Introduction to Data Management
CSE 414

Unit 4: RDBMS Internals

Logical and Physical Plans

Query Execution

Query Optimization

(3 lectures)

Introduction to Data Management
CSE 414

Lecture 15: Introduction to Query Evaluation

Announcements

- WQ5 (datalog) due tomorrow

- HW4 (datalog) due tomorrow

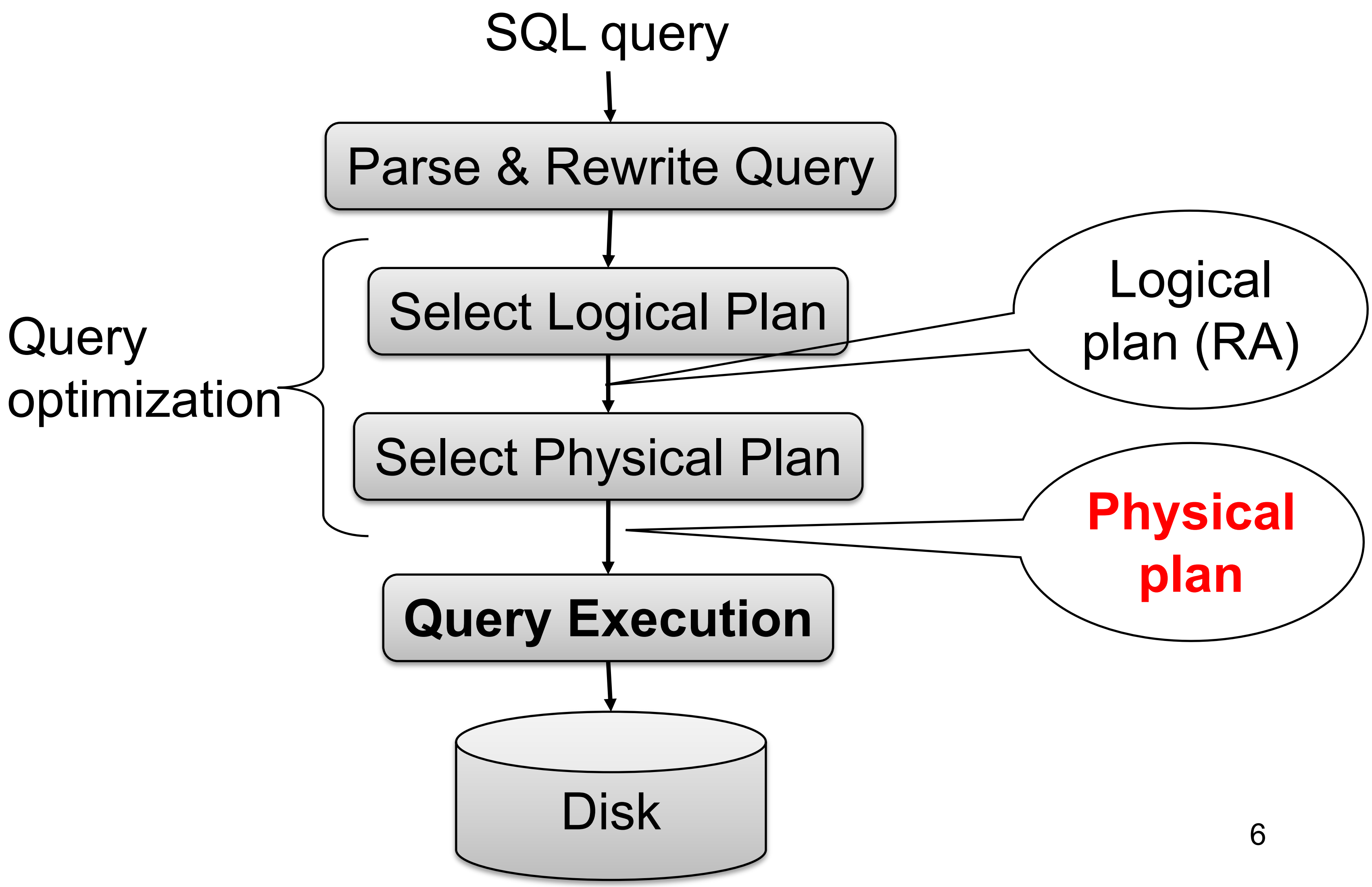
- Midterm review session this evening
  - 5:30pm, CSE 2nd Floor Breakout

Class Overview

- Unit 1: Intro
- Unit 2: Relational Data Models and Query Languages
- Unit 3: Non-relational data
- Unit 4: RDMBS internals and query optimization
- Unit 5: Parallel query processing
- Unit 6: DBMS usability, conceptual design
- Unit 7: Transactions
- Unit 8: Advanced topics (time permitting)

From Logical RA Plans to Physical Plans

Query Evaluation Steps Review



Logical vs Physical Plans

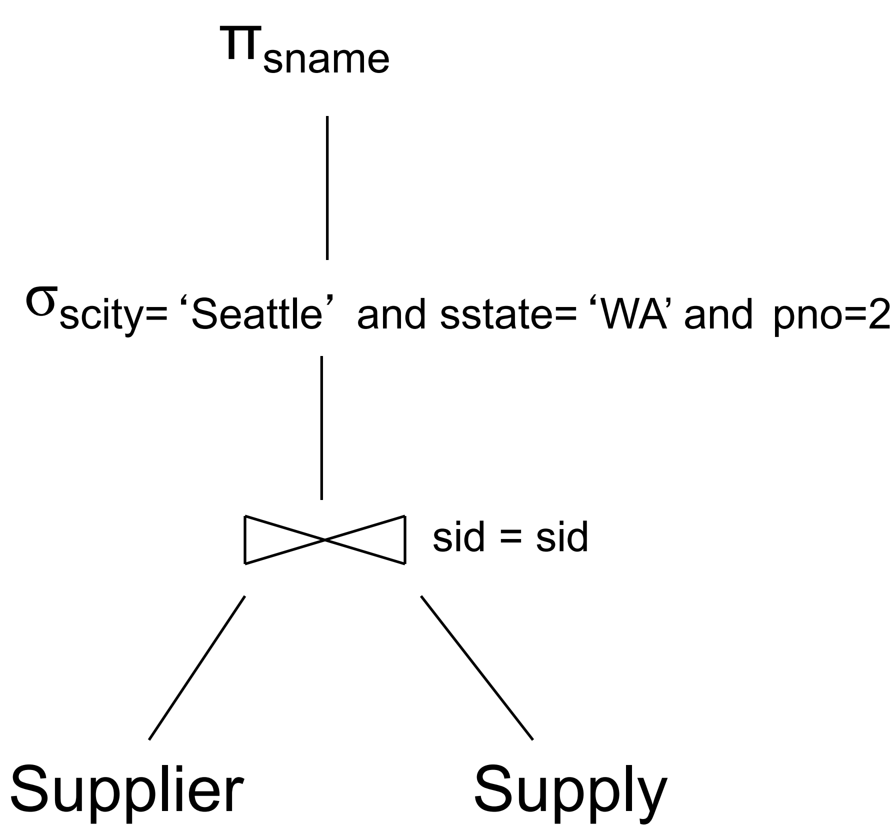
- Logical plans:
  - Created by the parser from the input SQL text
  - Expressed as a relational algebra tree
  - Each SQL query has many possible logical plans

- Physical plans:
  - Goal is to choose an efficient implementation for each operator in the RA tree
  - Each logical plan has many possible physical plans

Supplier(sid, sname, scity, sstate)
Supply(sid, pno, quantity)

Review: Relational Algebra

```sql
SELECT sname
FROM Supplier x, Supply y
WHERE x.sid = y.sid
    and  y.pno = 2
    and x.scity = ‘Seattle’
    and x.sstate = ‘WA’
```



Relational algebra expression is also called the “logical query plan”

Logical Plan v.s. Physical Plan

- Logical Plan = a Relational Algebra tree
- Physical Plan = a Logical Plan plus annotation of each operator with an algorithm

Query Optimization and Execution

- Query optimizer:
  - Choose a good logical plan
  - Refine it to a good physical plan
  - Sometimes these steps are intertwined
- Query execution
  - Execute the physical plan

Query Execution

Physical Operators

Relational algebra operators:

- Selection, projection, join, union, difference
- Group-by, distinct, sort

Physical operators:

- For each operators above, several possible algorithms
- Main memory algorithms, or disk-based algorithms

```
Supplier(sid, sname, scity, sstate)
Supply(sid, pno, quantity)
```

