CSE 444: Database Internals

Lecture 3

DBMS Architecture

Announcements

- **Should be well on your way to finishing part 1**
- **Tuple, TupleDesc,**
- **Quiz 1 and 2 merge, 3 and 4 merge. Same work**
- Lab 1 part 1 due tonight at 11pm
  - Turn in using script in local repo: `./turnInLab.sh lab1-part1`
  - Remember to confirm that the tag has been applied in GitLab!
- HW1 is due on Friday at 11pm
  - Turn in by uploading to GitLab (will post instructions online) or submit a paper copy in class or office hours on the due date.
  - Helps you think about Lab 1 before implementing it… but don't wait until Wednesday to continue on Lab 1!!!
- 544M first reading assignment due on Friday
- Lab 1 is due next Wednesday (1/17) 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!

- Try to save late days for later in the quarter

- But no late days for final lab

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

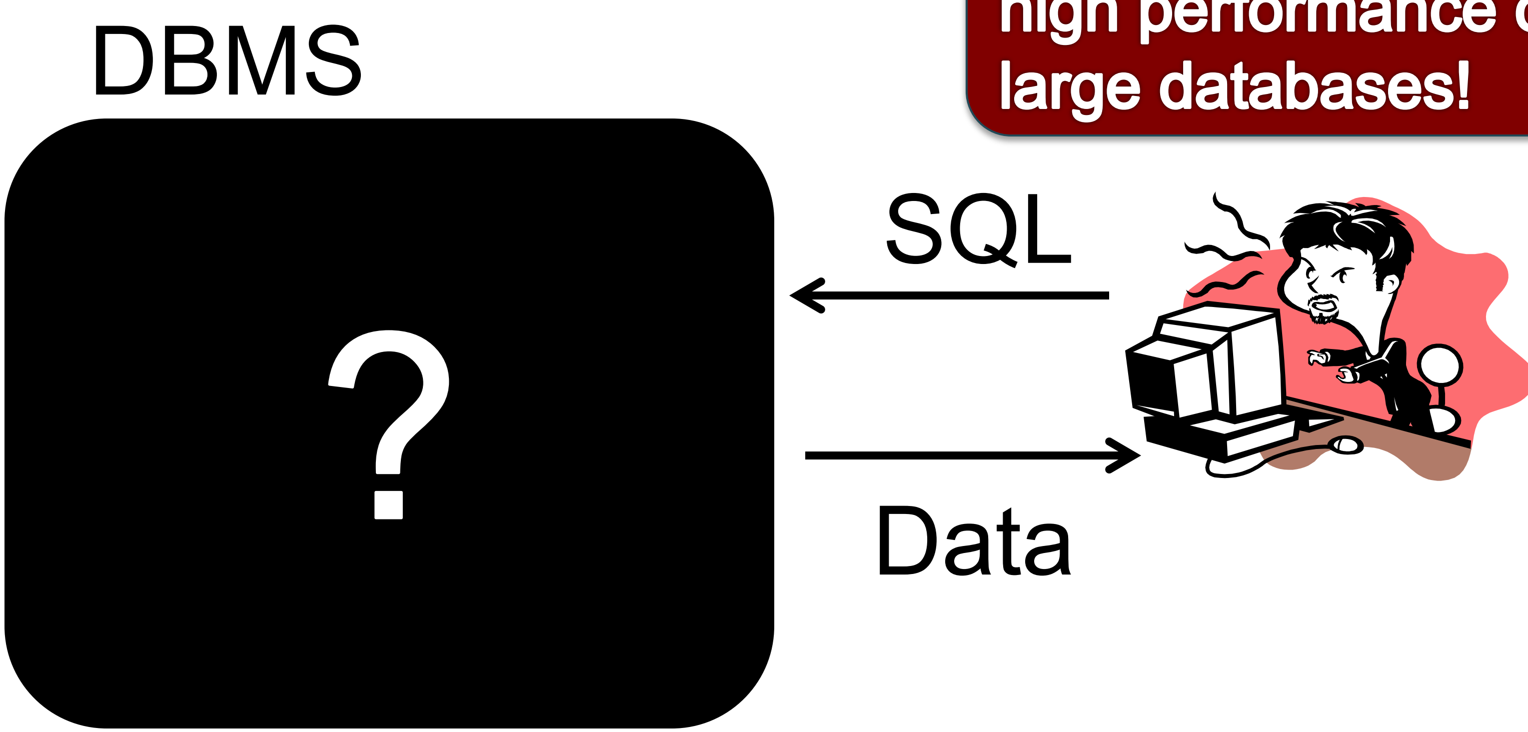
What we already know…

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*

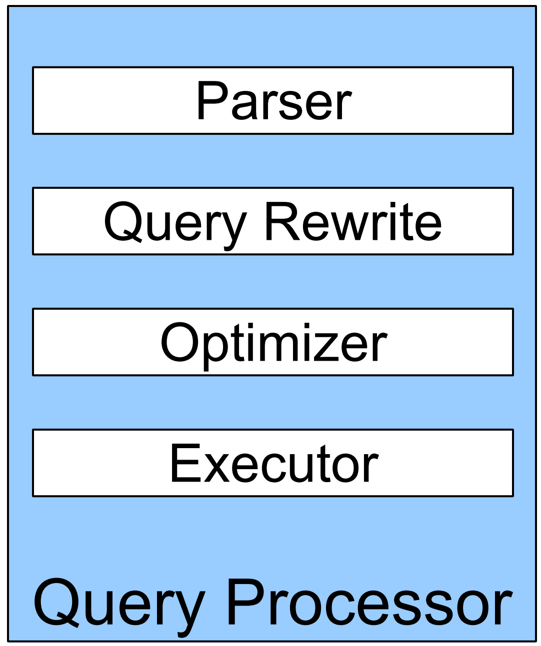
How to Implement a Relational DBMS?

Key challenge: Achieve high performance on large databases!

