CSE 444: Database Internals

Lecture 3

DBMS Architecture

Upcoming Deadlines

- Lab 1 Part 1 is due today at 11pm
  - Go through logistics of getting started
  - Start to make some small changes to the code
- HW1 is due on Wednesday at 11pm
  - Closely related to Lab 1
  - Helps you think about Lab 1 before implementing it… but don't wait until Wednesday to finish Lab 1!!!
- 544M first reading assignment due on Monday at 11pm
- Lab 1 is due next Friday at 11pm
  - A lot more work than part 1

Late Days

- 4 late days total – At most 2 per lab or homework
- Can use in 24 hour chunks at any time
- NO OTHER EXTENSIONS!

What we already know…

- Database = collection of related files
- DBMS = program that manages the database

What we already know…

- Data models: relational, semi-structured (XML), graph (RDF), key-value pairs
- Relational model: defines only the logical model, and does not define a physical storage of the data

What we already know…

Relational Query Language:

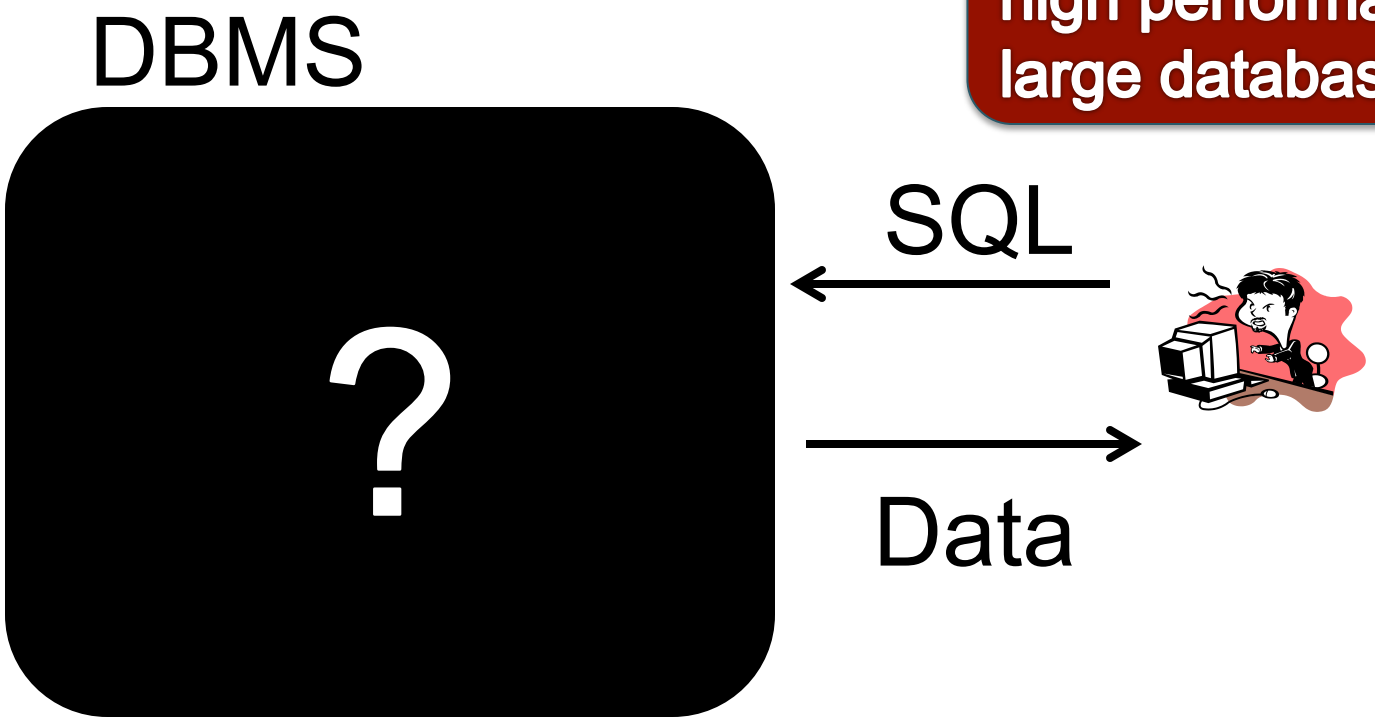
- Set-at-a-time: instead of tuple-at-a-time
- Declarative: user says what they want and not how to get it
- Query optimizer: from *what* to *how*

