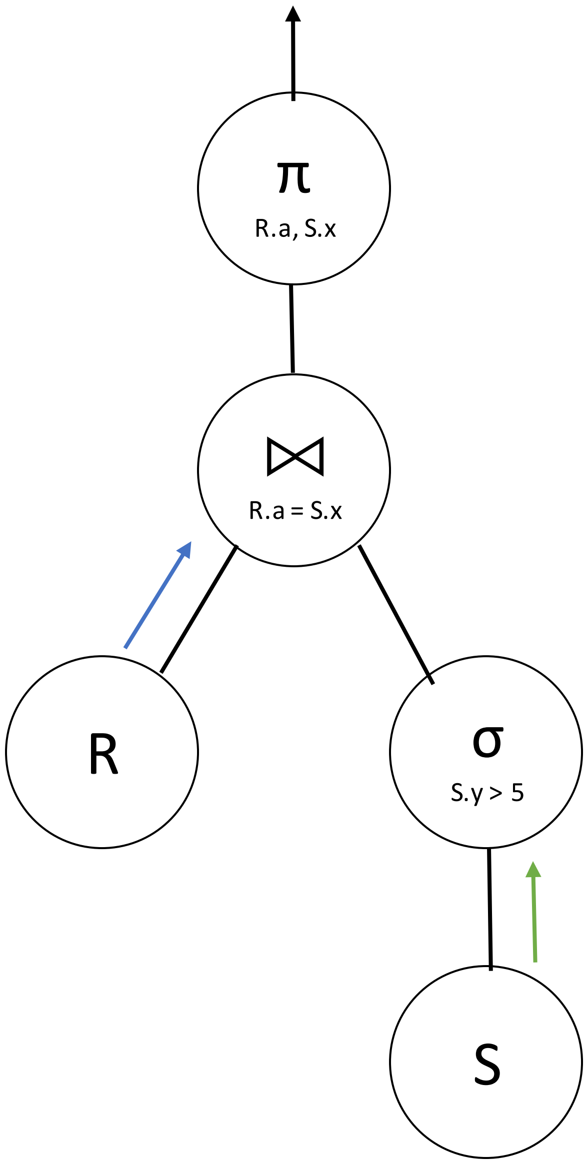

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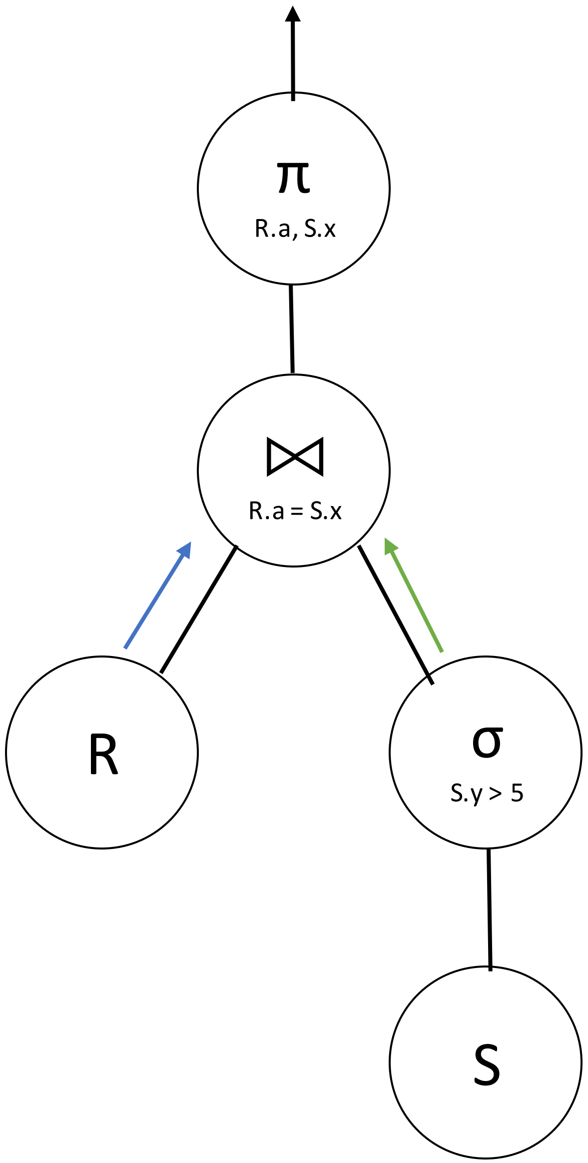