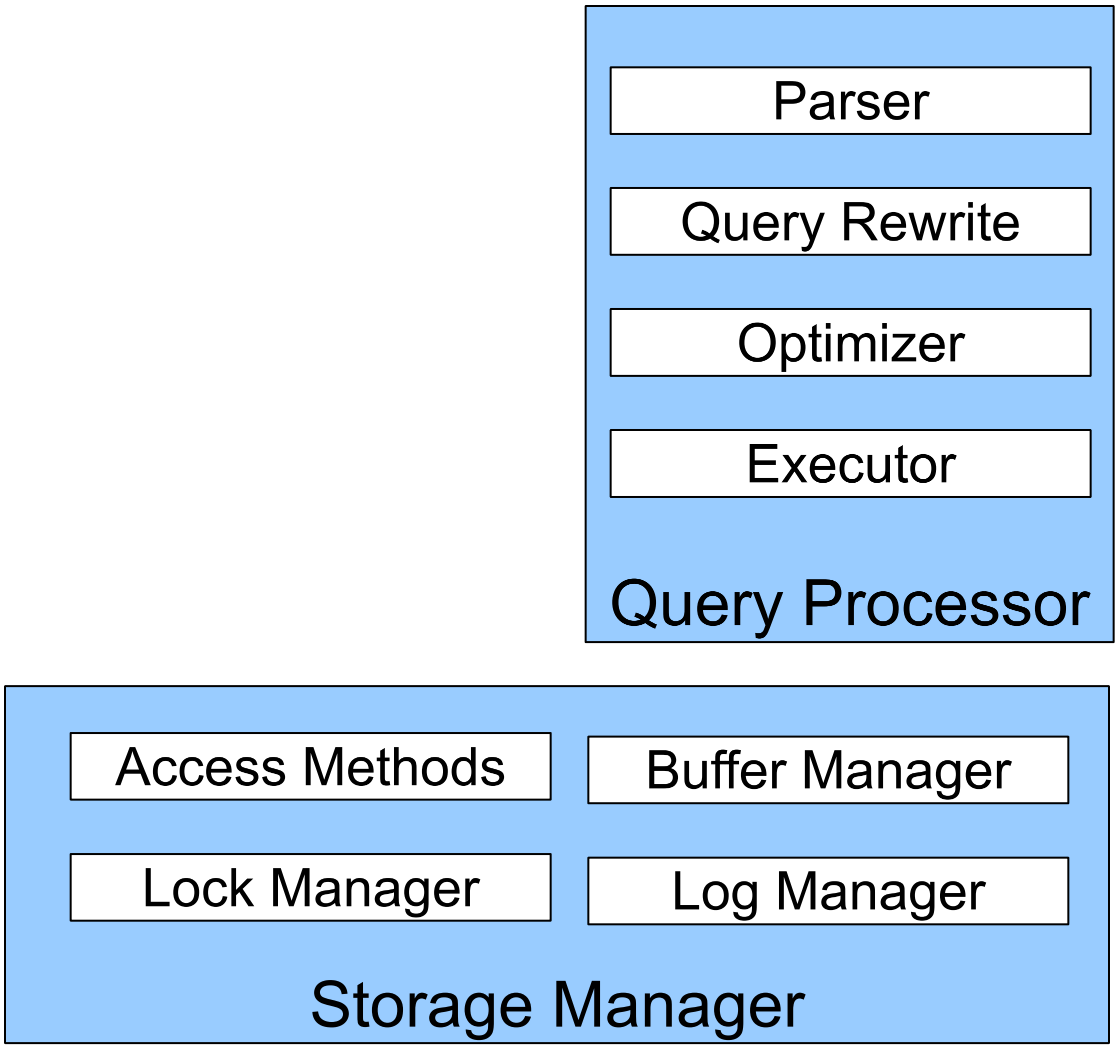


DBMS Architecture

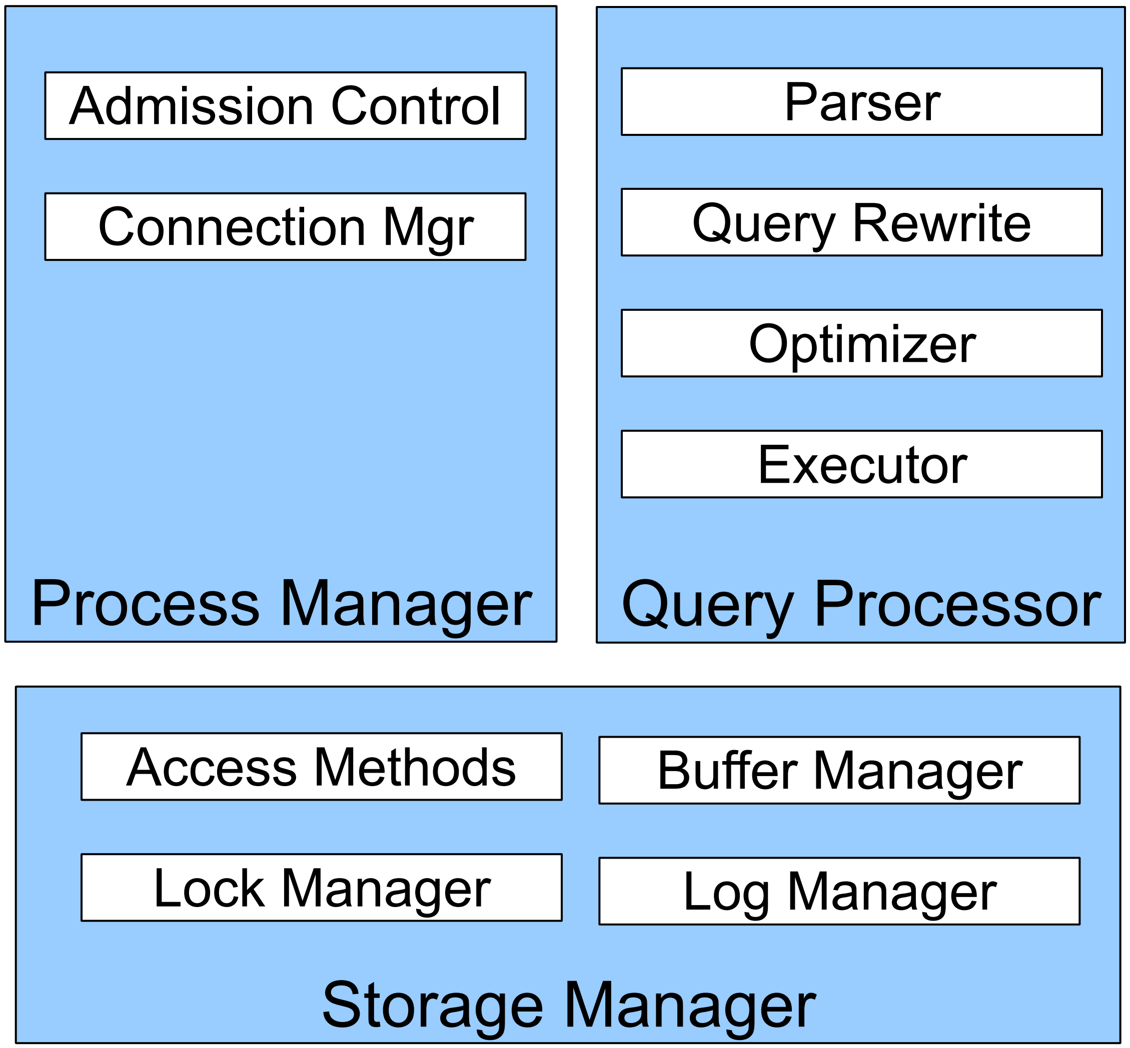
DBMS Architecture



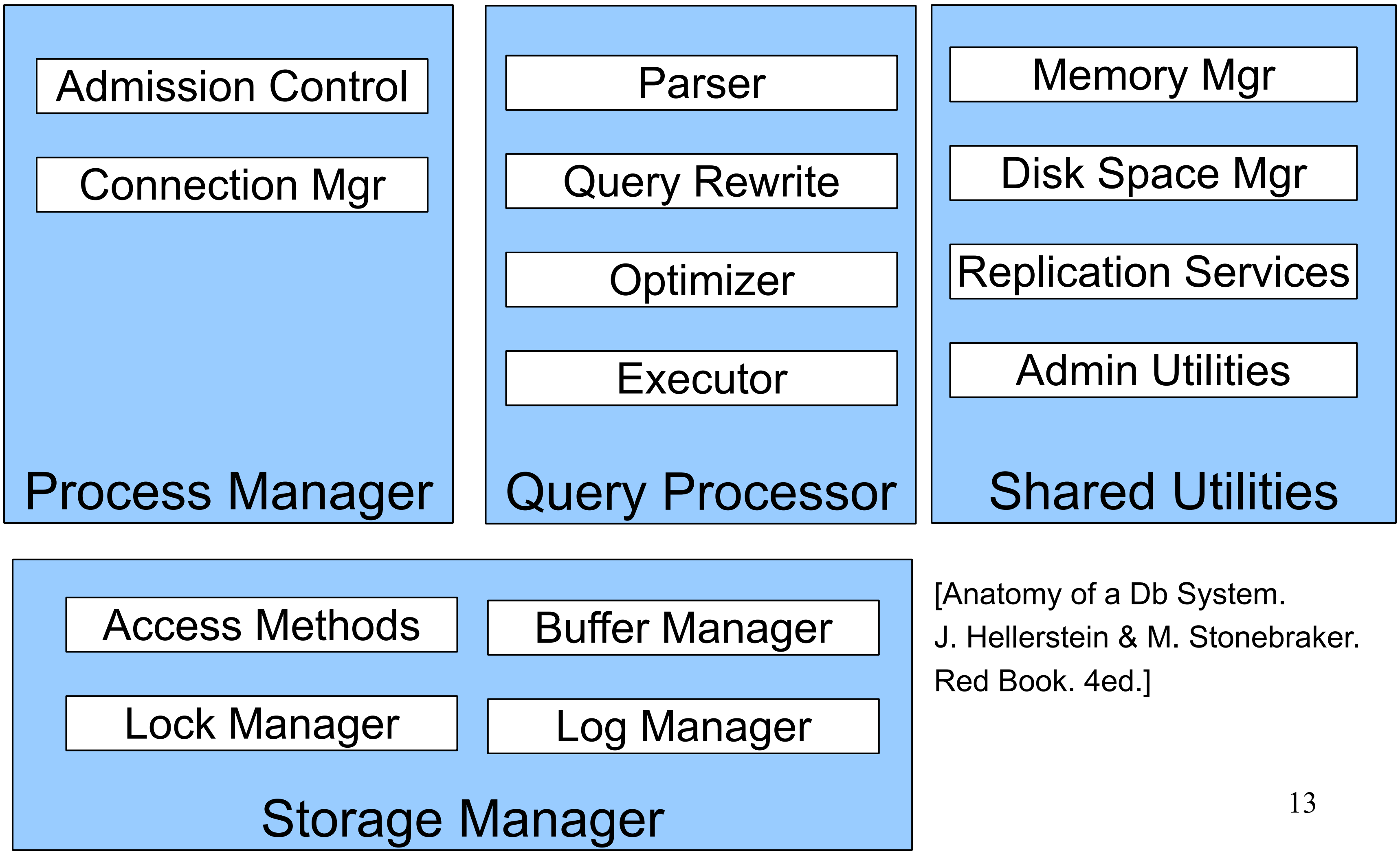
DBMS Architecture



DBMS Architecture



DBMS Architecture



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

Goal for Today

Overview of query execution

Overview of storage manager

Query Processor

Example Database Schema

Supplier(<u>sno</u>,sname,scity,sstate)

Part(<u>pno</u>,pname,psize,pcolor)

