CSE4/562 Database Systems

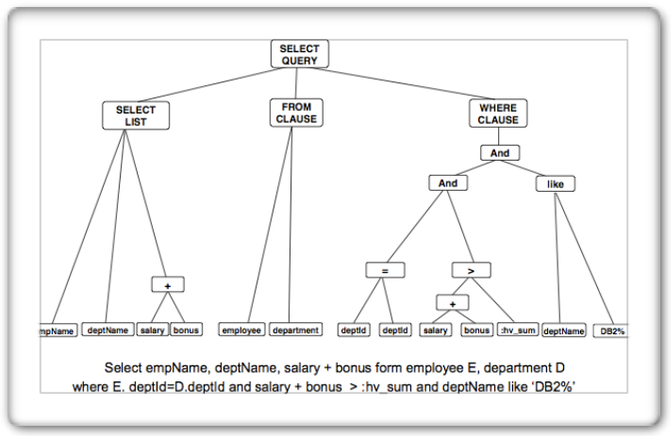
Practicum Component

02/16/2018

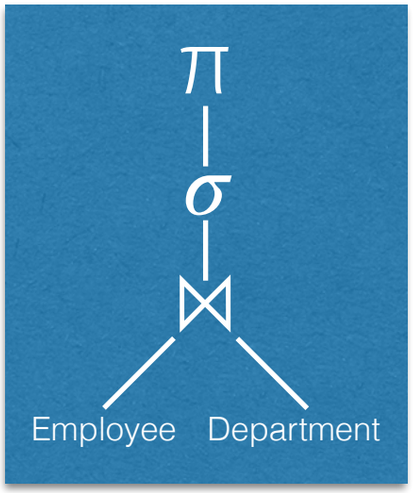
Recap

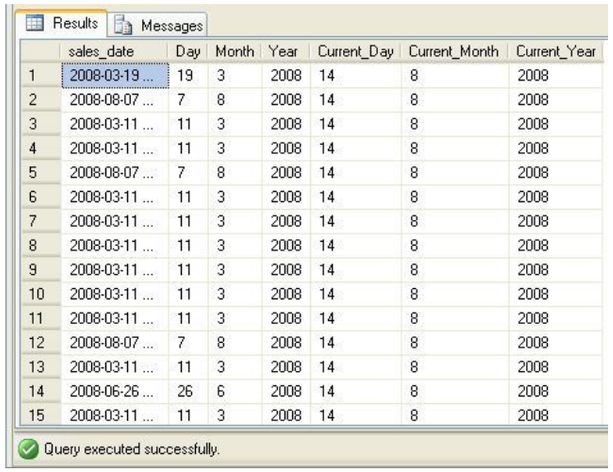
.sql

How does this work?



Parsed Query





Results

What does this look like? (last class)

Data

How does this work?

A Basic SQL Query

(optional) keyword indicating that the answer should **not** contain duplicates

```
SELECT  [DISTINCT] target-list
```

A list of attributes of relations in relation-list

```
FROM    relation-list
```

A list of relation names
(possibly with a range-variable after each name)

```
WHERE   condition
```

Comparisons ('=', '<>', '<', '>', '<=', '>=') and other boolean predicates,
combined using AND, OR, and NOT
(a boolean formula)

SQL

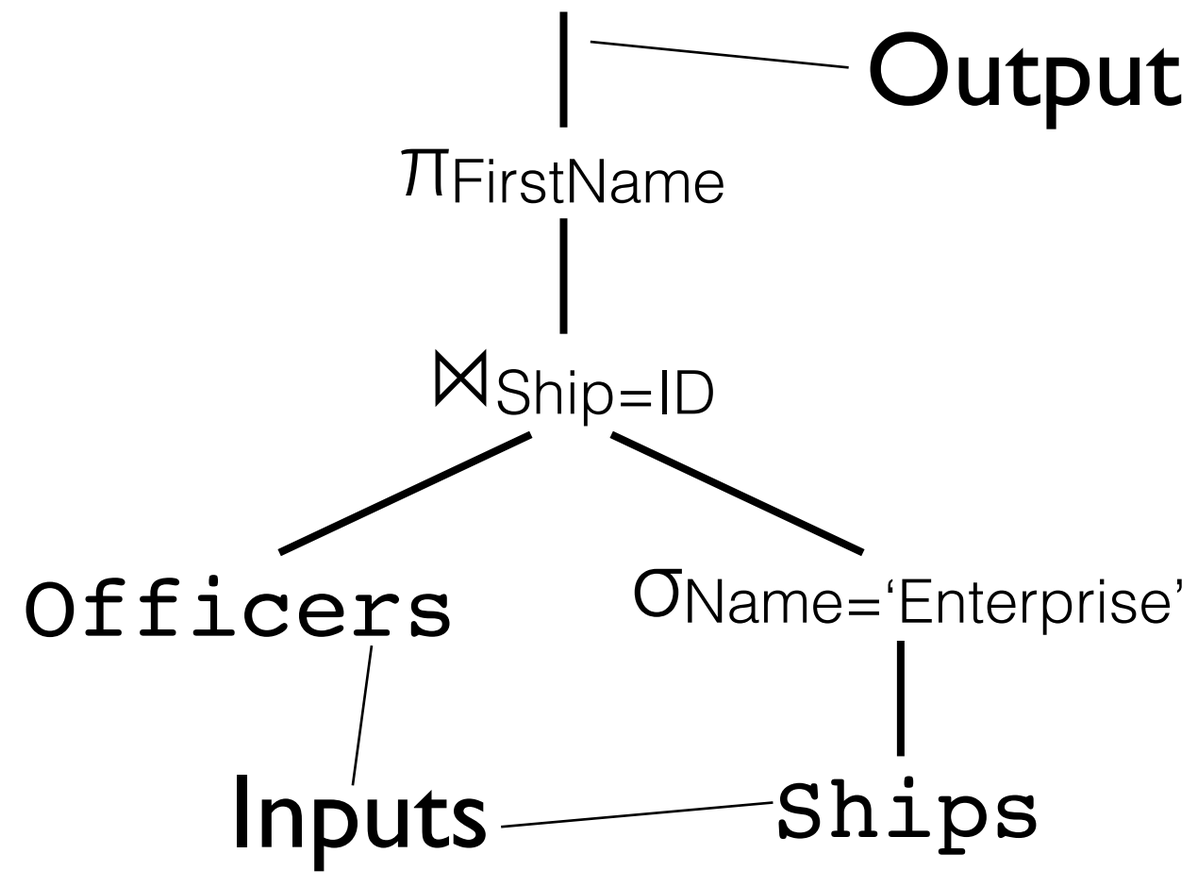
- SQL is a language for querying relations
  - **`SELECT`** to access (query) data
    - Different features for different access patterns.
  - **`INSERT INTO`**, **`DELETE FROM`** to modify data
  - **`CREATE TABLE`**, **`DROP TABLE`**, **`ALTER TABLE`** to modify relations

Relational Algebra Trees

```
SELECT O.FirstName
FROM Officers O, Ships S
WHERE O.Ship = S.ID
      AND S.Name = 'Enterprise'
```

$\pi_{\text{FirstName}}(\texttt{Officers} \bowtie_{\text{Ship=ID}} (\sigma_{\text{Name='Enterprise'}} \texttt{Ships}))$

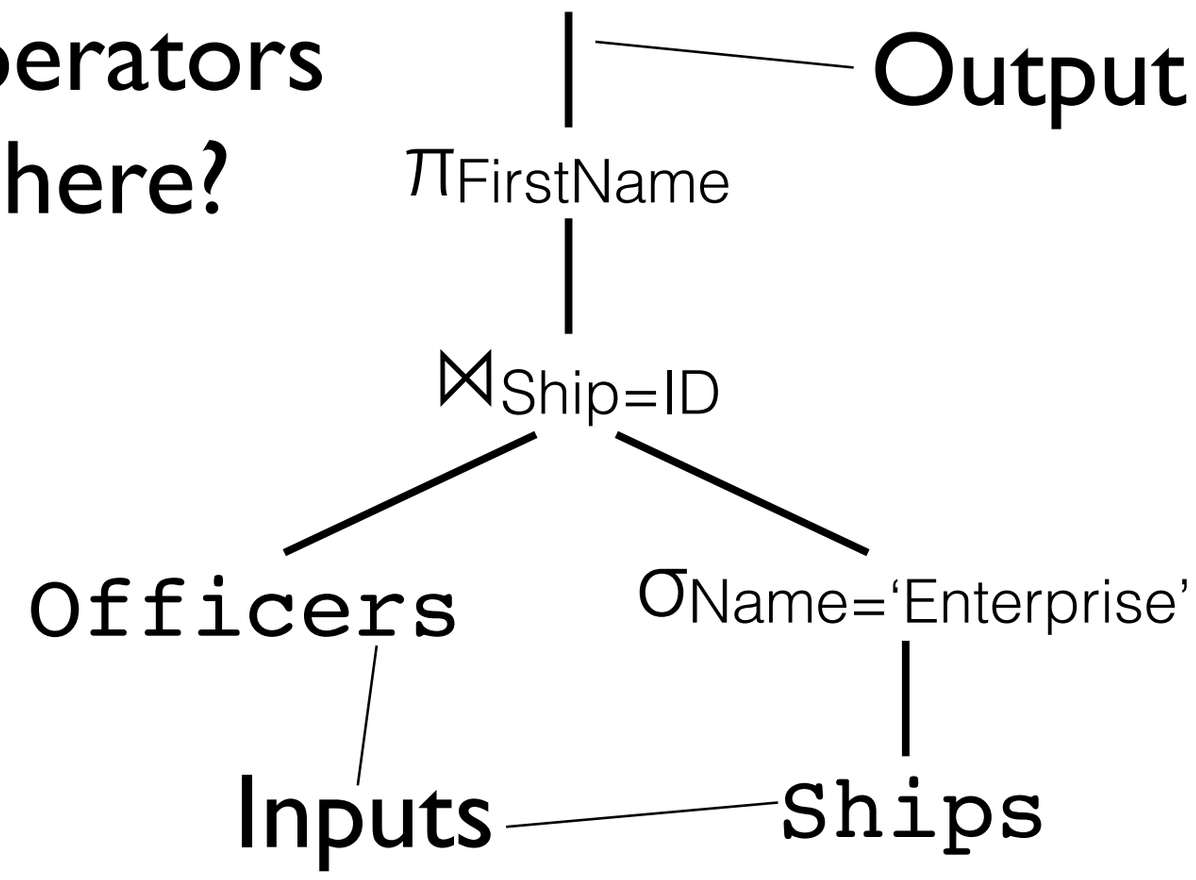
Relational Algebra Trees



$\pi_{\text{FirstName}}(\texttt{Officers} \bowtie_{\text{Ship=ID}} (\sigma_{\text{Name='Enterprise'}} \texttt{Ships}))$

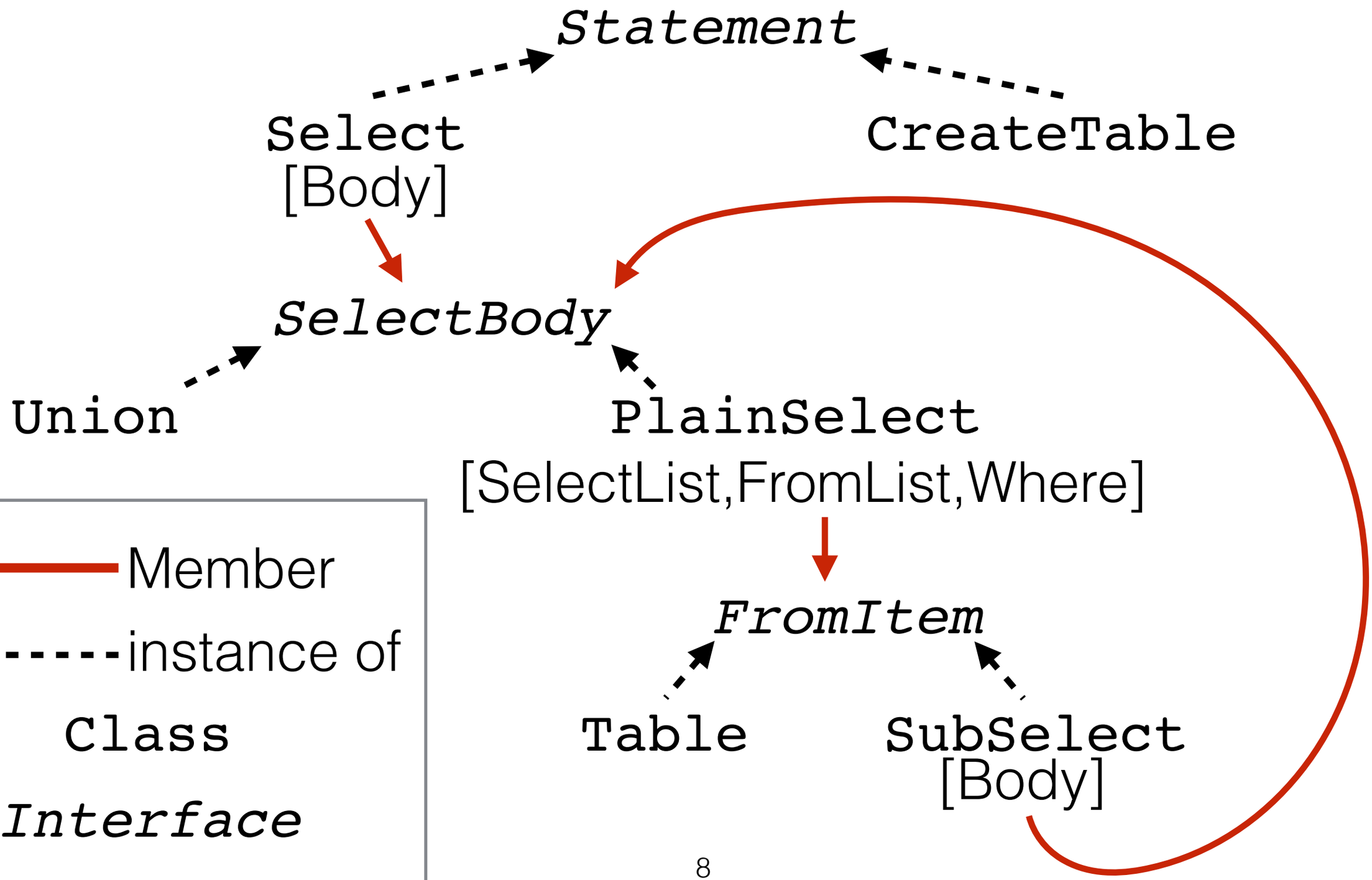
Relational Algebra Trees

How many operators do you see here?



$\pi_{\text{FirstName}}(\texttt{Officers} \bowtie_{\text{Ship=ID}} (\sigma_{\text{Name='Enterprise'}} \texttt{Ships}))$

Syntax Trees in Java



InstanceOf

```
Statement statement = parser.Statement();

if(statement instanceof Select) {
  Algebra raTree = parseTree((Select)statement);
  evaluate(raTree);

} else if(statement instanceof CreateTable) {
  loadTableSchema((CreateTable)statement);

}
```

Recommendation

Start by imagining how you would implement a relational algebra tree - and actually do it!

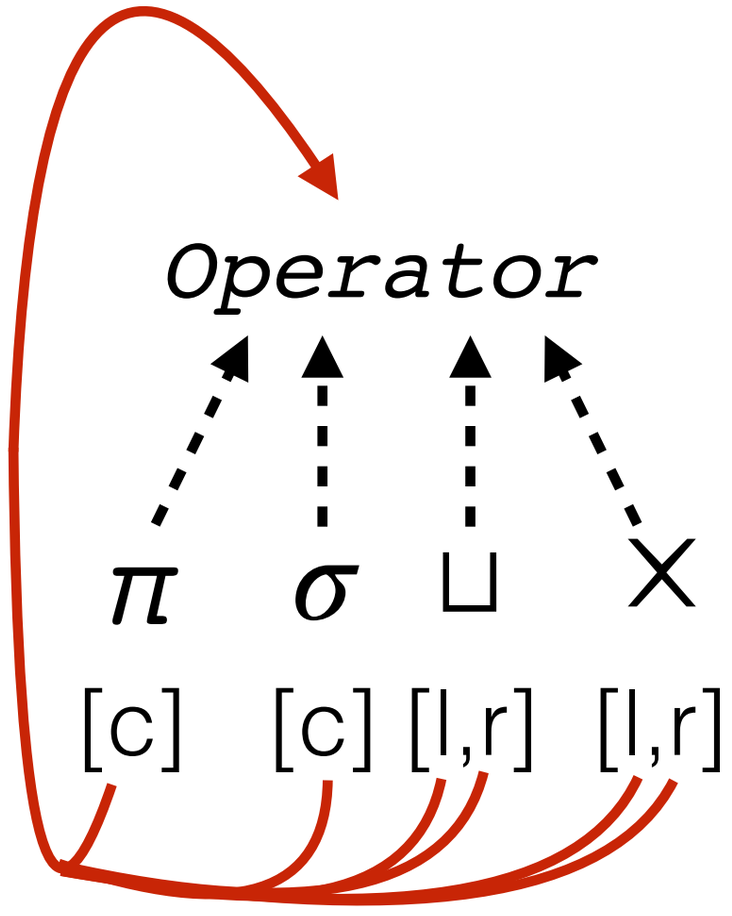
Determine inputs and outputs for each operator.