Main Memory Algorithms

Logical operator:

Supplier $\bowtie_{sid=sid}$ Supply

Propose three physical operators for the join, assuming the tables are in main memory:

1.
2.
3.

```
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Supply(sid, pno, quantity)
```

Main Memory Algorithms

Logical operator:

Supplier $\bowtie_{sid=sid}$ Supply

Propose three physical operators for the join, assuming the tables are in main memory:

1. Nested Loop Join O(??)
2. Merge join O(??)
3. Hash join O(??)

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```

Main Memory Algorithms

Logical operator:

Supplier $\bowtie_{sid=sid}$ Supply

Propose three physical operators for the join, assuming the tables are in main memory:

1. Nested Loop Join $O(n^2)$
2. Merge join $O(n \log n)$
3. Hash join $O(n) \dots O(n^2)$

BRIEF Review of Hash Tables

A (naïve) hash function:

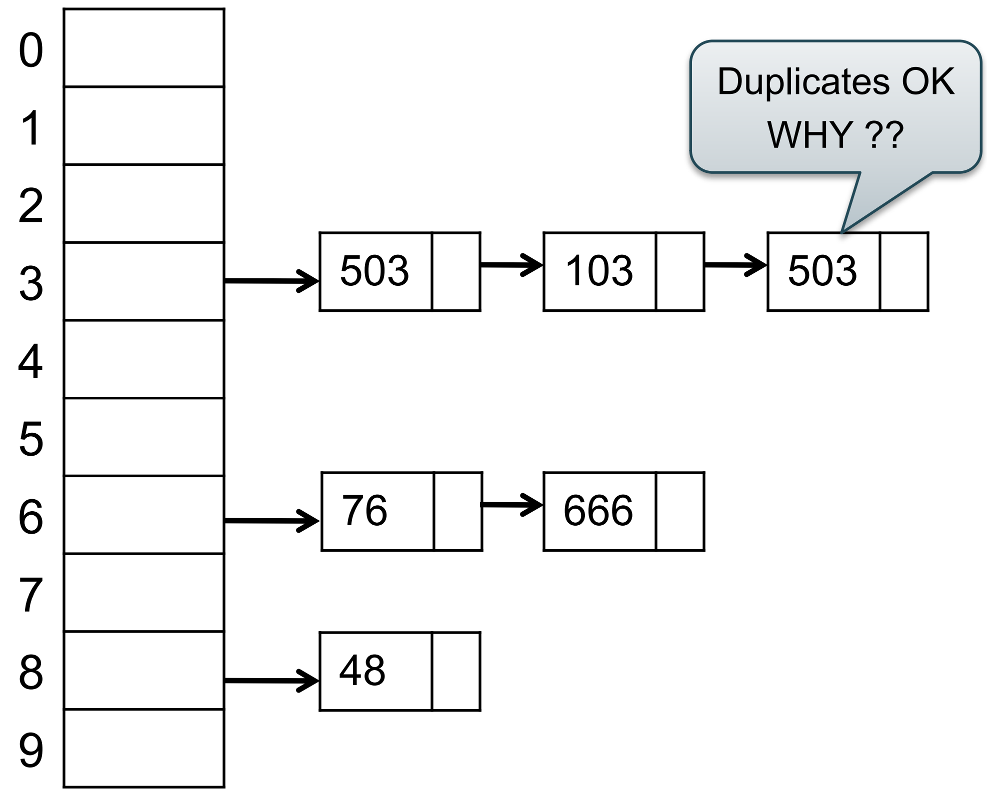
$h(x) = x \bmod 10$

Operations:

find(103) = ??

insert(488) = ??

Separate chaining:

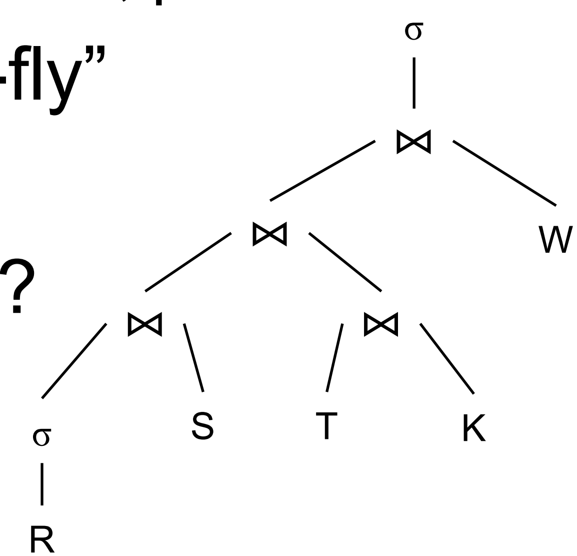


BRIEF Review of Hash Tables

- insert(k, v) = inserts a key k with value v
- Many values for one key
  - Hence, duplicate k's are OK
- find(k) = returns the ***list*** of all values v associated to the key k

Query Execution

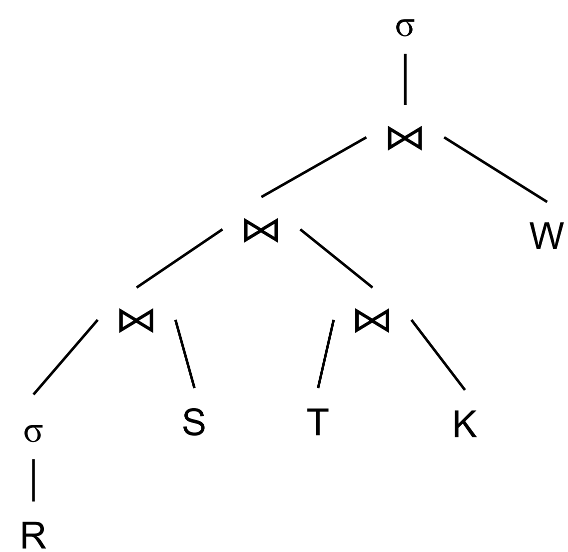
- Join R ⋈ S: e.g. using hash-join:
  - Nested-loop: forall x in R forall y in S do …
  - Hash–join: build a hash table on S, probe R
- Selection: σ(R): e.g. "on-the-fly"
- But what about a larger plan?
  - Each operator implements the Iterator Interface



Implementing Query Operators with the Iterator Interface

Each operator implements three methods:

- open()
- next()
- close()



Implementing Query Operators with the Iterator Interface

Example “on the fly” selection operator

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interface Operator {

}
```

Implementing Query Operators with the Iterator Interface

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  // initializes operator state
  // and sets parameters
  void open (...);









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  // calls next() on its inputs
  // processes an input tuple
  // produces output tuple(s)
  // returns null when done
  Tuple next ();


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```
class Select implements Operator {...
  void open (Predicate p,
             Operator child) {
    this.p = p; this.child = child;
  }
}
```

Implementing Query Operators with the Iterator Interface

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  }
  Tuple next () {
    boolean found = false;
    Tuple r = null;
    while (!found) {
       r = child.next();
       if (r == null) break;
       found = p(in);
    }

  }
}
```

Implementing Query Operators with the Iterator Interface

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    return r;
  }
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Implementing Query Operators with the Iterator Interface

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    }
    return r;
  }
  void close () { child.close(); }
}
```

Implementing Query Operators with the Iterator Interface

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  void open (...);


  // calls next() on its inputs
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  Tuple next ();


