David Eccles

INFO90002 Database Systems & Information Modelling

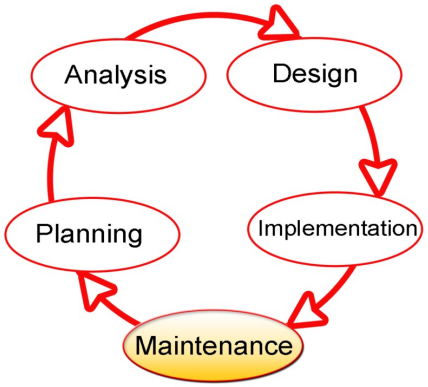
Lecture 15: Database Architecture & Administration

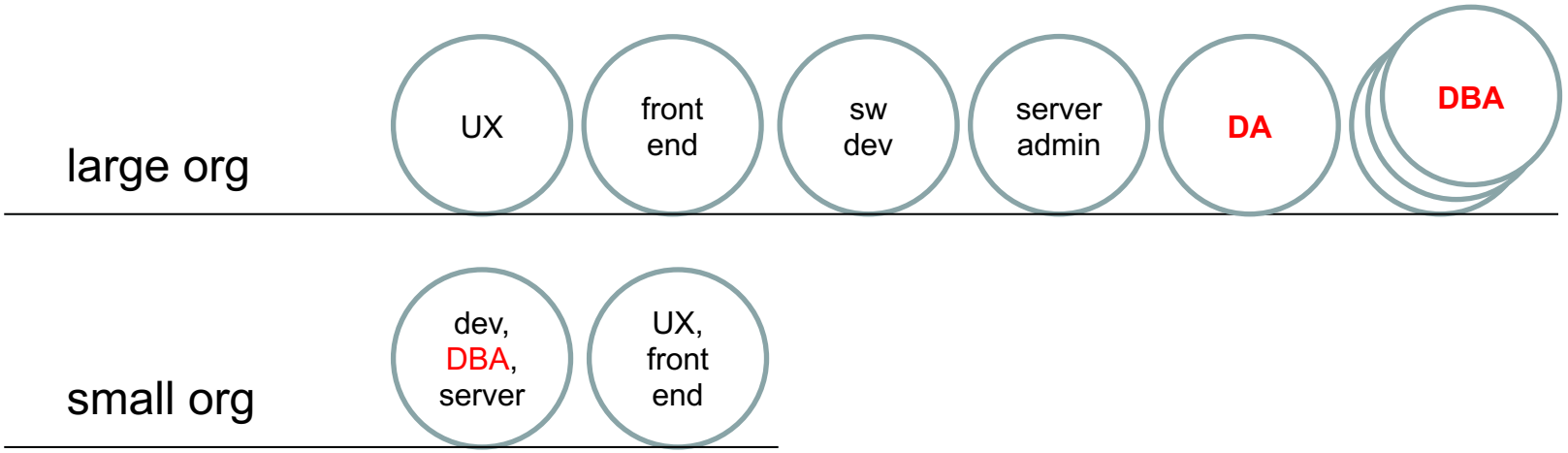
Today's Session…

- The 'Database Administrator' role
- Architecture – Understanding the DBMS
  - concepts
- Performance improvement
  - concepts
  - common approaches e.g. indexes

The DBA role

- primarily concerned with “maintenance” / “ops” phase
- but should be consulted during all phases of development
- “Database Administrator” or “DBA”
- often framed as a “job” or a “person”
- Large companies – many DBA’s
- Small company developer is the DBA
- DBA role can be made redundant by Cloud-based DBMS or “database as a service” DAAS (often IAAS or PAAS)





Data and Database Administration

- Data Administrator (CDO / CSO) (management role)
  - data policies, procedures and standards
  - planning
  - data conflict resolution
  - managing info repository
  - internal marketing & education
  - Compliance with legislation (EU GDPR AUS Privacy Act)
  - Compliance with company policy (e.g. Unimelb privacy policy)
- Database Administrator (technical role)
  - analyze and design DB
  - select DBMS / tools / vendor
  - install and upgrade DBMS
  - tune DBMS performance
  - manage security, privacy, integrity
  - backup and recovery