Supplies(<u>sno,pno</u>,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)`
`Supplies(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**
- **Step 2: Query rewrite**
  - View rewriting, flattening, etc.

```
Supplier(sno,sname,scity,sstate)
Part(pno,pname,psize,pcolor)
Supplies(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 (expanding NearbySupp view):

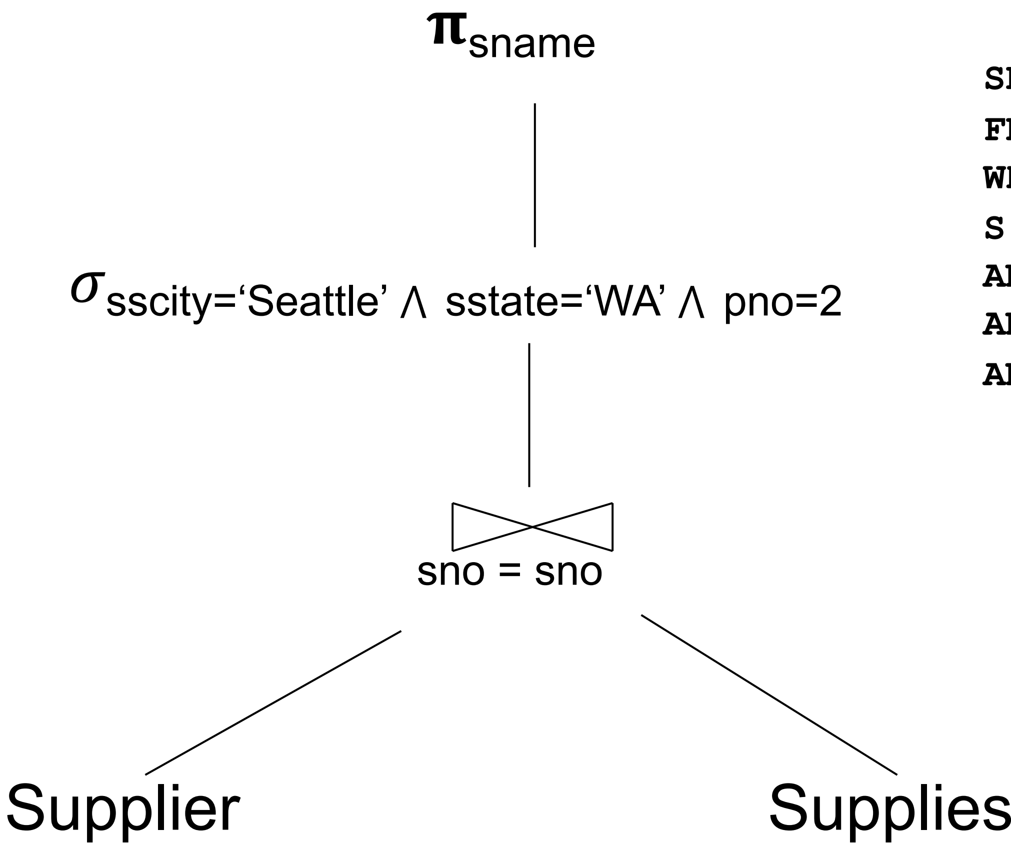
```
SELECT S.sname
FROM Supplier S, Supplies U
WHERE S.scity='Seattle' AND S.sstate='WA'
AND S.sno = U.sno
AND U.pno = 2;
```

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

Logical Query Plan



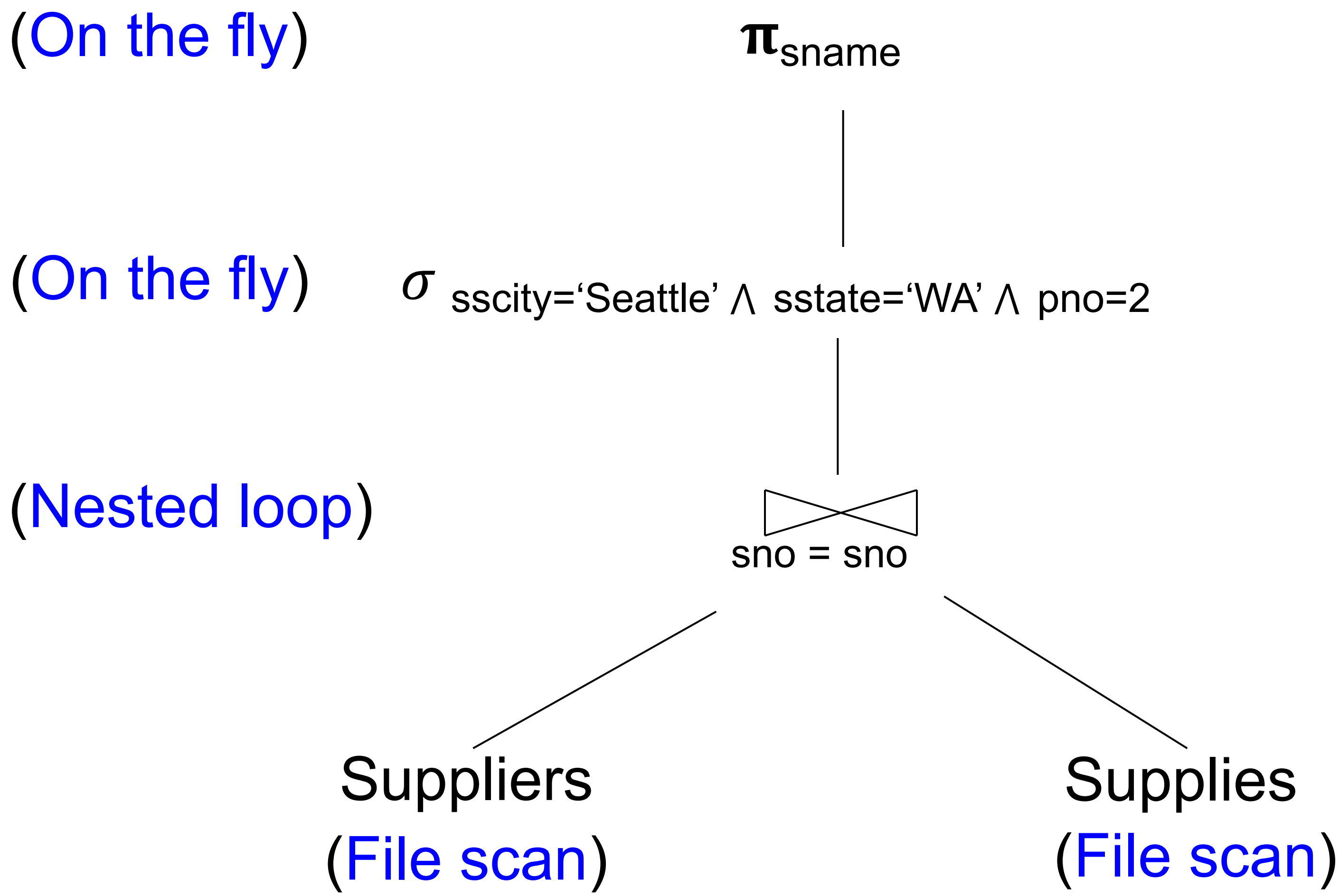