  // cleans up (if any)
  void close ();
}
```

Query plan execution

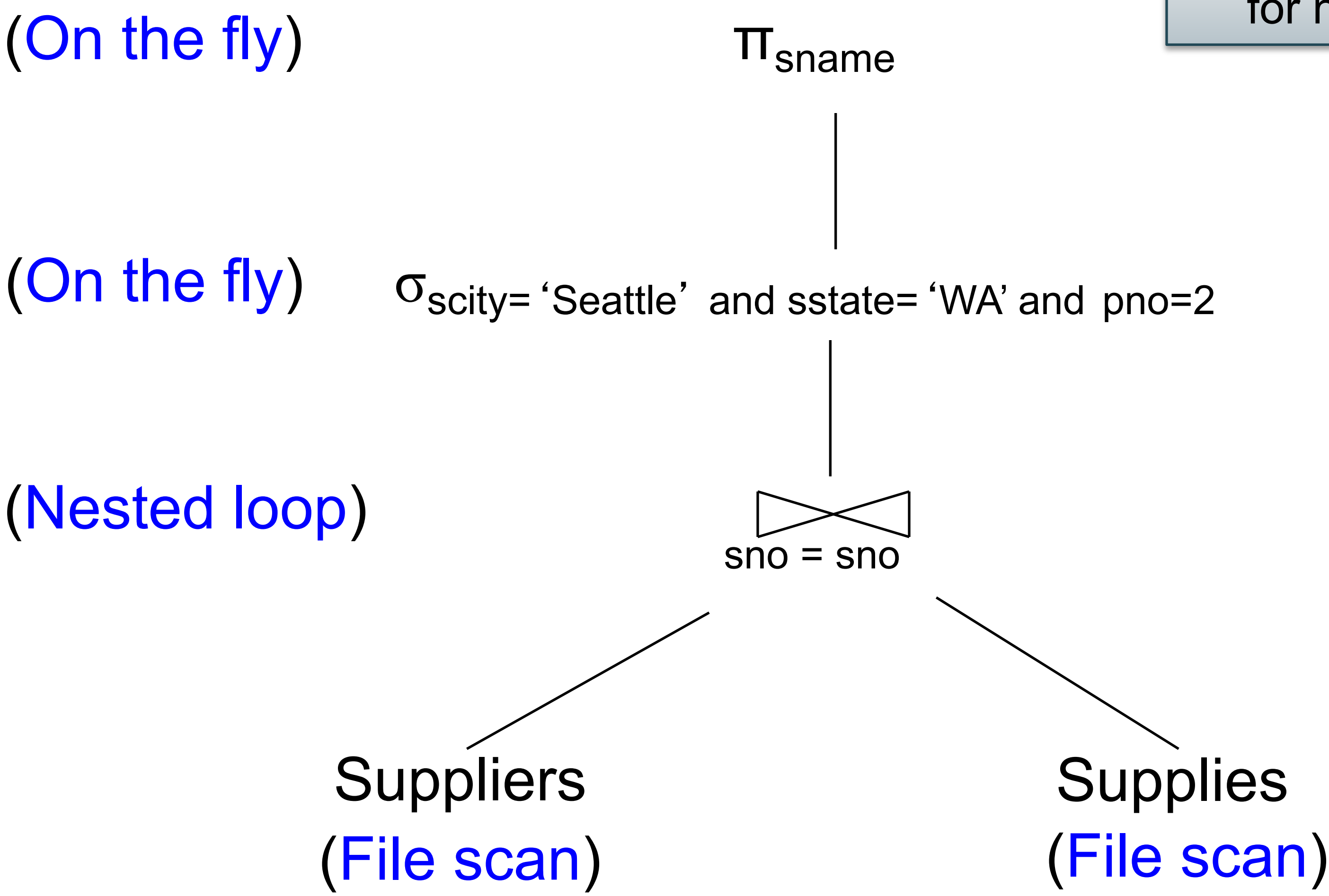
```
Operator q = parse("SELECT ...");
q = optimize(q);