Treat table scan as an operator

Syntax Trees in Java

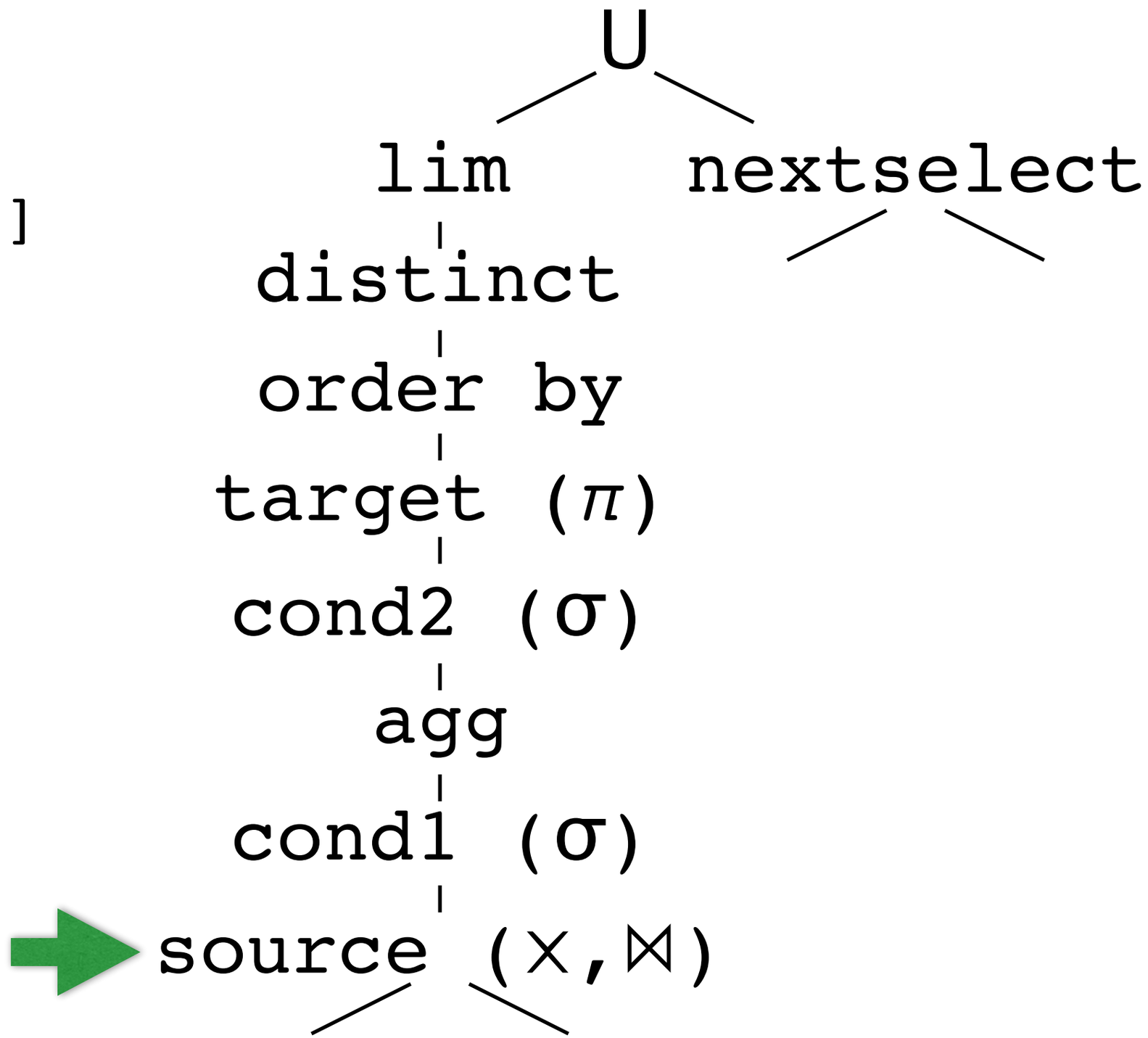
What would a class hierarchy look like for Relational Algebra?

Syntax Trees in Java



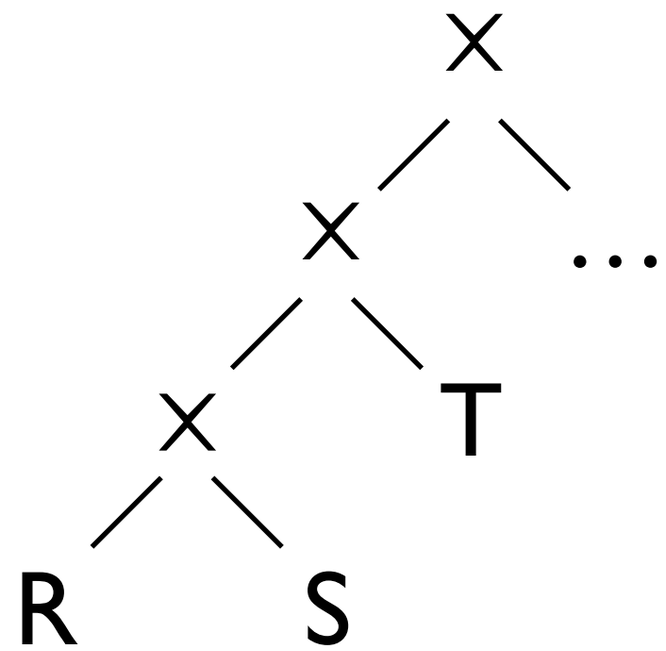
SQL to RA

```
SELECT [DISTINCT]
       target
FROM source
WHERE cond1
GROUP BY …
HAVING cond2
ORDER BY order
LIMIT lim
UNION nextselect
```



FROM Clause

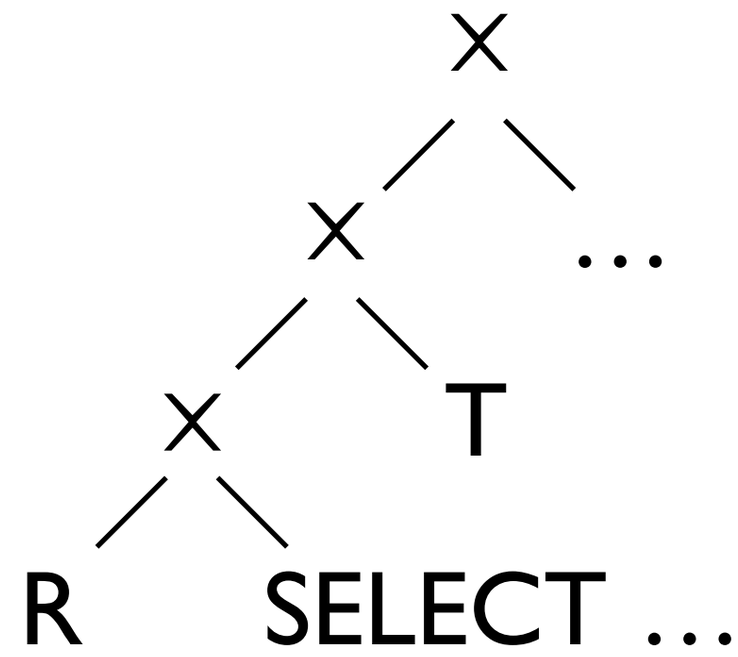
```
FROM R, S, T, …
```



What happens if I have a FROM-nested query?

FROM Clause

```
FROM R, (SELECT …) S, T, …
```



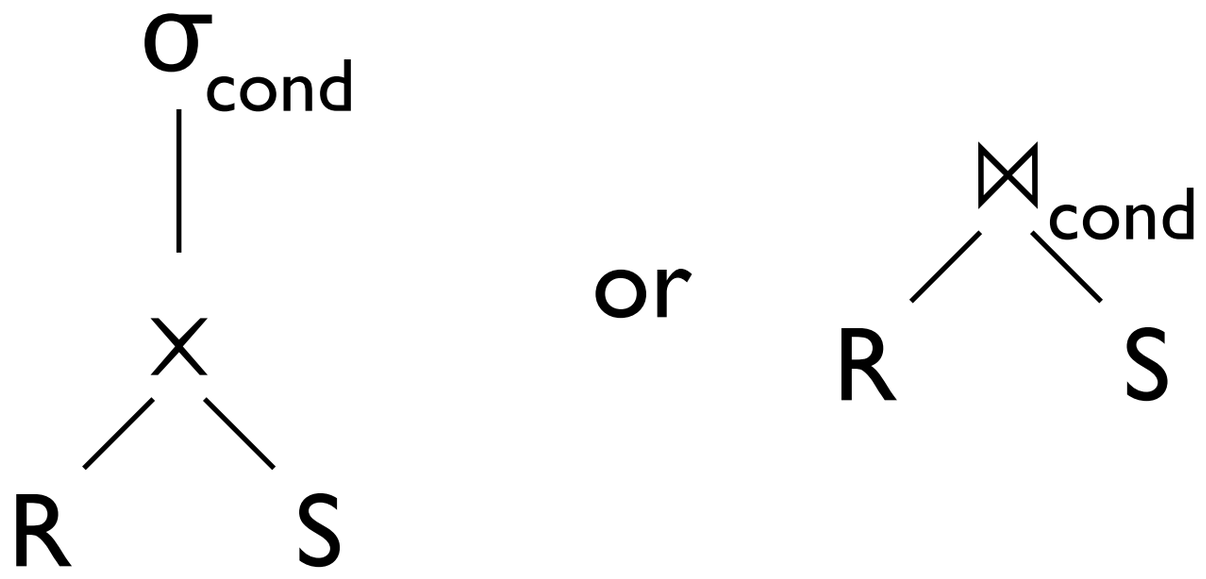
Selects are just relations!

FROM Clause

```
FROM R JOIN S ON cond
```

FROM Clause

```
FROM R JOIN S ON cond
```

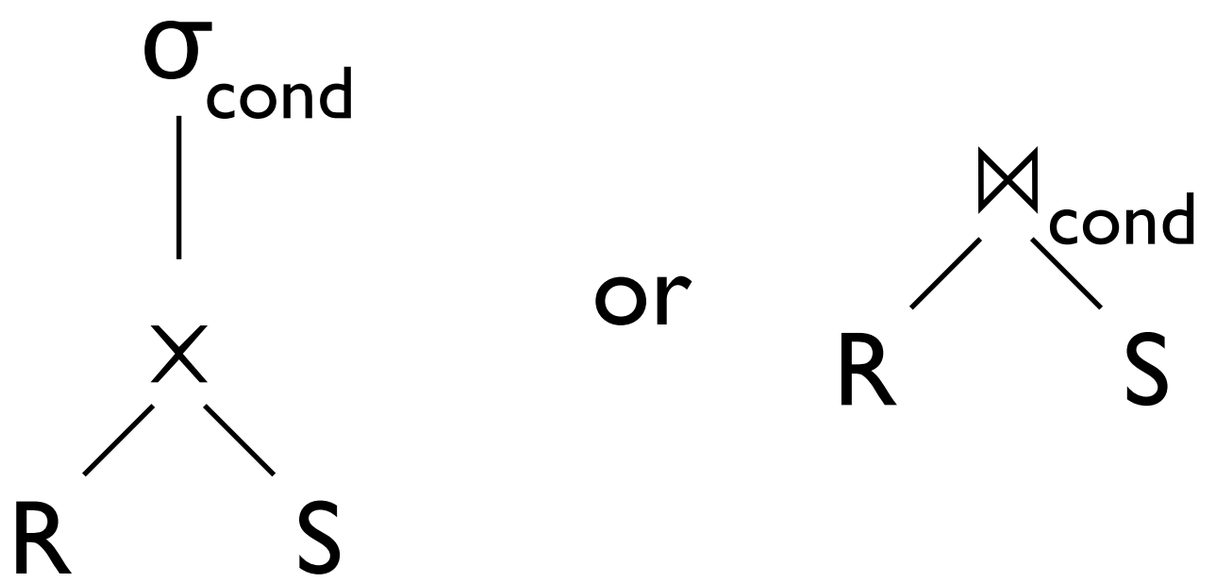


FROM Clause

```
FROM R NATURAL JOIN S
```

FROM Clause

```
FROM R NATURAL JOIN S
```

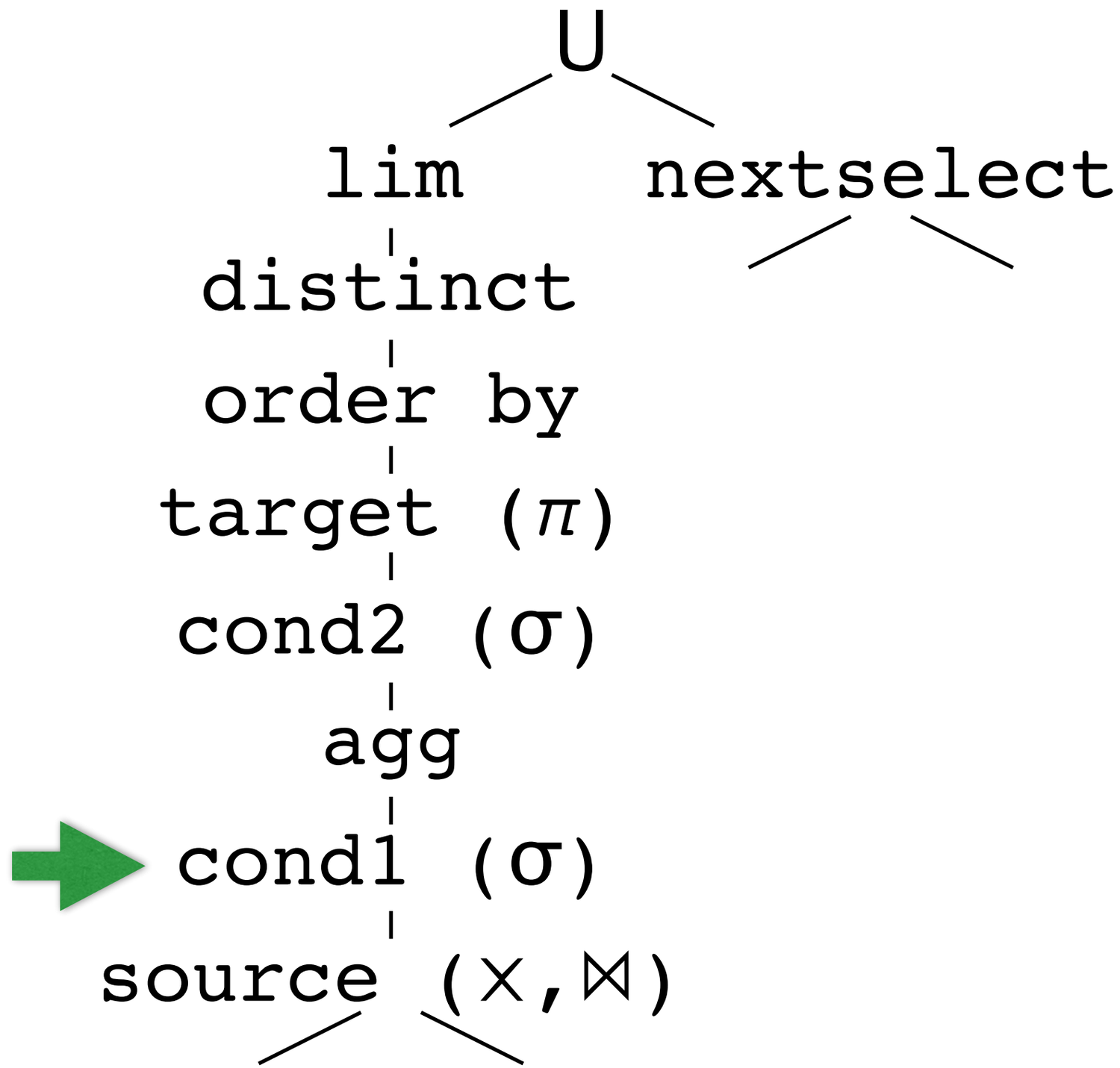



```
cond = schema(R) ∩ schema(S)
```

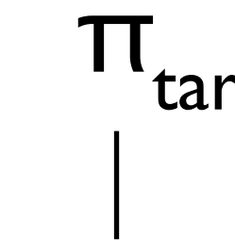
You need to be able to compute the schema of a RA operator

SQL to RA

```
SELECT [DISTINCT]
       target
FROM source
WHERE cond1
GROUP BY …
HAVING cond2
ORDER BY order
LIMIT lim
UNION nextselect
```



SELECT (target) Clause




```
SELECT *
```
no π (or target = `schema(input)`)

```
SELECT A, B, …
```
`targets = A, B, …`

```
SELECT R.*, S.*
```
`targets =`
`schema(input)` from R, S

Schemas need both Table Alias & Attribute Name (see Column class)

EvalLib

```
SELECT A + B
    How do you evaluate A + B

 WHERE A + B > 5
    How do you evaluate A + B > 5
```

EvalLib

```
SELECT A + B

    How do you evaluate A + B

  WHERE A + B > 5

    How do you evaluate A + B > 5
```

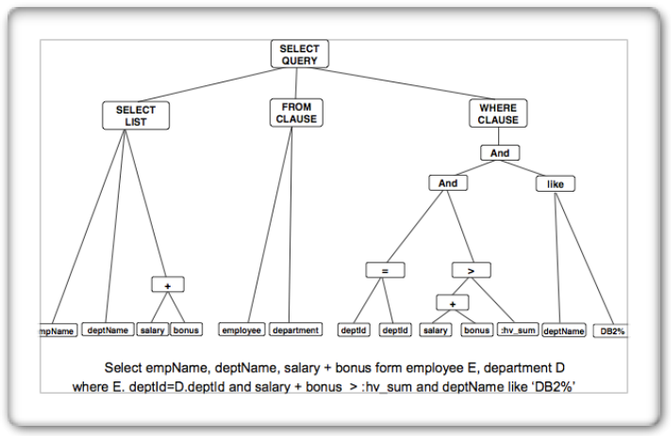
Tip 1: You can evaluate expressions recursively