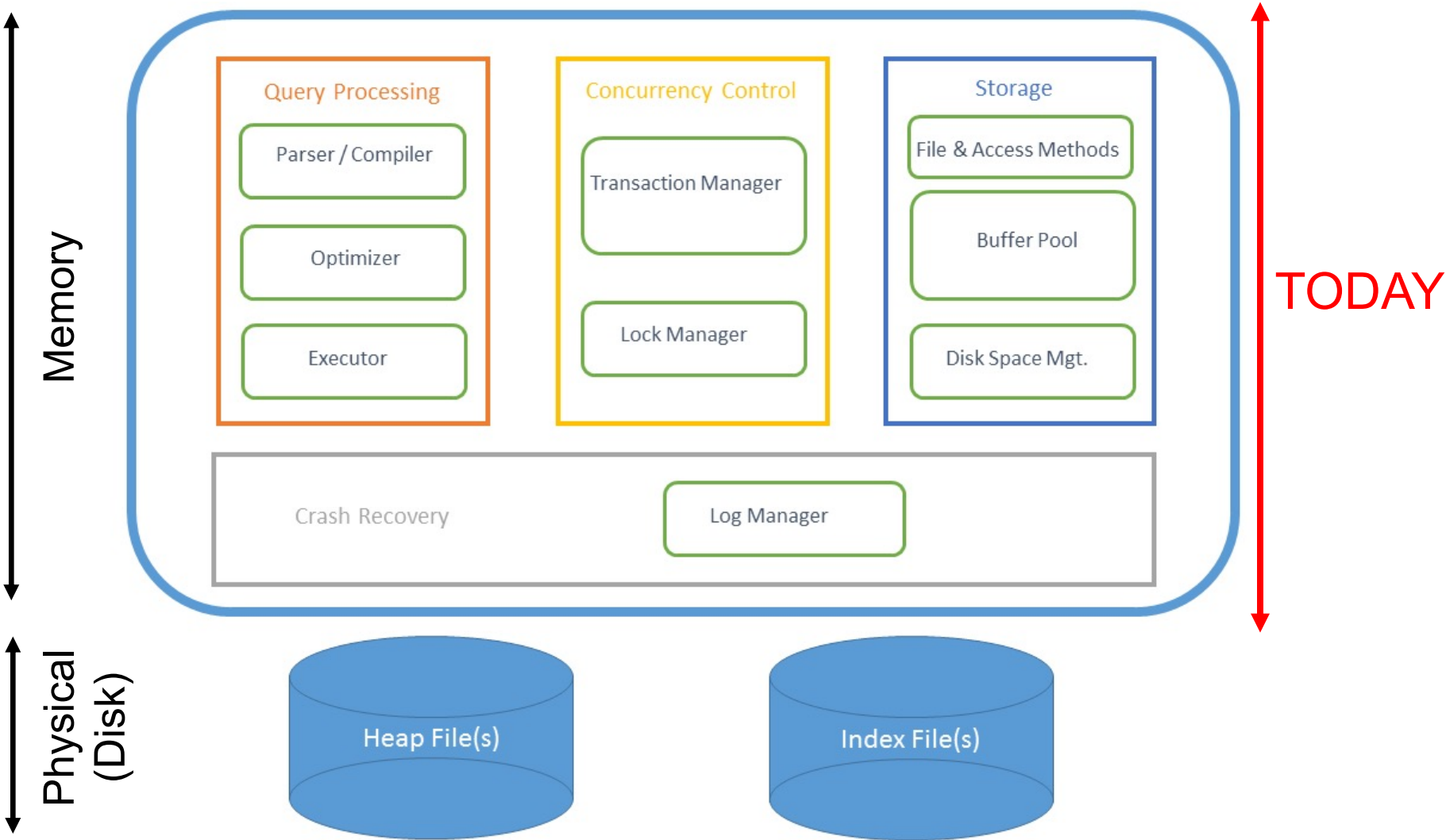
THE UNIVERSITY OF MELBOURNE

Architecture of a Database Management System (DBMS)

Database Systems Architecture

- A Database Management System (DBMS)
- Exists as one entity in two places
  - In Memory
  - Physically on disk
- Both places manage
  - Data (the reason we have the DBMS)
  - Performance (how it performs as it is used & grows)
  - Concurrency (manages high volumes of users)
  - Recoverability (assist in recovery and availability)
- One place is persistent the other transient
  - Disk representation is always present
  - Memory – transient – only exists when DBMS is running

DBMS Overview



Graphic Courtesy of
Dr Renata Borovica-Gajic

Query Processing

Parsing

- Syntax is correct & can “compile”
- DBMS User Permissions
- Resources (Data, Code, be able to Record Changes/Retrieve results)

