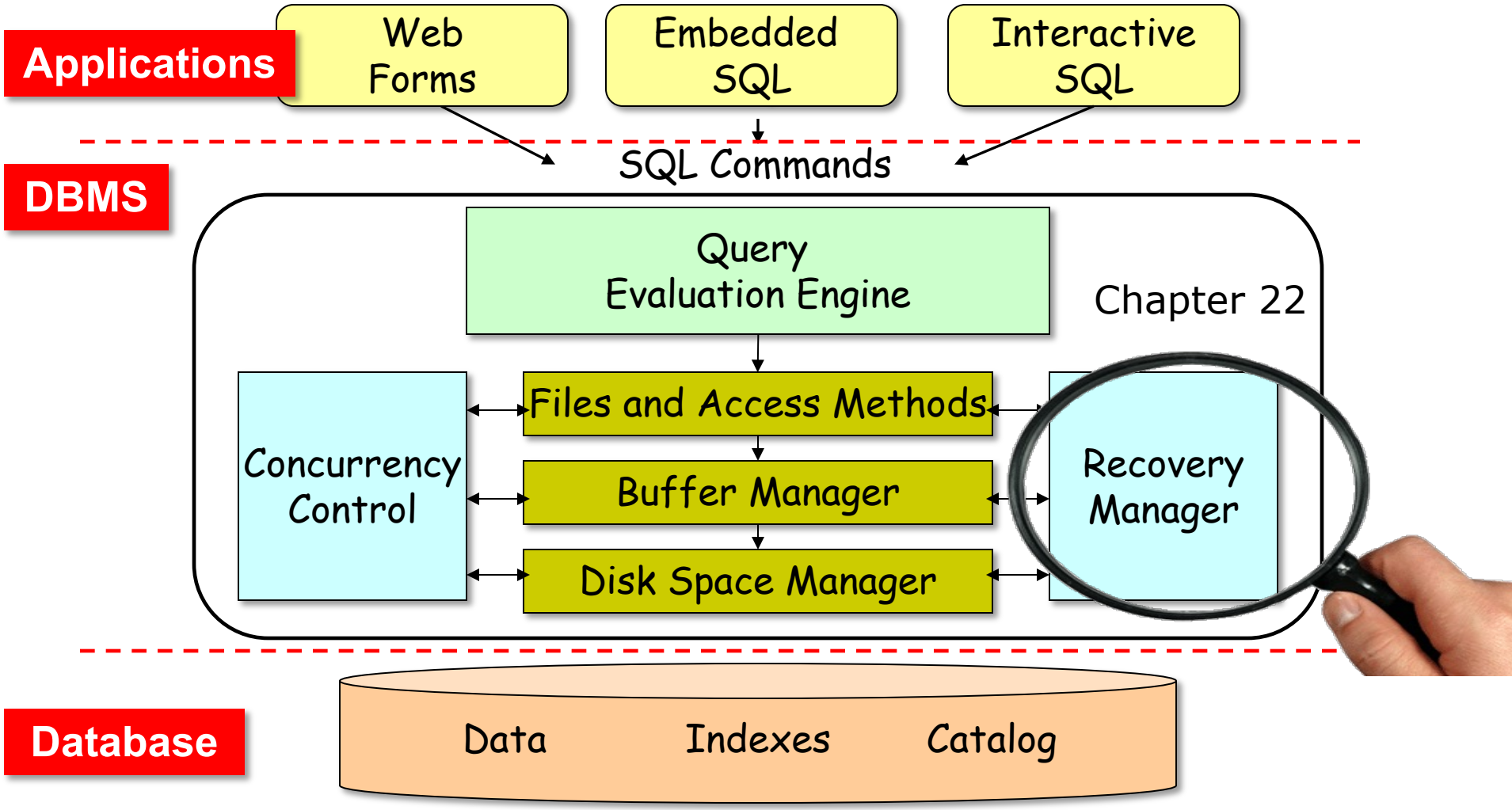
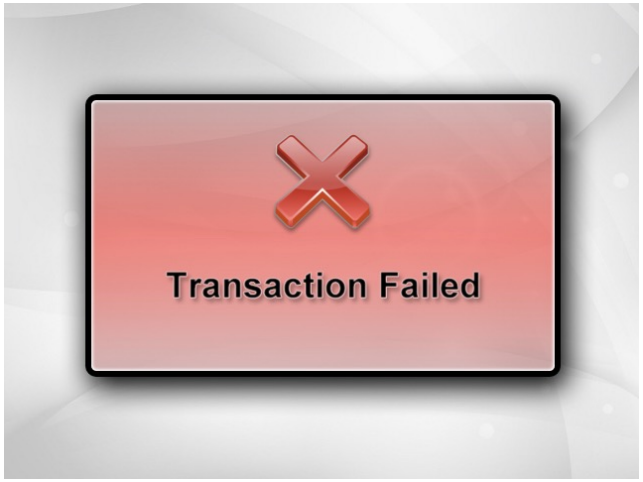
Database Management System (DBMS)