Tip 2: Use visitor pattern

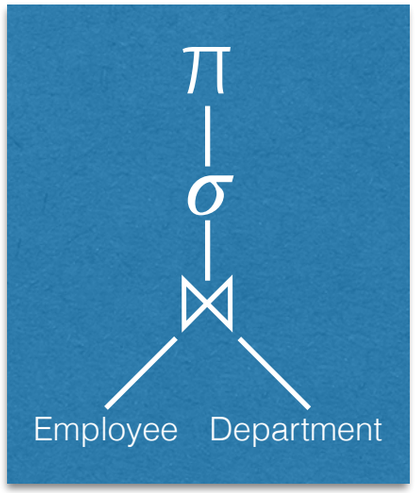
Evaluating RA

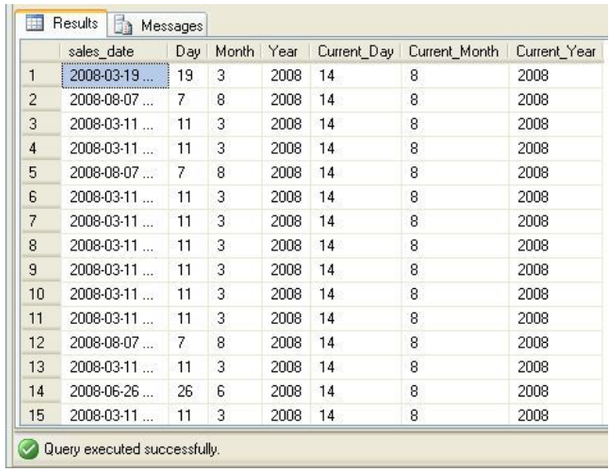
The Evaluation Pipeline

.sql



Parsed Query





	sales_date	Day	Month	Year	Current_Day	Current_Month	Current_Year
1	2008-03-19 ...	19	3	2008	14	8	2008
2	2008-08-07 ...	7	8	2008	14	8	2008
3	2008-03-11 ...	11	3	2008	14	8	2008
4	2008-03-11 ...	11	3	2008	14	8	2008
5	2008-08-07 ...	7	8	2008	14	8	2008
6	2008-03-11 ...	11	3	2008	14	8	2008
7	2008-03-11 ...	11	3	2008	14	8	2008
8	2008-03-11 ...	11	3	2008	14	8	2008
9	2008-03-11 ...	11	3	2008	14	8	2008
10	2008-03-11 ...	11	3	2008	14	8	2008
11	2008-03-11 ...	11	3	2008	14	8	2008
12	2008-08-07 ...	7	8	2008	14	8	2008
13	2008-03-11 ...	11	3	2008	14	8	2008
14	2008-06-26 ...	26	6	2008	14	8	2008
15	2008-03-11 ...	11	3	2008	14	8	2008

Results Messages

Query executed successfully.

Results

Data

How does this work? (now)

Evaluation Strategies

- **Staged Evaluation**: Start at leaves, Evaluate each operator as one step.

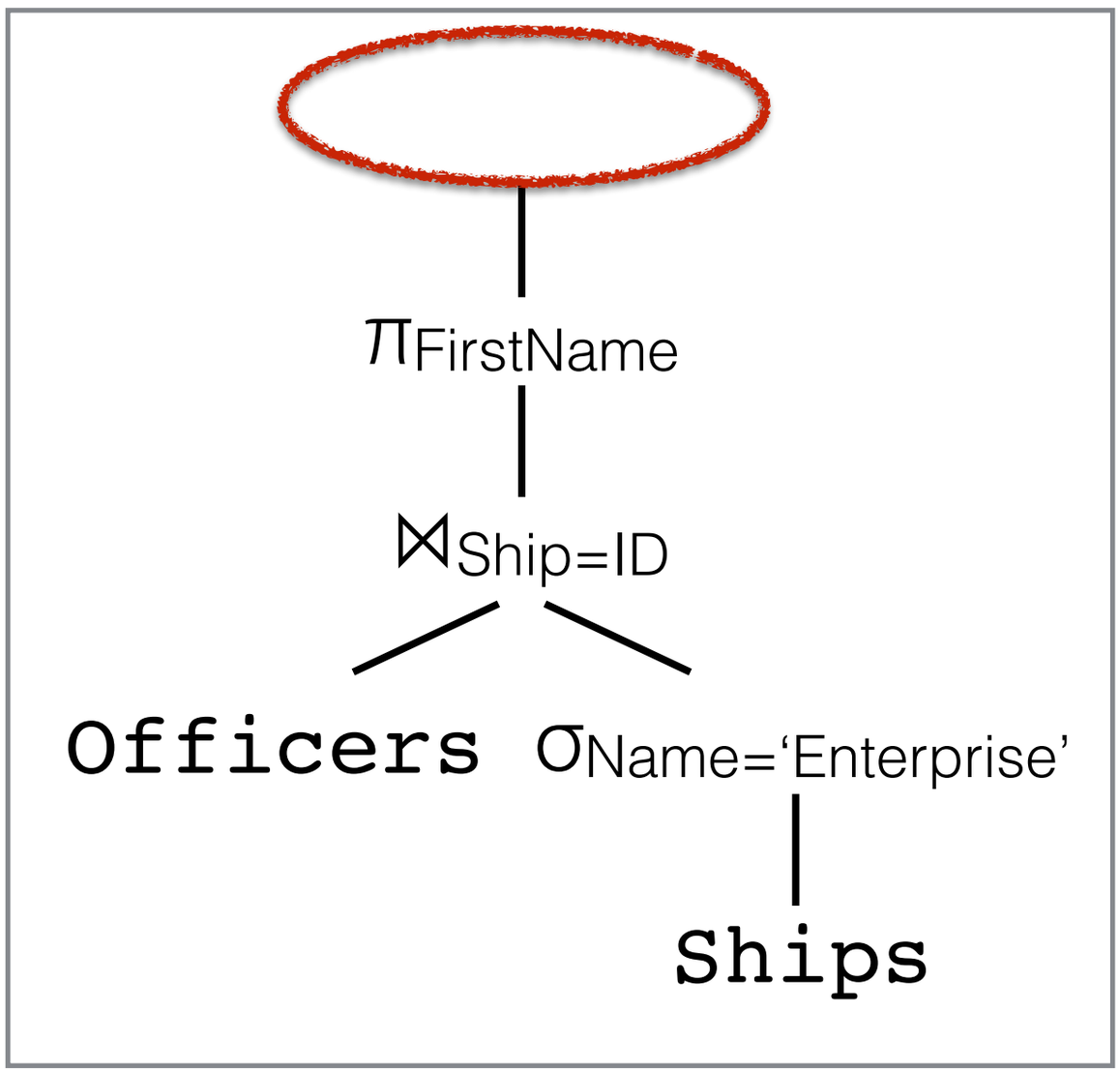
- **Pull Model**: Tuple-at-a-time Iterator for each operator (also called *Volcano Operators*) reads from source iterator(s).

- **Push Model**: Thread-per operator reads from input buffer(s) and writes to output buffer.

Evaluation Strategies

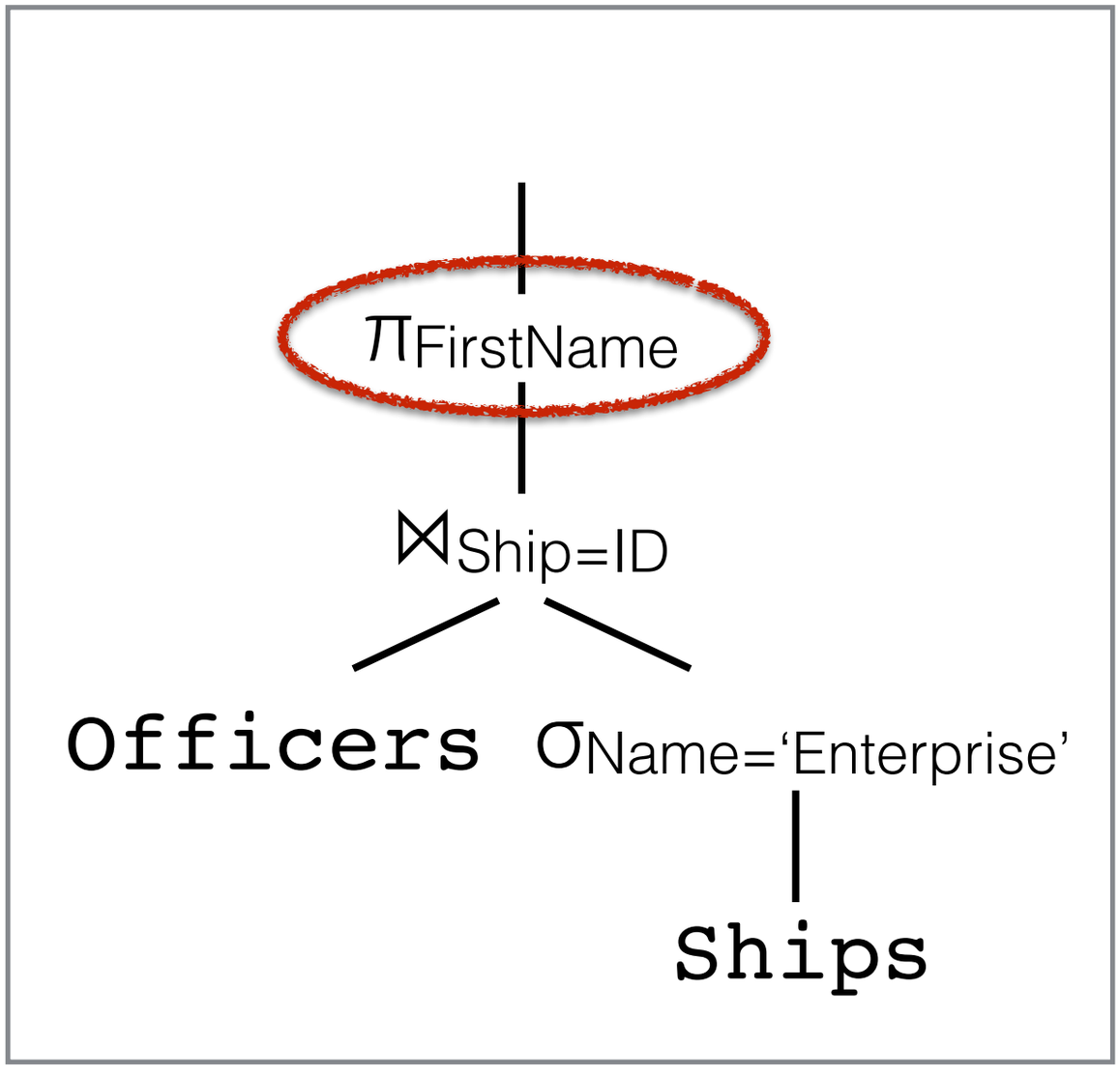
- **Pull Model**: Tuple-at-a-time Iterator for each operator (also called *Volcano Operators*) reads from source iterator(s).

Staged Evaluation



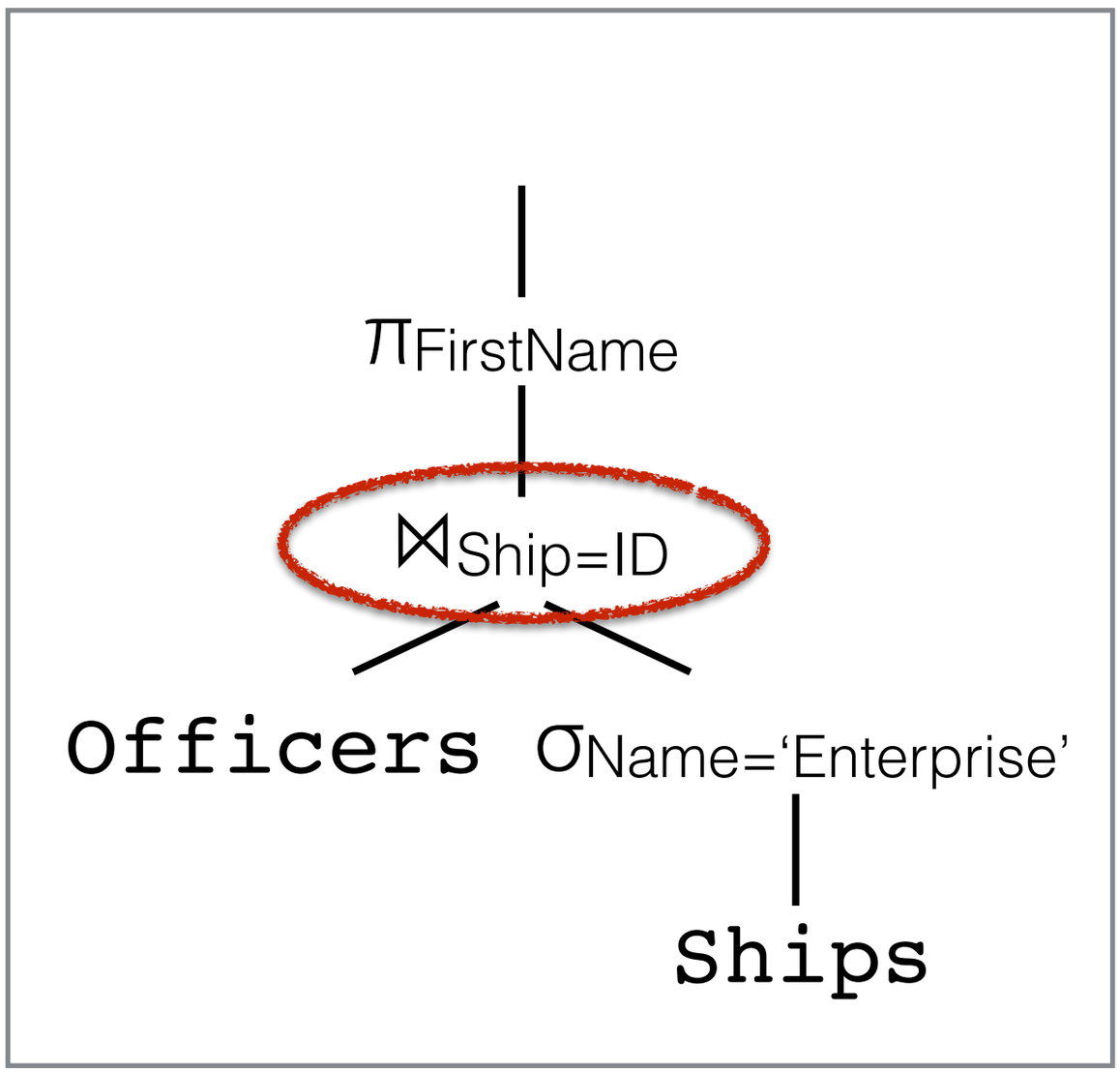
Compute the Output

Staged Evaluation



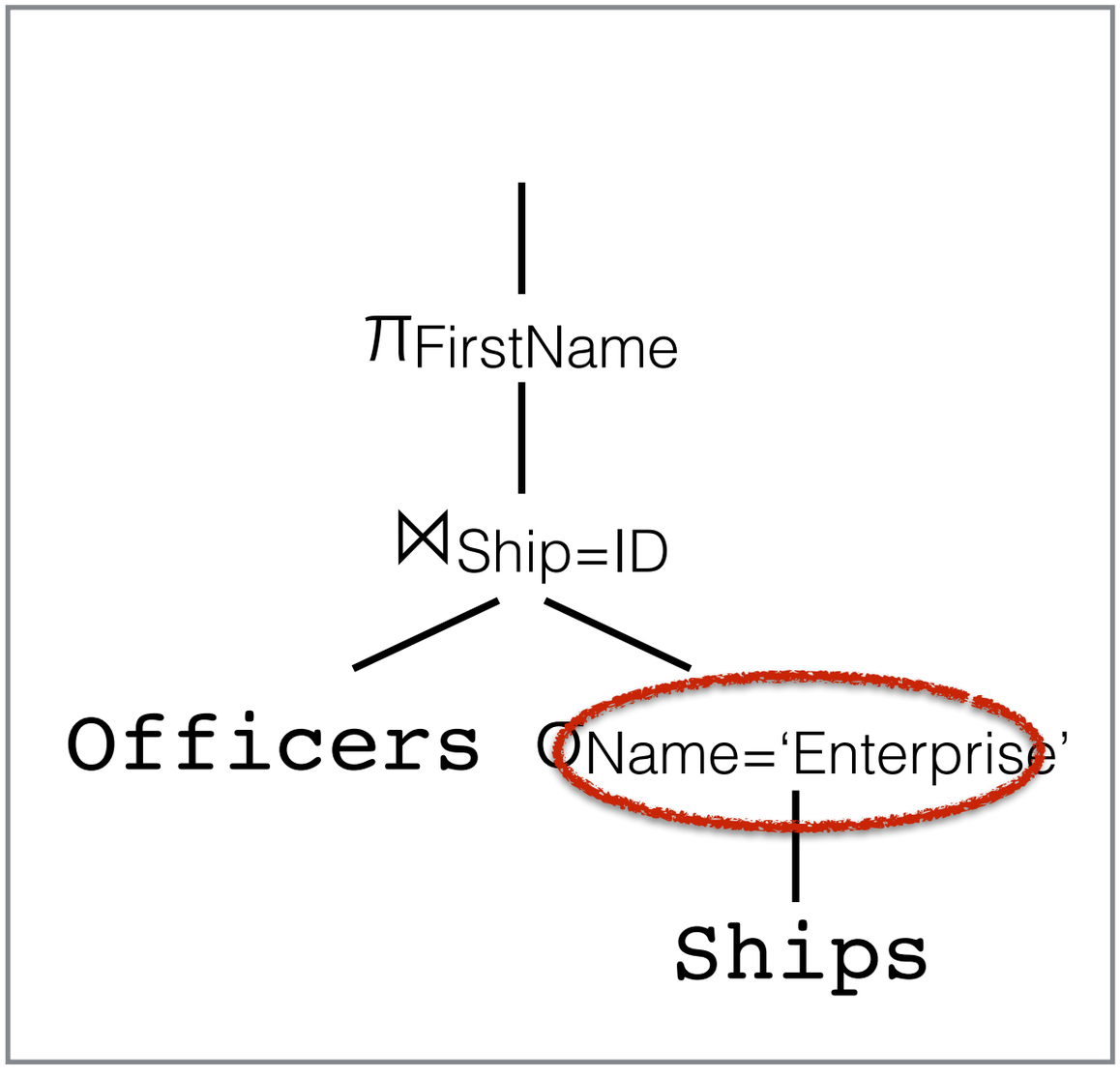
Compute the Output
Dependency: Compute π