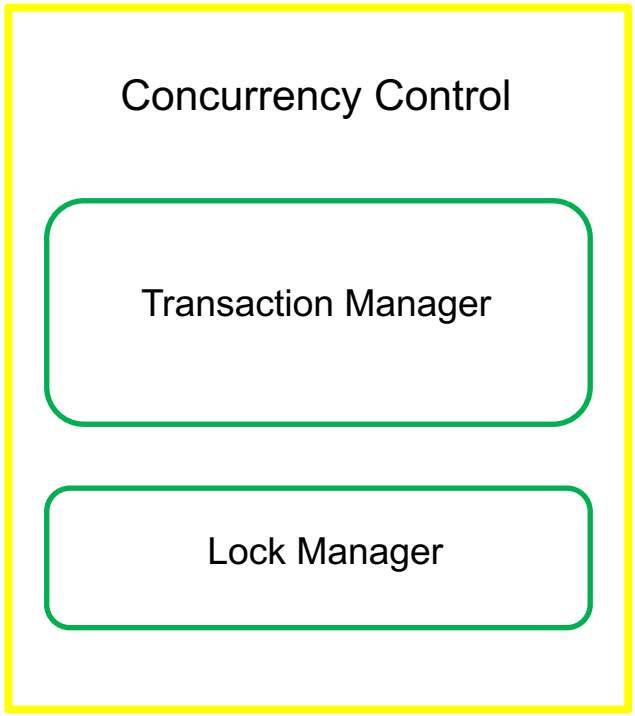
Optimizing

- Execution Plan & Execution Cost
- Evaluate indexes, table scans, hashing
- Eliminate worst, consider best options
- Lowest cost theoretically “best”

Execution

- Meet the ACID test,
- Atomic: All rows succeed, or all fail
- Ensure resources are available
  - Data, Log changes, Memory, Cursor to do the work for the USER

Concurrency Control

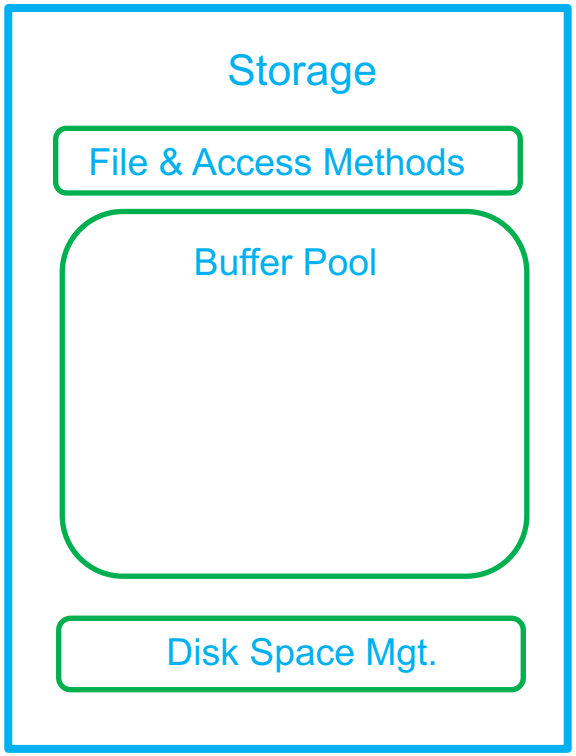


- Manages the work of the DBMS.
- Transaction Manager handles all aspects of the SQL transaction - which DBMS user wants WHAT resource
- Lock Manager is a list of what resources are locked and by which user at what level (& who is waiting)
- not only tables, indexes
  - buffers, cursor, memory addresses of resources

Concurrency Control

- Essential to manage large scalable DBMS
- Enables 1,000,000s of concurrent users
- Like a Traffic Policemen controlling the flow of traffic
  - Who can do what (allowed to do what they need to do)
  - Who has to wait (queue)
  - Who can travel through the intersection concurrently
    - Usually *readers* of data
- What transactions have completed, in progress, compiled.
  - What resources are involved with that transaction
  - Who last used, is using and wants those resources
    - SQL, Cursor, Index, Table, Rows, File Access, Recovery Logs

Storage



- File & Access Methods
  - Disk to Memory to Disk
  - Read a buffer or a block of buffers
- Buffer Pool
  - Data in memory
    - Row data
    - Index data
  - Organised
- Disk Space Management
  - How to organise growth of data on disk efficiently by writing efficiently.

