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
  - You need lecture 4 to do the homework
  - 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 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!

- Try to save late days for later in the quarter

- But no late days for final project

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:

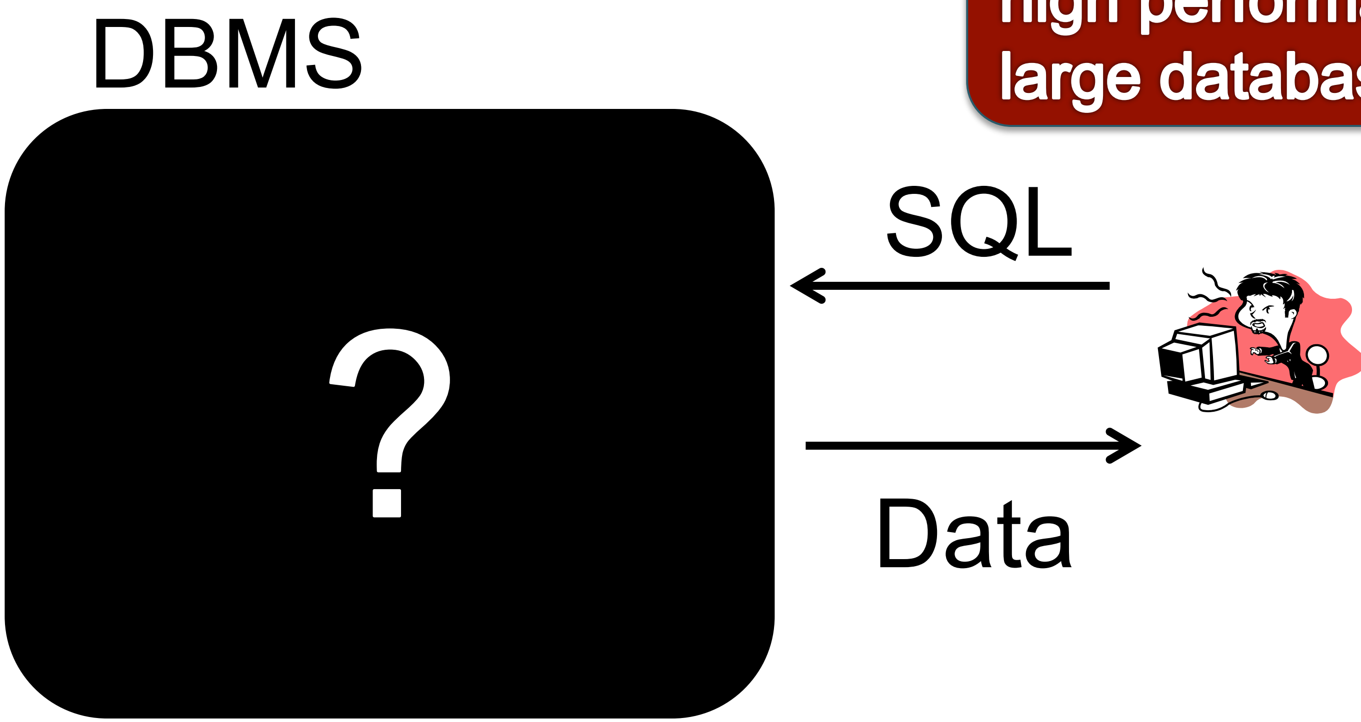
- Set-at-a-time: instead of tuple-at-a-time
- Declarative: user says what they want and not how to get it
- Query optimizer: from *what* to *how*

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

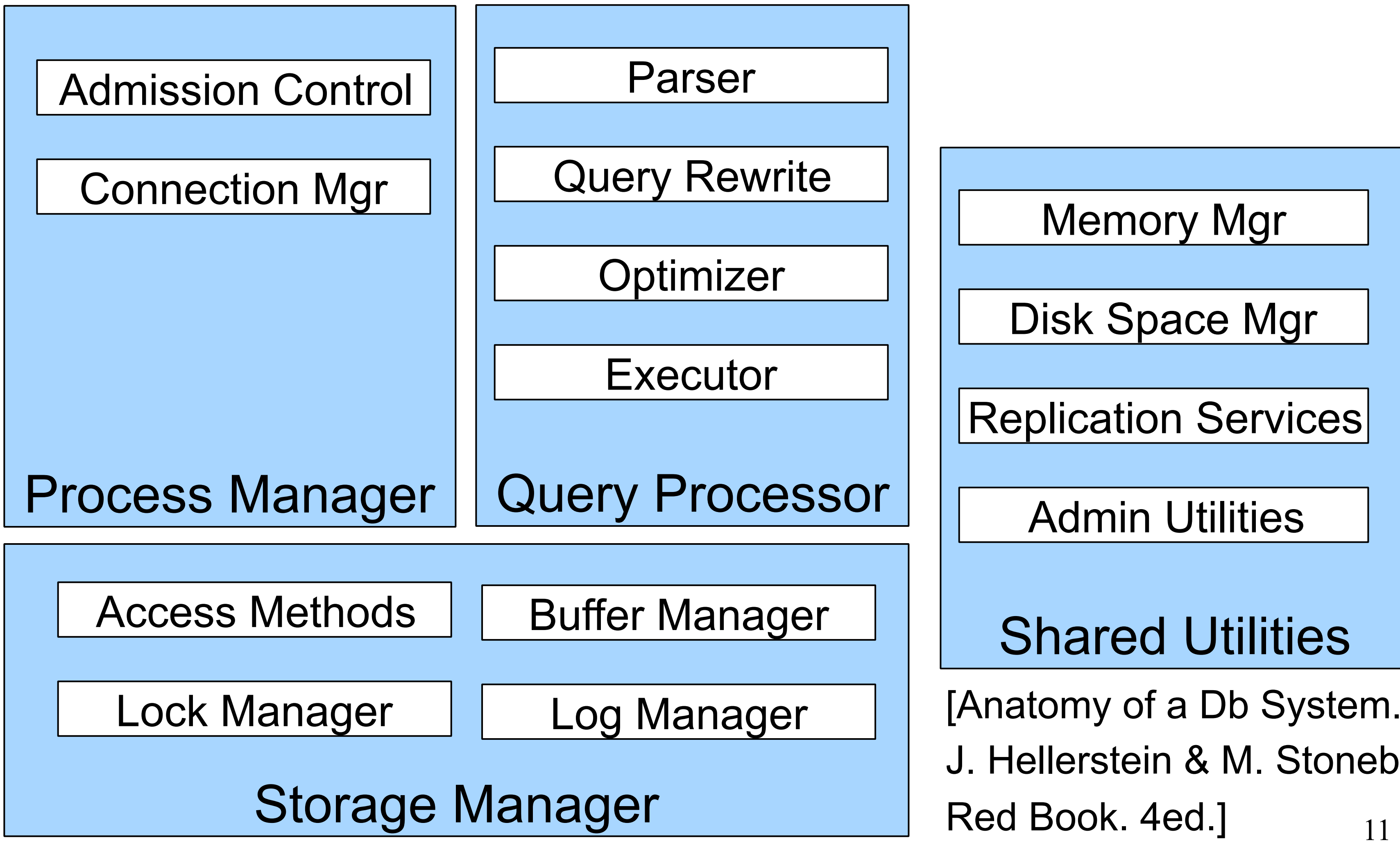
Overview of DBMS architecture