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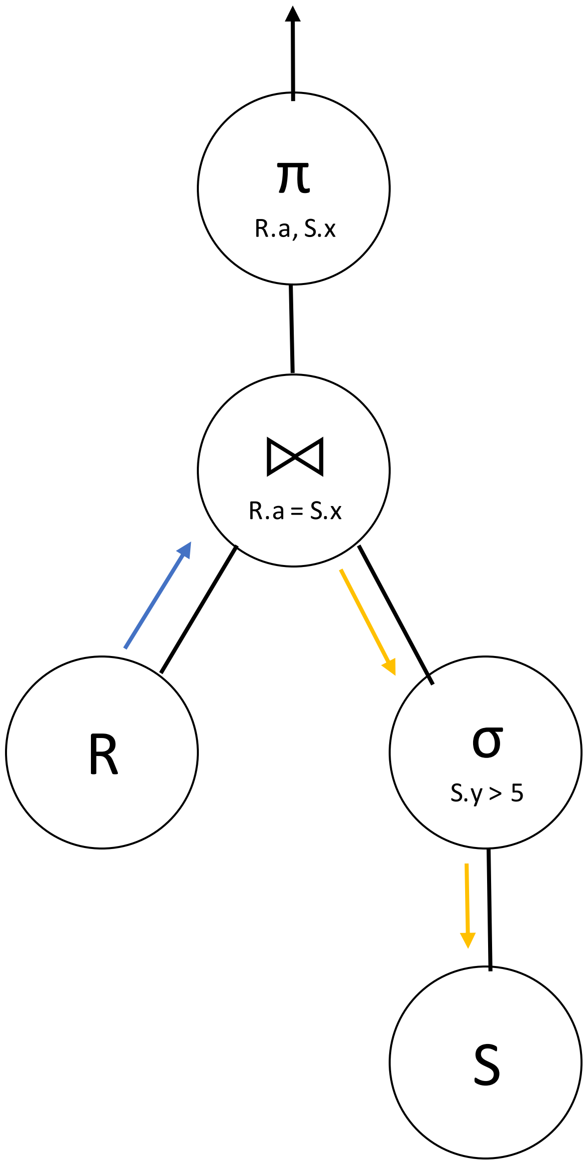

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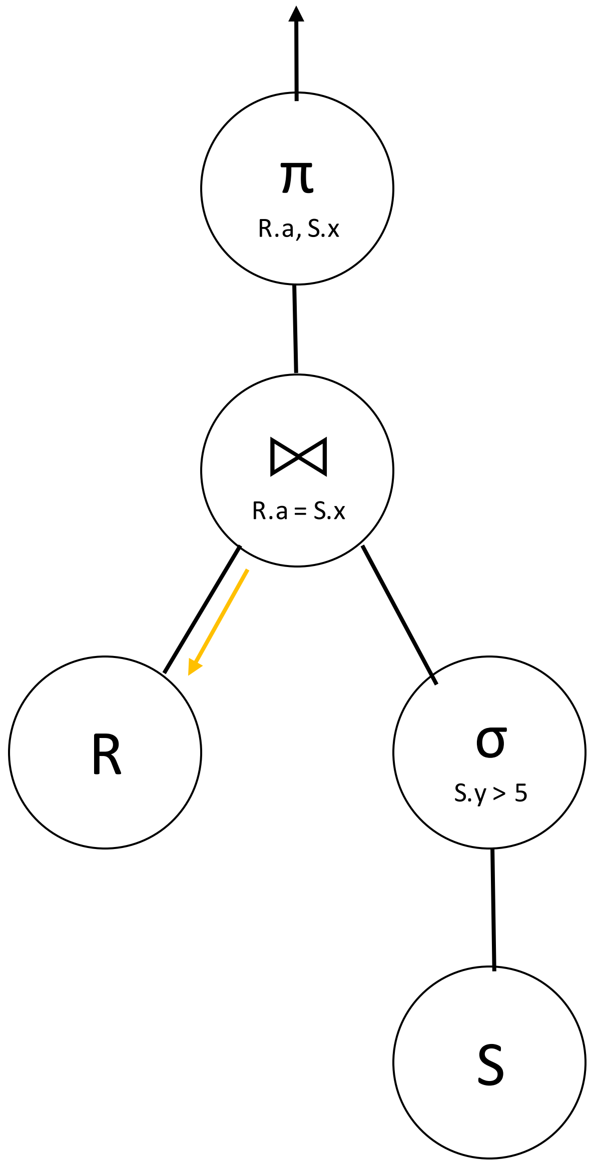