Storage (cont.) - File Management

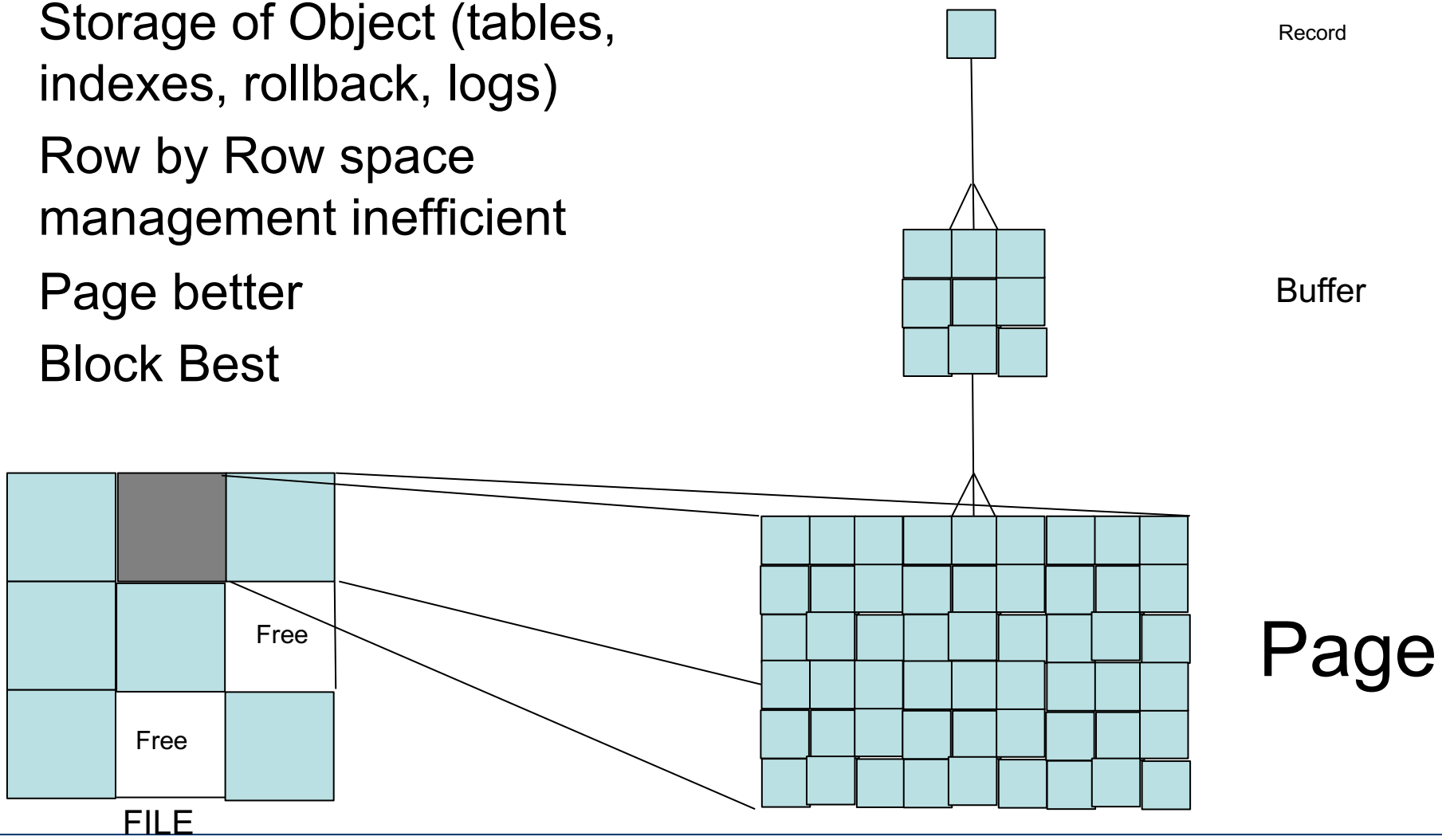
- How to access the file
  - Full Scan (full table scan)
    - From beginning to end of the entire file
  - Partial Scan (index range)
    - Using an index to scan a range of values
      - (2 > deptno > 9)
  - Page only (file header and page)
  - Read the index ***and*** data file

Storage (Buffer Pool & Disk Space)

- Buffer Pool
  - All data (including indexes) is stored in the buffer
  - May contain multiple copies of the same data
    - Need to know which copy is the current committed version
  - Organised using a double linked list (see Storage & Indexing lecture)
- Disk Space Management
  - How to allow files to grow on disk (and set max growth size)
  - File organization
    - e.g. index reorganization;
    - varchar growth e.g. Brown (5) grows to Nicholson (9) for last name

Storage – Disk Space Management

- Hierarchical Structure
- Storage of Object (tables, indexes, rollback, logs)
- Row by Row space management inefficient
- Page better
- Block Best

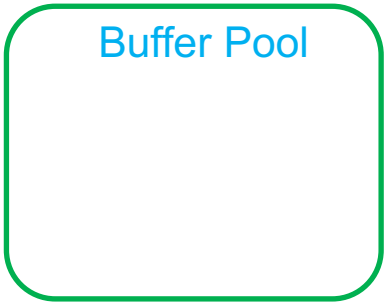


Buffer Pool

- Many Object Types (Tables, Indexes, Undo)
- Each buffer contains rows, b+ tree leaf etc.
- Each buffer can have one of four status types:
  - Current
    - In use current committed version of data (row)
  - Active
    - Most recent change (may not be committed)