q.open();
while (true) {
  Tuple t = q.next();
  if (t == null) break;
  else printOnScreen(t);
}
q.close();
```

`Supplier(sid, sname, scity, sstate)`
`Supply(sid, pno, quantity)`

Pipelining

Discuss: open/next/close for nested loop join



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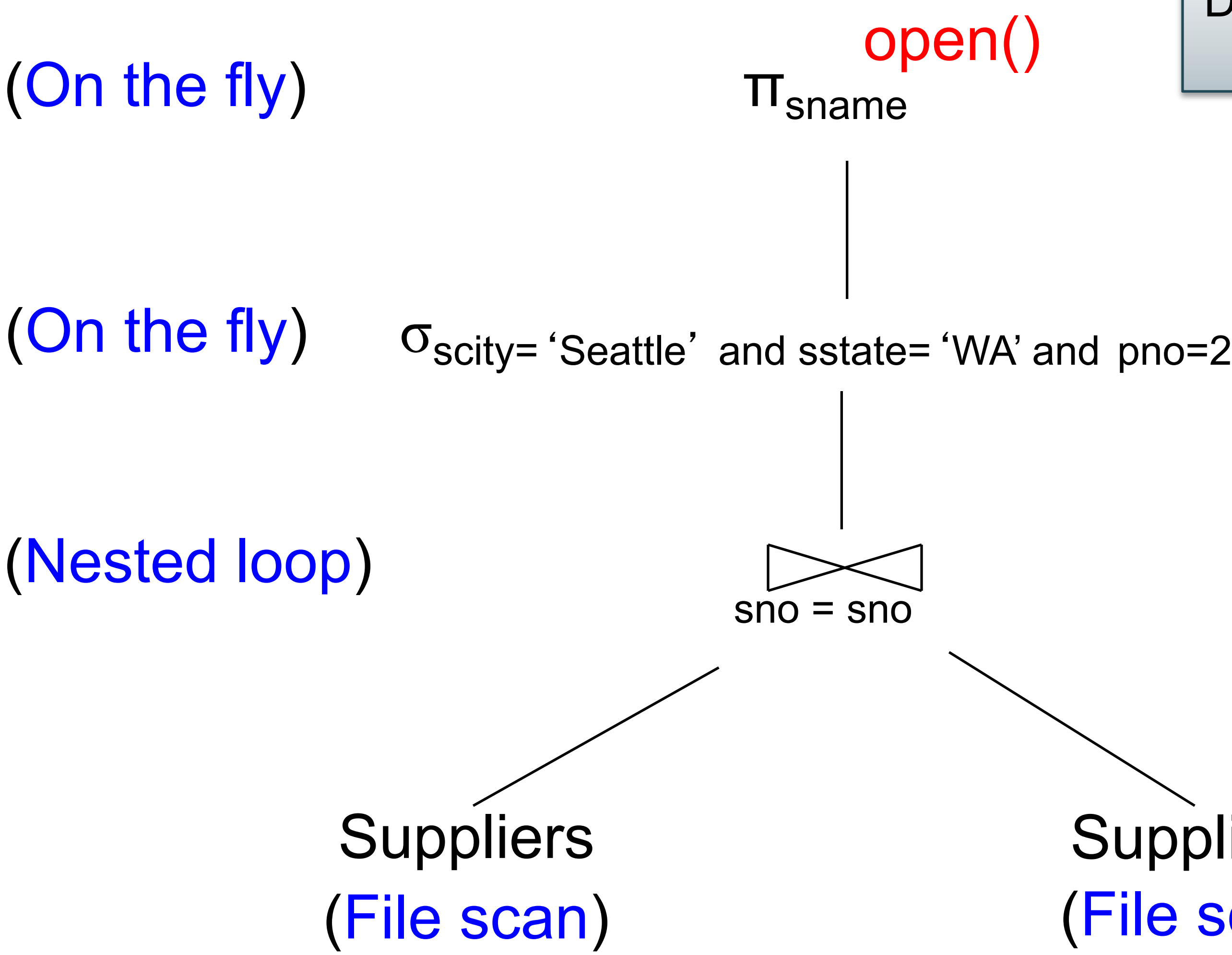

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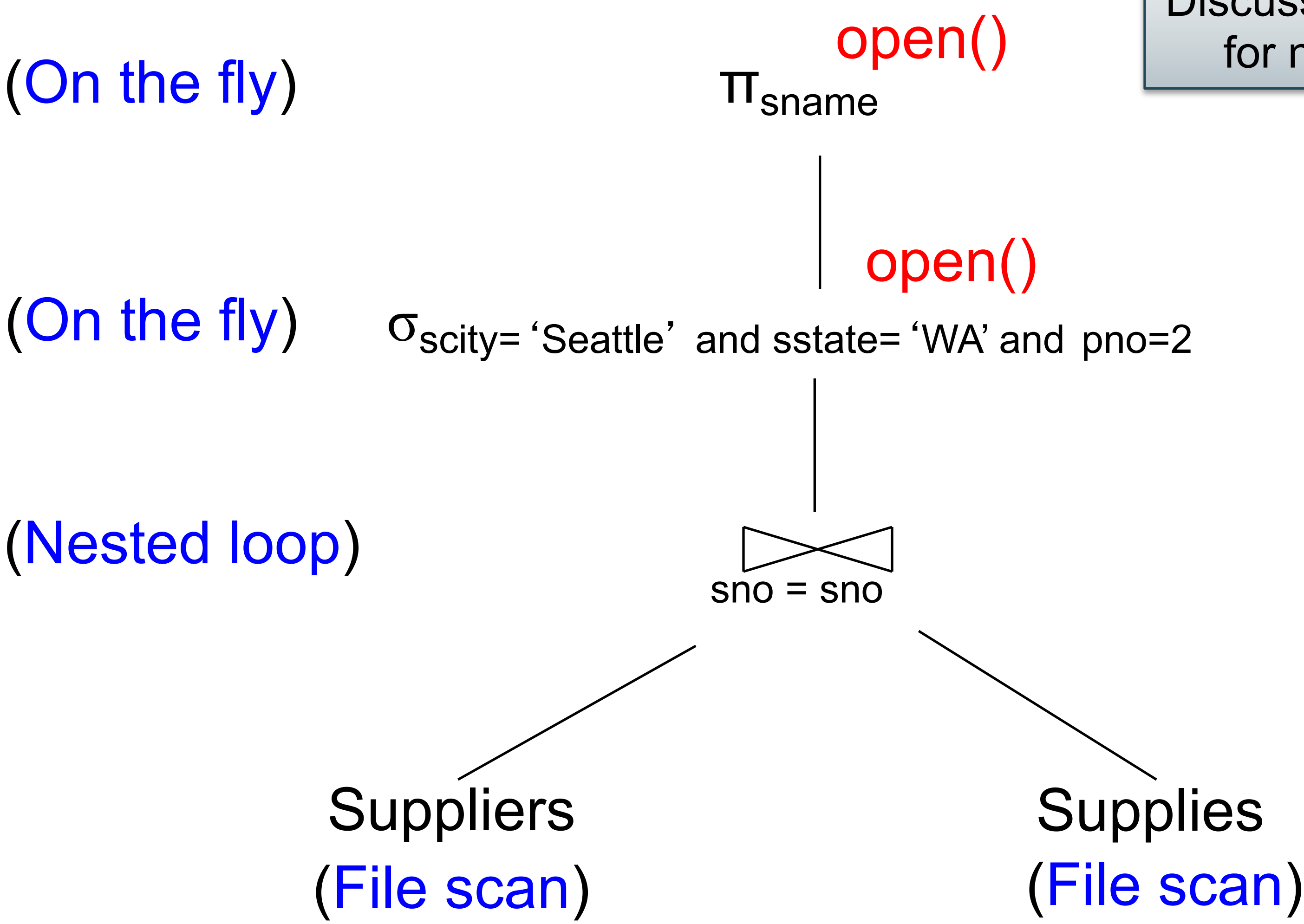

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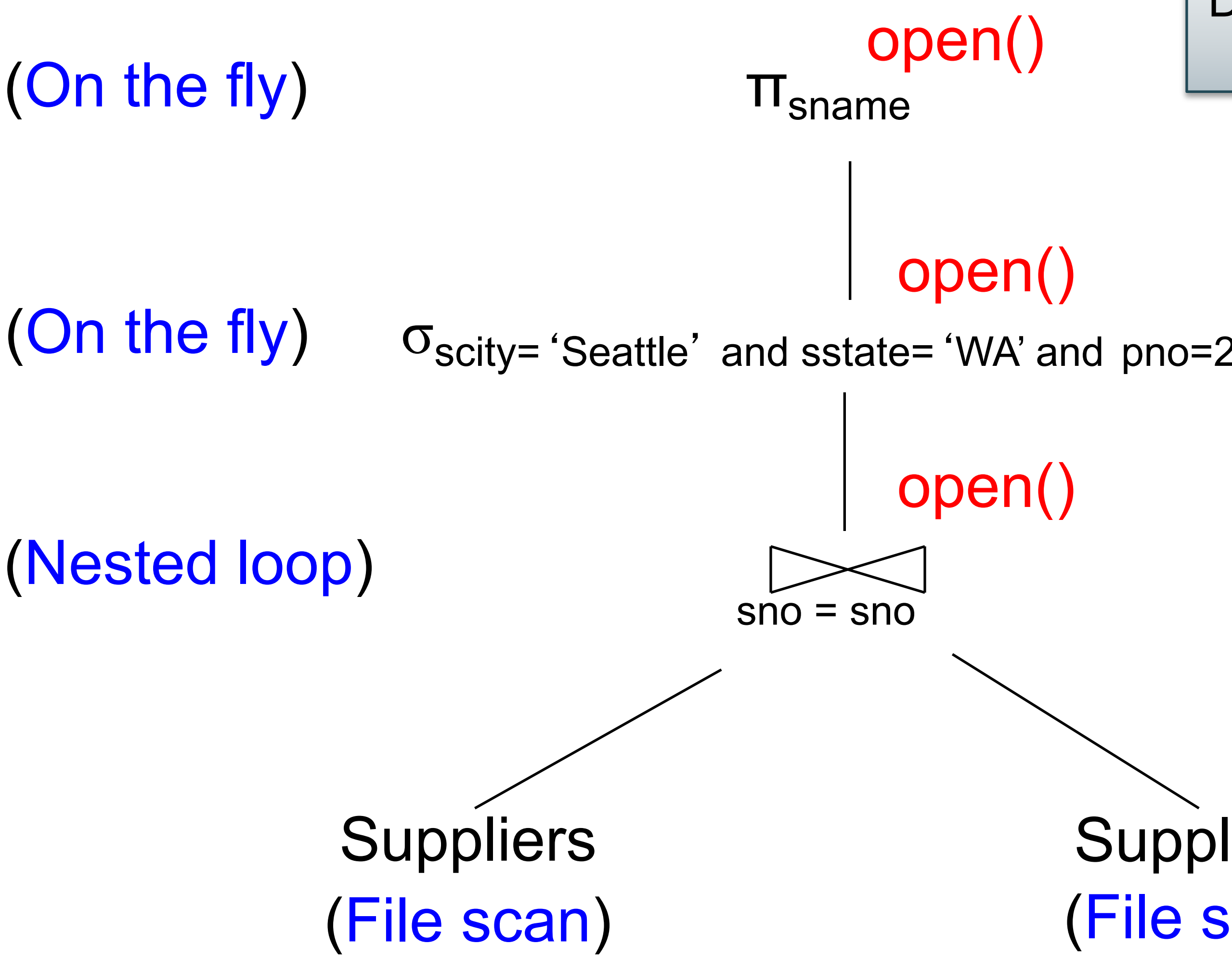