Many Things Can Go Wrong

- **Interference with other concurrent activities**

- User may decide to interrupt the program
- Account number does not exist
- Integer overflow
- disk head crash, system goes down
- Buffer congestion
- Error during data transfer
- Power failure



ACID Properties

Property	Dealt with by
A, D	**Recovery Techniques**
I	Concurrency Control Techniques
C	Checks, Assertions,Triggers Applications Programmers

Purpose of Database Recovery

- To bring the database into the last consistent state, which existed prior to the failure
- To preserve transaction properties:
  - Atomicity & Durability

- Example: System crashes before a fund transfer transaction completes its execution
  - The database must be restored to the state before the transaction modified any of the accounts.

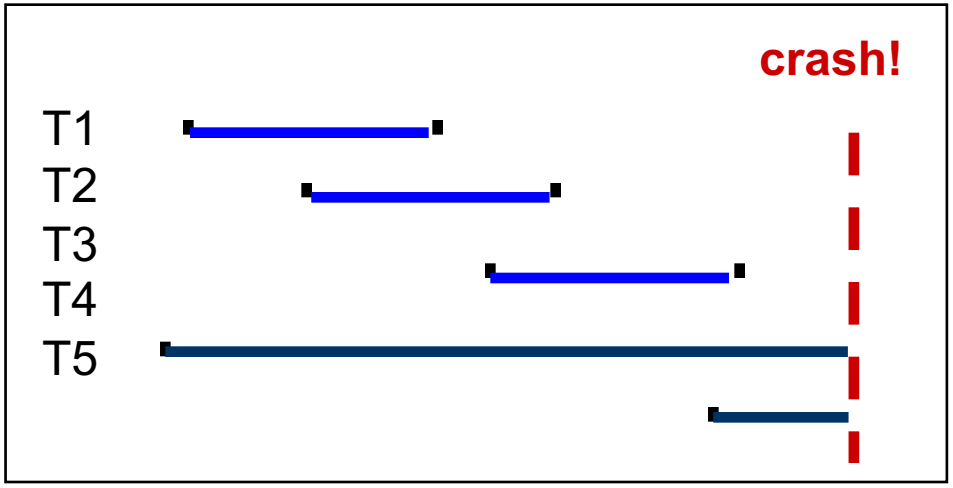
Types of Failures

- Transaction failure:
  - Incorrect input, deadlock, etc.
- System failure:
  - Addressing error, application error, operating system fault, RAM failure, etc.
- Media failure:
  - Disk head crash, power disruption, etc.

Motivation

- Atomicity:
  - Transactions may abort (“Rollback”)
- Durability:
  - What if DBMS stops running?

- Desired Behavior after system restarts:
  - T1, T2 & T3 should be durable
  - T4 & T5 should be aborted (effects not seen)



The Goals of Recovery

1. When a transaction *T* ***commits***
   - Make the updates permanent in the database so that they can survive subsequent failures
2. When a transaction *T* ***aborts***
   - Obliterate any updates on data items by aborted transaction in the database
   - Obliterate the effects of *T* on other transactions; i.e., transactions that read data items updated by *T*
3. When the system ***crashes*** after a system failure
   - Bring the database to its most recent consistent state

Recovery Actions

- Recovery protocols implement two actions:
  - **Undo** action:
    - Required for atomicity
    - Undoes all updates on the stable storage by an uncommitted transaction
  - **Redo** action:
    - Required for durability
    - Redoes the update on the stable storage of committed transaction

Logging

- A ***log*** *or journal* is a sequence of records which represent all modifications to the database in the order in which they actually occurred
- Log records may describe either *physical* changes or *logical* database operations
  - A *physical log* contains information about the actual values of data items written by transactions.
    - State before change, ***before image***
    - State after change, ***after image***
    - Transition causing the change
  - A *logical log* represents higher level operations; e.g., insert a record

Transaction Log

Types of log record:

1. [start_transaction,T]: Records that transaction T has started execution
2. [write_item,T,X,old_value,new_value]: Records that transaction T has changed the value of database item X from old_value to new_value.
3. [read_item,T,X]: Records that transaction T has read the value of database item X
4. [commit,T]: Records that transaction T has completed successfully
5. [abort,T]: Records that transaction T has been aborted

Transaction Log

TID	Back P	Next P	Operation	Data Item	BFIM	AFIM
T1	0	2	Begin			
T1	1	4	W	X	X = 100	X = 200
T2	0	7	Begin			
T1	2	5	W	Y	Y = 50	Y = 100
T1	4	8	R	M	M = 200	M = 200
T3	0	9	Begin			
T2	3	10	W	N	N = 20	N = 10
T1	5	nil	End			
T3	6	11	W	N	N = 10	N = 30