COMMIT (Current: DepartmentID=9)

  - Stale
    - An old version of the data
  - Aged
    - Old and about to be removed from buffer pool



Log Manager

- Recovery
- Log Manager records ALL changes
  - Statement
  - Transaction
    - Statement
    - Rollback values
    - Before and After values
    - Timestamp begin
      - transaction, savepoint & commit timestamps
  - Database
    - Data Dictionary Changes

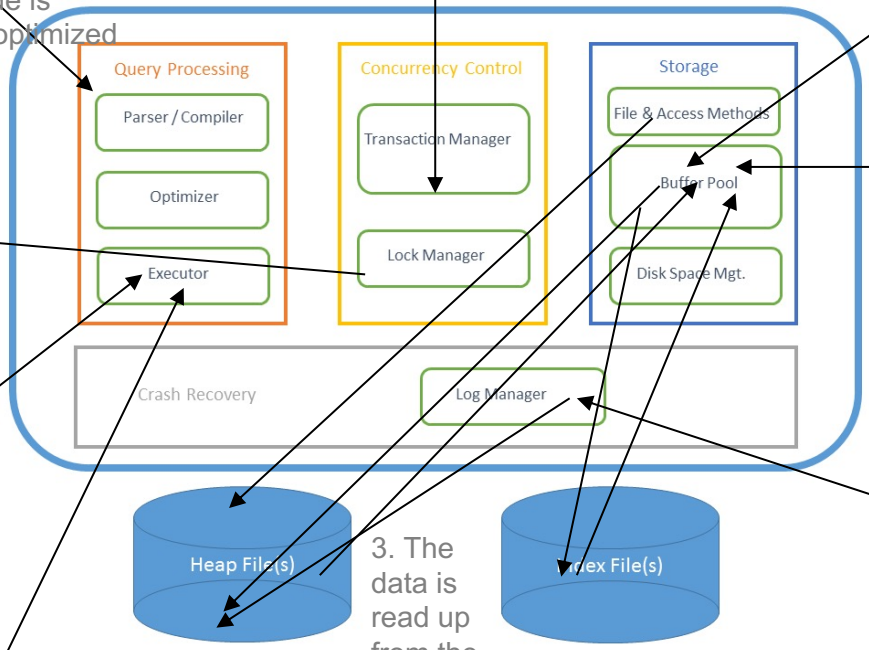
DBMS – How a transaction works

```
UPDATE employee
SET departmentid = 9
WHERE firstname = 'Nancy'
AND departmentid = 8;
```

1. The code is parsed & optimized

4. The Transaction manager ensures all the tables and index data is in the buffer pool and ready to be used in the execution of the SQL.

6a In the buffer pool we record the before value the after value and the change to the value