Benefits of relational model

- Physical data independence
  - Can change physical data organization on disk for performance *without affecting applications*
  - Thanks to logical data model and set-at-a-time query language
- Logical data independence
  - Can change logical schema *without affecting applications*
  - Thanks to views and query rewriting

How to Implement a Relational DBMS?

Key challenge: Achieve high performance on large databases!



Goal for Today

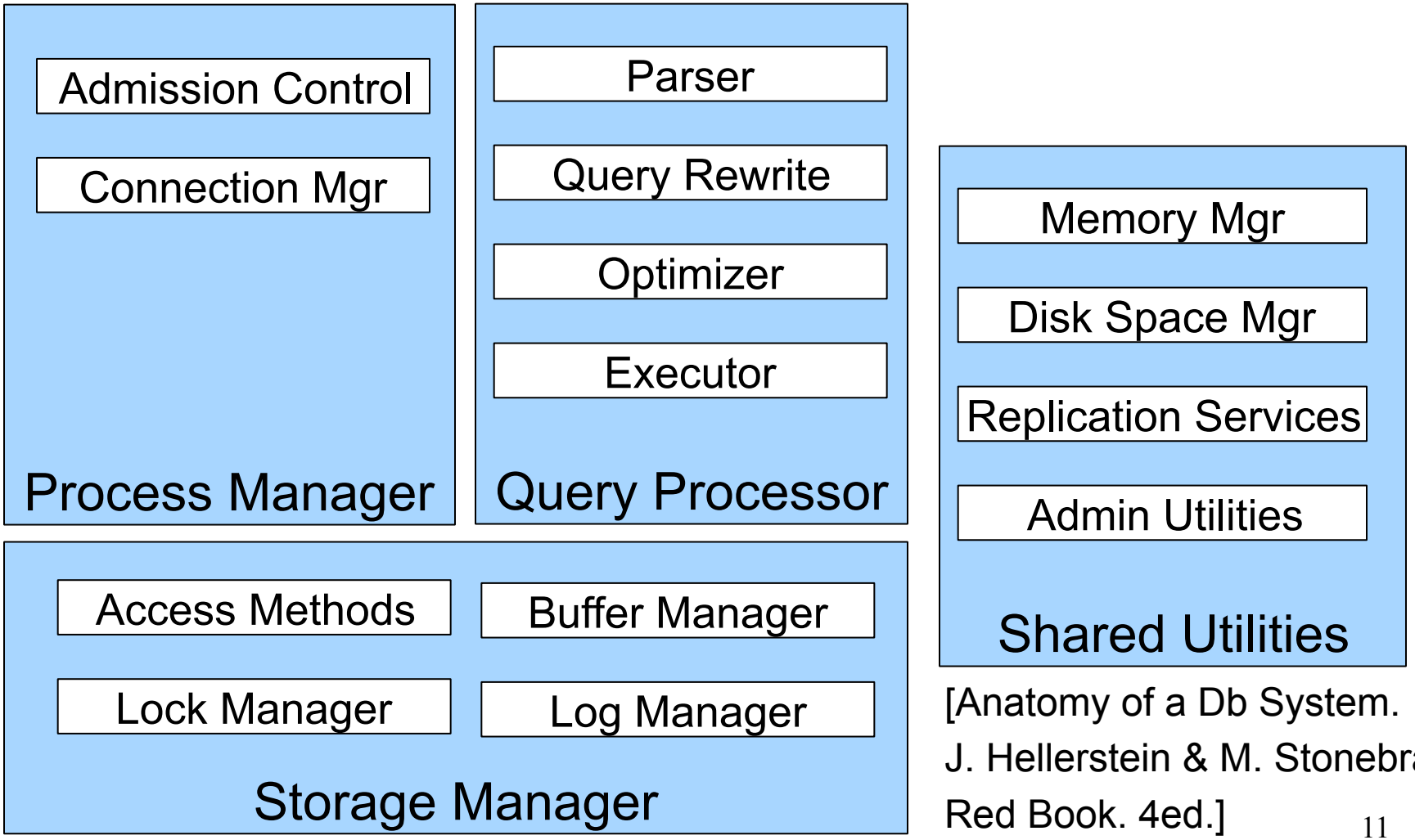
Overview of DBMS architecture

Overview of query execution

DBMS Architecture

(on the white board)

DBMS Architecture



[Anatomy of a Db System. J. Hellerstein & M. Stonebraker. Red Book. 4ed.]

Query Processor

Example Database Schema

```
Supplier(sno,sname,scity,sstate)
Part(pno,pname,psize,pcolor)
Supply(sno,pno,price)
```

View: Suppliers in Seattle

```
CREATE VIEW NearbySupp AS
SELECT sno, sname
FROM Supplier
WHERE scity='Seattle' AND sstate='WA'
```

```
Supplier(sno,sname,scity,sstate)
Part(pno,pname,psize,pcolor)
Supply(sno,pno,price)
```

Example Query

- Find the names of all suppliers in Seattle who supply part number 2

```
SELECT sname FROM NearbySupp
WHERE sno IN ( SELECT sno
               FROM Supplies
               WHERE pno = 2 )
```

Query Processor

- **Step 1: Parser**
  - Parses query into an internal format
  - Performs various checks using catalog
    - Correctness, authorization, integrity constraints
    - Typically, catalog is stored in the form of set of relations
- **Step 2: Query rewrite**
  - View rewriting, flattening, etc.

```
Supplier(sno,sname,scity,sstate)
Part(pno,pname,psize,pcolor)
Supply(sno,pno,price)
```

Rewritten Version of Our Query

Original query:

```
SELECT sname
FROM NearbySupp
WHERE sno IN ( SELECT sno
               FROM Supplies
               WHERE pno = 2 )
```

Rewritten query:

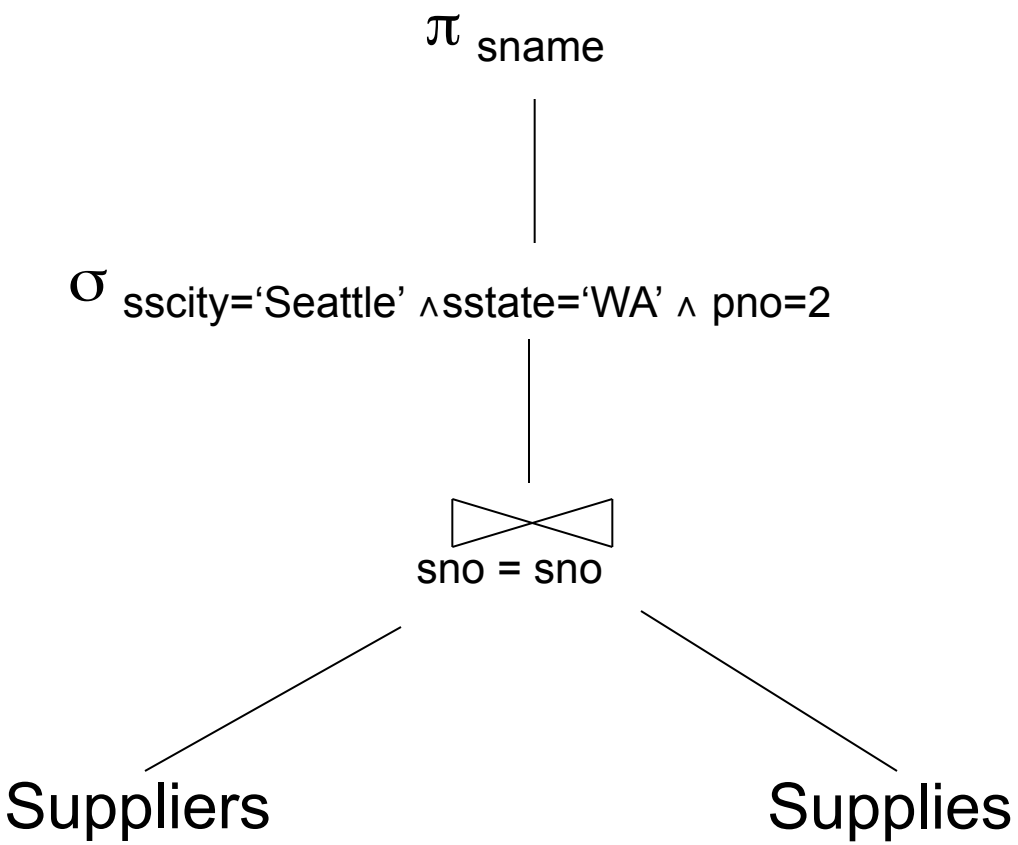
```
SELECT S.sname
FROM Supplier S, Supplies U
WHERE S.scity='Seattle' AND S.sstate='WA'
AND S.sno = U.sno
AND U.pno = 2;
```

Query Processor

- **Step 3: Optimizer**
  - Find an efficient query plan for executing the query
  - A **query plan** is
    - **Logical**: An extended relational algebra tree
    - **Physical**: With additional annotations at each node
      - Access method to use for each relation
      - Implementation to use for each relational operator
- **Step 4: Executor**
  - Actually executes the physical plan

Supplier(<u>sno</u>,sname,scity,sstate)
Part(<u>pno</u>,pname,psize,pcolor)
Supply(<u>sno,pno</u>,price)

Logical Query Plan



Physical Query Plan

- Logical query plan with extra annotations
- **Access path selection** for each relation
  - Use a file scan or use an index
- **Implementation choice** for each operator
- **Scheduling decisions** for operators