Staged Evaluation



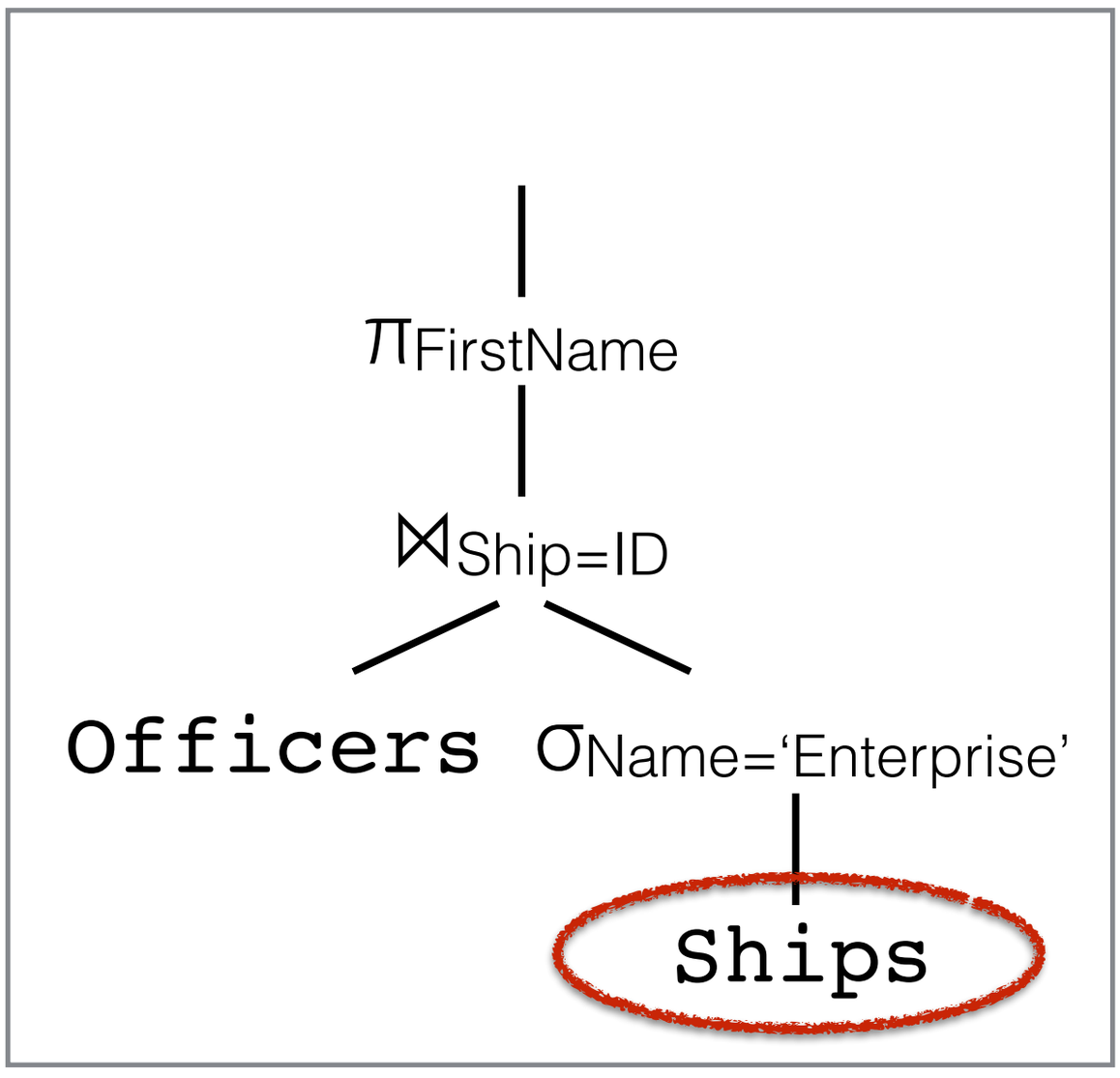
Compute the Output
Dependency: Compute π
Dependency: Compute ⋈

Staged Evaluation



Compute the Output
Dependency: Compute π
Dependency: Compute ⋈
Dependency: Compute σ

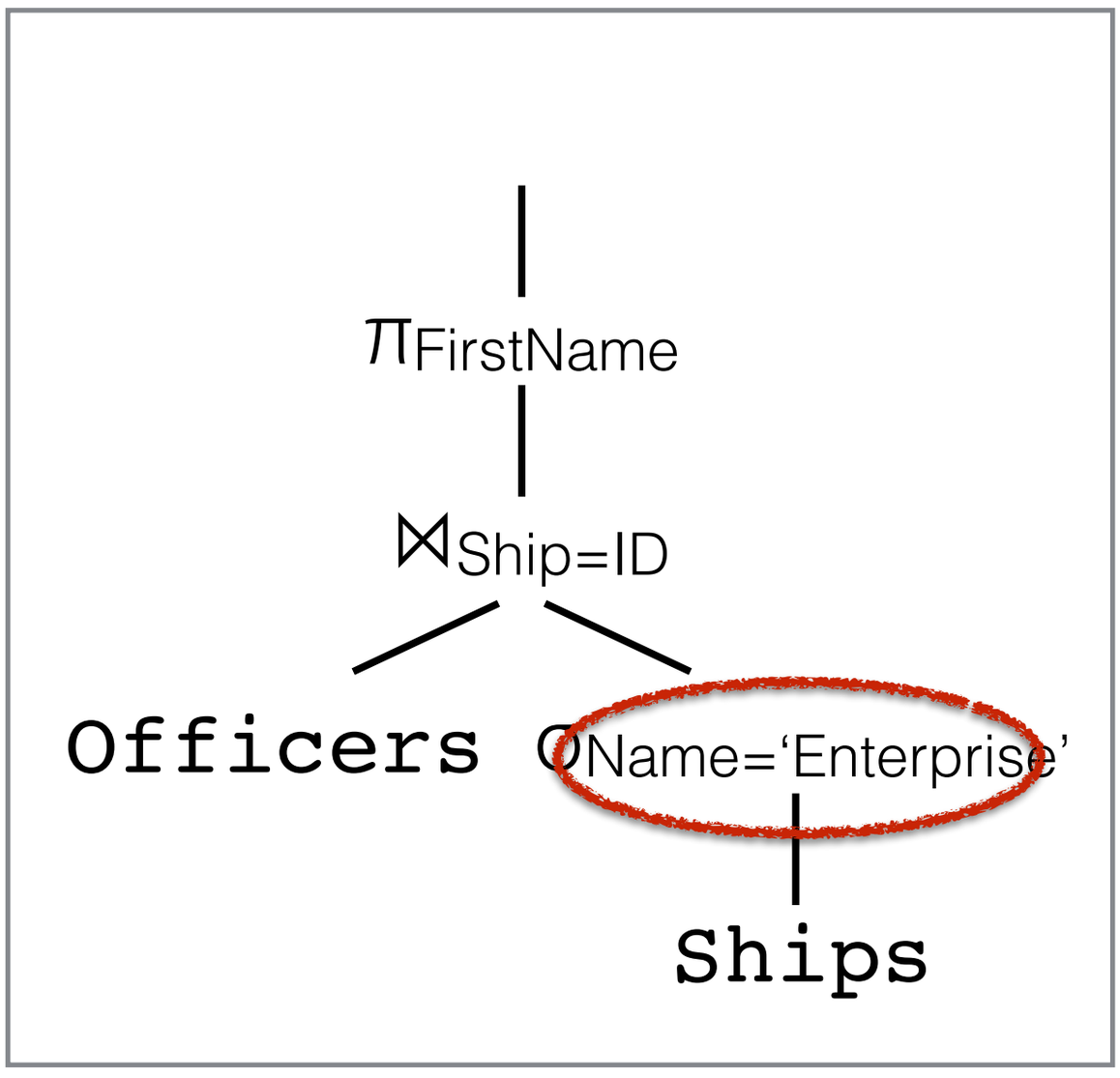
Staged Evaluation



Compute the Output
Dependency: Compute π
Dependency: Compute ⋈
Dependency: Compute σ
Dependency: Load `Ships`

ID,	Name
[1701,	Enterprise]
[DS9,	Deep Space 9]
[74656,	Voyager]
[75633,	Defiant]

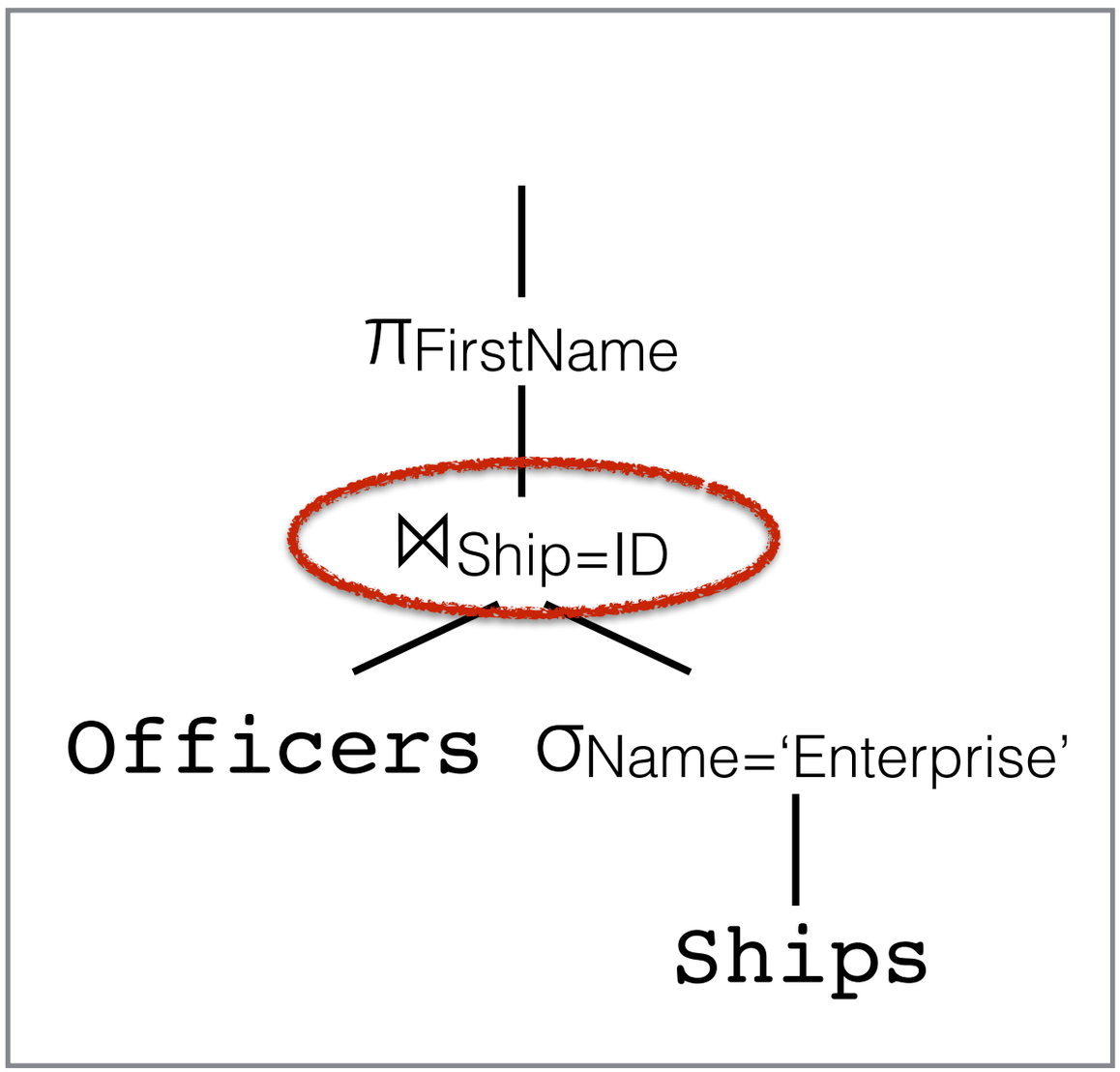
Staged Evaluation



Compute the Output
Dependency: Compute π
Dependency: Compute ⋈
Dependency: Compute σ

ID,	Name
[1701,	Enterprise]
[DS9,	Deep Space 9]
[74656,	Voyager]
[75633,	Defiant]

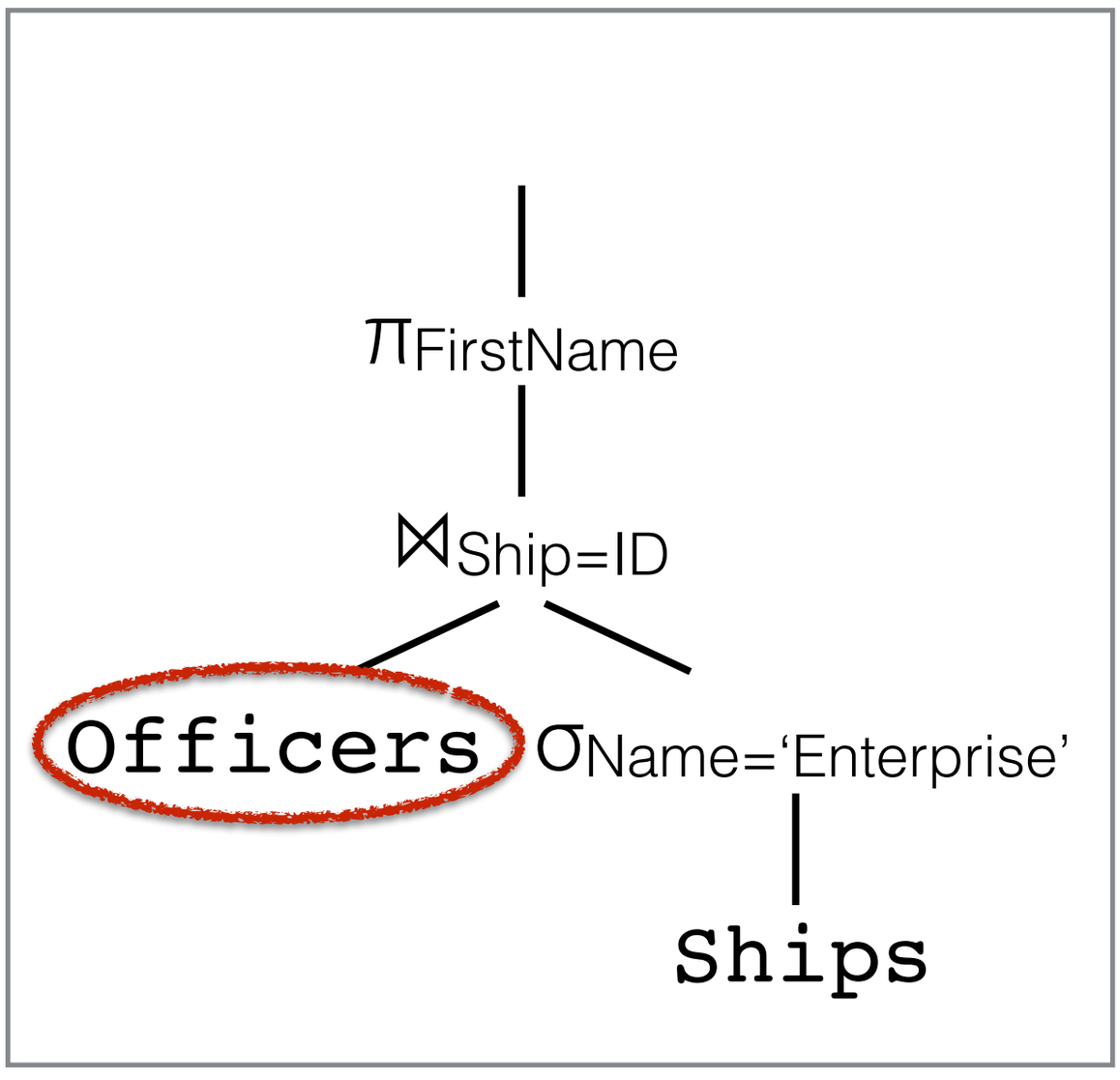
Staged Evaluation



Compute the Output
Dependency: Compute π
Dependency: Compute ⋈

ID,	Name
[1701,	Enterprise]