```
SELECT S.sname
FROM Supplier S, Supplies U
WHERE
S.scity='Seattle'
AND S.sstate='WA’
AND S.sno = U.sno
AND U.pno = 2;
```

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)
Part(pno,pname,psize,pcolor)
Supplies(sno,pno,price)

Physical Query Plan



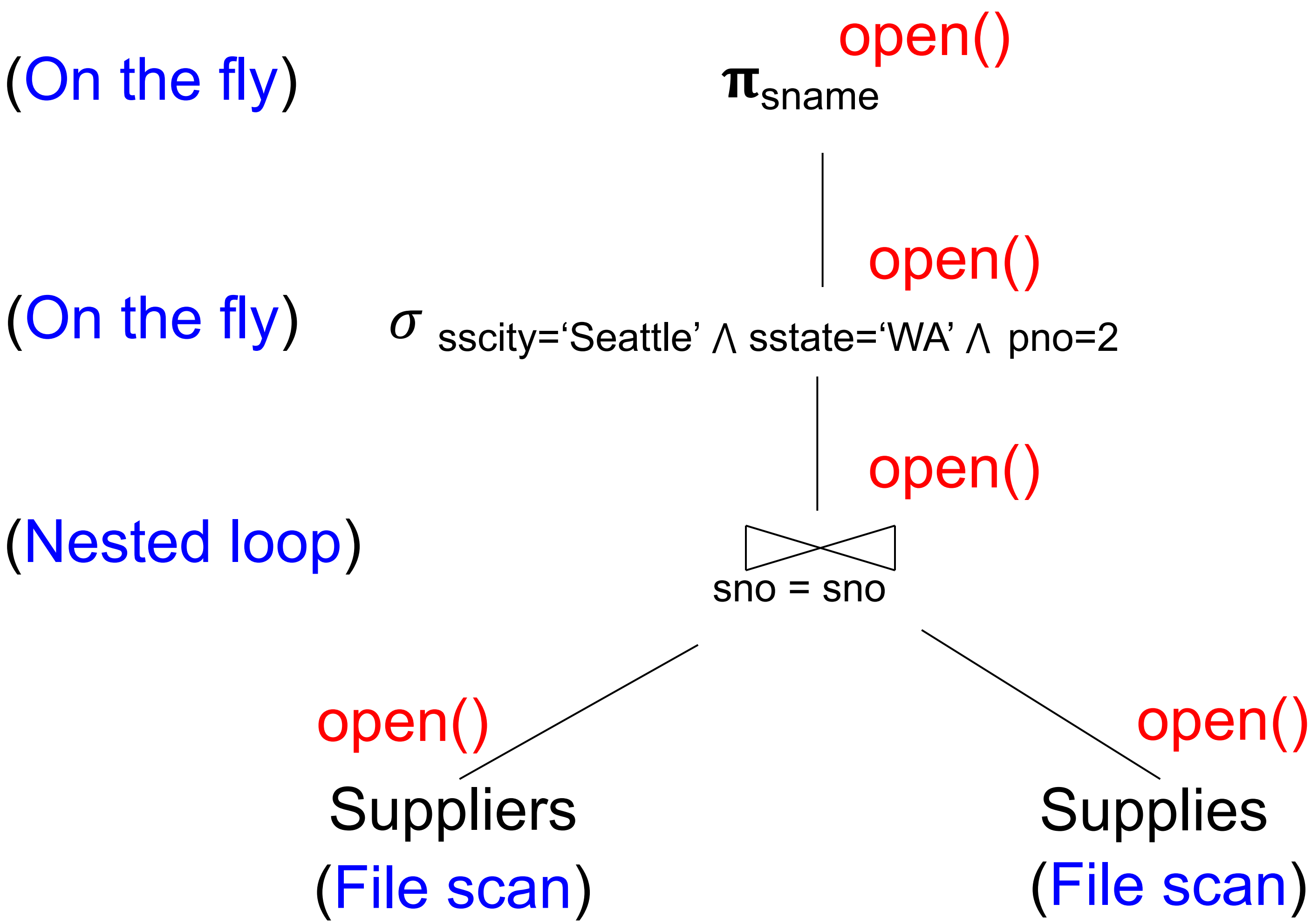
Query Executor

Iterator Interface

- Each **operator implements this interface**
- **open()**
  - Initializes operator state
  - Sets parameters such as selection predicate
- **next()**
  - Operator invokes next() recursively on its inputs
  - Performs processing and produces an output tuple
- **close()**: clean-up state
- Operators also have reference to their **child** operator in the query plan

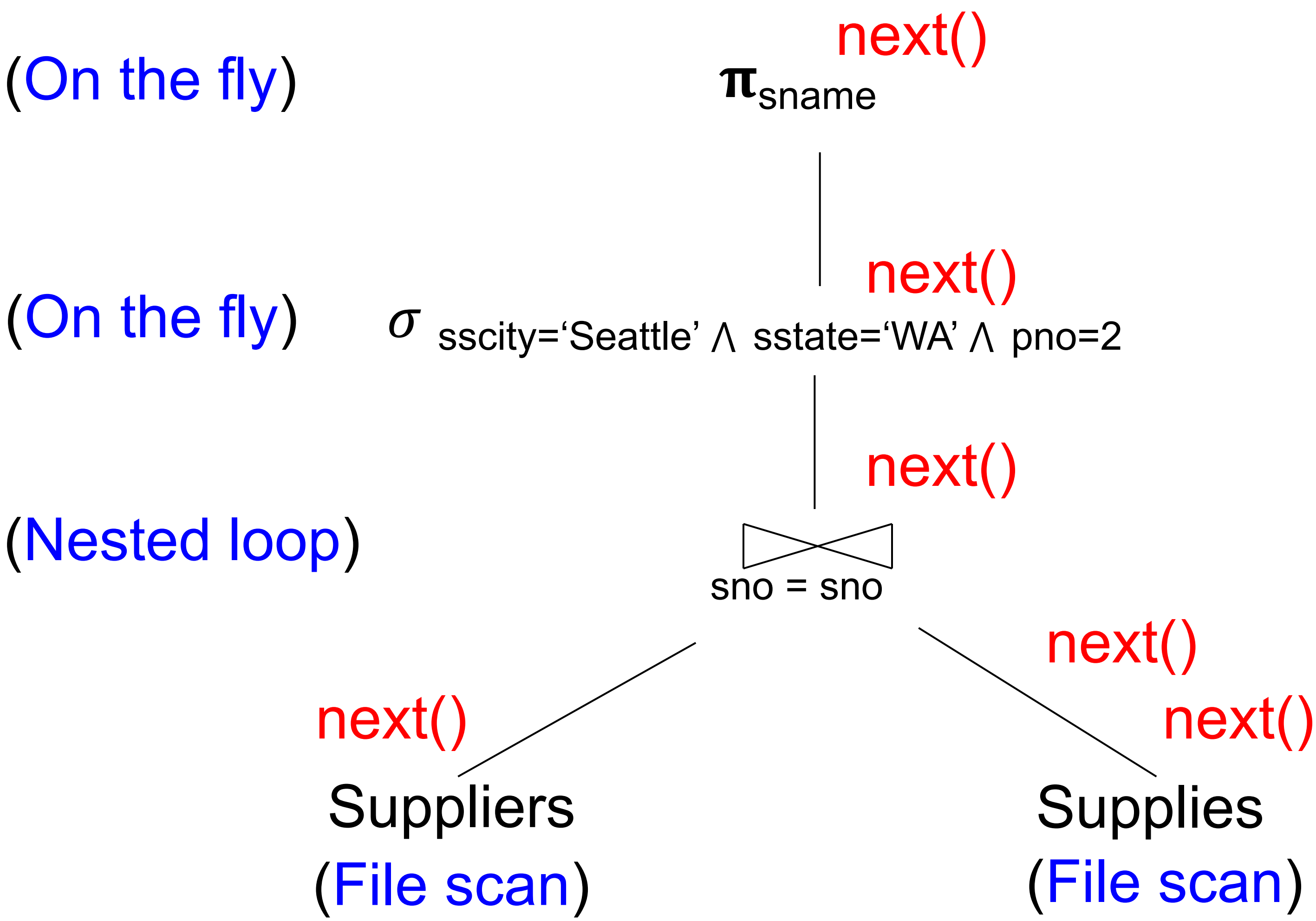
Supplier(sno,sname,scity,sstate)
Part(pno,pname,psize,pcolor)