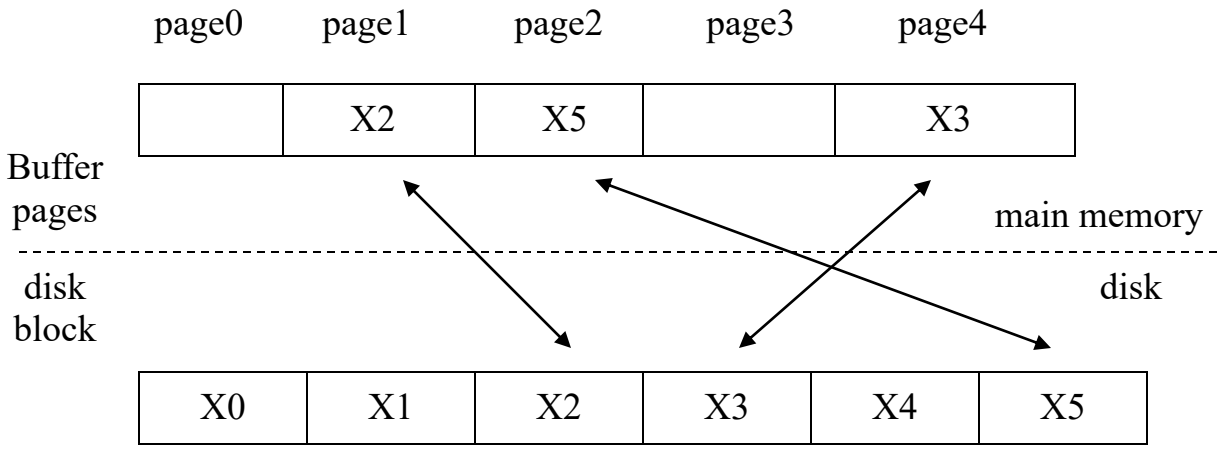
- **BFIM**: old values before modification (BeFore IMage)
- **AFIM**: new value after modification (AFter IMage)
- **Back P** and **Next P** point to the previous and next log records of the same transaction

What & How to Recover?

- What & how to undo?
  - For all uncommitted transactions
  - Scan the log from end to beginning
  - Use the BFIM
- What & how to redo?
  - For all committed transactions
  - Scan the log from beginning to end
  - Use the AFIM

Buffer Manager

- The goal of Cache or Buffer Manager is to maximize the likelihood that a block of data needed by a transaction is in main memory
- The main memory is partitioned into *buffer blocks or buffer pages* (or simply buffers, blocks or pages)
- The size of a page is equal to the *disk block* size



Cache Flushing

- **Steal**: A cache page can be flushed before transaction commits – when?
- **No-Steal**: A cache cannot be flushed before transaction commits

- **Force**: Cache is flushed to disk when transaction commits
- **No-Force**: Otherwise! So when is it flushed?

Cache Flushing

- Leads to four different ways for handling recovery:
  - Steal/No-Force (Undo/Redo),
  - Steal/Force (Undo/No-redo),
  - No-Steal/No-Force (No-undo/Redo) and
  - No-Steal/Force (No-undo/No-redo).

Simplest Recovery Manager

- Force
  - No redo of committed transactions
- No-Steal
  - No undo of incomplete transactions

	No Steal	Steal
Force	Simple	
No Force		

Simplest Recovery Manager - Problems

- Force
  - High I/O costs!
- No-Steal
  - Large cache!

- **Practical Recovery**
- No-Force
  - Need to Redo
- Steal
  - Need to Undo

	No Steal	Steal
Force	**Simple**	
No Force		**Practical**

Write-Ahead Logging (WAL)

- Log is necessary for recovery and it must be available to recovery manager
- The **Write-Ahead Logging** (WAL) protocol states that:
- **For Undo**:
  - Before a data item's AFIM is flushed to the database disk (overwriting the BFIM) its BFIM must be written to the log and the log must be saved on a stable store (log disk)
- **For Redo**:
  - Before a transaction executes its commit operation, all its AFIMs must be written to the log and the log must be saved on a stable store

Commit Point of a Transaction

- A transaction T reaches its **commit point** when:

1. All its operations have been executed successfully
2. The effect of all the transaction operations on the database has been recorded in the log.

- Beyond the commit point, its effect is assumed to be *permanently recorded* in the database.
- The transaction then writes an entry [commit,T] into the log.
- **Rollback of transactions:** Needed for transactions that have a [start_transaction,T] entry into the log but no commit entry [commit,T]

Recall: What & How to Recover?

- What & how to undo?
  - For all uncommitted transactions
  - Scan the log from end to beginning
  - Use the BFIM
- What & how to redo?
  - For all committed transactions
  - Scan the log from beginning to end
  - Use the AFIM

Checkpoint

- Scanning the whole log is time-consuming!
- Checkpoint
  - Periodically written to the log
  - All cache pages are flushed to disk

- What transactions should be undo?
- What transactions should be redo?