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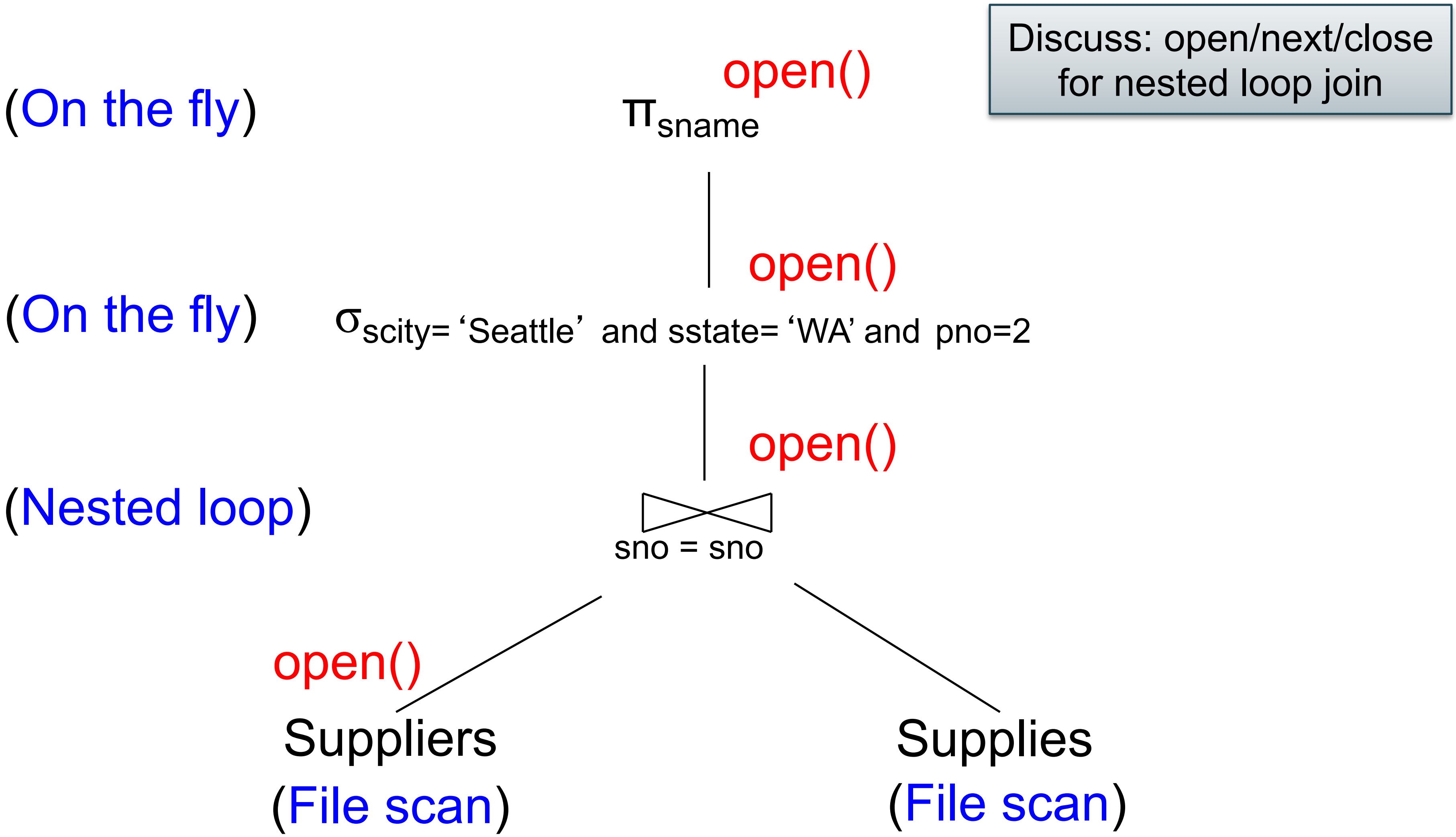

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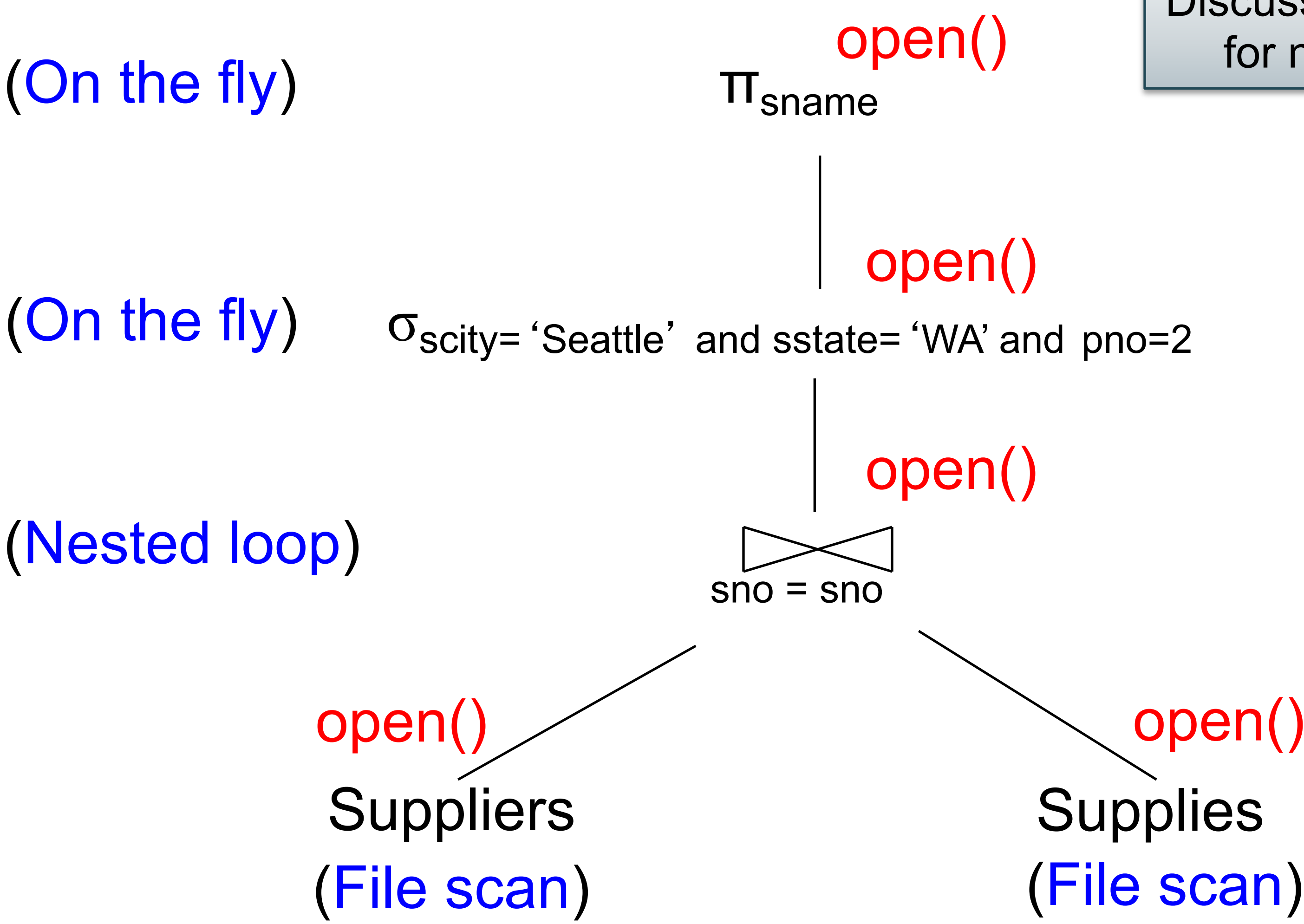

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Pipelining

Discuss: open/next/close for nested loop join

(On the fly) π_{sname} next()

(On the fly) $\sigma_{scity=\text{'Seattle'} \text{ and } sstate=\text{'WA'} \text{ and } pno=2}$

(Nested loop) $\bowtie_{sno = sno}$

Suppliers (File scan)

Supplies (File scan)