2. We check if the table & index data (rows) are in the buffer pool. If it is we skip to 4. If not we go to 3.

5a When the rows & indexes are locked we execute the query

5b. The SQL is executed

3. The data is read up from the table & index on disk

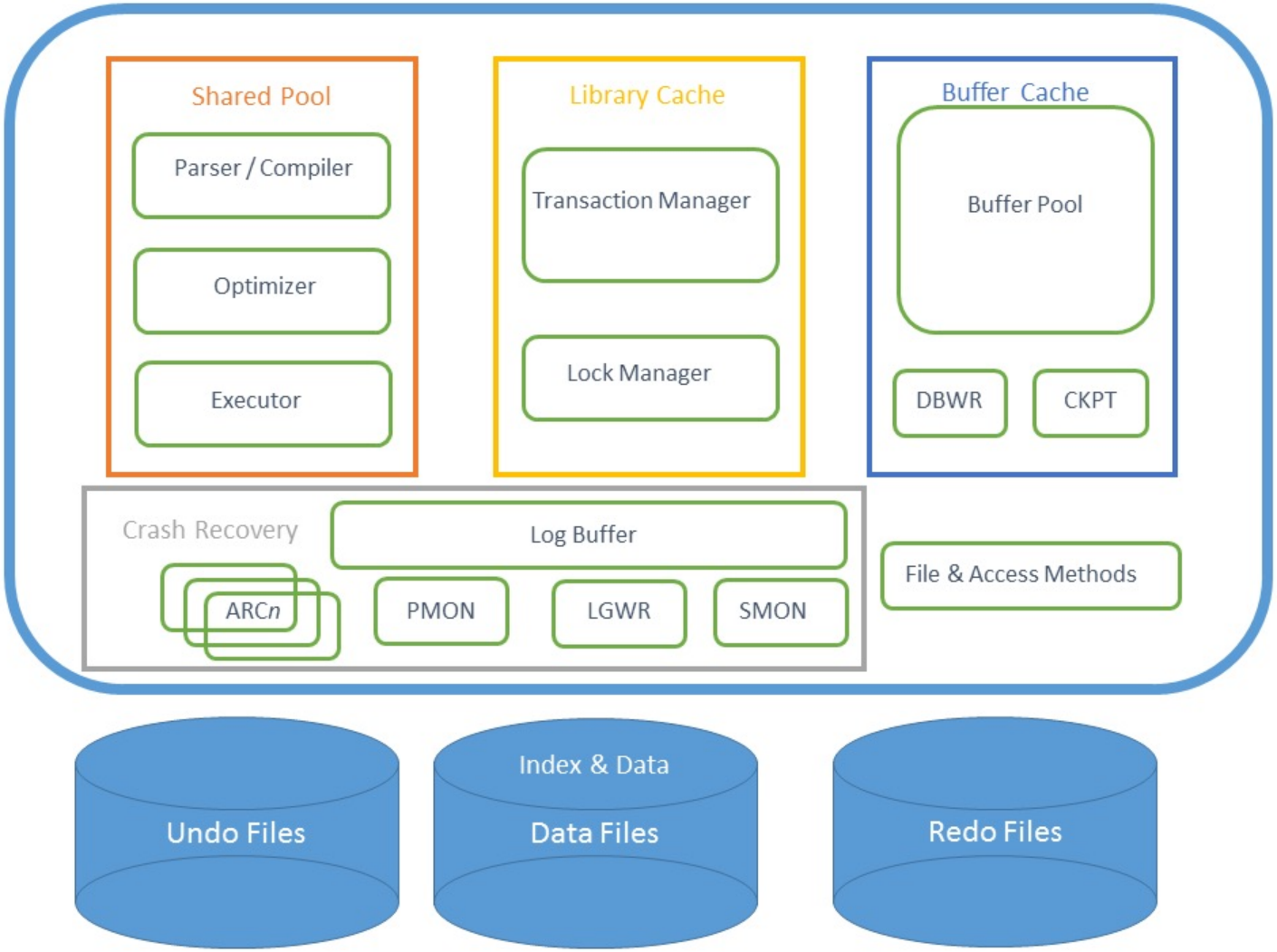
6b We record a timestamp and the before value, the after value and the change to the value for all transactions in the Log Manager