Supplies(sno,pno,price)

Query Execution



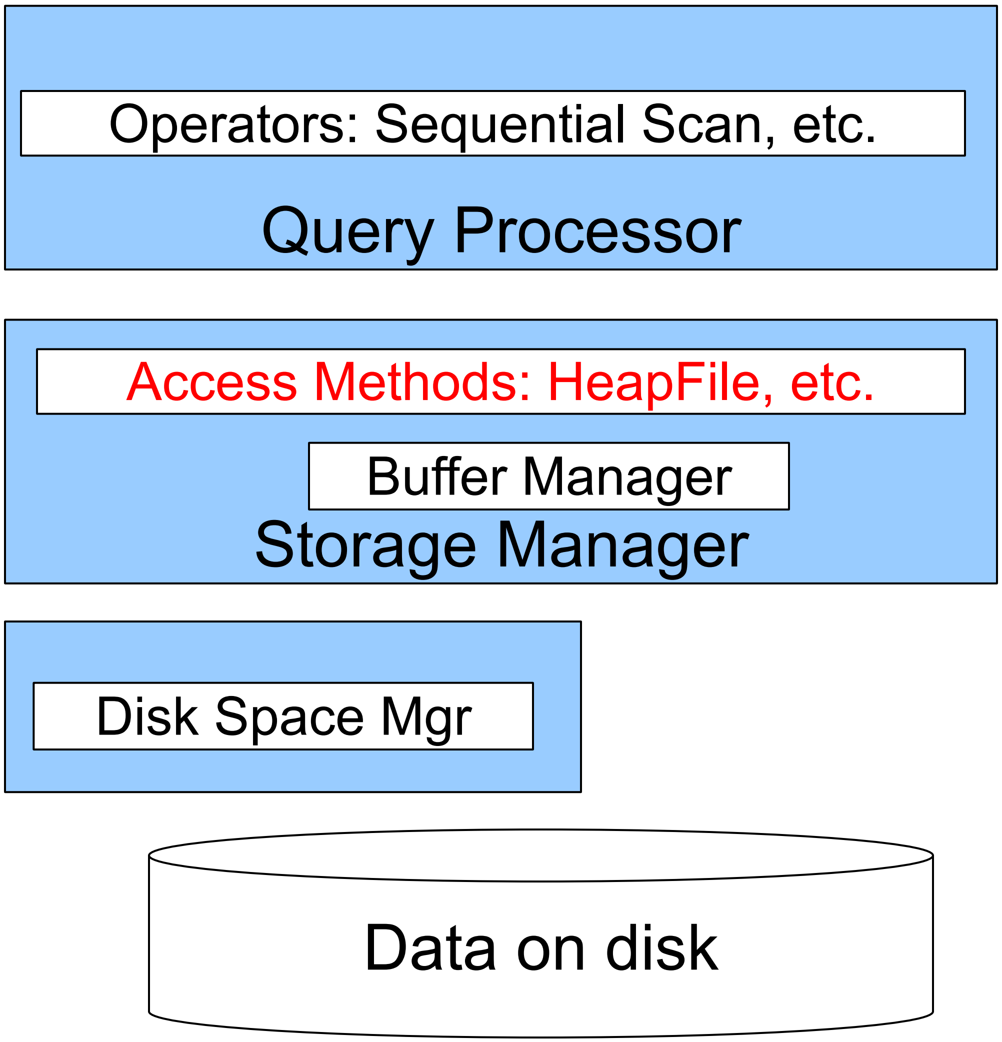
```
Supplier(sno,sname,scity,sstate)
Part(pno,pname,psize,pcolor)
Supplies(sno,pno,price)
```

Query Execution



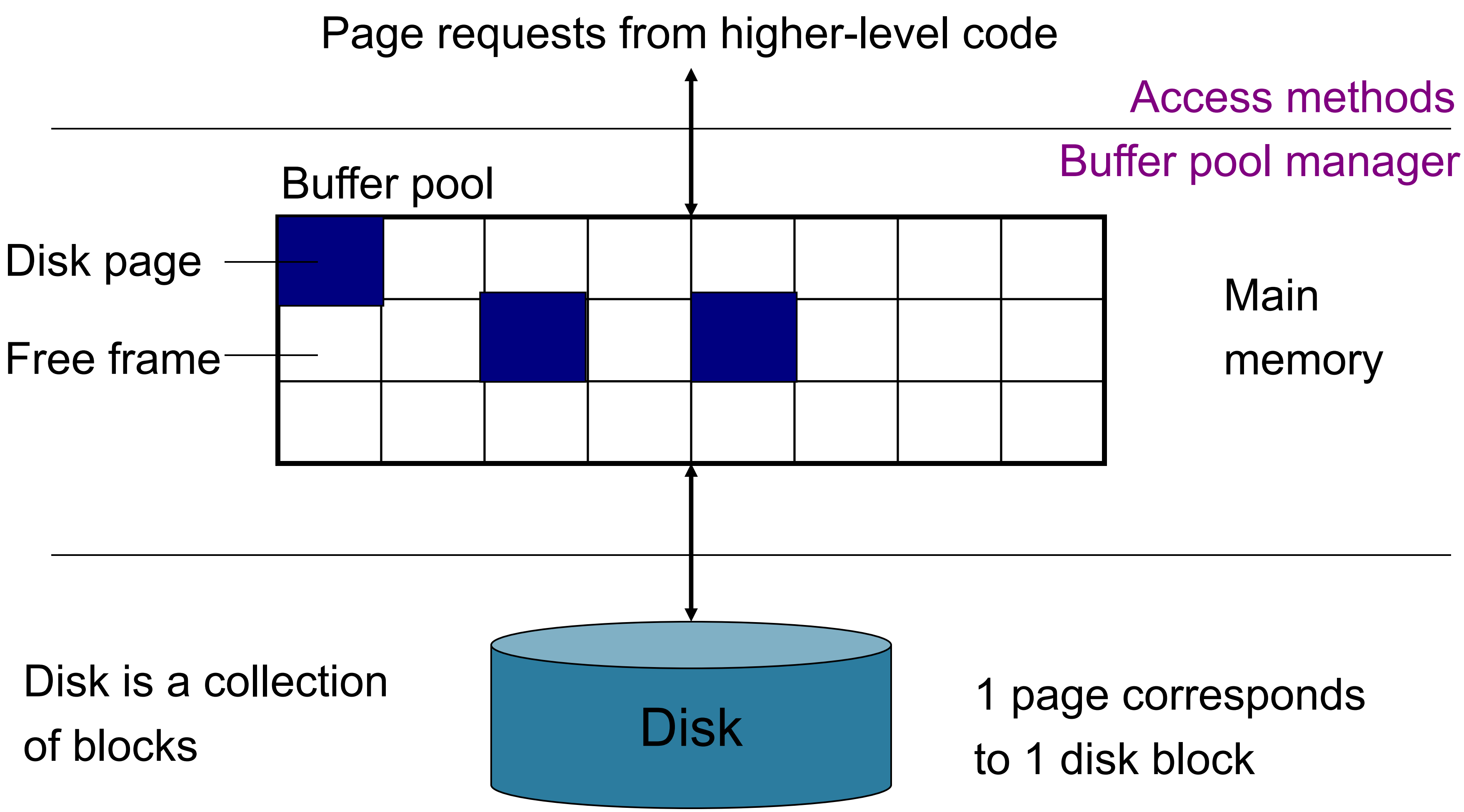
Storage Manager

Access Methods



- **Operators:** Process data
- **Access methods**: Organize data to support fast access to desired subsets of records
- **Buffer manager**: Caches data in memory. Reads/writes data to/from disk as needed
- **Disk-space manager**: Allocates space on disk for files/access methods

Buffer Manager



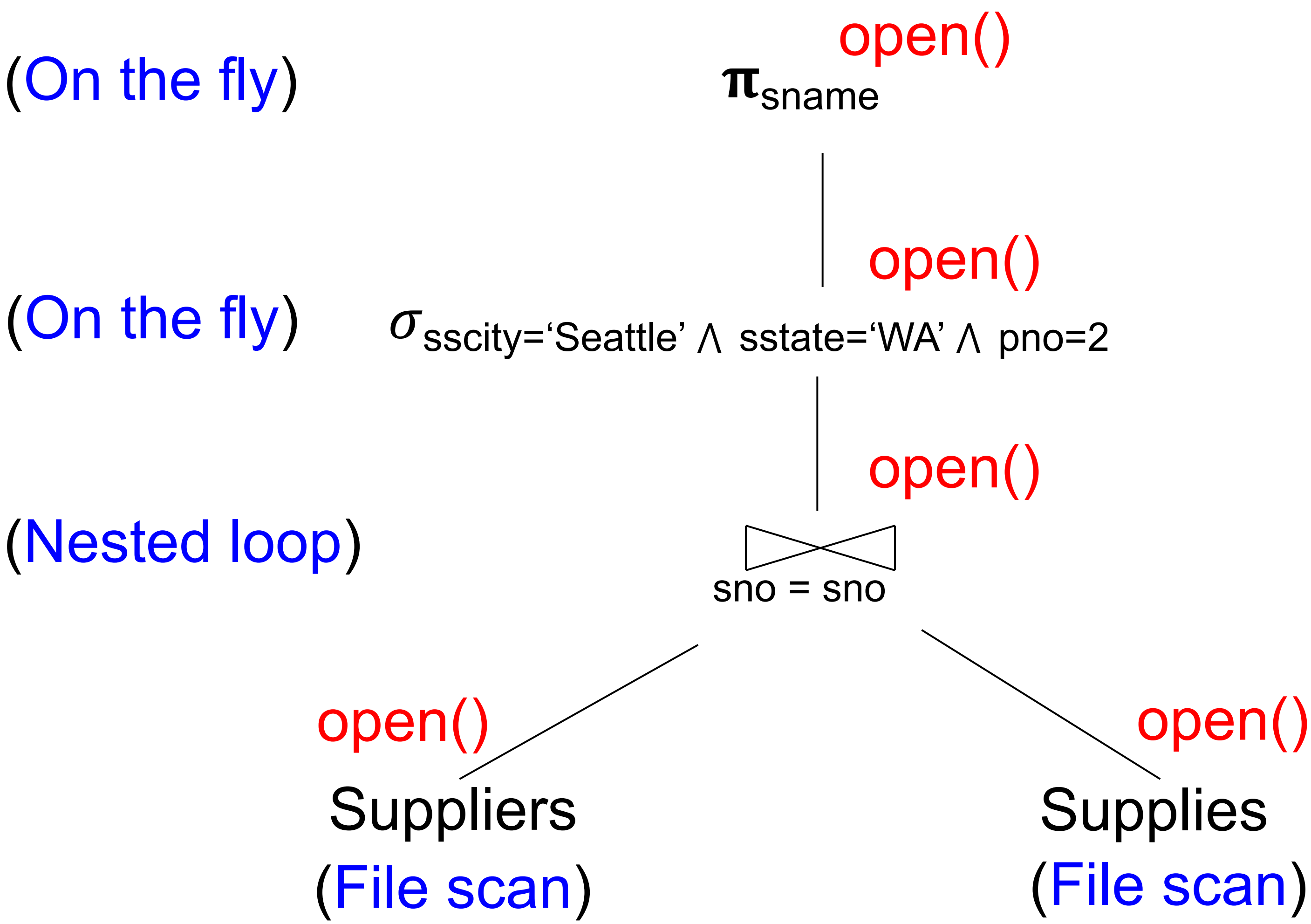
Buffer Manager

- Brings pages in from memory and caches them
- Eviction policies
  - Random page (ok for SimpleDB)
  - Least-recently used
  - The “clock” algorithm (see book)
- Keeps track of which **pages are dirty**