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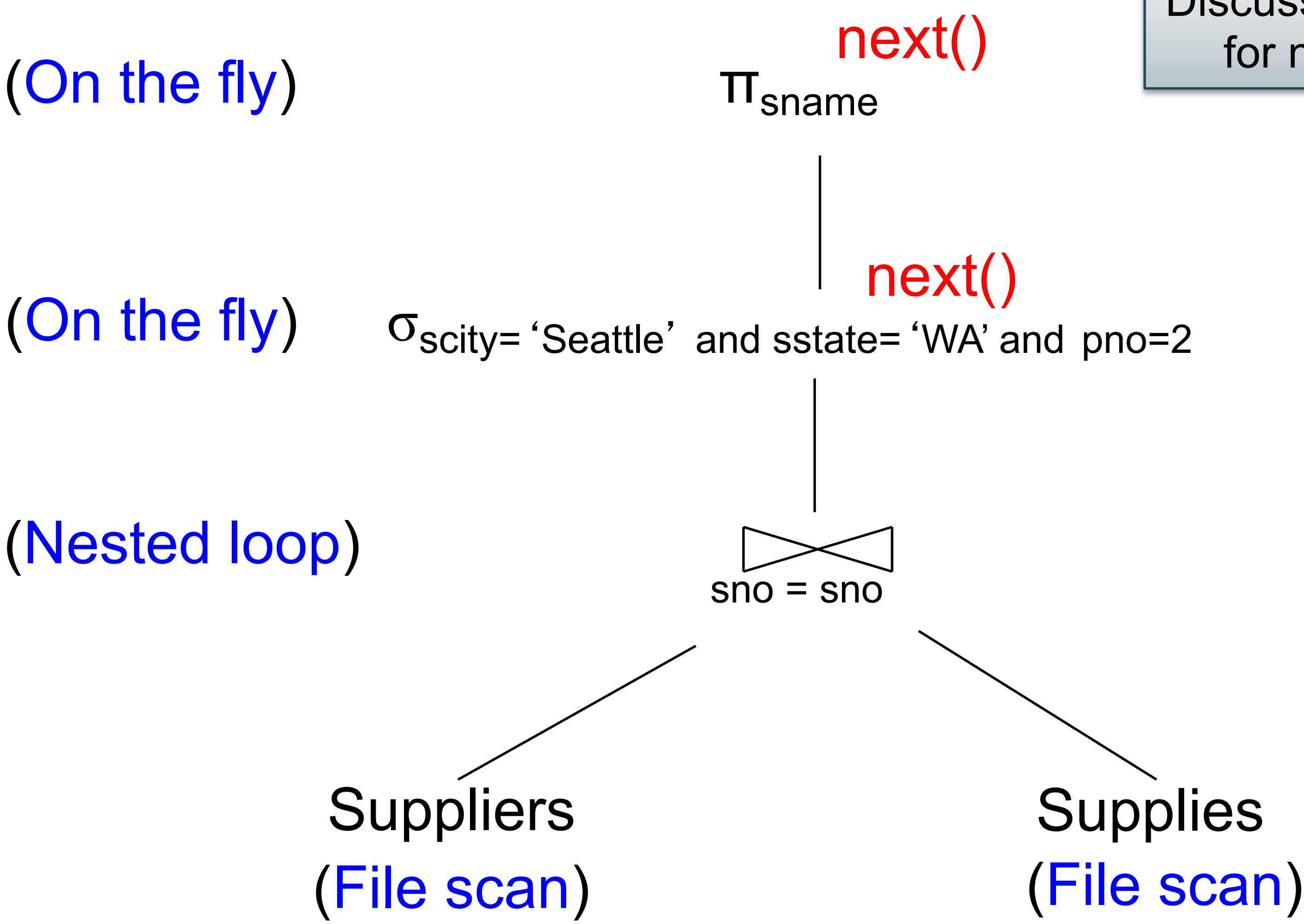

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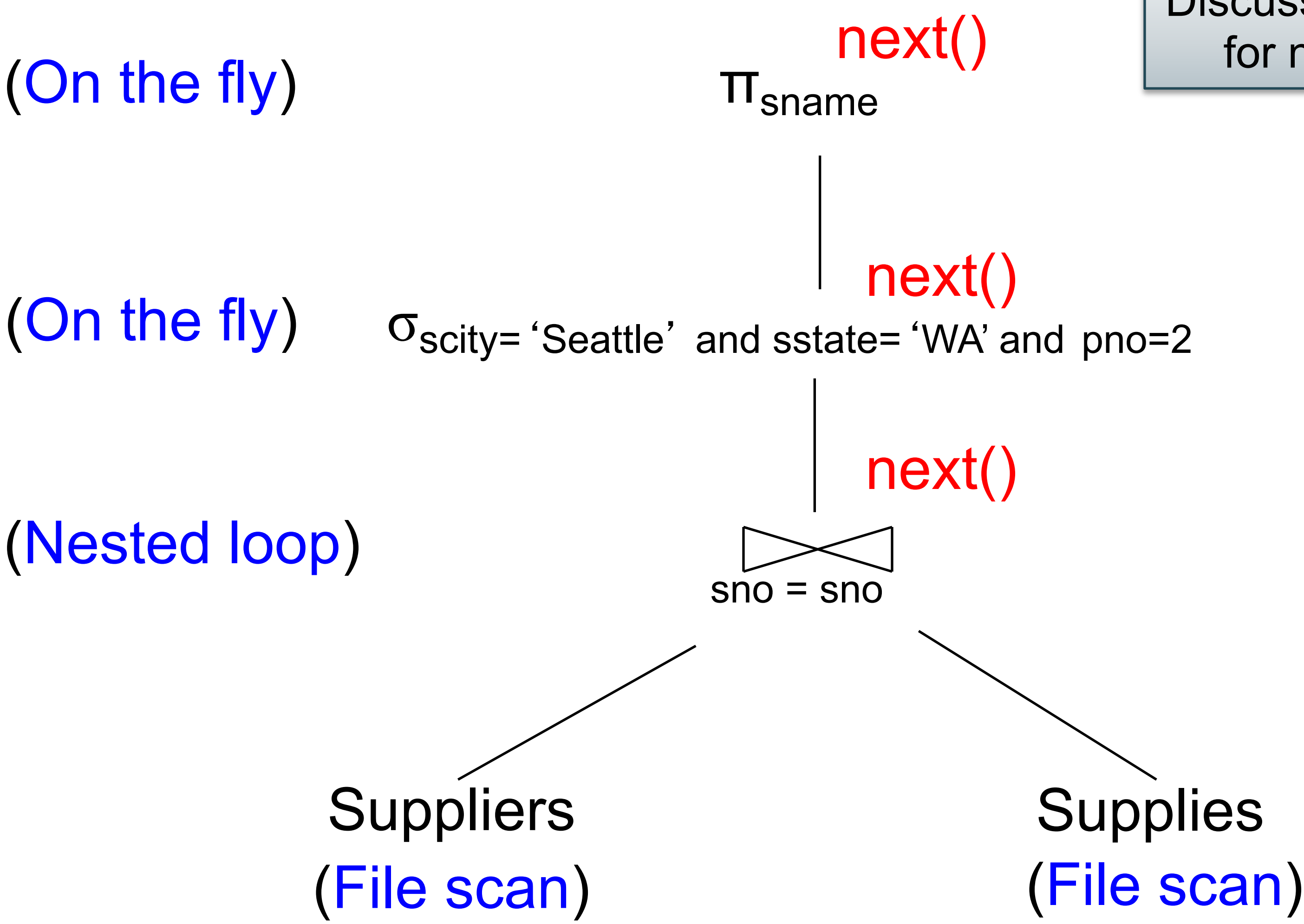

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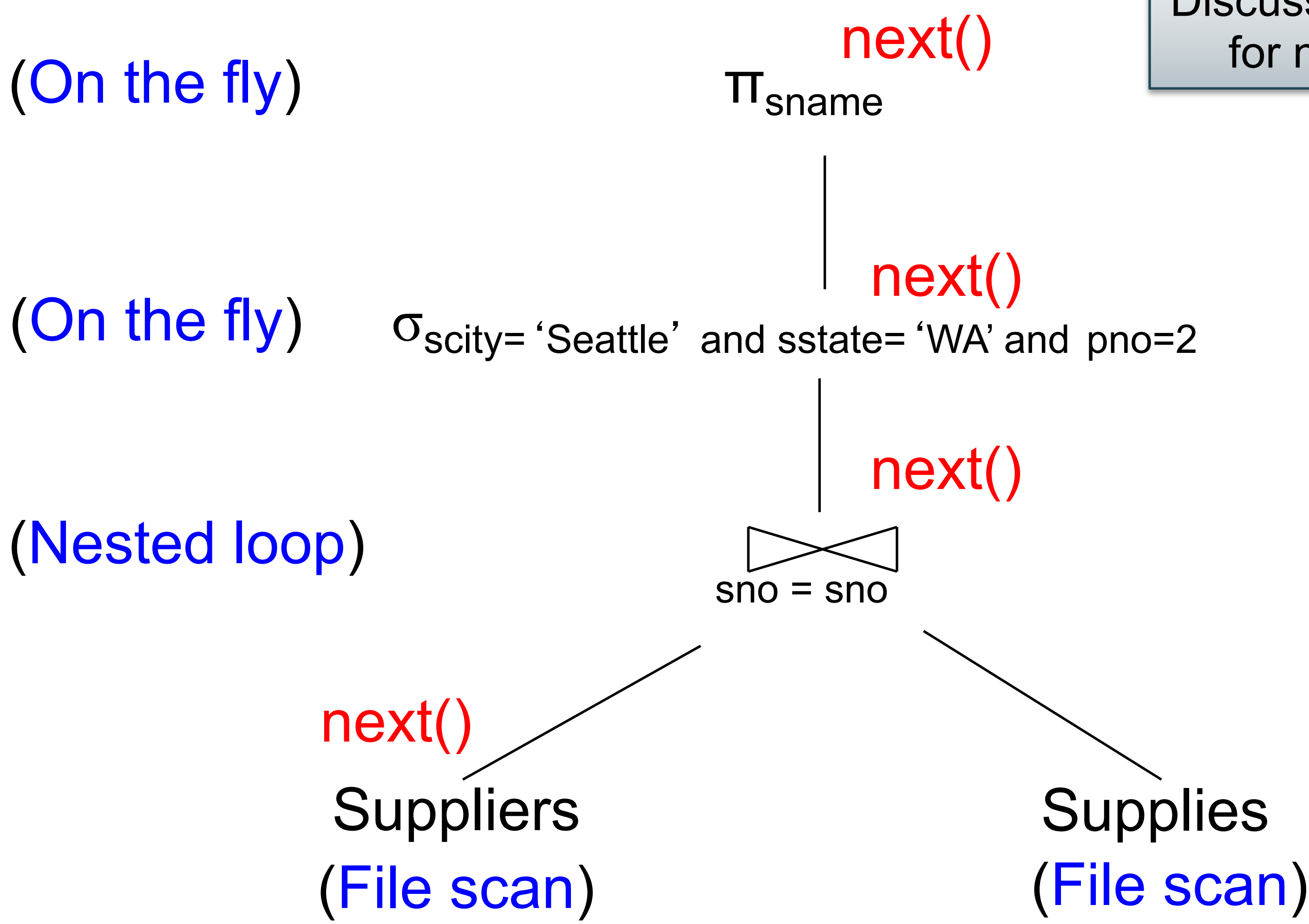

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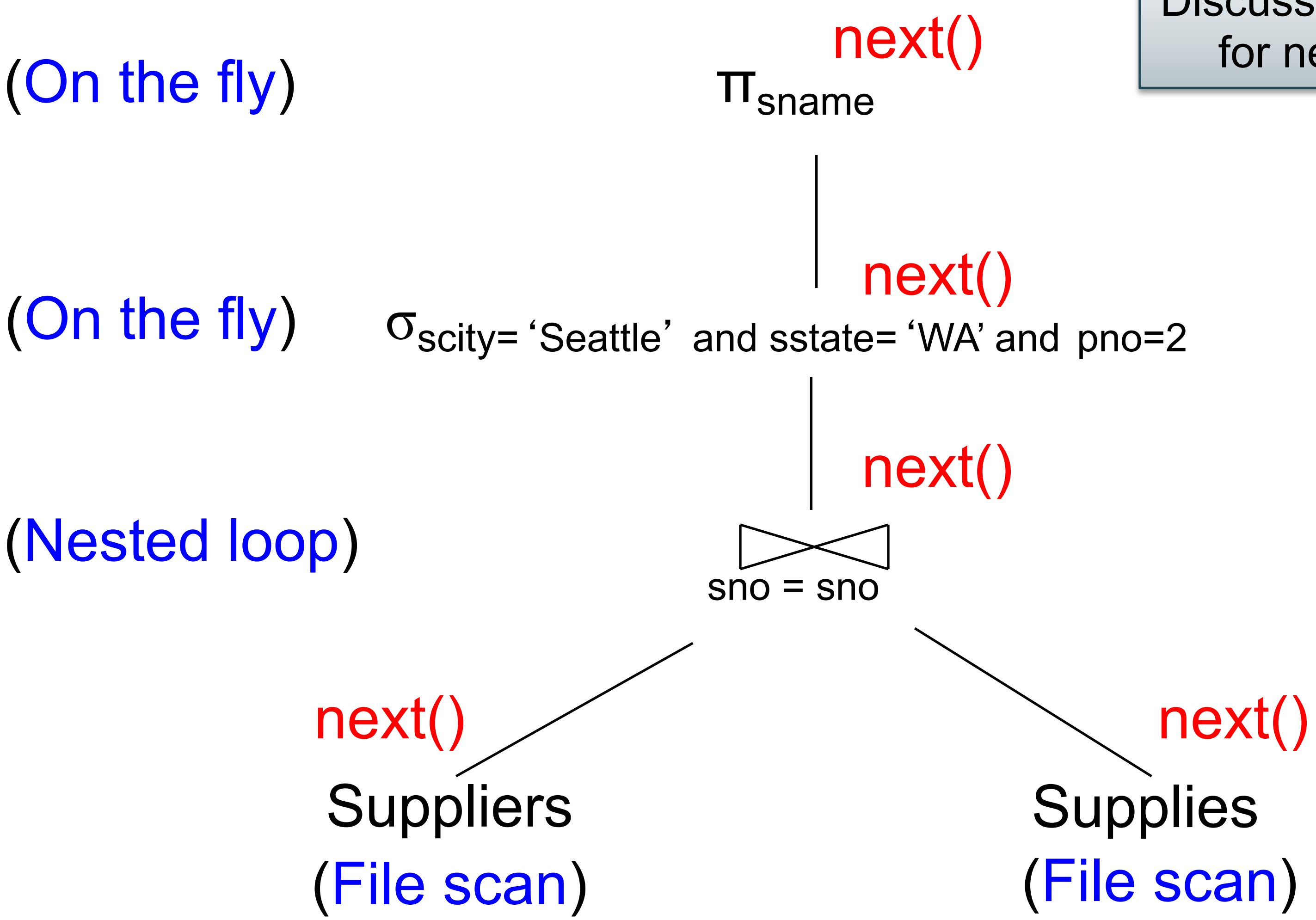

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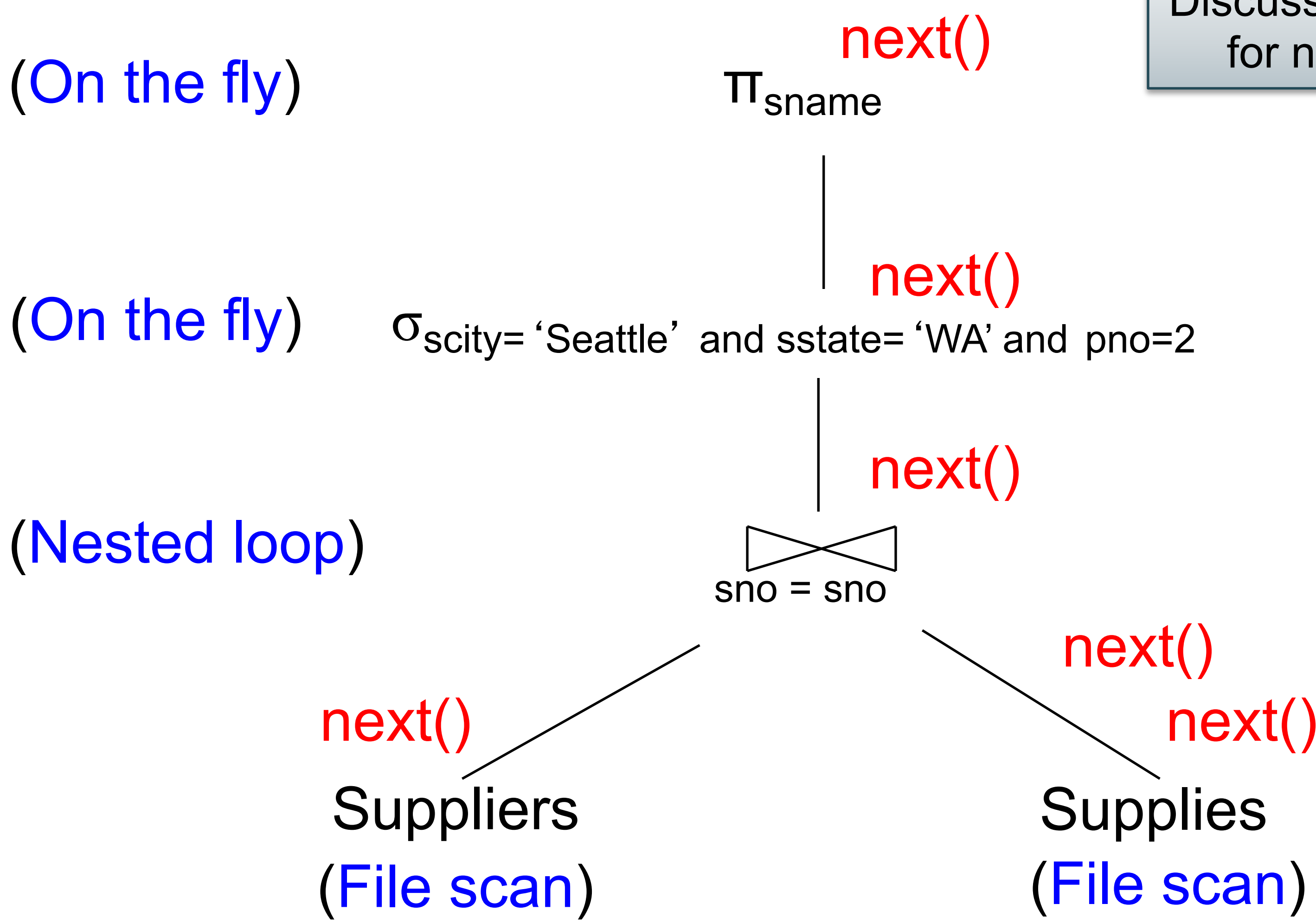

`Supplier(sid, sname, scity, sstate)`

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Pipelining