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

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

Supply(<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)
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(sno,sname,scity,sstate)
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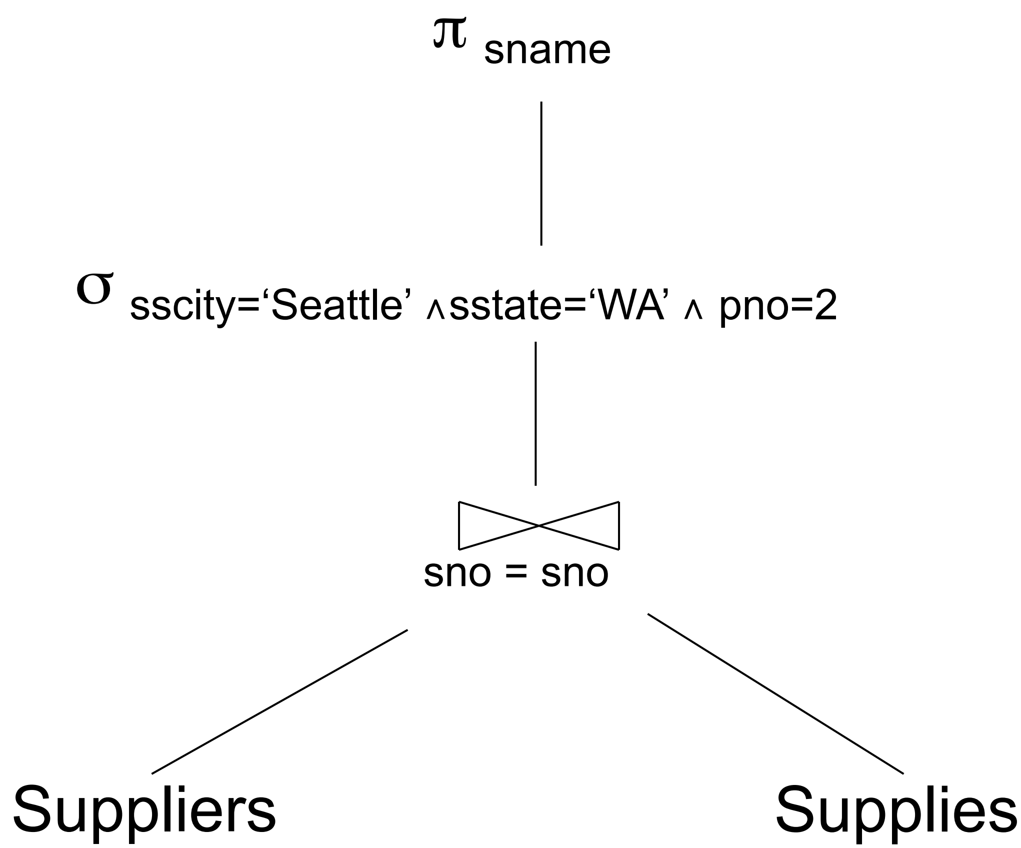