Staged Evaluation

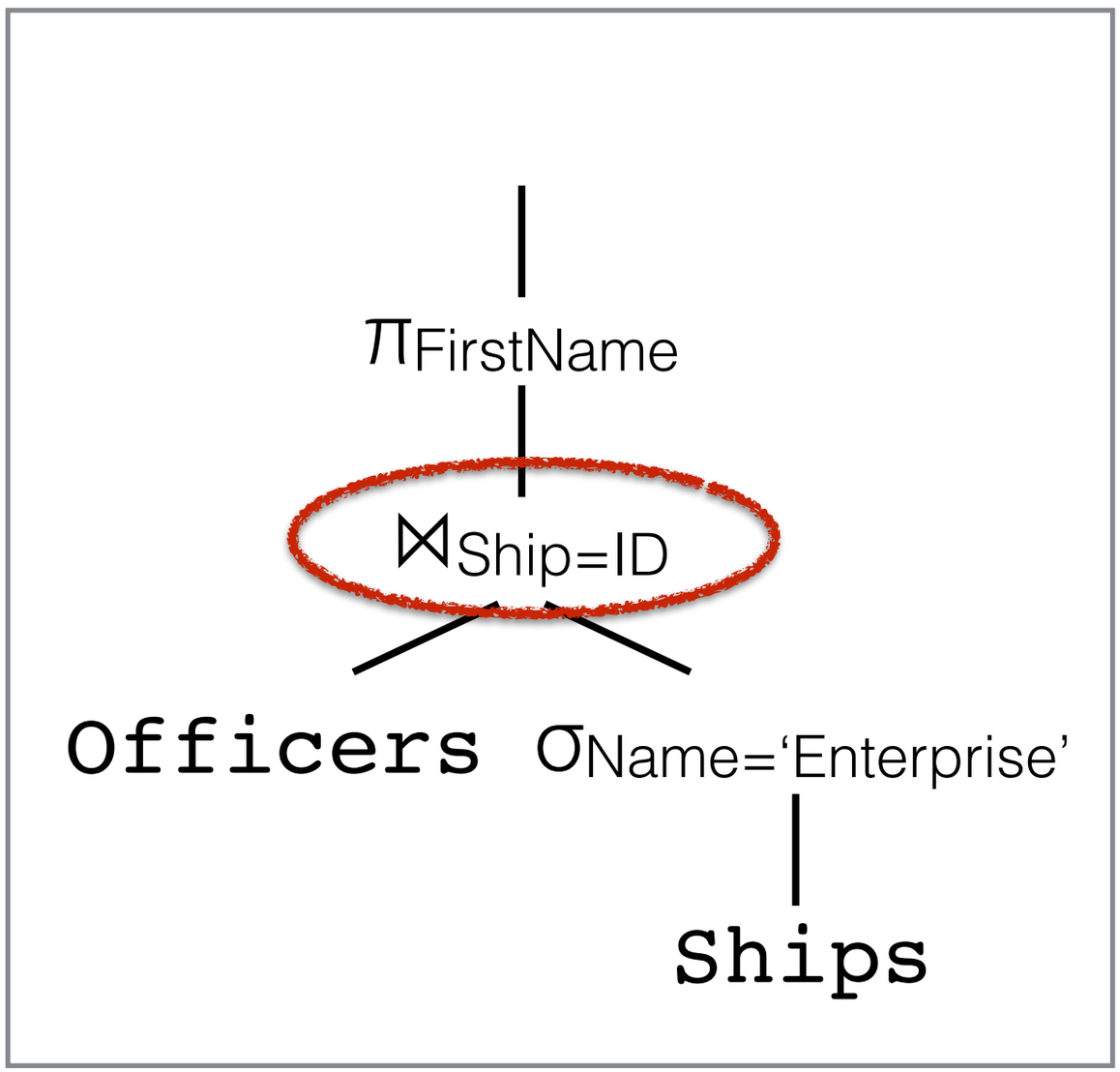


Compute the Output
Dependency: Compute π
Dependency: Compute ⋈
Dependency: Load `Officers`

ID,	Name
[1701,	Enterprise]

FirstName,	LastName,	Rank,	Ship
[James,	Kirk,	4.0,	1701]
[Jean Luc,	Picard,	4.0,	1701D]
[Benjamin,	Sisko,	3.0,	DS9]
[Kathryn,	Janeway,	4.0,	74656]
[Nerys,	Kira,	2.5,	75633]
[Spock,	NULL,	2.5,	1701]
[William,	Riker,	2.5,	1701D]
[Nerys,	Kira,	2.5,	DS9]
[Chakotay,	NULL,	3.0,	74656]

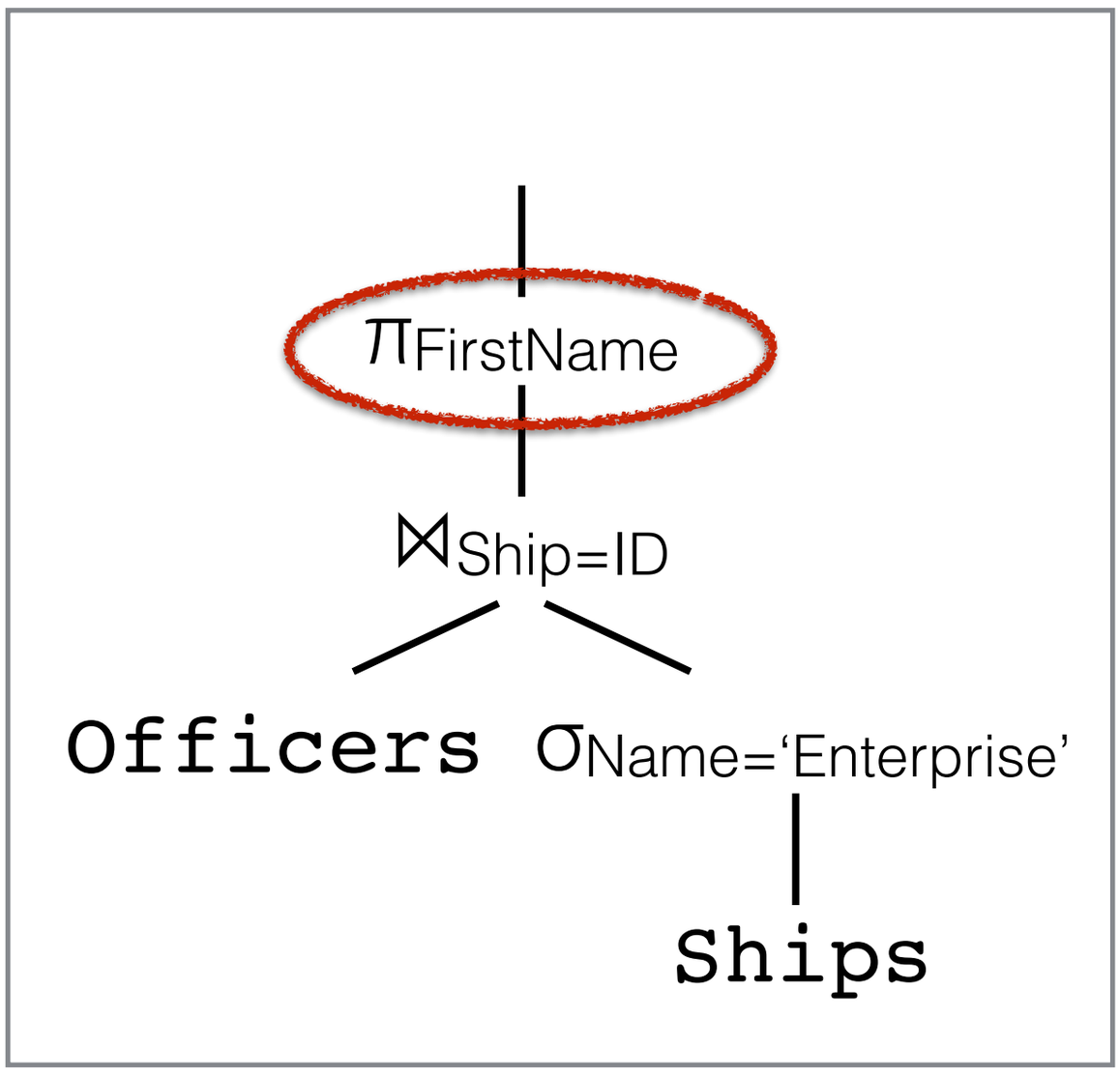
Staged Evaluation



Compute the Output
Dependency: Compute π
Dependency: Compute ⋈

FirstName,	LastName,	Rank,	Ship,	ID,	Name
[James,	Kirk,	4.0,	1701,	1701,	Enterprise]
[Spock,	NULL,	2.5,	1701,	1701,	Enterprise]

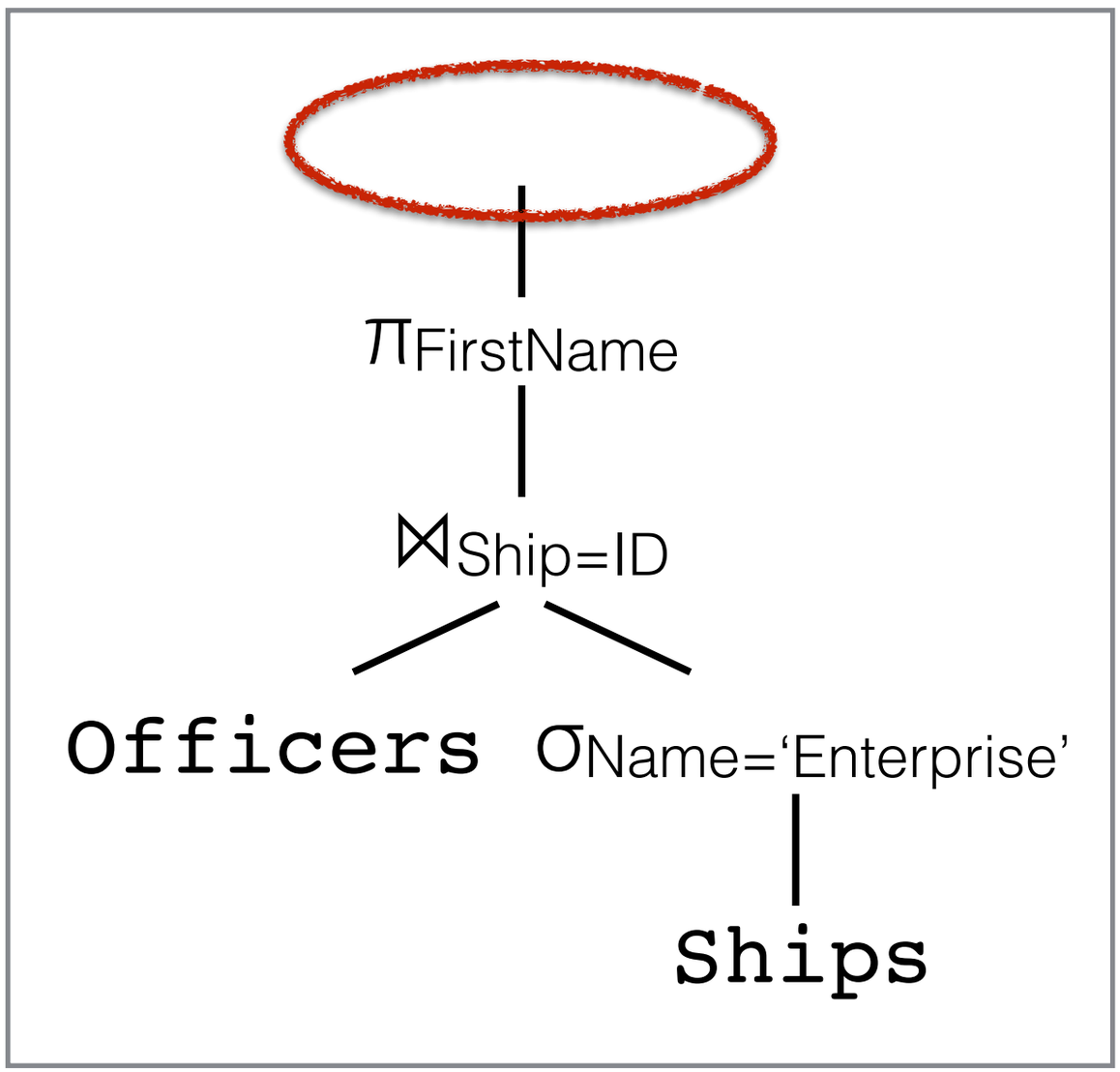
Staged Evaluation



Compute the Output
Dependency: Compute π

FirstName,	LastName,	Rank,	Ship,	ID,	Name
[James,]	Kirk,	4.0,	1701,	1701,	Enterprise]
[Spock,]	NULL,	2.5,	1701,	1701,	Enterprise]

Staged Evaluation



Compute the Output

FirstName
James
Spock

Staged Evaluation

Can we do better?

Staged Evaluation

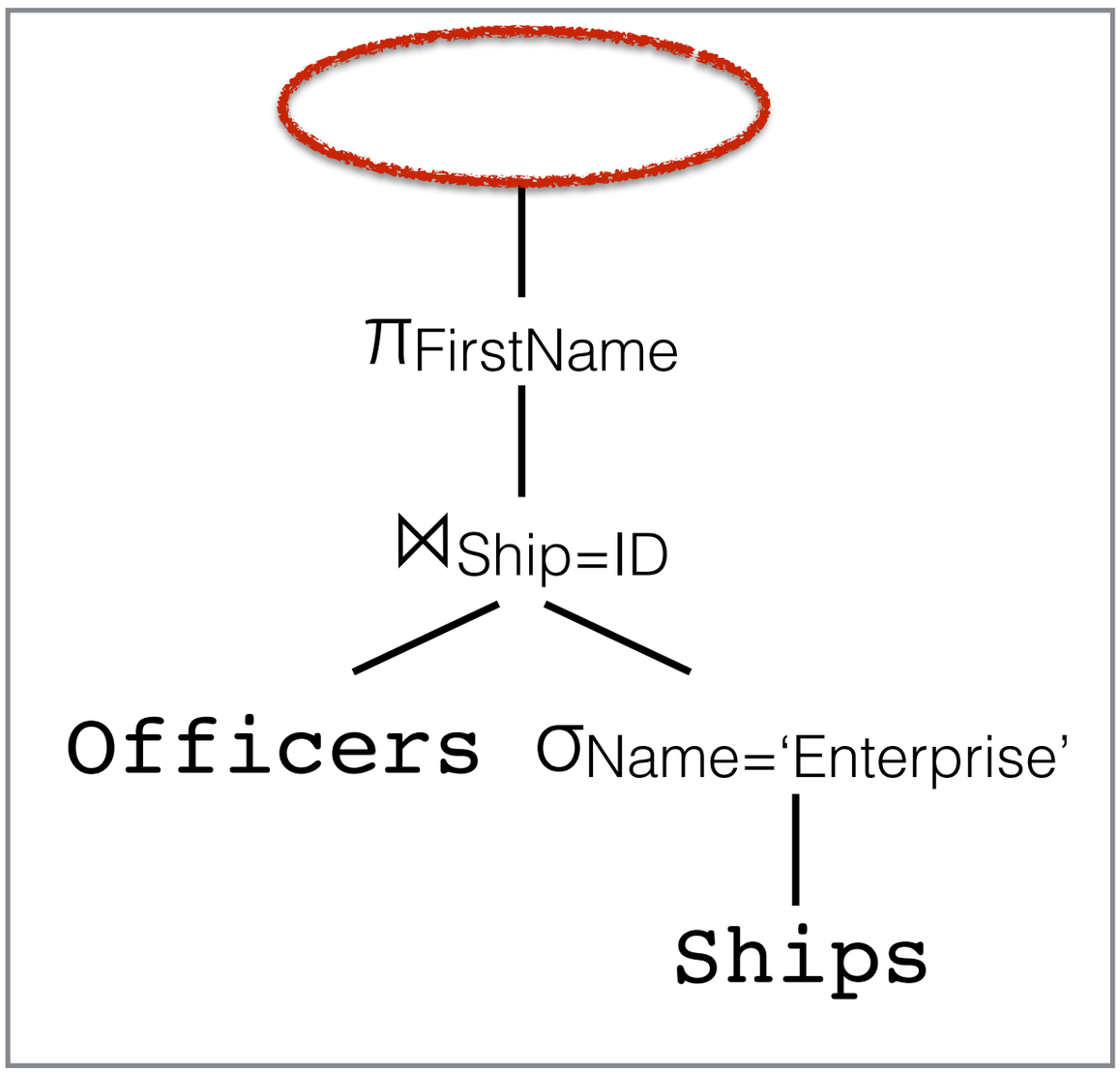
- **Expensive**: Lots of Bulk Copies
- **Cache Locality**: Repeated Scans over Full Tables
- **Memory Use**: Working Set is a Full Table (or more)

How do we do better?

