DataBase Systems Architecture

Databases III

Author: Eng. Carlos Andrés Sierra, M.Sc.
cavirguezs@udistrital.edu.co

Lecturer
Department of Computer Engineer
School of Engineering
Universidad Distrital Francisco José de Caldas

2025-I

Outline

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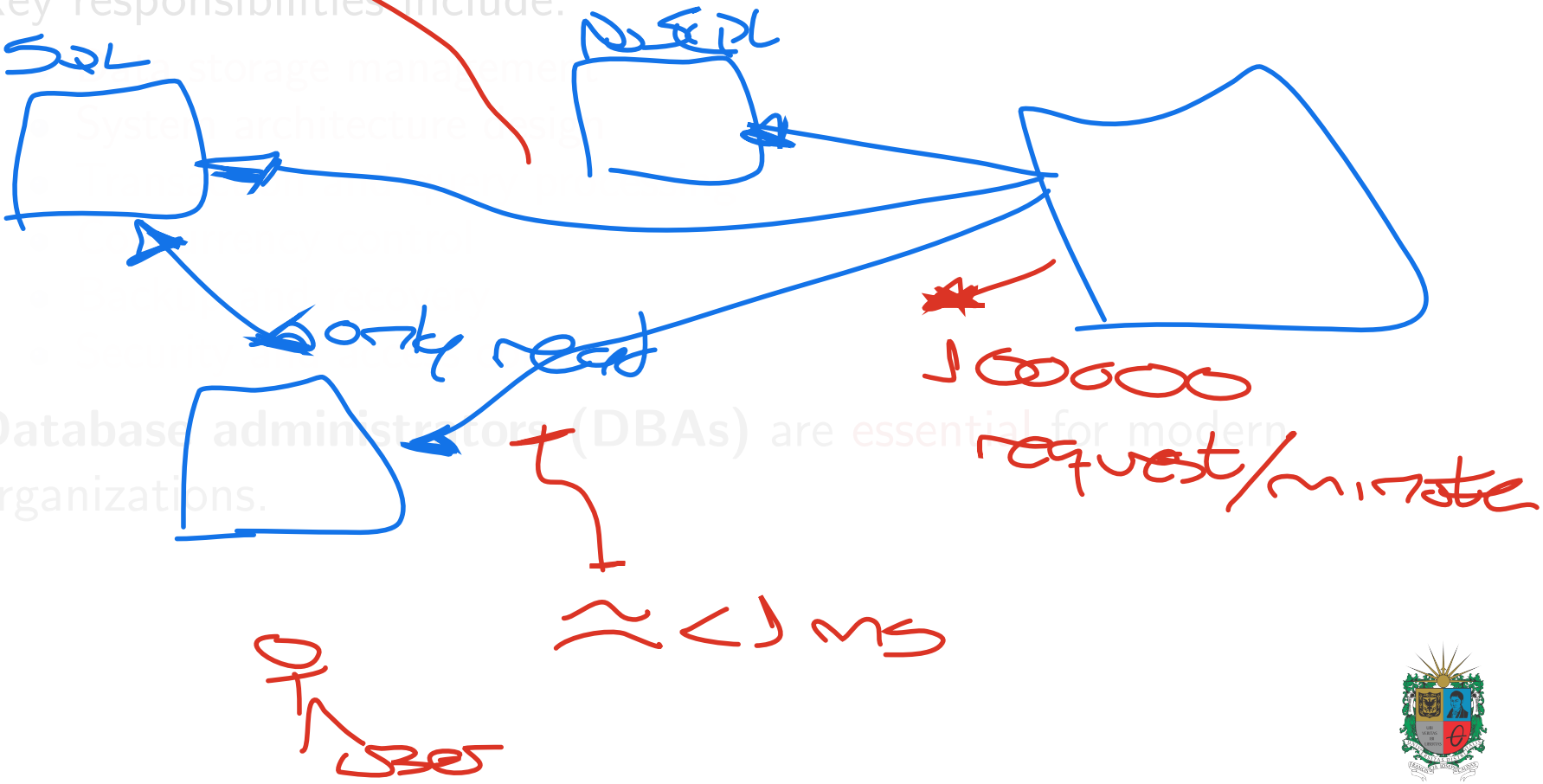
Database System Administration

- **Database system administration** is the discipline of managing, configuring, and maintaining *database systems* to ensure their `reliability`, `performance`, `security`, and `availability`.