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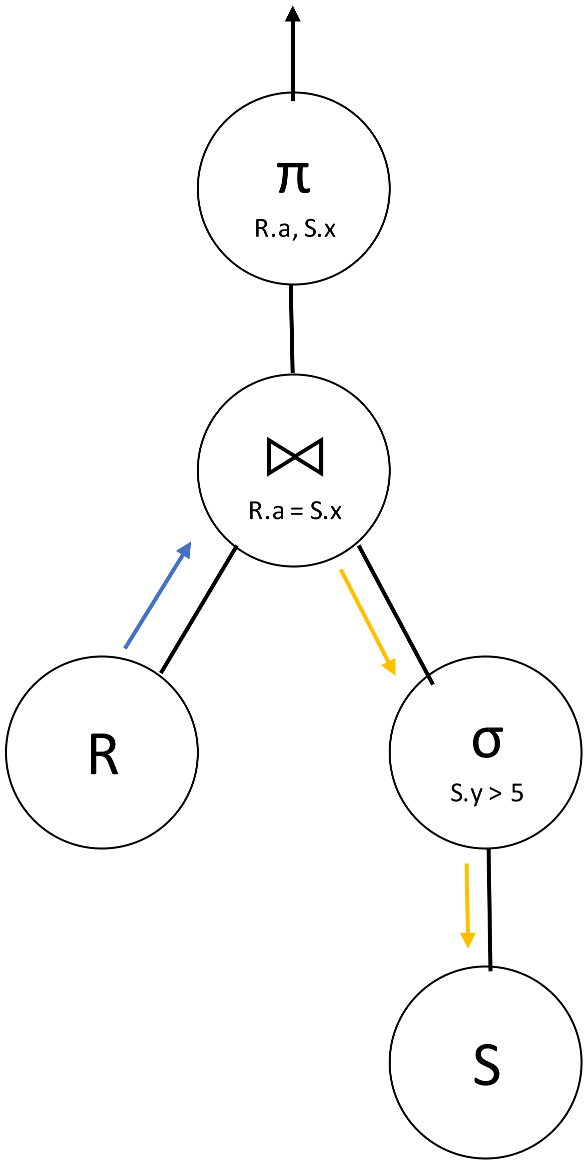

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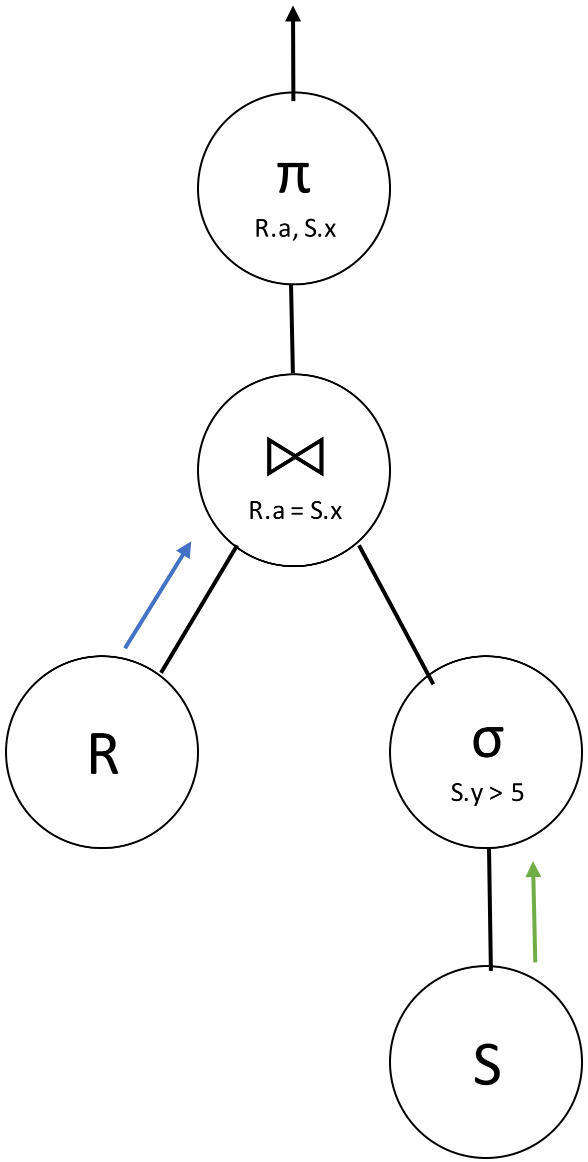