Logical Query Plan

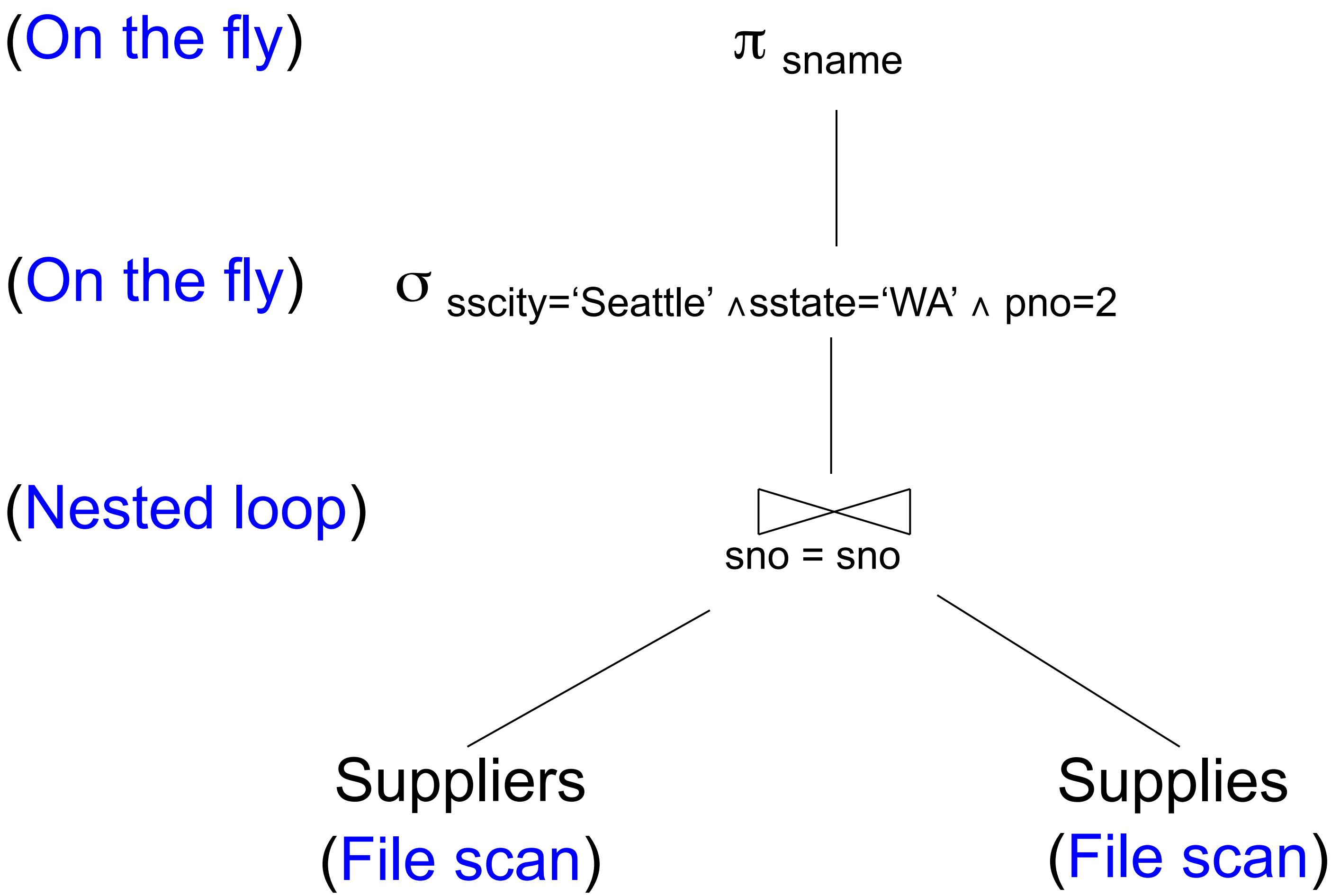


Physical Query Plan

- 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)
Part(pno,pname,psize,pcolor)
Supply(sno,pno,price)
```

Physical Query Plan



Query Executor

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