The Memory Hierarchy and You

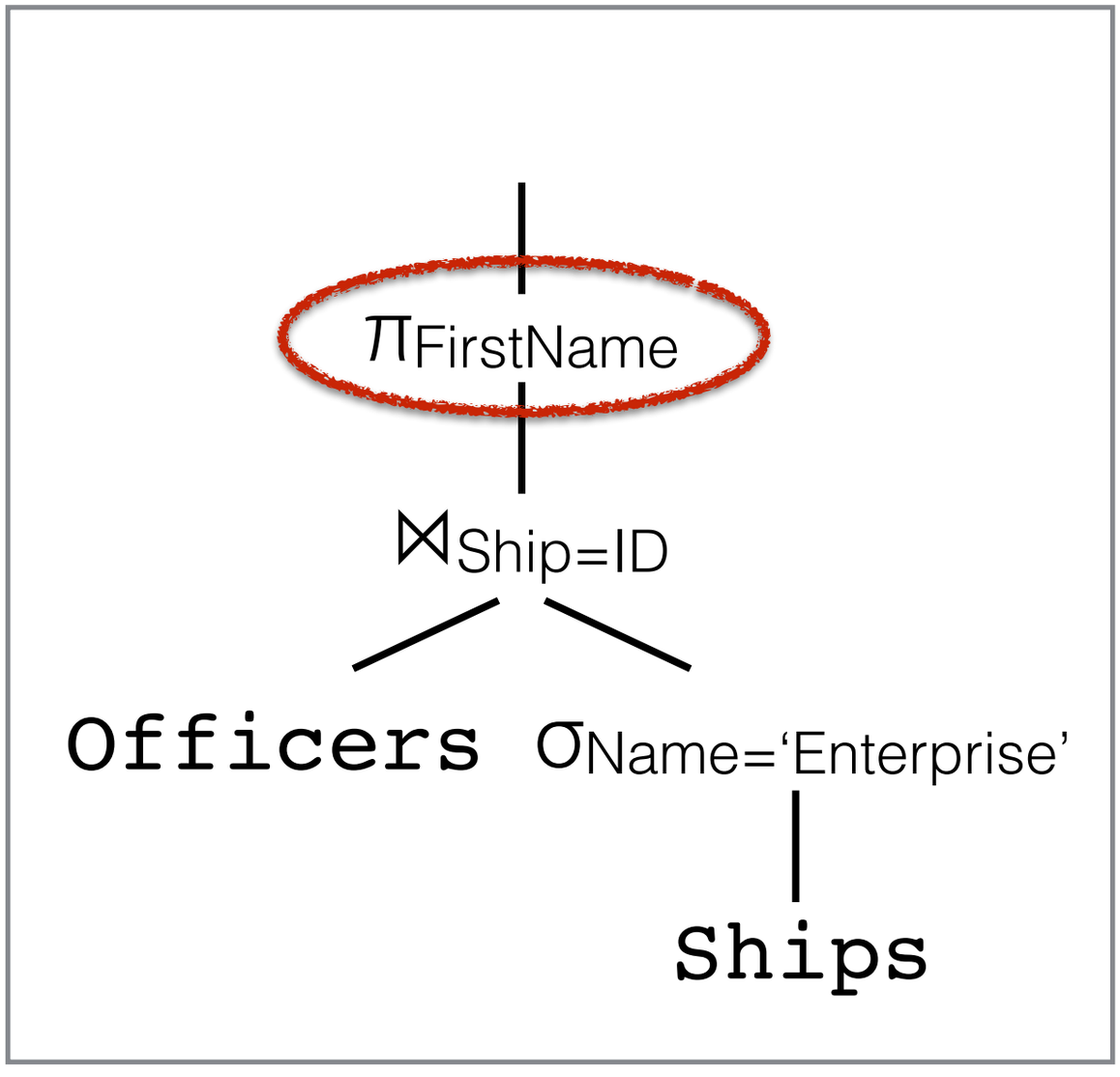
- We want to keep data as close to the CPU as possible
  - Faster memory == Smaller memory
- **Solution 1:** Minimize the Working Set Size!
  - (the memory used at any one time)
- **Solution 2:** Aggressively Batch & Reuse Data

Volcano Evaluation



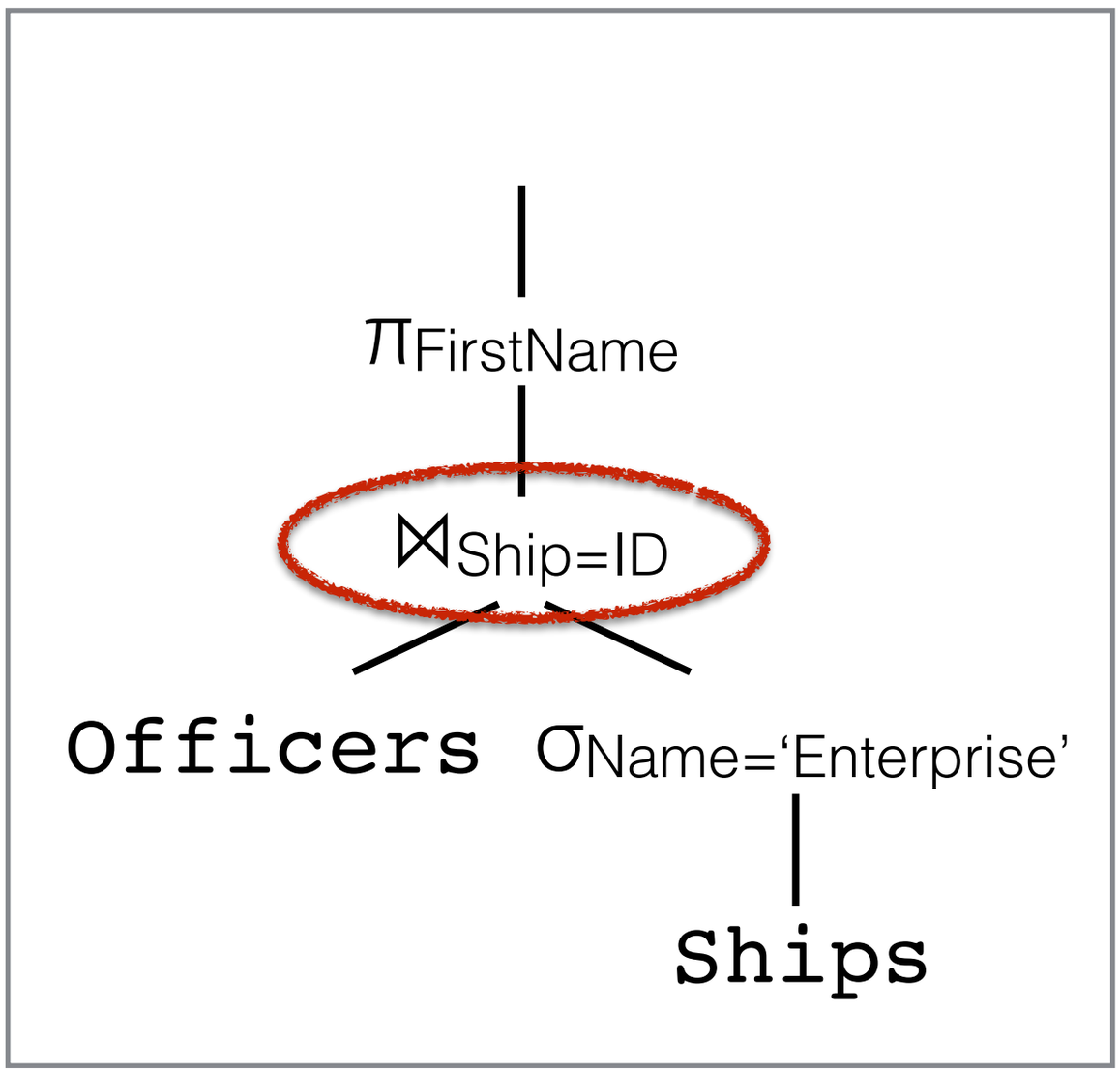
Compute one tuple

Volcano Evaluation



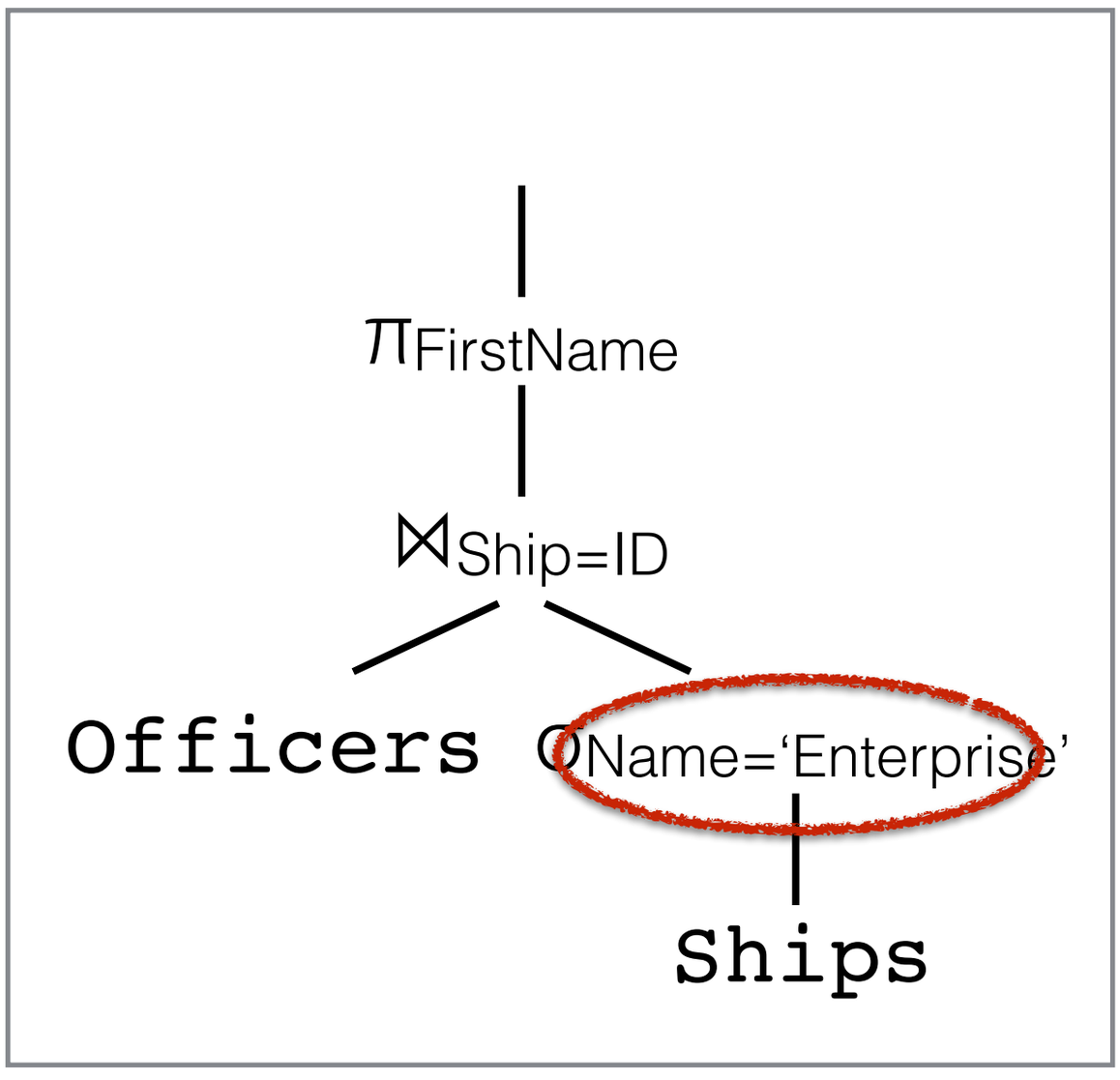
Compute one tuple
Dependency: Next tuple from π

Volcano Evaluation



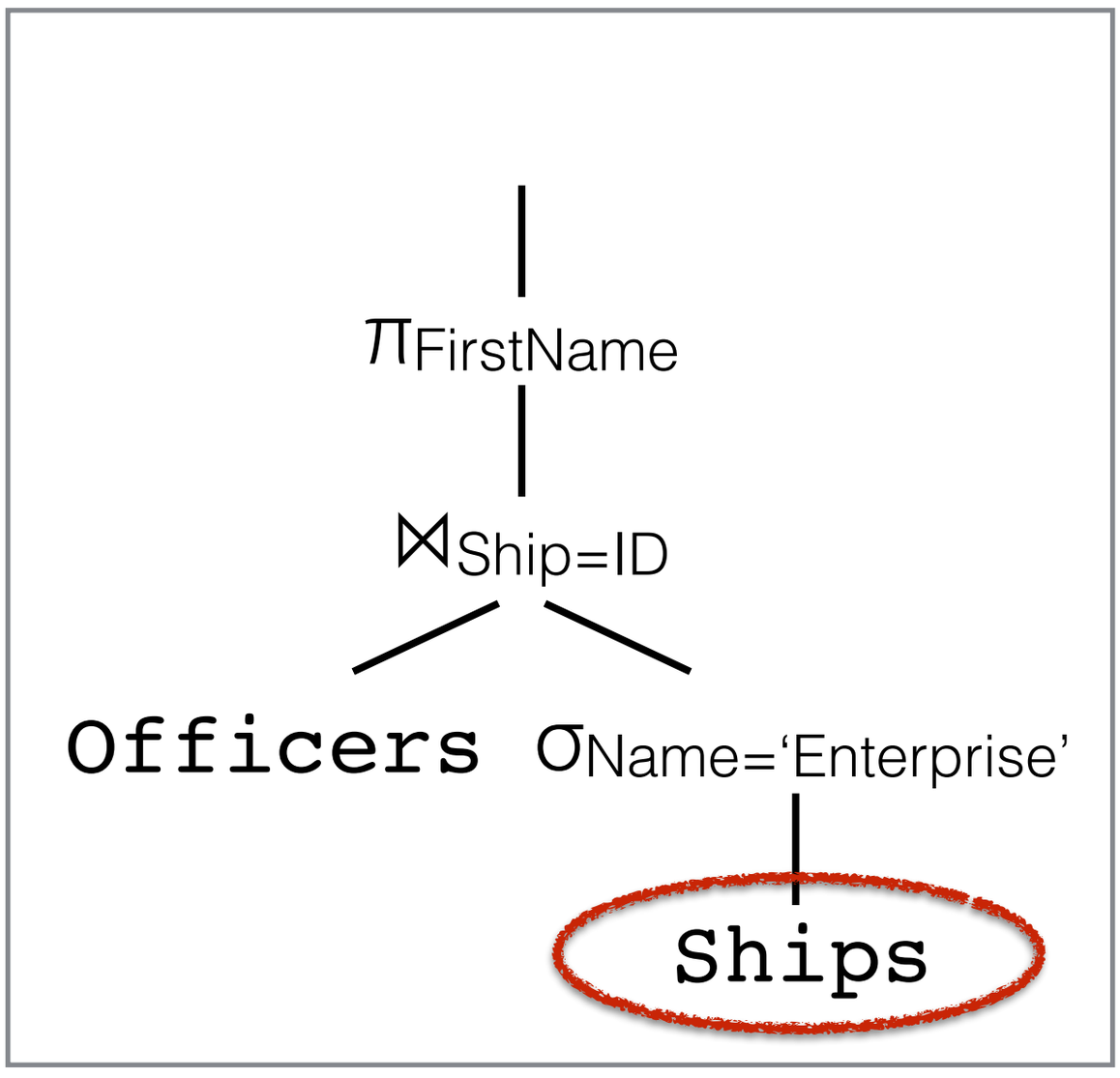
Compute one tuple
Dependency: Next tuple from π
Dependency: Next tuple from ⋈

Volcano Evaluation



Compute one tuple
Dependency: Next tuple from π
Dependency: Next tuple from ⋈
Dependency: Next tuple from σ

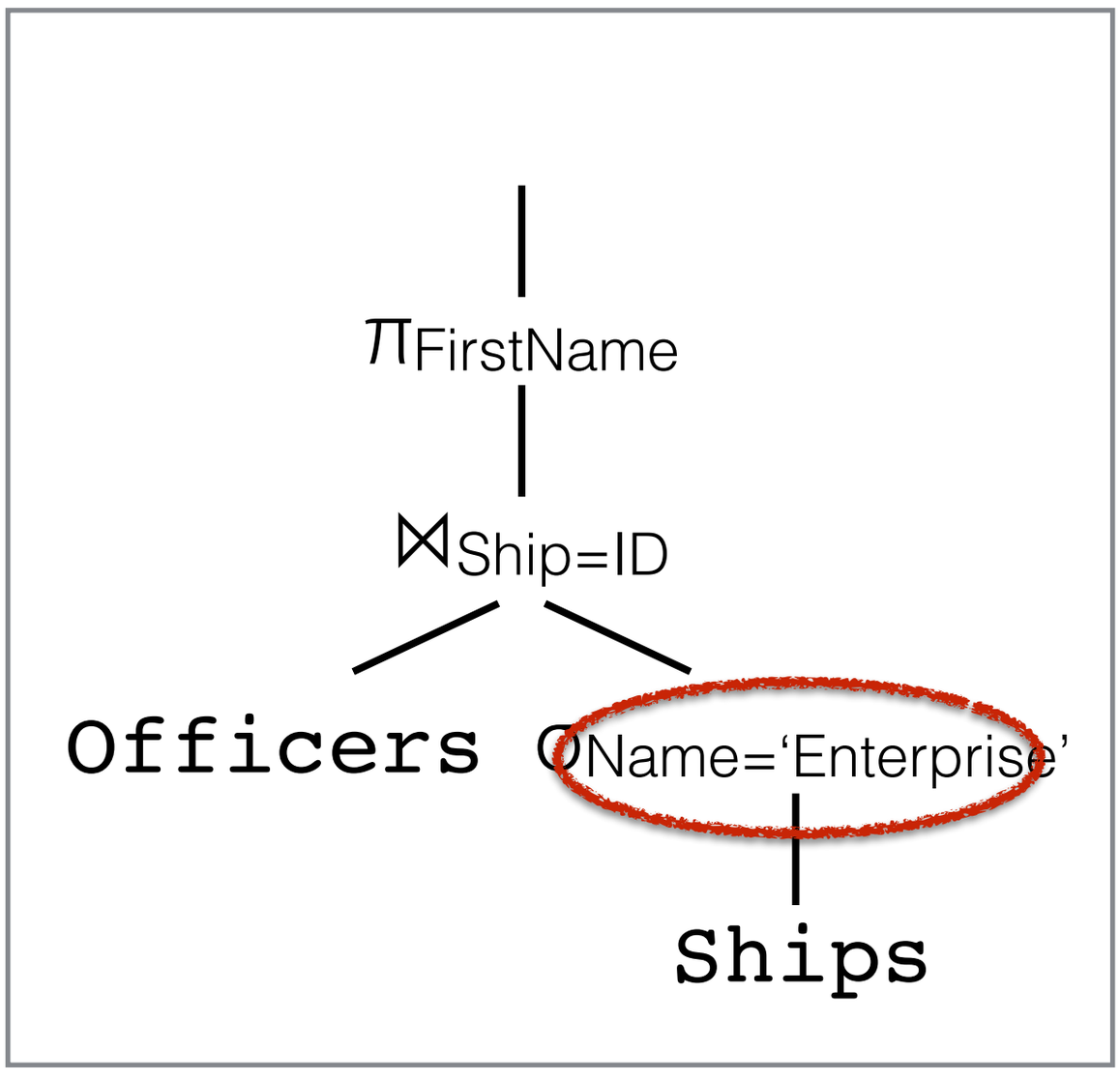
Volcano Evaluation



Compute one tuple
Dependency: Next tuple from π
Dependency: Next tuple from ⋈
Dependency: Next tuple from σ
Dependency: Tuple from `Ships`