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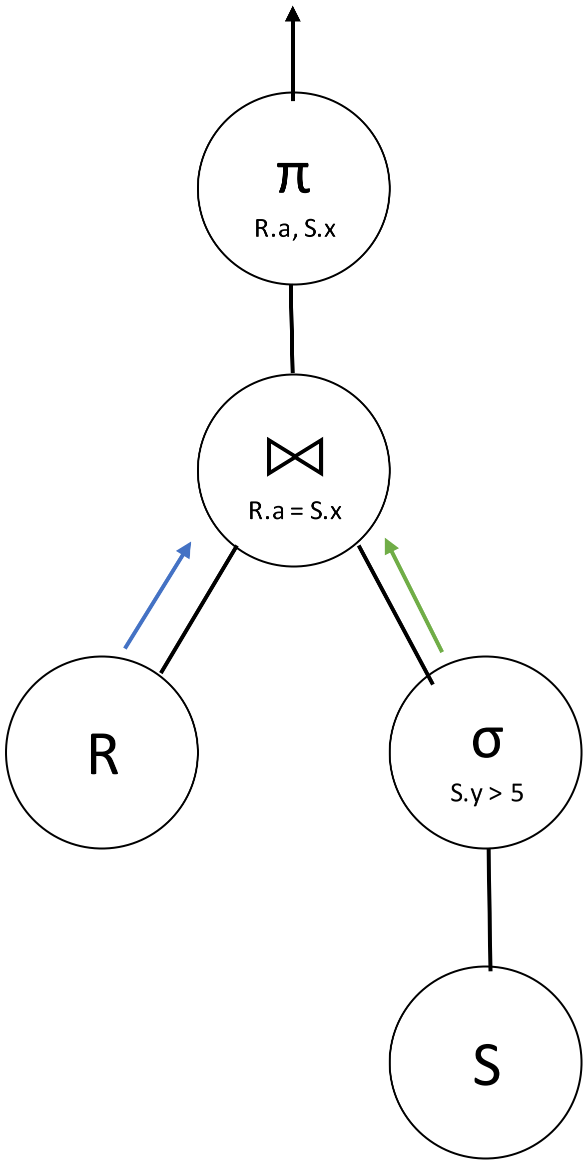

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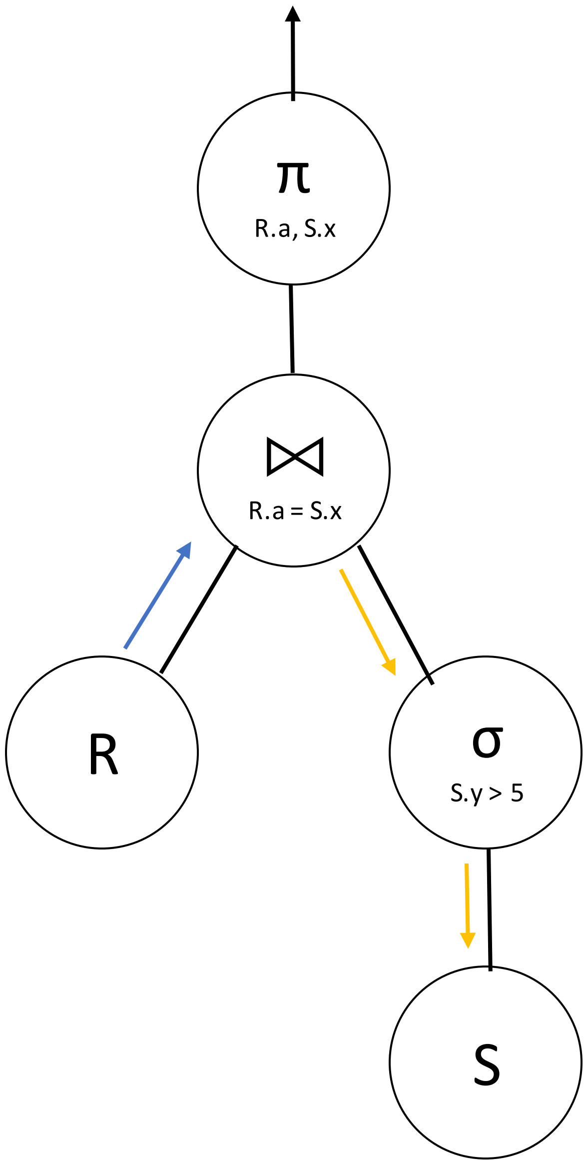