Discuss hash-join in class

(On the fly) π_{sname}

(On the fly) $\sigma_{scity='Seattle' \text{ and } sstate='WA' \text{ and } pno=2}$

(Hash Join) $\bowtie_{sno = sno}$

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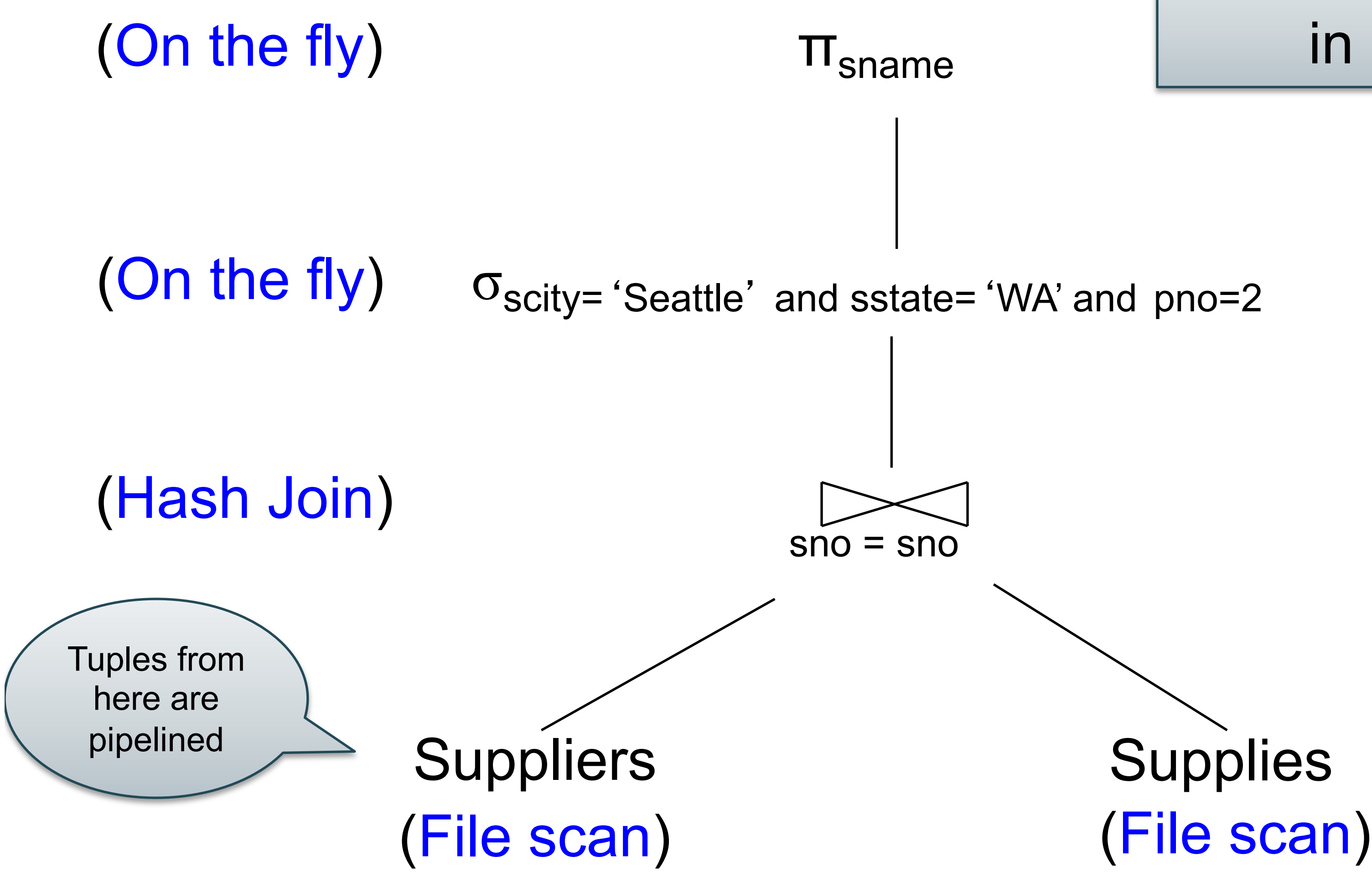

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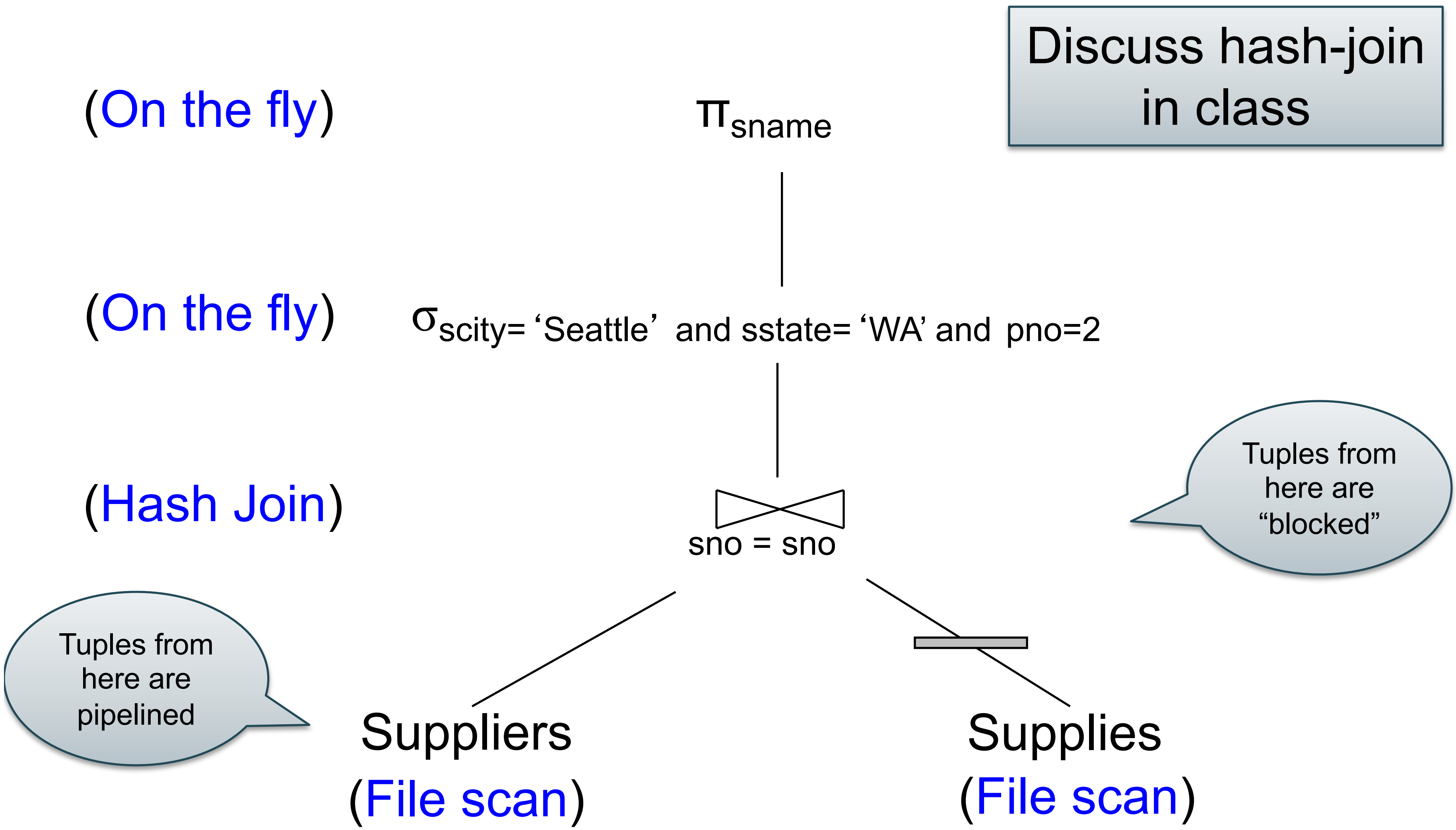

Pipeline v.s. Blocking

- Pipeline
  - A tuple moves all the way through up the query plan
  - Advantages: speed
  - Disadvantage: need all hash at the same time in memory
- Blocking
  - The entire result of the subplan is computed (and stored to disk) before the first tuple is sent up the plan
  - Advantage: saves memory
  - Disadvantage: slower

Discussion on Physical Plan

More components of a physical plan:

- **Access path selection** for each relation
  - Scan the relation or use an index (next lecture)
- **Implementation choice** for each operator
  - Nested loop join, hash join, etc.
- **Scheduling decisions** for operators
  - Pipelined execution or intermediate materialization