ID,	Name
[1701,	Enterprise]

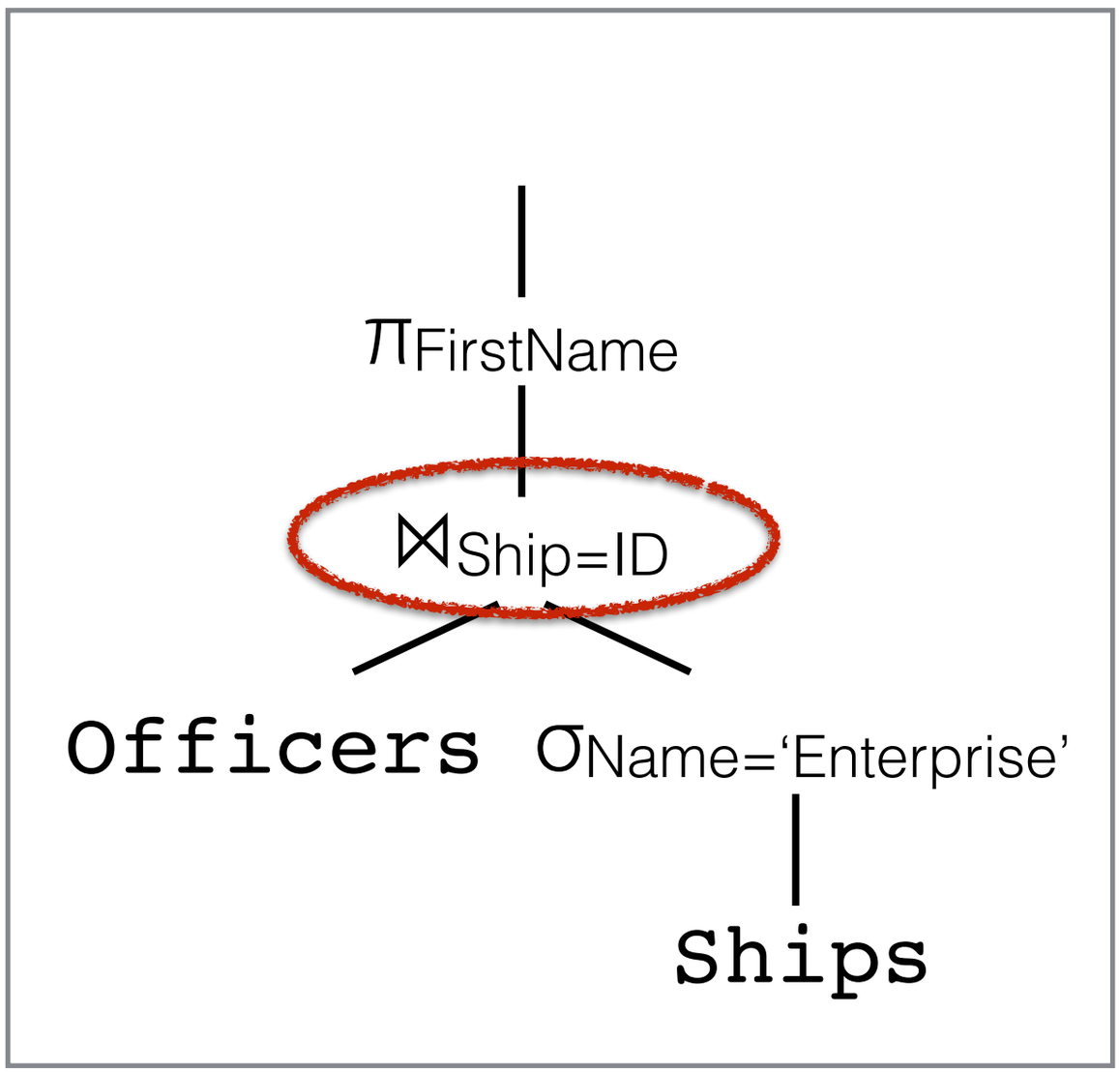
Volcano Evaluation



Compute one tuple
Dependency: Next tuple from π
Dependency: Next tuple from ⋈
Dependency: Next tuple from σ

ID,	Name
[1701,	Enterprise]

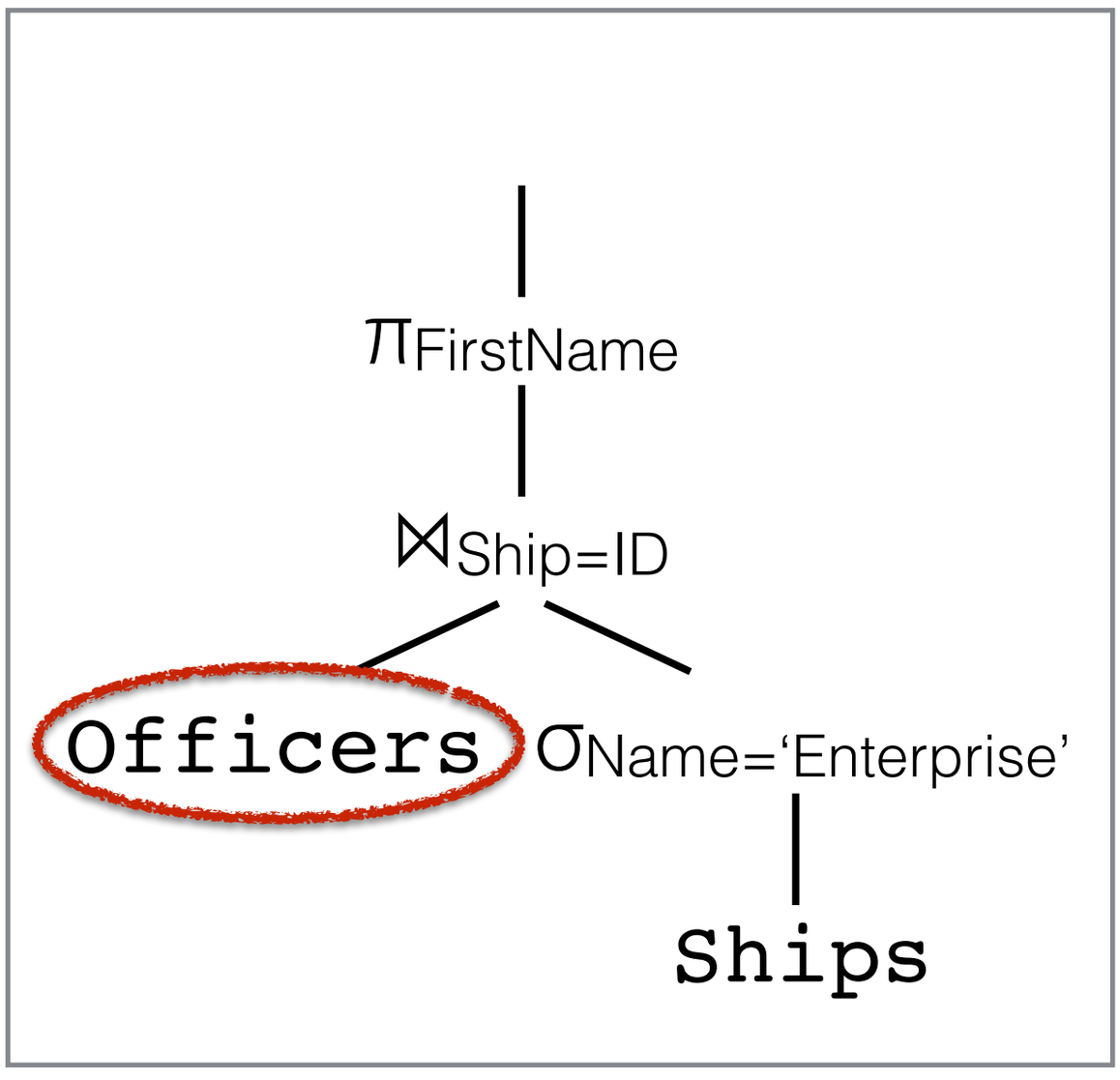
Volcano Evaluation



Compute one tuple
Dependency: Next tuple from π
Dependency: Next tuple from ⋈

ID,	Name
[1701,	Enterprise]

Volcano Evaluation

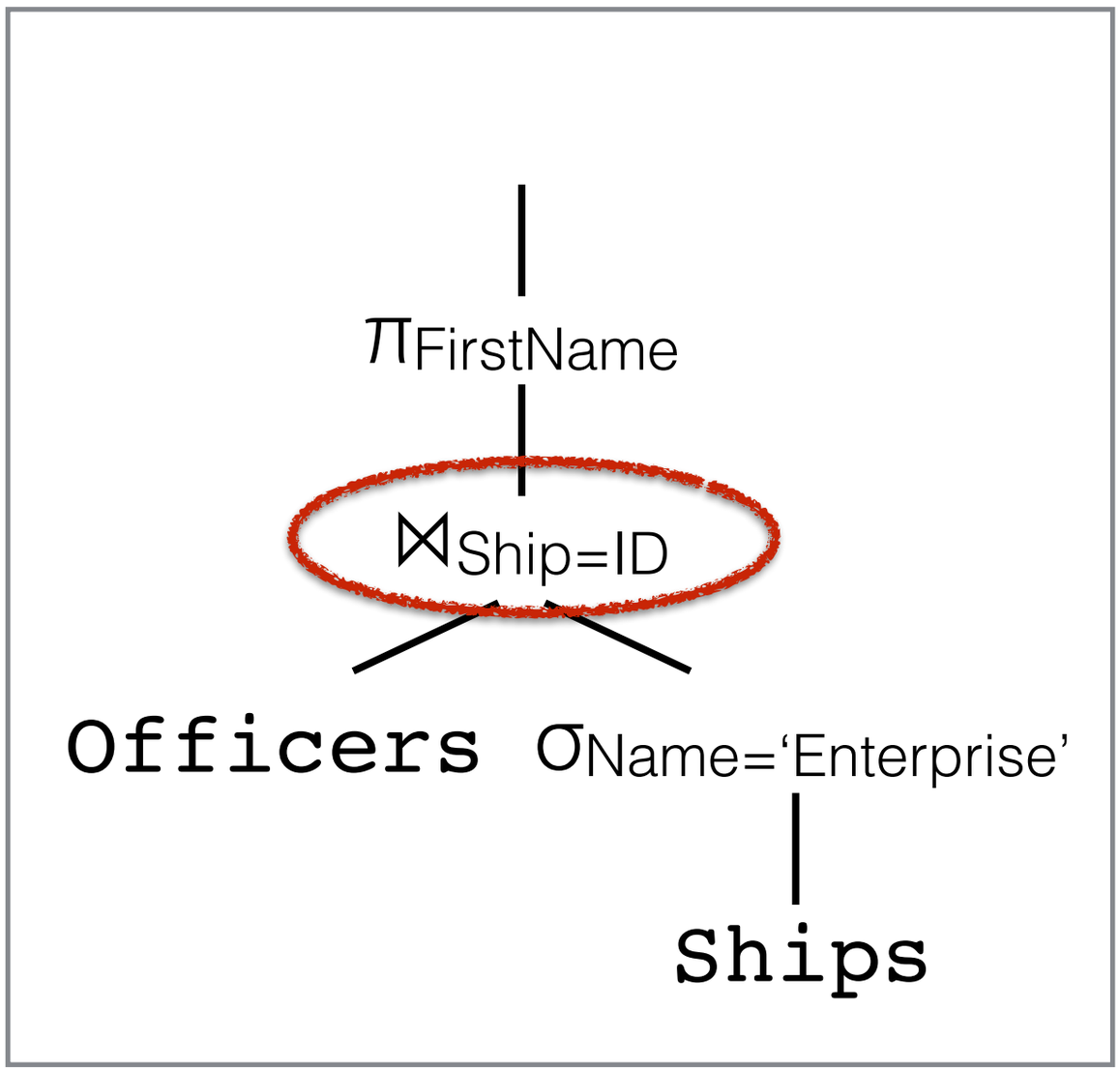


Compute one tuple
Dependency: Next tuple from π
Dependency: Next tuple from ⋈
Dependency: Tuple f. `Officers`

ID,	Name
[1701,	Enterprise]

FirstName,	LastName,	Rank,	Ship
[James,	Kirk,	4.0,	1701]

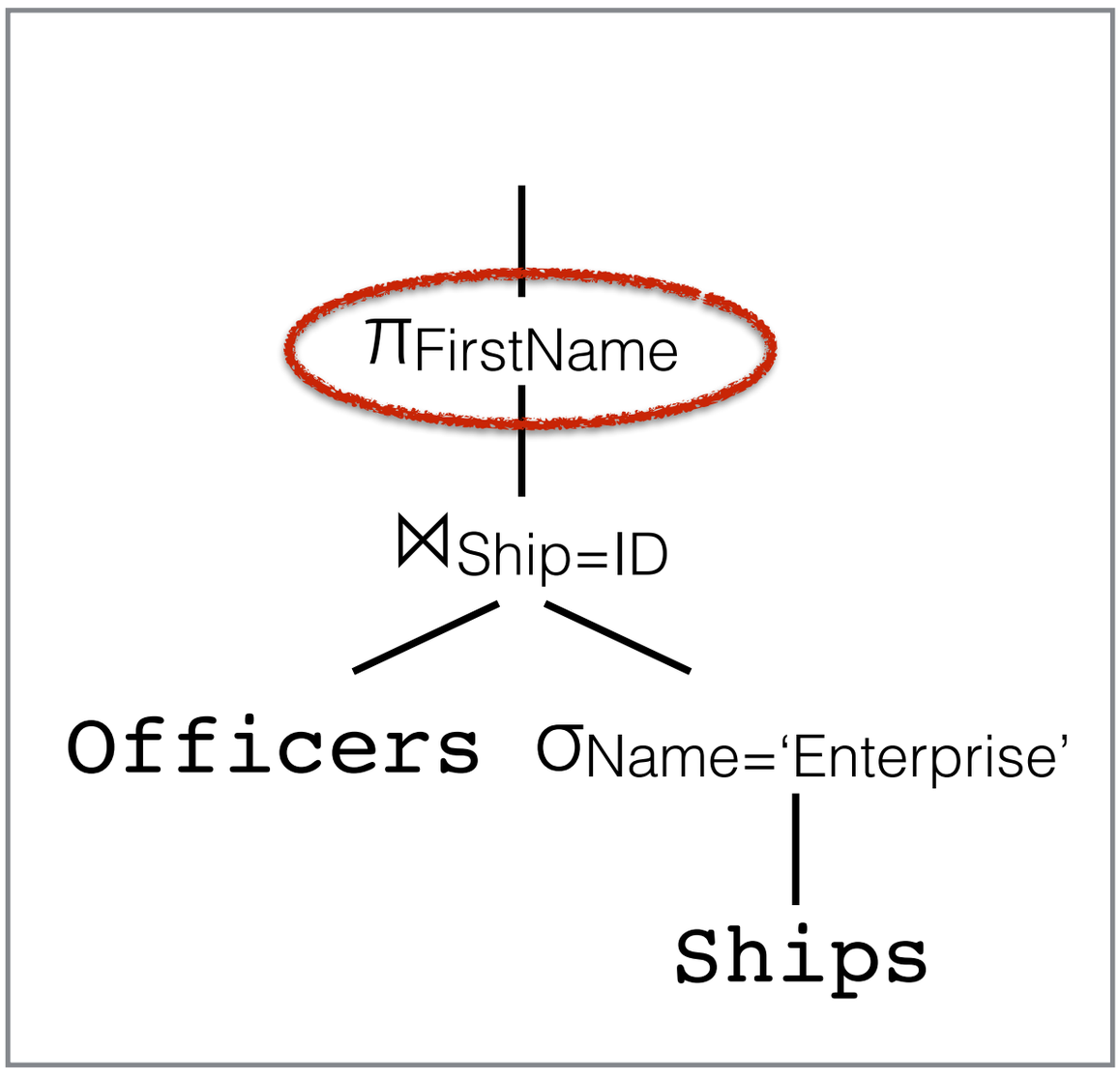
Volcano Evaluation



Compute one tuple
Dependency: Next tuple from π
Dependency: Next tuple from ⋈

FirstName,	LastName,	Rank,	Ship,	ID,	Name
[James,	Kirk,	4.0,	1701,	1701,	Enterprise]