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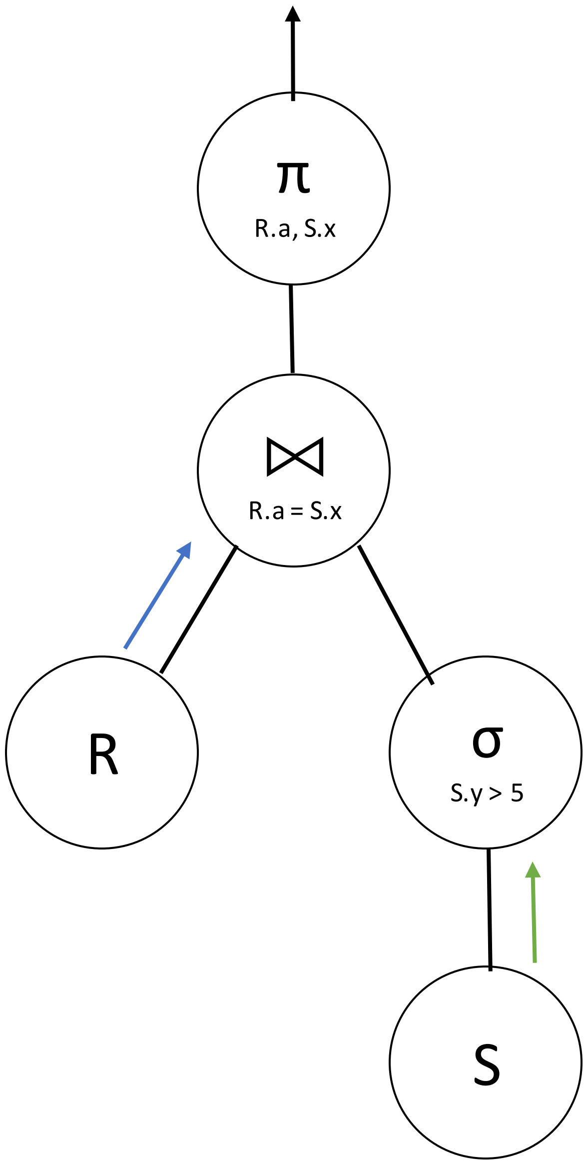

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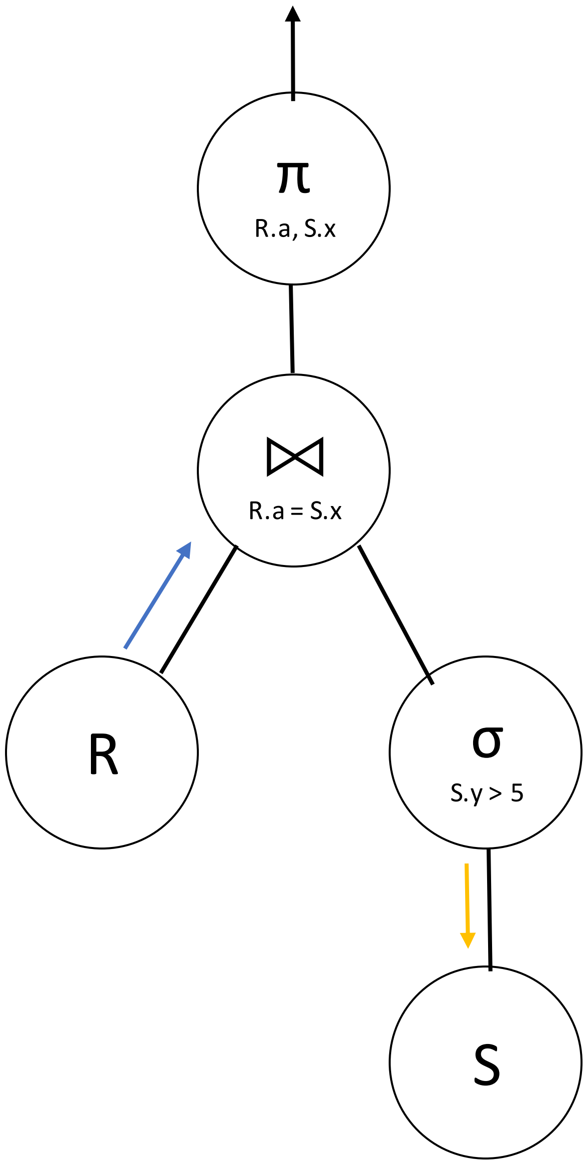