Supplier(sno,sname,scity,sstate)
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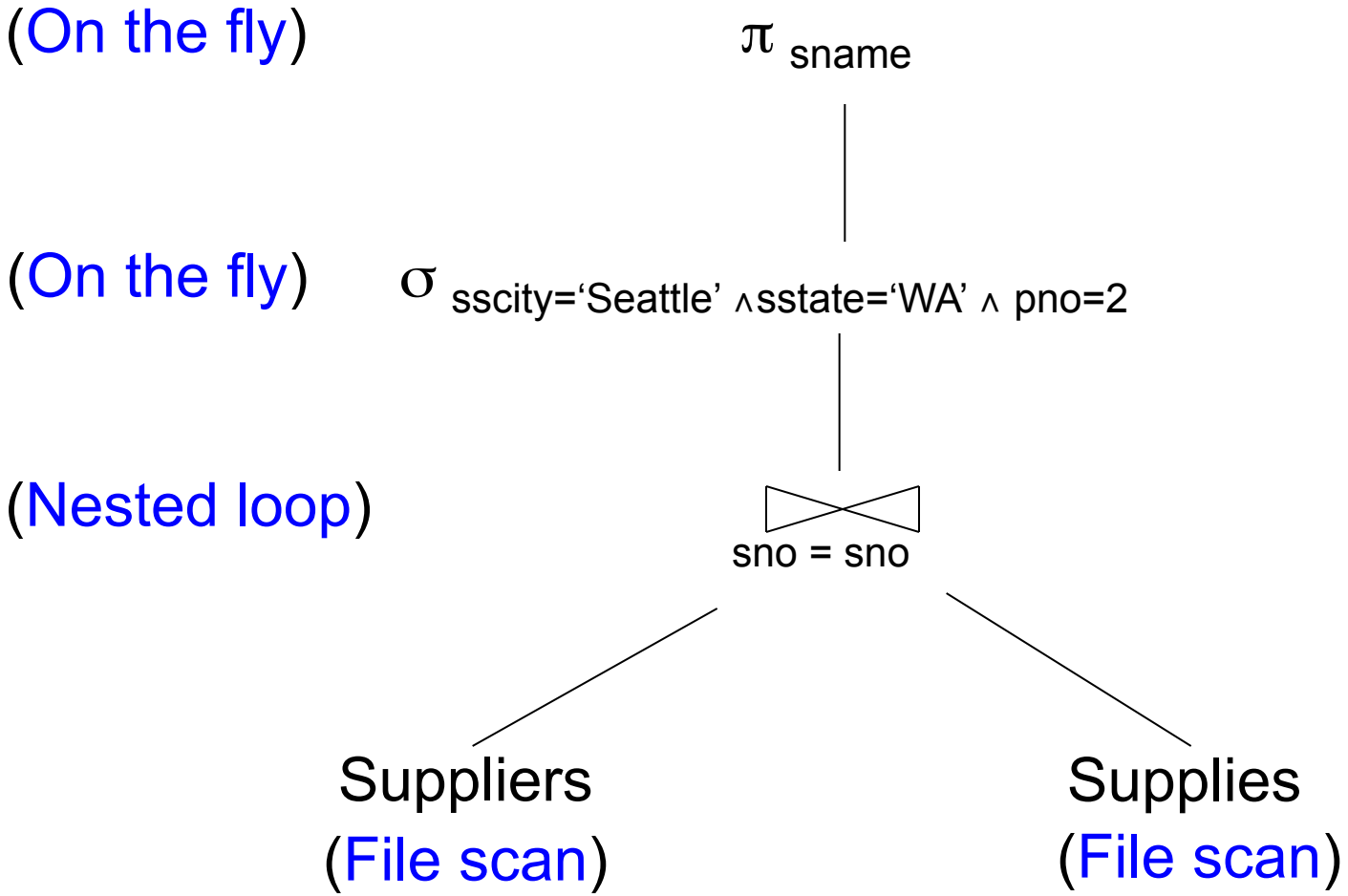
Physical Query Plan



Iterator Interface

- Each **operator implements this interface**

- **open()**
  - Initializes operator state
  - Sets parameters such as selection condition
- **next()**
  - Operator invokes next() recursively on its inputs
  - Performs processing and produces an output tuple
- **close()**: clean-up state