7. The user commits the change to make it permanent

8. The changed data and transaction log are written to disk

Graphic Courtesy of
Dr Renata Borovica-Gajic

How Oracle* DBMS looks



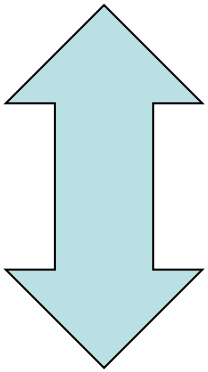
*** This slide is not examinable**

THE UNIVERSITY OF
MELBOURNE

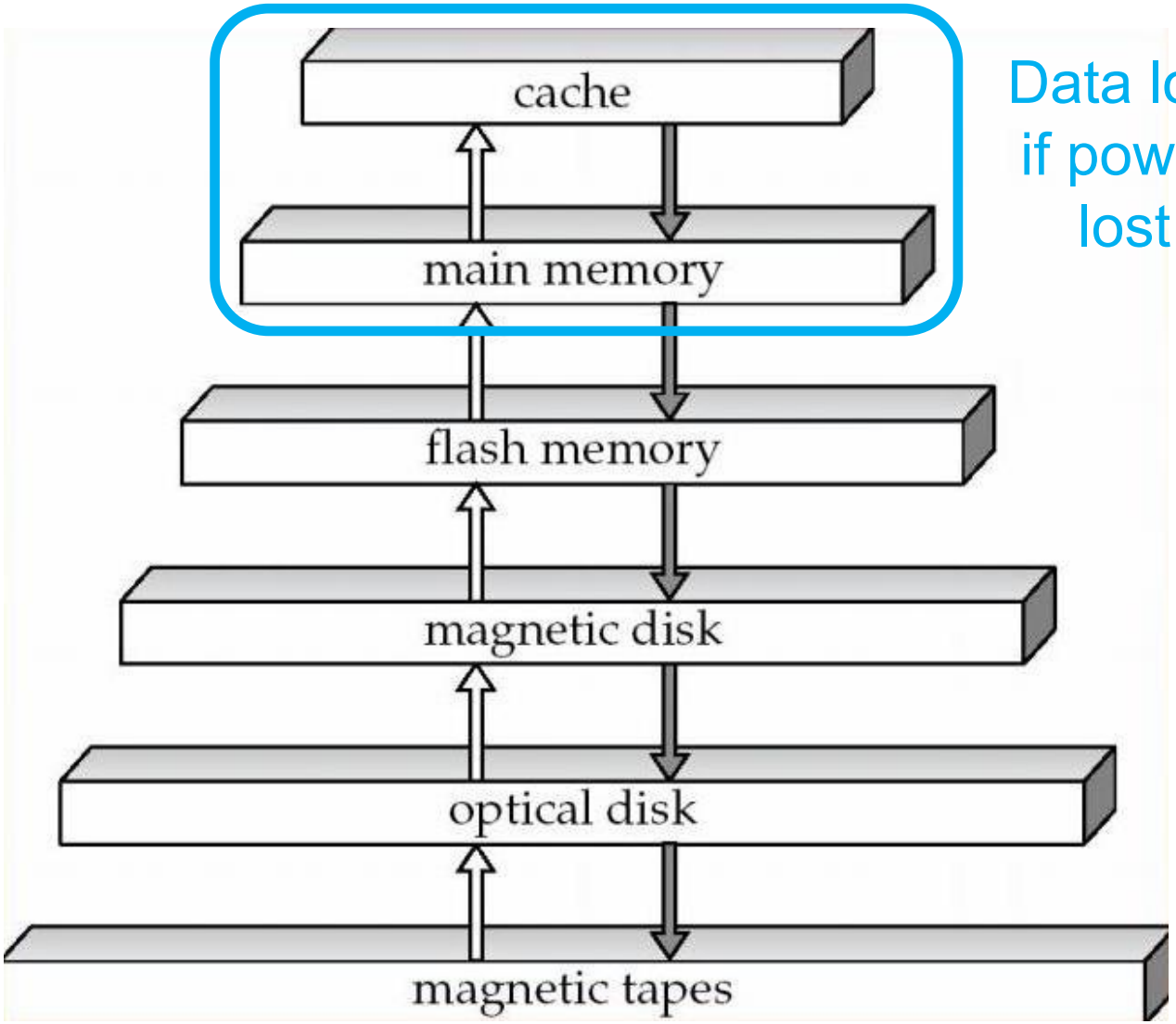
Database Performance

Storage media hierarchy

faster, more expensive, smaller capacity



slower, cheaper, *older*, bigger capacity



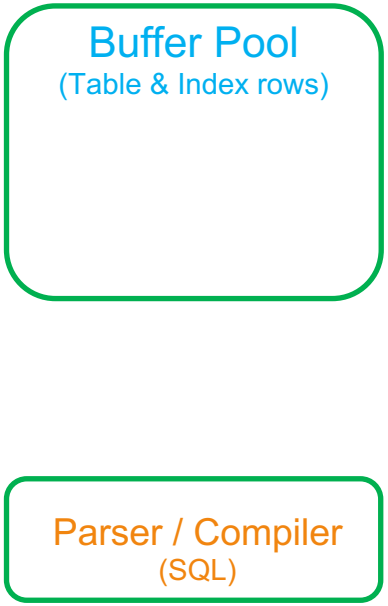
Data lost if power lost

What affects database performance?

- Caching data in memory, e.g. data buffers
- Placement of data files across disc drives
- Fast storage such as SSD
- Database replication and server clustering
- Use of indexes to speed up searches and joins
- Good choice of data types (especially PKs)
- Good program logic (no long running CRUD)
- Good query execution plans
- Good code (no deadlocks)

Caching Data in Memory

- Data and Code found in memory
- Avoids a read
- Reads are expensive
- Goal in to minimize reads (& writes)
  - Writes are necessary (recovery logs, changed data)
- “in memory databases”
  - all code all data loaded into memory on db start & stays until shutdown



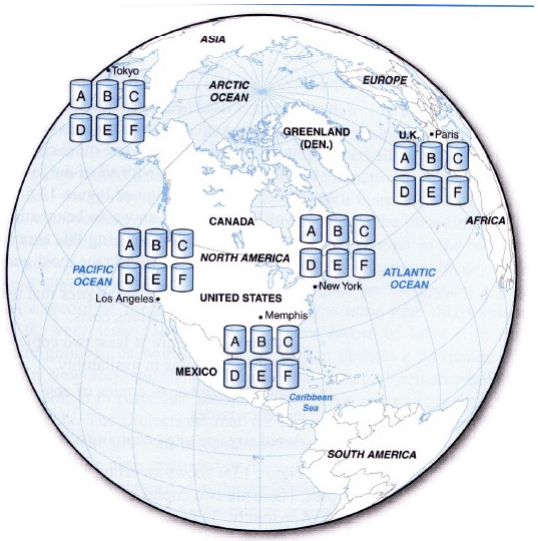
Data file location & Fast Disks (SSD)