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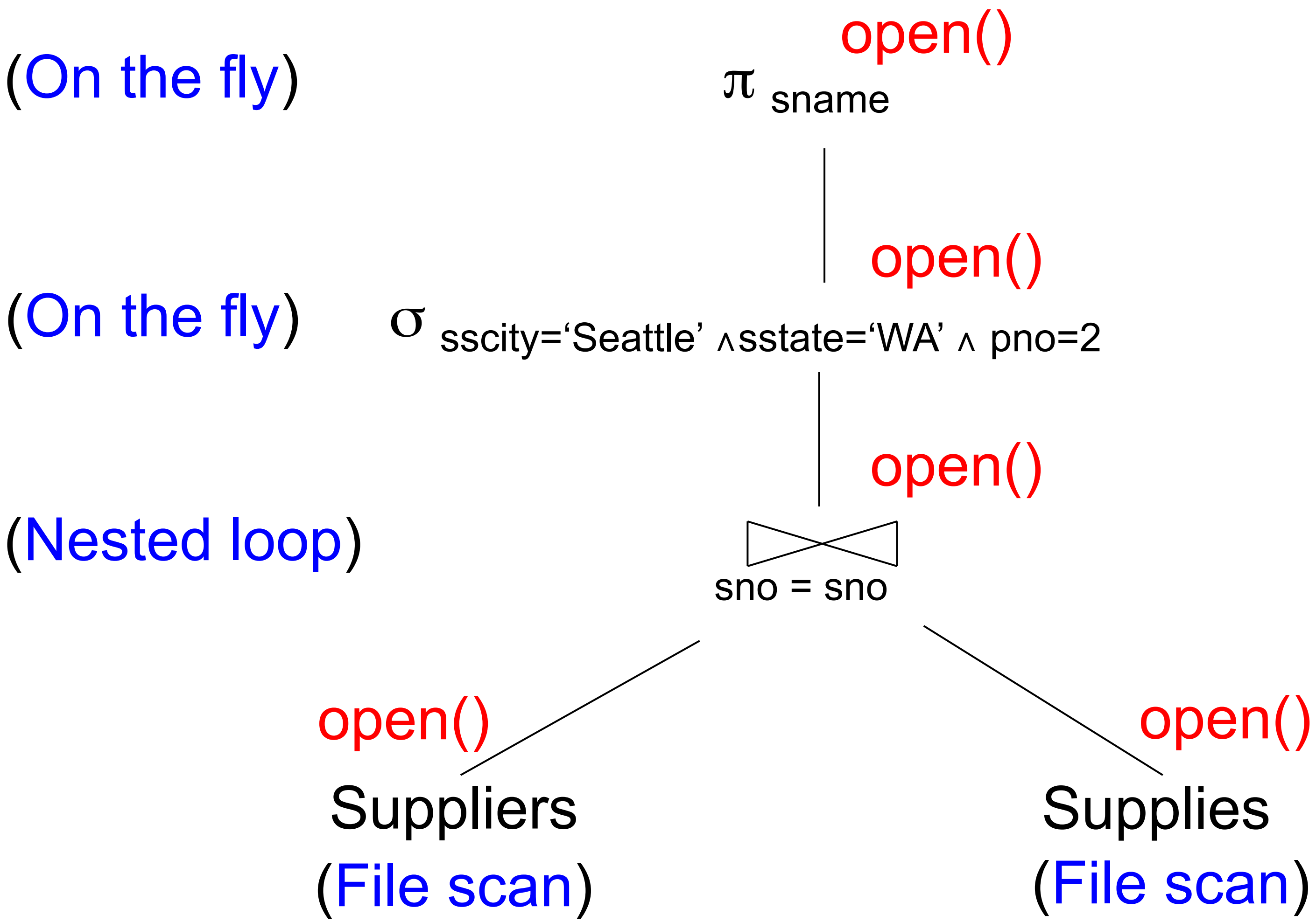
Supply(sno,pno,price)
```

Query Execution



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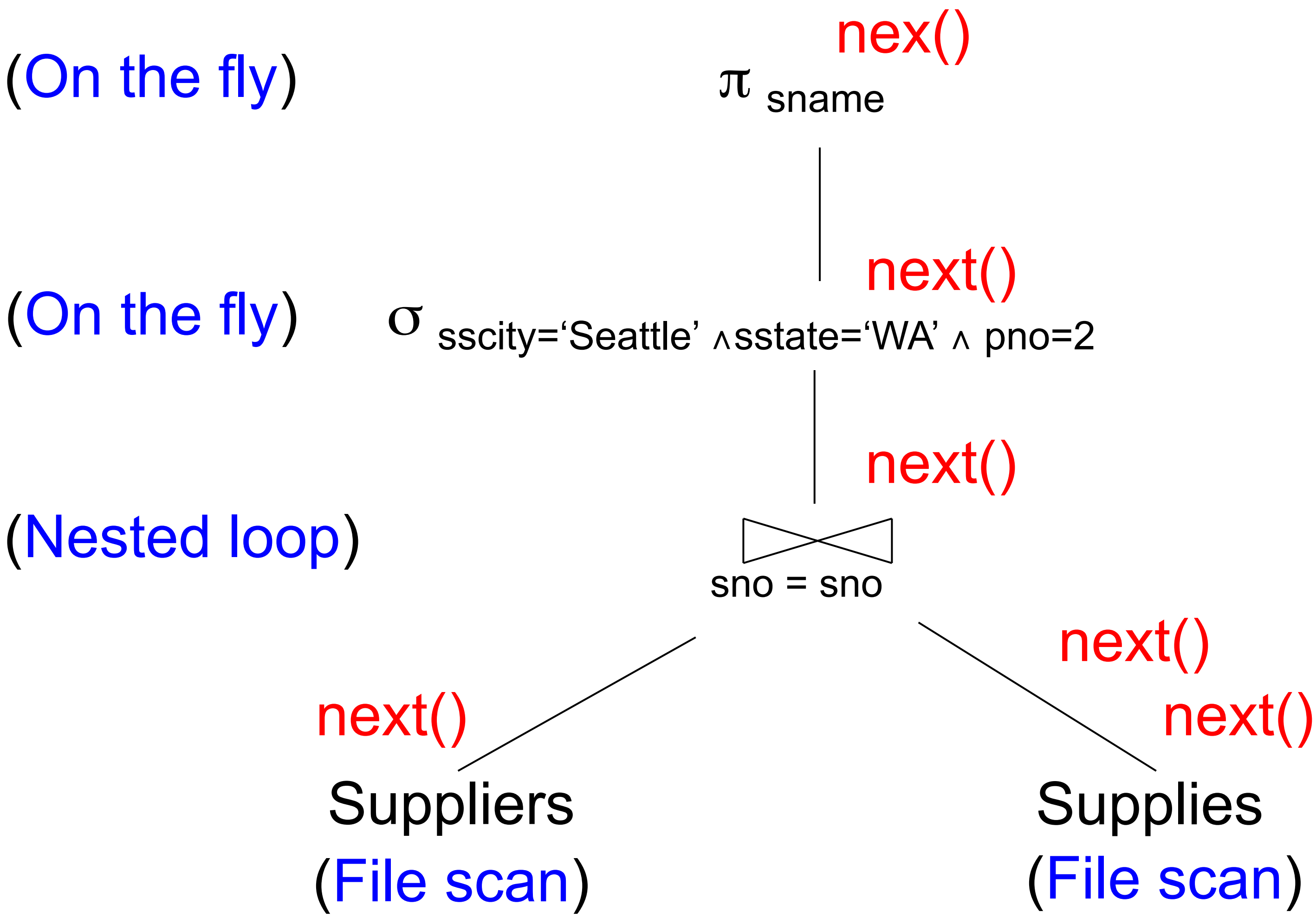
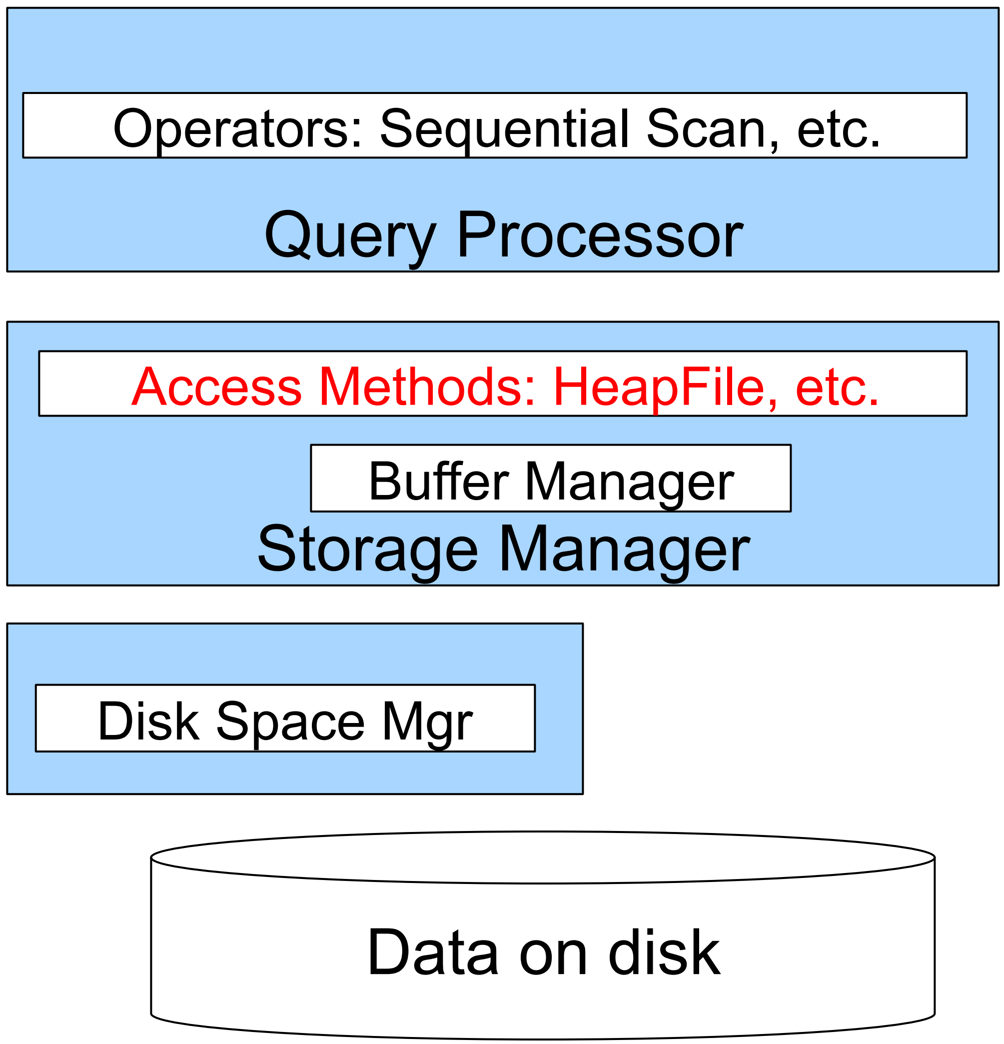
```

Query Execution



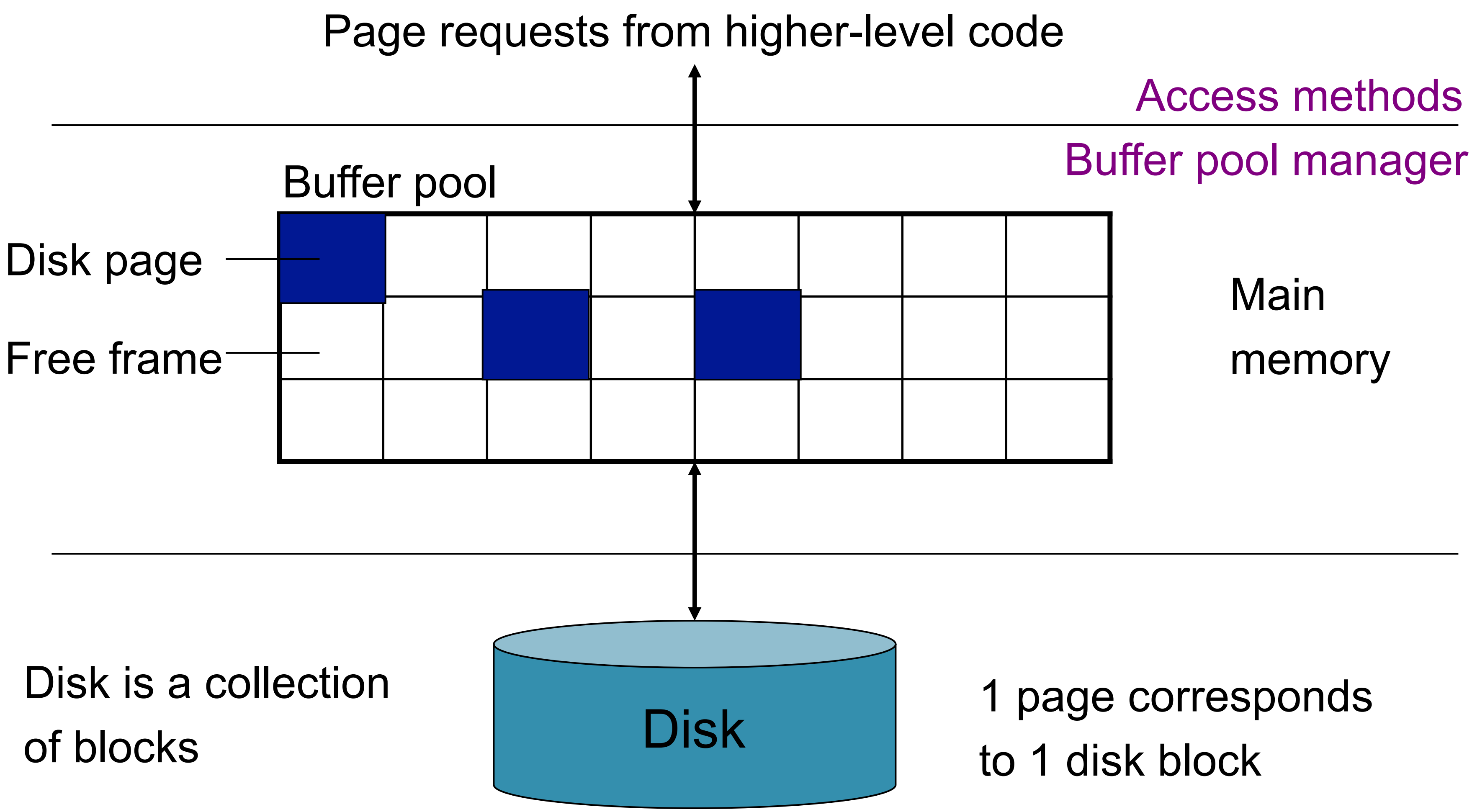
Storage Manager