  - A dirty page has changes not reflected on disk
  - Implementation: Each page includes a dirty bit

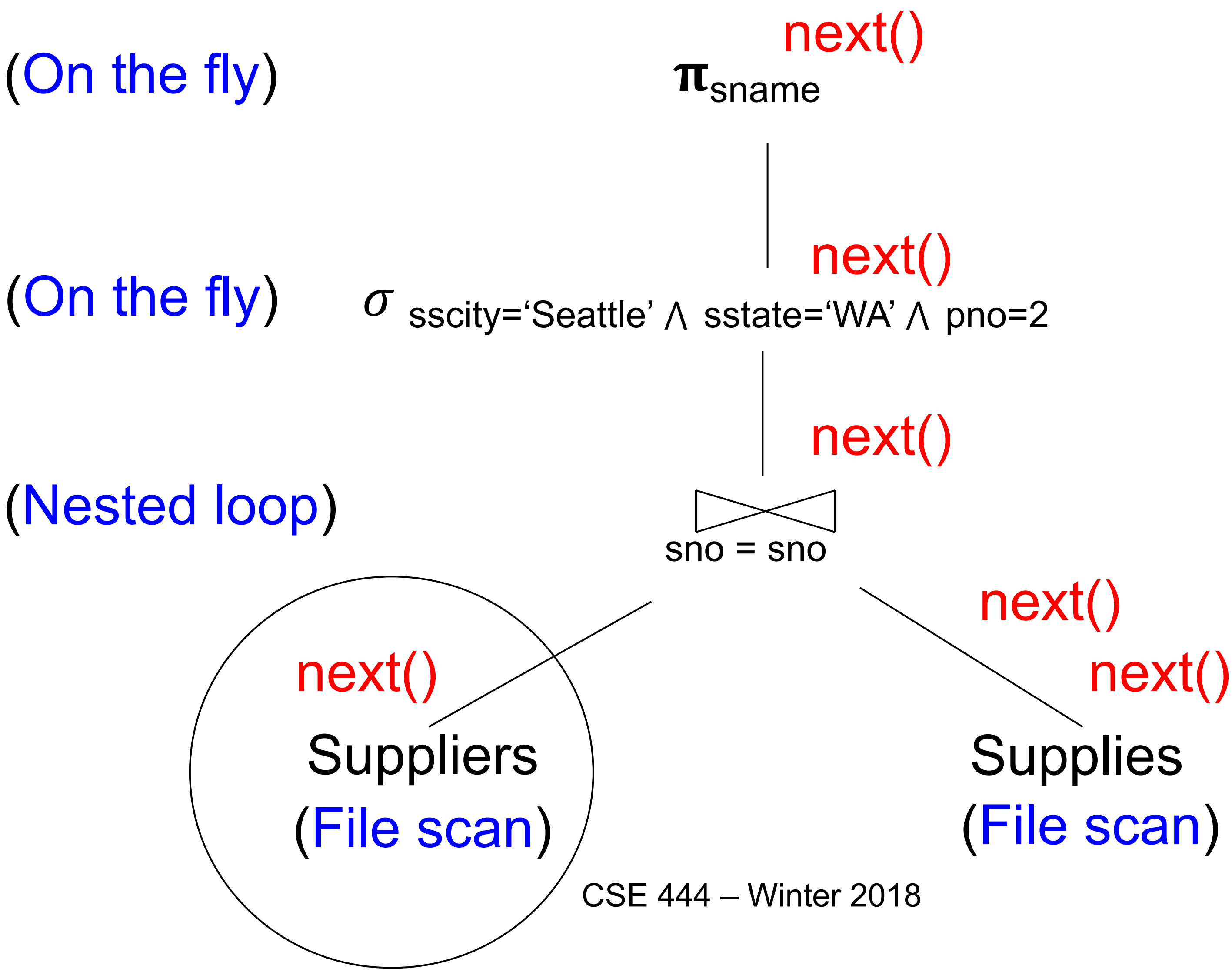
Access Methods

- A DBMS stores data on disk by breaking it into *pages*
  - A page is the size of a disk block.
  - A page is the unit of disk IO
- Buffer manager caches these pages in memory
- Access methods do the following:
  - They organize pages into collections called DB *files*
  - They organize data inside pages
  - They provide an API for operators to access data in these files
- Discussion:
  - OS vs DBMS files
  - OS vs DBMS buffer manager

Query Execution
How it all Fits Together



Query Execution
How it all Fits Together



Query Execution In SimpleDB

open()

next()

SeqScan

Operator at bottom of plan

open()

next()