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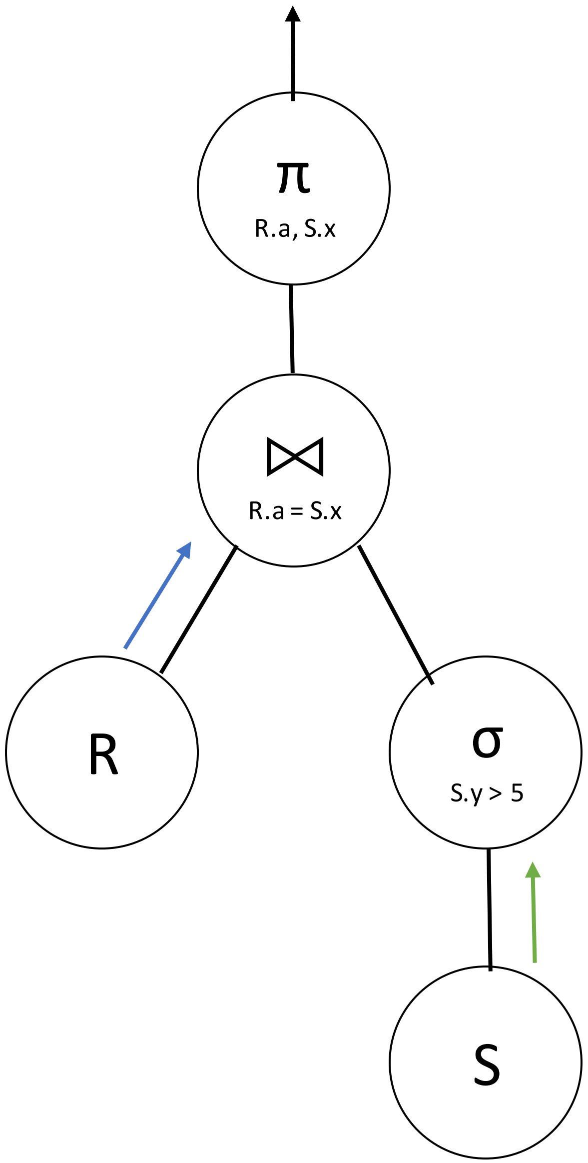

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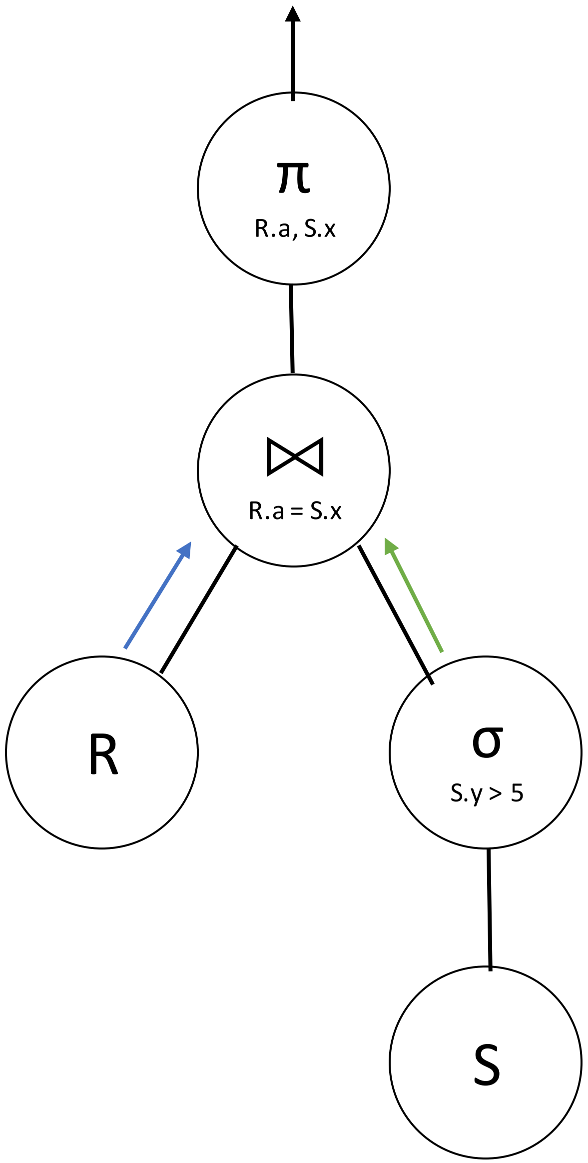