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



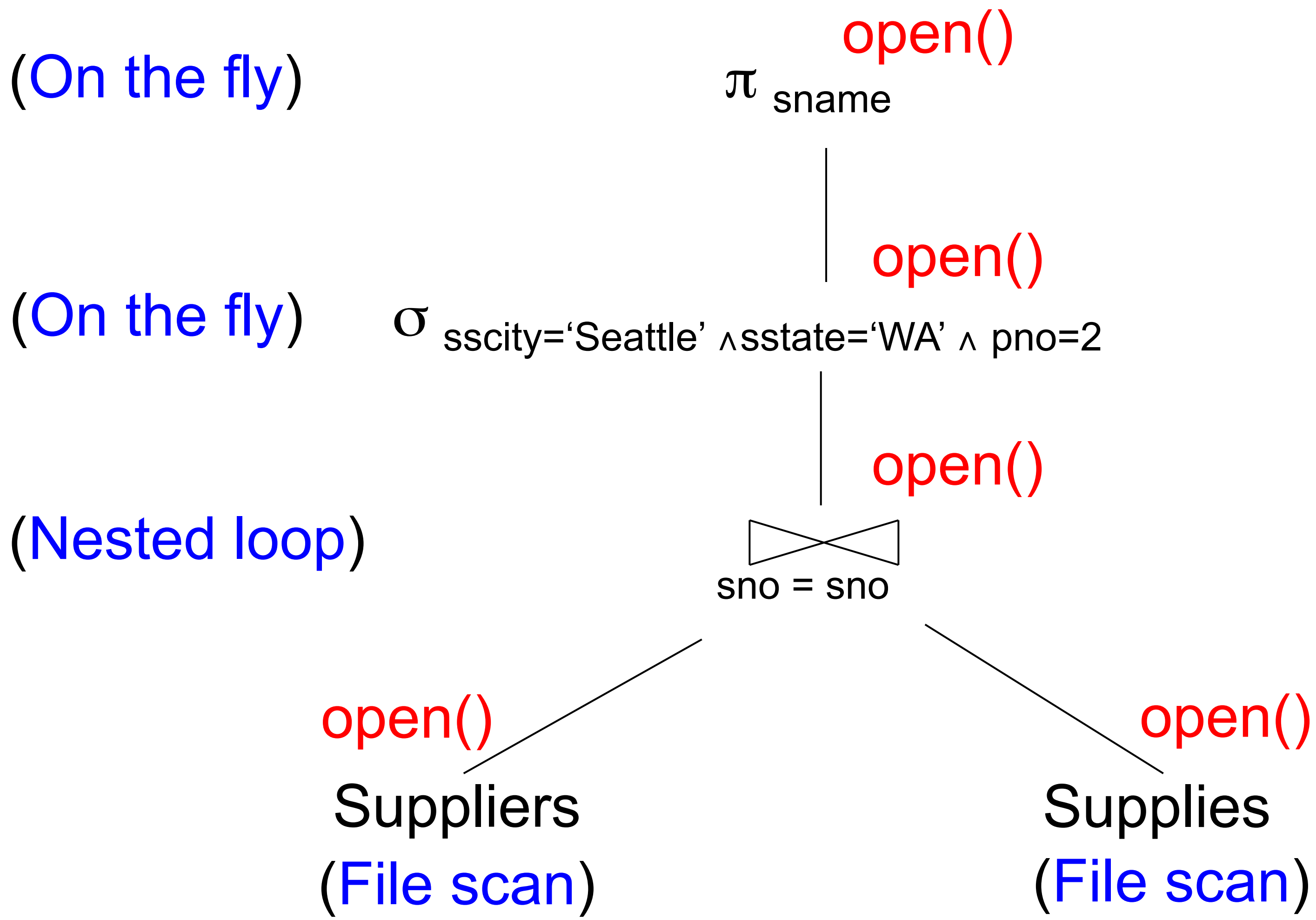
Buffer Manager

- Brings pages in from memory and caches them
- Eviction policies
  - Random page (ok for SimpleDB)
  - Least-recently used
  - The "clock" algorithm (see whiteboard or 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