In SimpleDB, SeqScan can find HeapFile in Catalog

Heap File Access Method

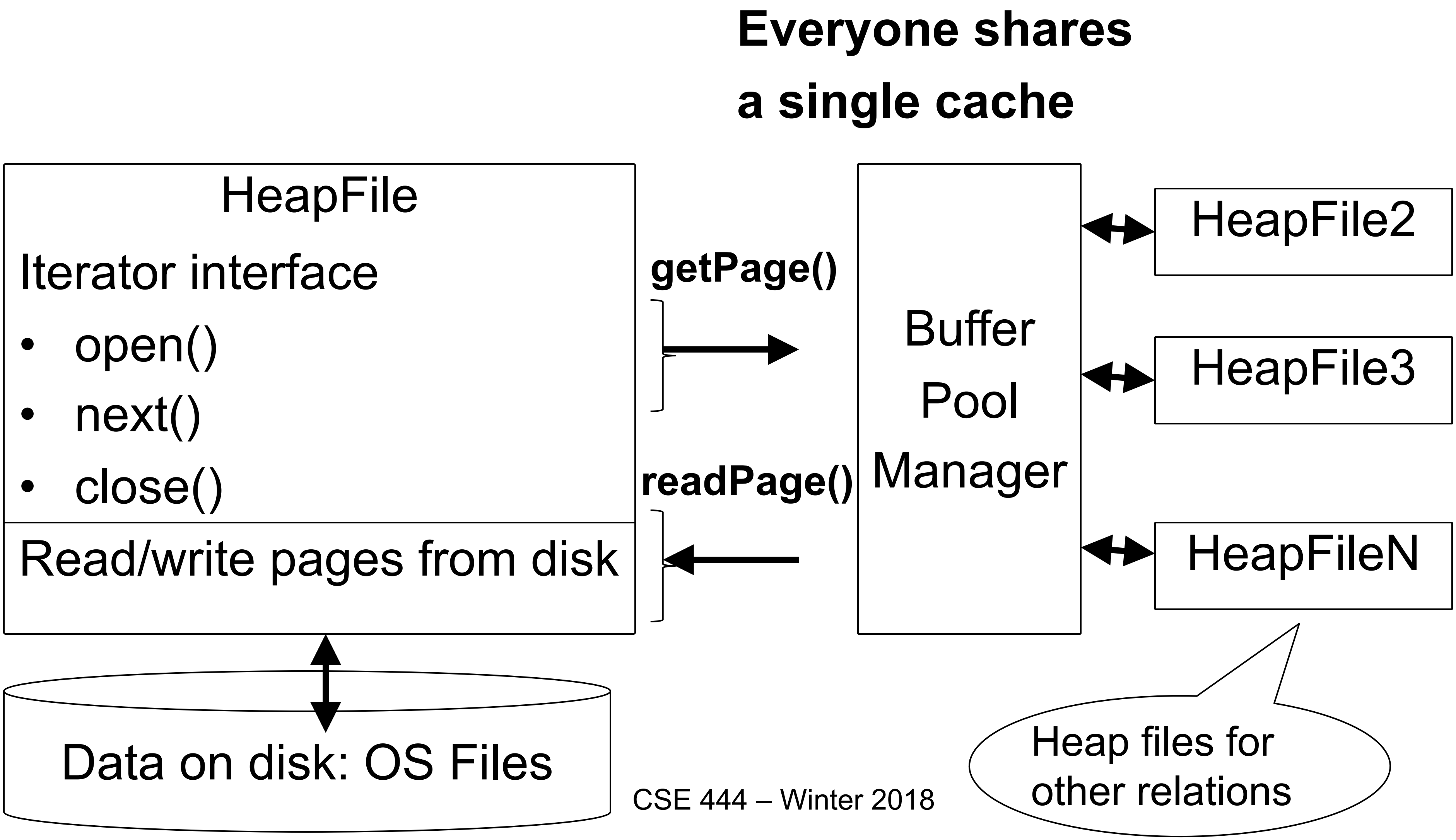
Offers iterator interface

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

Knows how to read/write pages from disk

But if Heap File reads data directly from disk, it will not stay cached in Buffer Pool!

Query Execution In SimpleDB



HeapFile In SimpleDB

- Data is stored on disk in an OS file. HeapFile class knows how to “decode” its content
- Control flow:
  - SeqScan calls methods such as "iterate" on the HeapFile Access Method
  - During the iteration, the HeapFile object needs to call the BufferManager.getPage() method to ensure that necessary pages get loaded into memory.
  - The BufferManager will then call HeapFile .readPage()/writePage() page to actually read/write the page.