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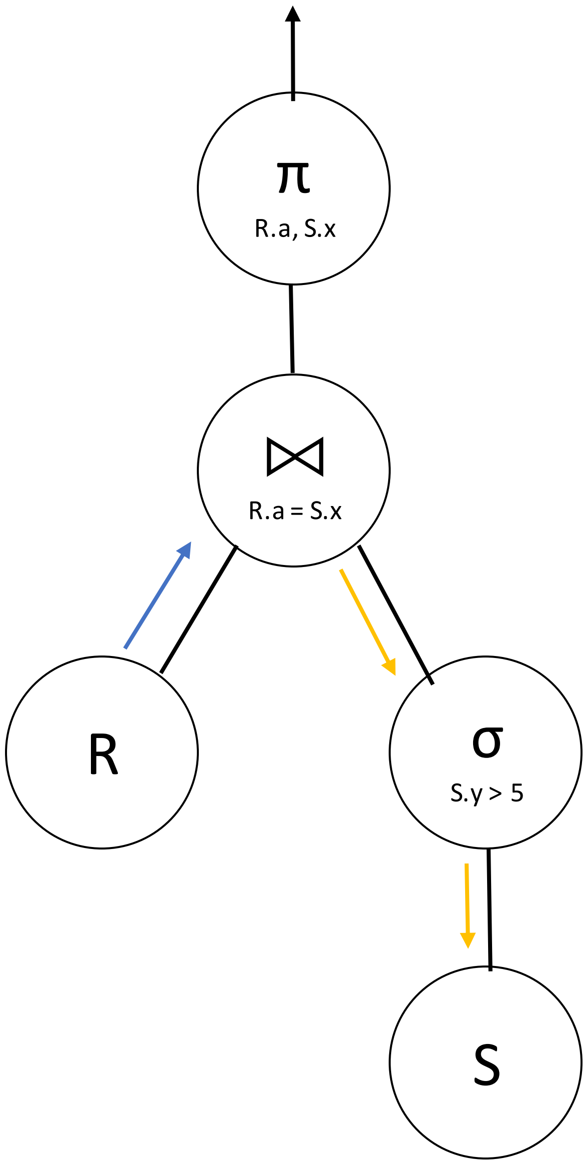


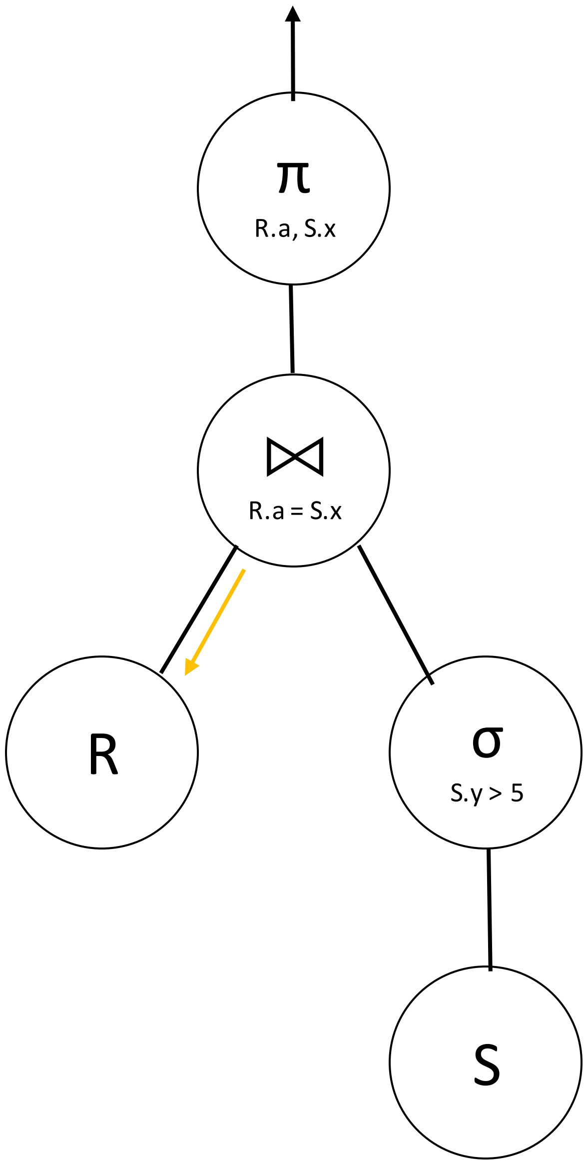
Example

- SELECT R.a, S.x
  FROM R, S
  WHERE R.a = S.x AND S.y > 5;