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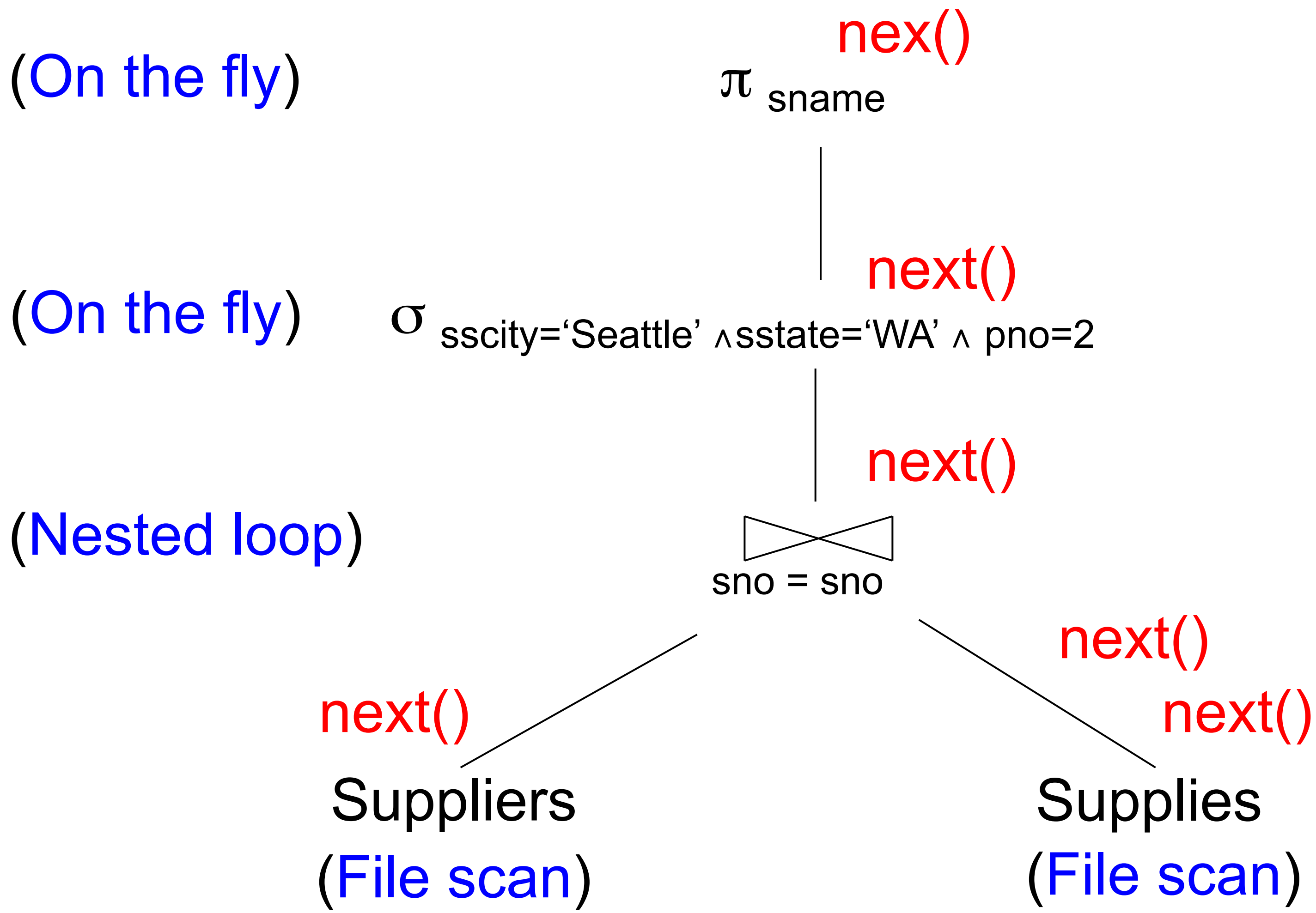


Query Execution In SimpleDB

open()

nex()

SeqScan

Operator at bottom of plan

open()

nex()

In SimpleDB, SeqScan can find HeapFile in Catalogue

Heap File Access Method

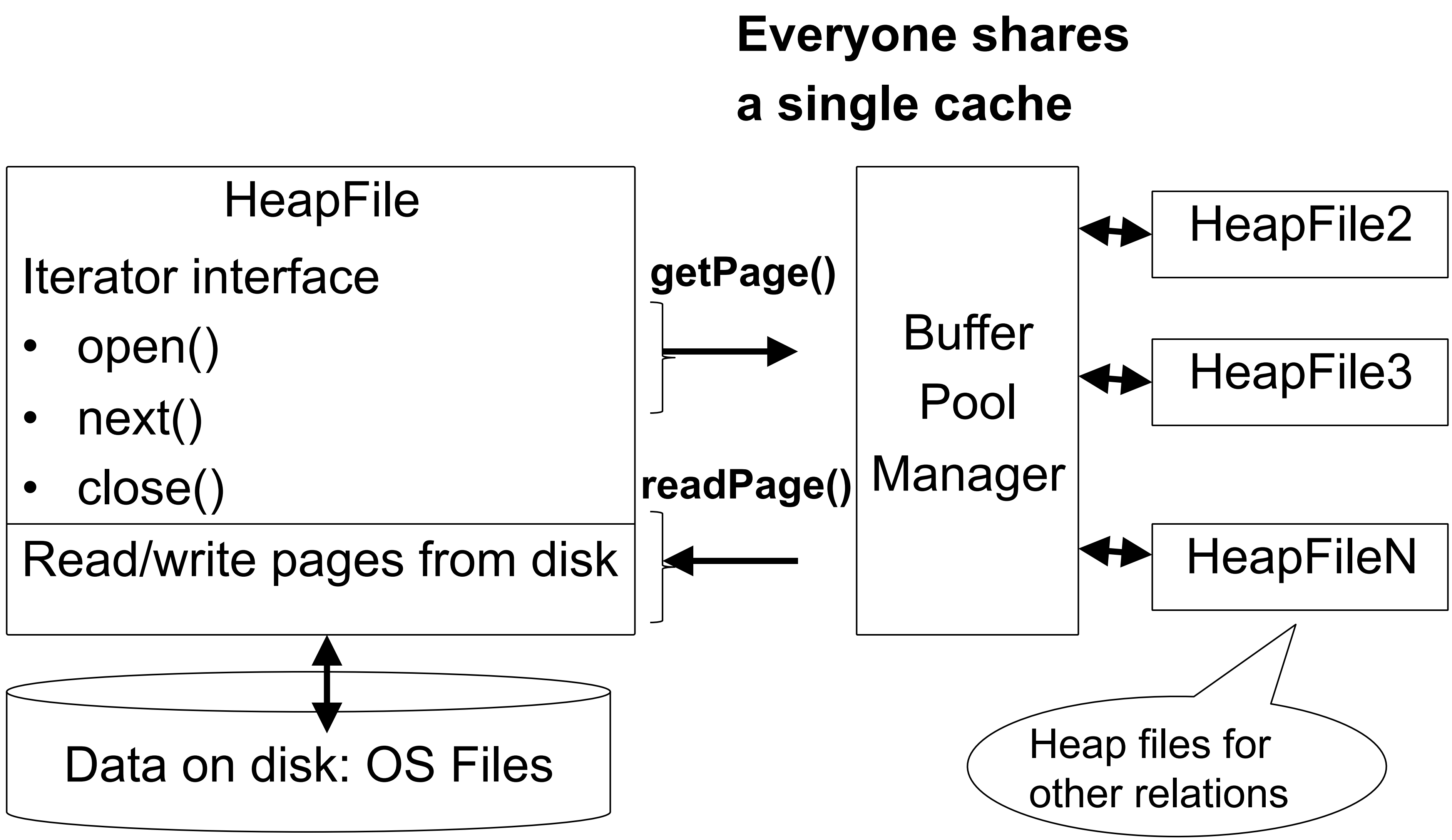
Offers iterator interface

- 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 DbFile Access Method
  - During the iteration, the DbFile object needs to call the BufferManager.getPage method to ensure that necessary pages get loaded into memory.
  - The BufferManager will then call DbFile.read/write page to actually read/write the page.