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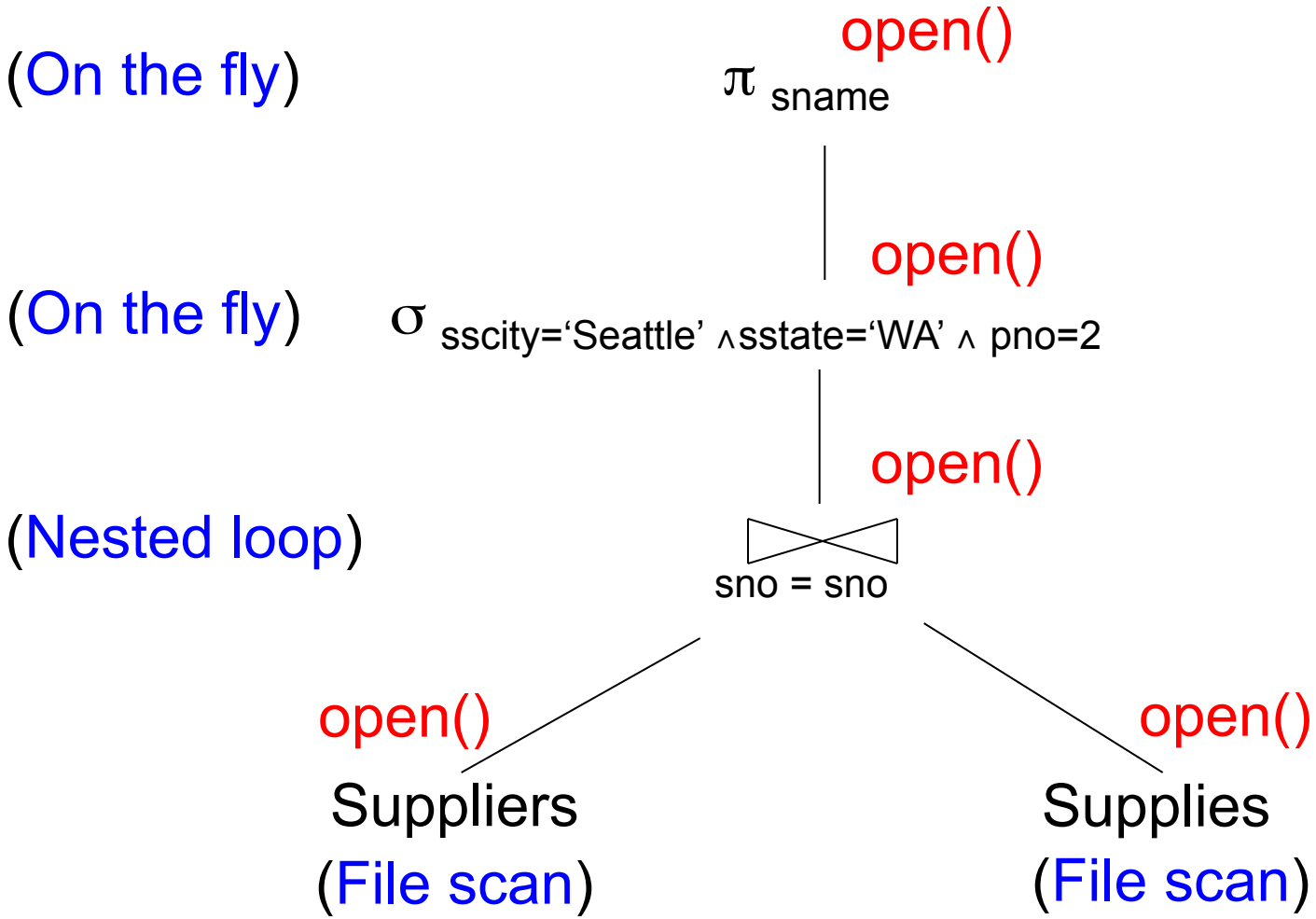
Query Execution