- Relational Algebra:
  $\pi_{R.a,\, S.x}(\sigma_{S.y > 5}(S) \bowtie_{R.a = S.x} R)$

R.a	R.b
1	2
2	7
3	4

S.x	S.y
2	10
3	5
4	8



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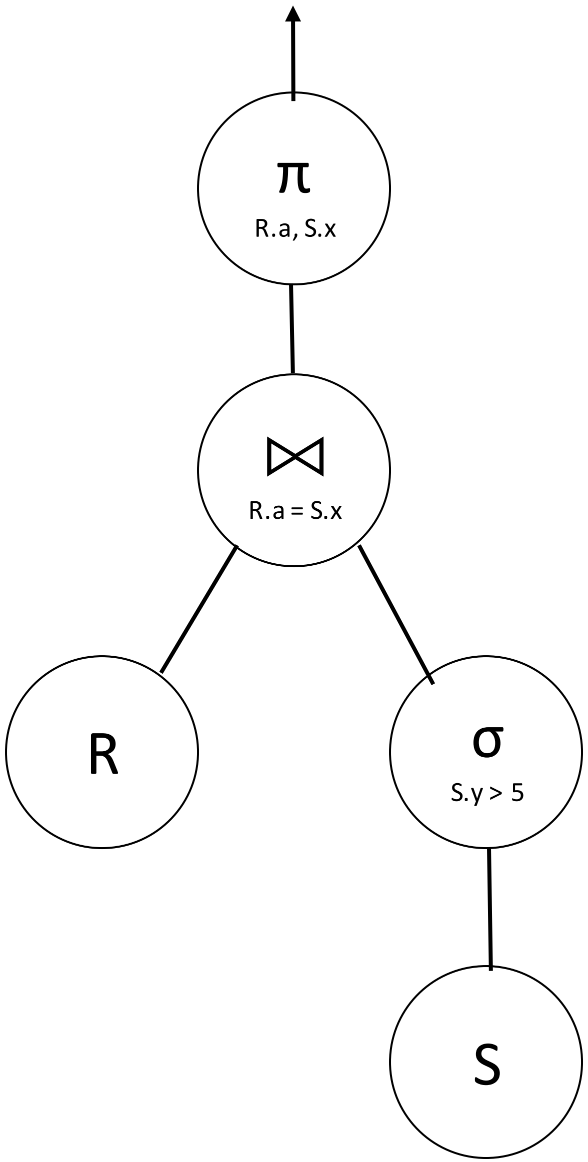

Hash Join

- Hash Join is a specialized Join algorithm that only works when the join predicate is an equality predicate (e.g. R.a = S.x)
  - Hash Join relies on hashing, and thus only equality is guaranteed to be a meaningful predicate for the hash function to operate on
  - Hash Join only requires a single pass through the input relations, compared to a Nested Loop which requires iterating through multiple times
- Two phases of a Hash Join:
  1. Construct a Hash Table on the join attribute for the smaller relation (assume it is small enough to fit in memory)
  2. For every tuple in the larger relation, probe the hash table for a match on the join predicate

Implementing Hash Join in Minibase

- For Project 3, you will not have to implement a Hash Join entirely from scratch
- You can rely on the already-existing HashIndex class and the IndexScan class you will be implementing

Minibase Hash Join

1. Transform any input Iterators into an IndexScan on a HashIndex with the appropriate SearchKey for the join predicate
   - **NOTE: You cannot simply cast the input Iterators as an IndexScan – you must build a temporary HeapFile and HashIndex and populate it with the result, and then open an IndexScan**
   - You should now have two IndexScan operators, constructed on HashIndexes with the appropriate SearchKey – this means the buckets of the two HashIndexes should correspond
2. Iterate through the HashIndexes, one bucket at a time. For each bucket, maintain a Hash Table of observed Tuples and report a match when it occurs
3. After exhausting all tuples in one bucket in both IndexScans, move to the next bucket. Repeat until all tuples are exhausted