- Spread the files across the physical server
  - RAID (0, 0 +1, 5)
- We can't avoid writes
  - Spread files across many disks
    - Avoid contention
      - (many users competing for same resource)
  - Recovery Logs (always writing)
    - faster disk
- SSD (Solid State Drives)
  - No moving parts – nothing to break down
  - Faster I/O (Input & Output compared to other disk types)

Distribution & Replication

- Distributed data
  - Spreads the load
  - Data kept only where it is needed
  - Less work per physical server – faster response times

- Replicated Data
  - Spreads Load
  - Less work per physical server – faster response times



When to create indexes

- for each table, choose the columns you will index:
- *queried frequently* (used in WHERE clauses)
- used for *joins (PK to FK)*
- primary *keys* (automatic in most DBMS)
- foreign *keys* (automatic in MySQL)
- unique columns (automatic in most DBMS)
- large tables only - small tables do not require indexes
  - if you frequently retrieve less than about 15% of the rows
- wide range of values (good for regular indexes).
- small range of values (good for bitmap/hash indexes).

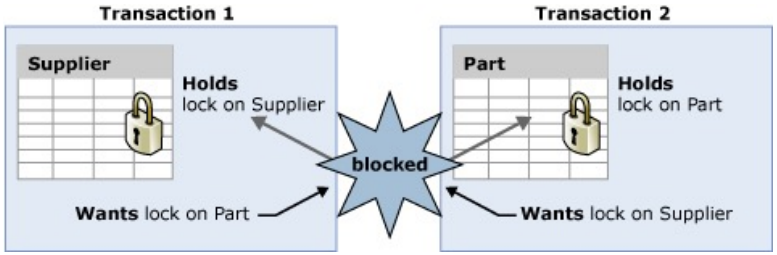
covered already in week 6

source: Oracle® Database Application Developer's Guide

Good Choices

- Good Data Types
  - INTEGERS for PK FK & PFK (for performance)
- Good Program Logic & Code
  - Transaction design

    BEGIN TRANSACTION
    SELECT
    UPDATE
    UPDATE
    UPDATE
    COMMIT
  - Avoid Long Complex Transactions that never commit or savepoint
  - Avoid coding deadlocks!
  - Appropriate Locking strategy
    - Row b4 Buffer b4 Table b4 Database
    - Consider Lock Timeouts (if not automatic)



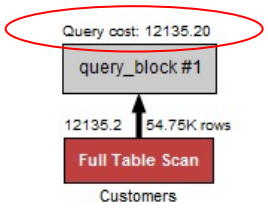
Deadlock Scenario

Good Execution Plans

- The best execution plan has the lowest “cost”
- Known as Cost Based Optimization (CBO)

```
SELECT cust_first_name, cust_last_name, cust_marital_status,
cust_city, cust_income_level
FROM Customers
WHERE cust_last_name = 'Parkburg'
AND cust_first_name = 'Peter'
AND cust_city = 'Trafford';
```

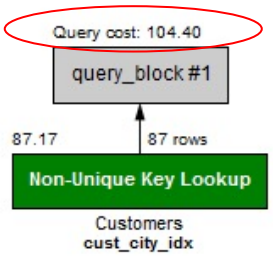
	cust_first_name	cust_last_name	cust_marital_status	cust_city	cust_income_level
	Peter	Parkburg	single	Trafford	H: 150.000 - 169.999



Index on where condition (cust_city) improves cost:

```
CREATE INDEX cust_city_idx
ON customers(cust_city);

SELECT cust_first_name, cust_last_name, cust_marital_status,
cust_city, cust_income_level
FROM Customers
WHERE cust_last_name = 'Parkburg'
AND cust_first_name = 'Peter'
AND cust_city = 'Trafford';
```



What is examinable

- What a DBA and Data Administrator do
  - And the difference in each role
- Database Architecture
  - Label all memory structures & know their role
- What affects database performance
  - Caching; Datafile placement; Fast Storage; Indexes; Data types; Query Execution plans; Efficient code;
- When to create an index

* All material is examinable – these are the suggested key skills you would need to demonstrate in an exam scenario

Next

- Distributed Databases

David Eccles

INFO90002 Database Systems & Information Modelling

Lecture 15

Database Architecture

&

Administration