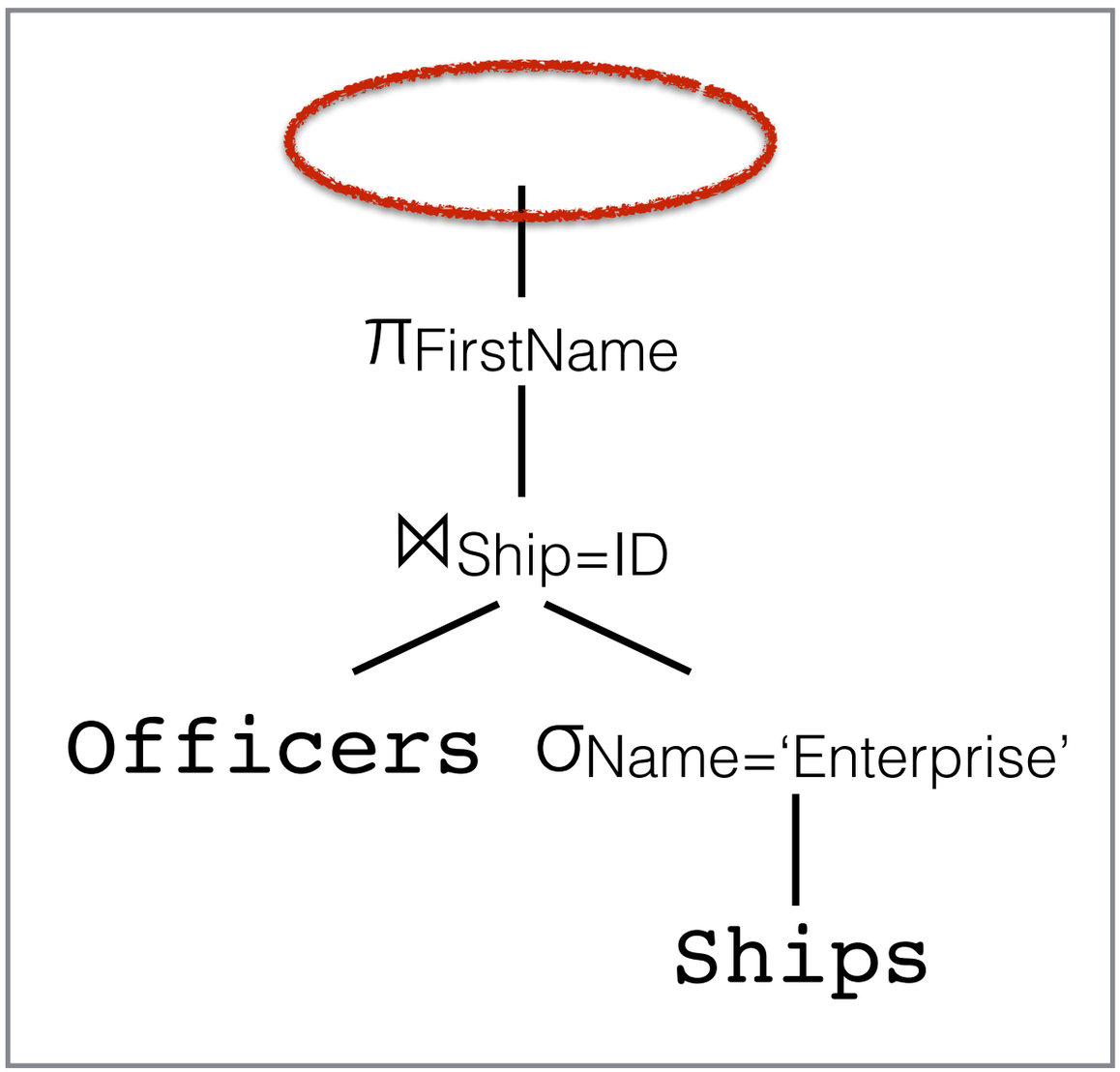
Volcano Evaluation



Compute one tuple
Dependency: Next tuple from π

FirstName,	LastName,	Rank,	Ship,	ID,	Name
[James,]	Kirk,	4.0,	1701,	1701,	Enterprise]

Volcano Evaluation



Compute one tuple

FirstName
[James]

Iterators

```
void open() {
  // call open() on child iterators
  // prepare the iterator
}

Tuple getNext() {
  // read, process, and return a tuple
}

void close() {
  // clean-up the iterator
  // call close() on child iterators
}
```

GetNext()

Relation (I called this "scan operator" before)

Read One Line from File

↓

Split Line into Fields

↓

Parse Field Types

↓

Return Tuple

What is the Working Set Size?

GetNext()

Projection (π)

Read One Tuple

↓

Compute Projected Attributes

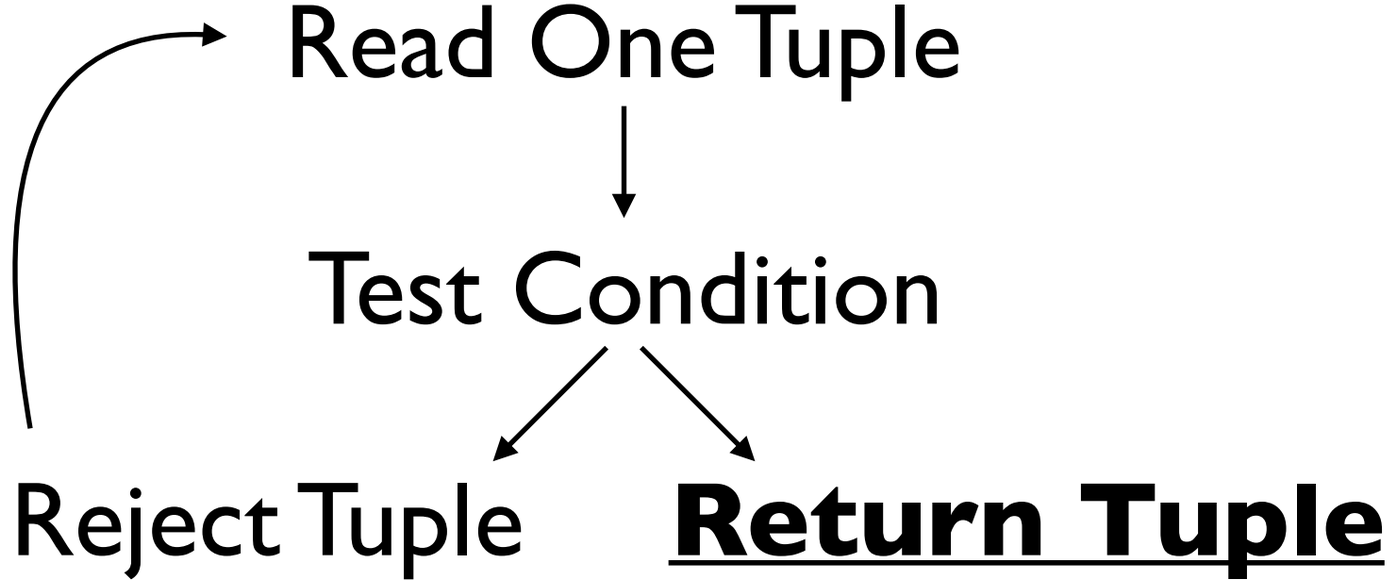
↓

Return Tuple

What is the Working Set Size?

GetNext()

Selection (σ)



What is the Working Set Size?

GetNext()

Union (U)

Read One Tuple from R

↓

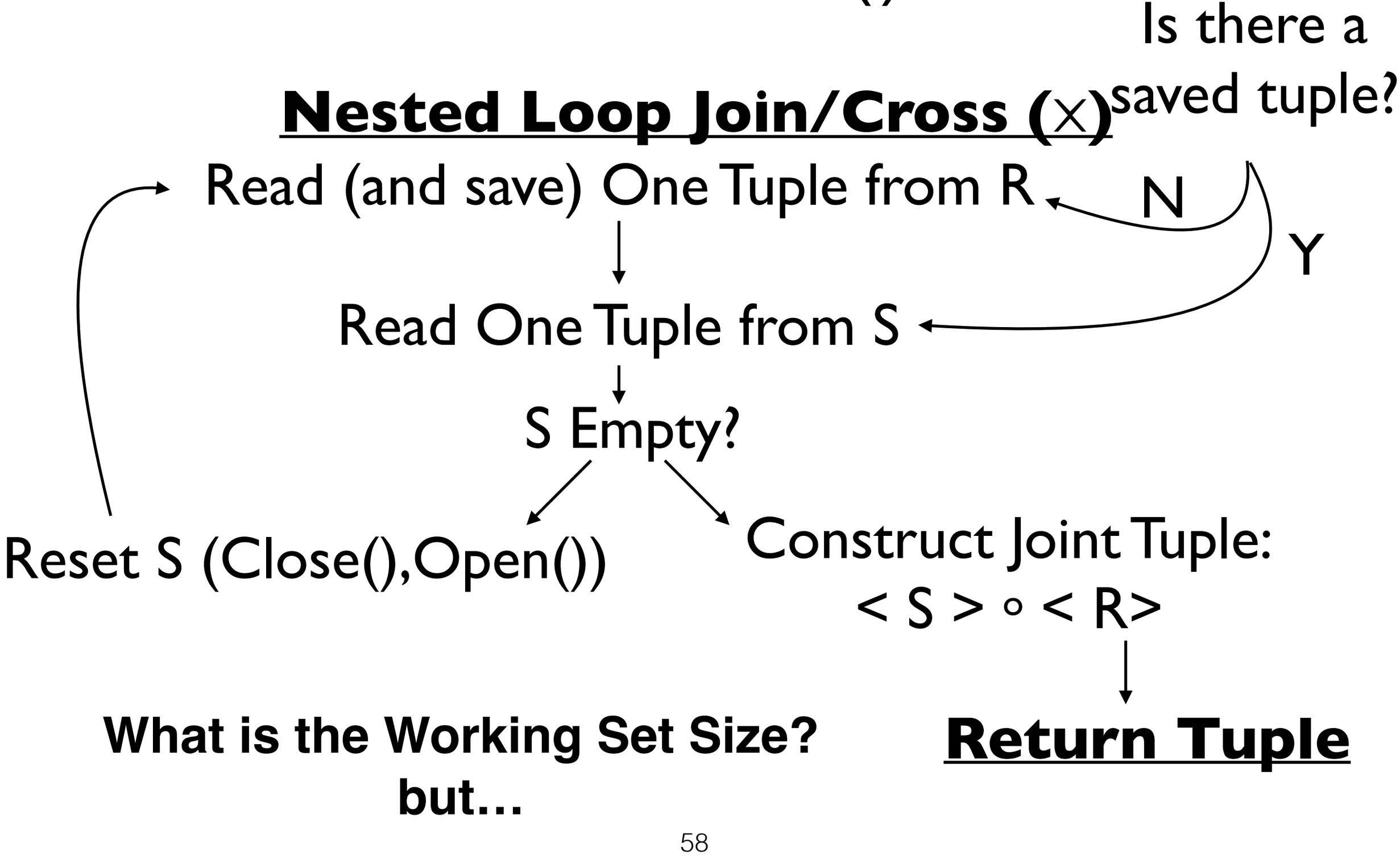
R Empty?

↙ ↘

Read One Tuple from S → **Return Tuple**

What is the Working Set Size?

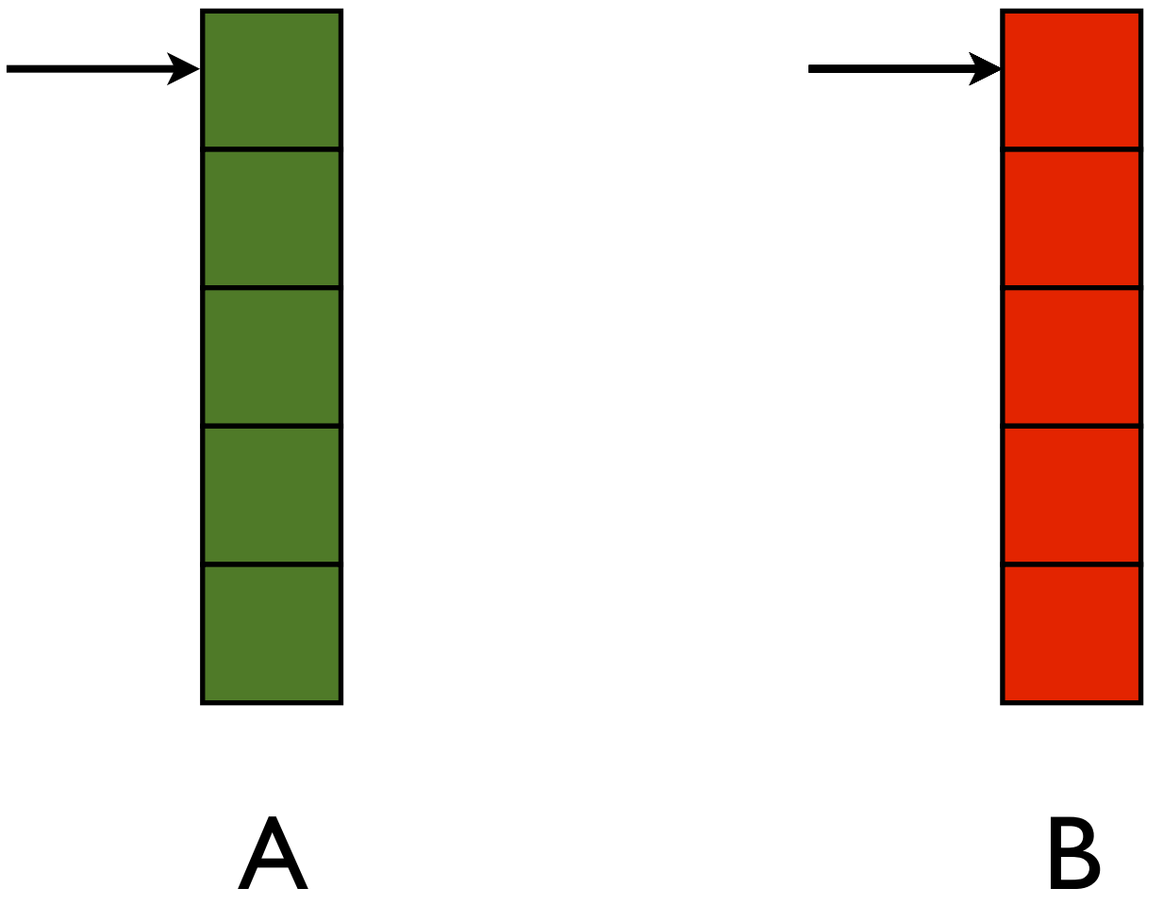
GetNext()


Nested Loop Join/Cross (×)
Read (and save) One Tuple from R
Read One Tuple from S
S Empty?
Reset S (Close(),Open())
Construct Joint Tuple:
< S > ∘ < R>
Is there a saved tuple?
N
Y
What is the Working Set Size?
but…
Return Tuple

Implementing: Joins

Solution 1 (Nested-Loop)

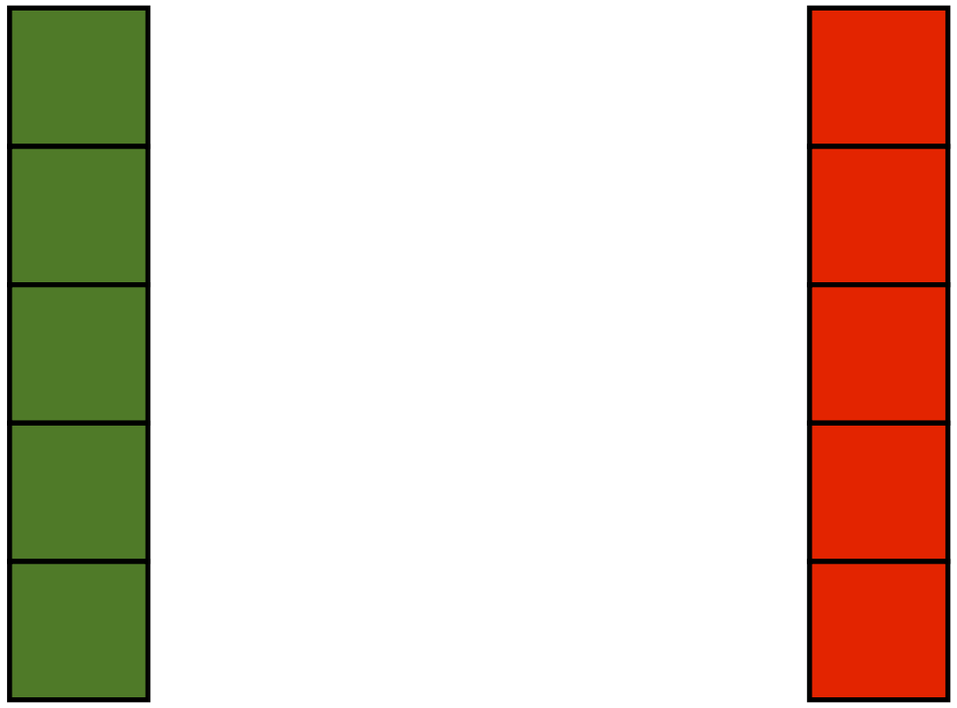
For Each (a in A) { For Each (b in B) { emit (a, b); }}



A B

Implementing: Joins

Solution 2 (Block-Nested-Loop)



Implementing: Joins

Solution 2 (Block-Nested-Loop)

1) Partition into Blocks 2) NLJ on each pair of blocks