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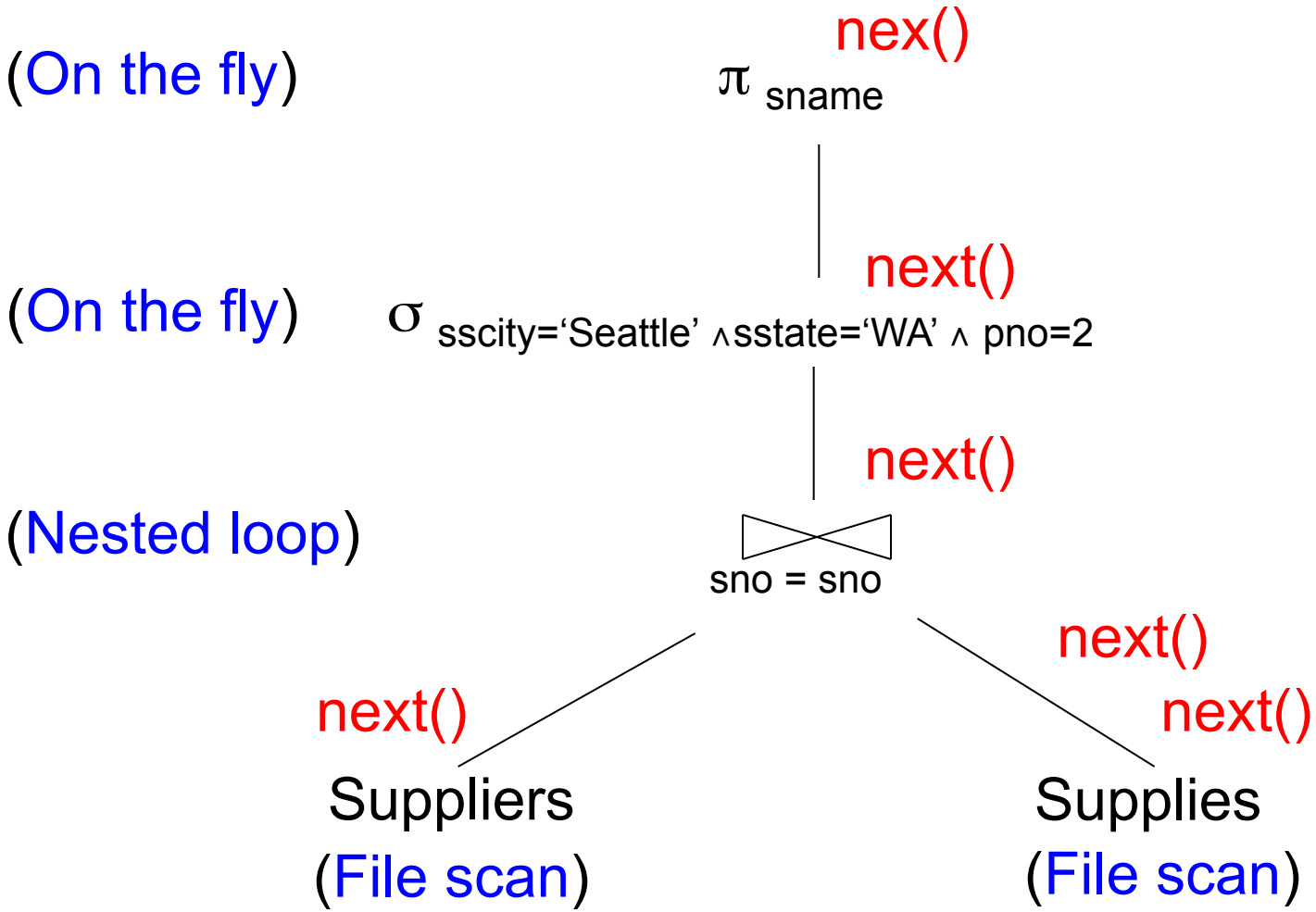
Query Execution



Storage Manager

Storage Manager

- **Buffer Manager**
  - Caches data in memory
  - Reduces the number of disk IO operations
  - Care is needed to support ACID transactions!
- **Access Methods**
  - Organize relation data on disk
  - Files (“heap files”) and indexes
- **Log and Lock Managers**
  - Necessary to support transactions

Process Manager

Process Manager

- **Connection Manager**
  - Process per user or thread per user?
  - Various variants exist, partly for historical reasons
- **Admission Control**
  - To avoid thrashing
  - And provide “graceful degradation” under load
  - Second level of admission control: before running a query

Shared Utilities

Shared Utilities

- **Memory Manager**
  - Manages memory used by various components: internal operator state, query optimizer, etc.
  - Note: Buffer manager holds only *data*
- **Disk Space Manager**
  - Two basic deployment alternatives:
    - Use “raw” disk device interface directly
    - Use OS files
  - DB file abstraction on top of disk or OS file abstraction

Shared Utilities

- **Replication Services**
  - For increased fault-tolerance
  - Or for increased performance
- **Admin Utilities**
  - Collecting statistics about data for optimizer
  - Re-organize data on disk, build indexes, etc.
  - Backup or export database