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  - Data storage management
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  - Transaction and query processing
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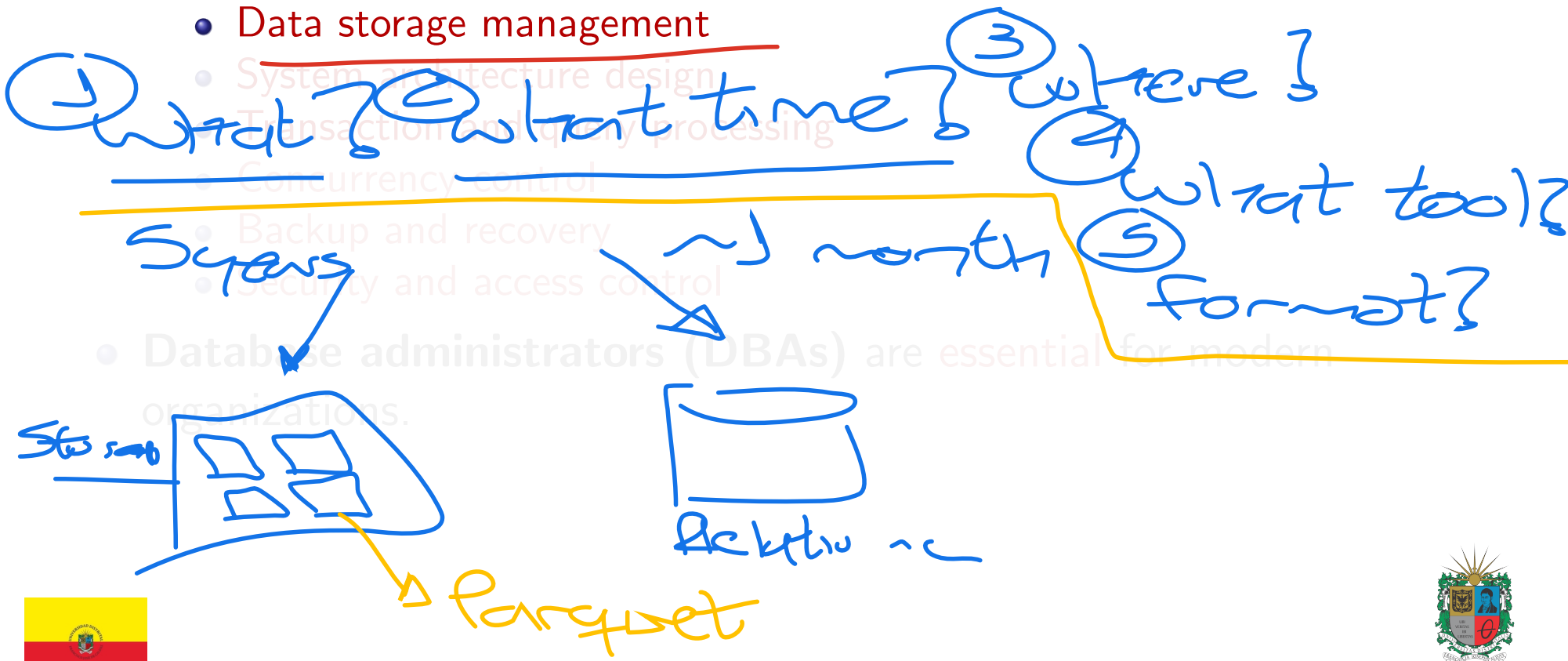

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physical infrastructure → on-premise? cloud? hybrid?

logical architecture → SQL? NoSQL? mirrors? sync? scaling? etl-elt? data lake? data warehouse? data mart?

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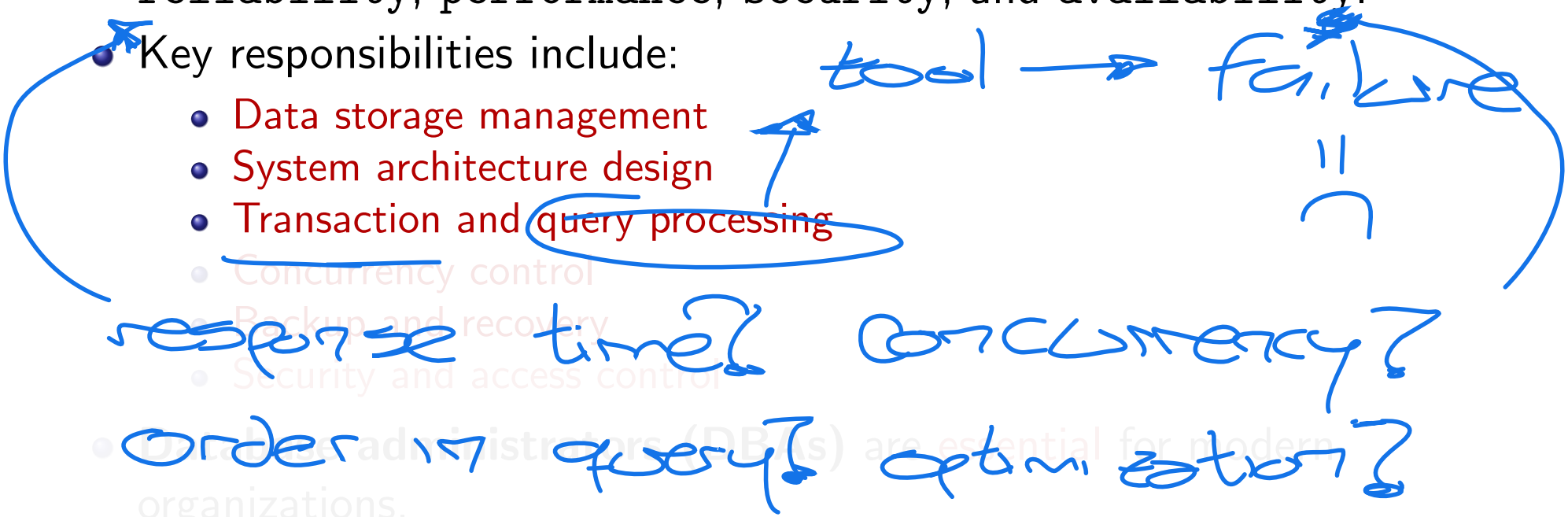

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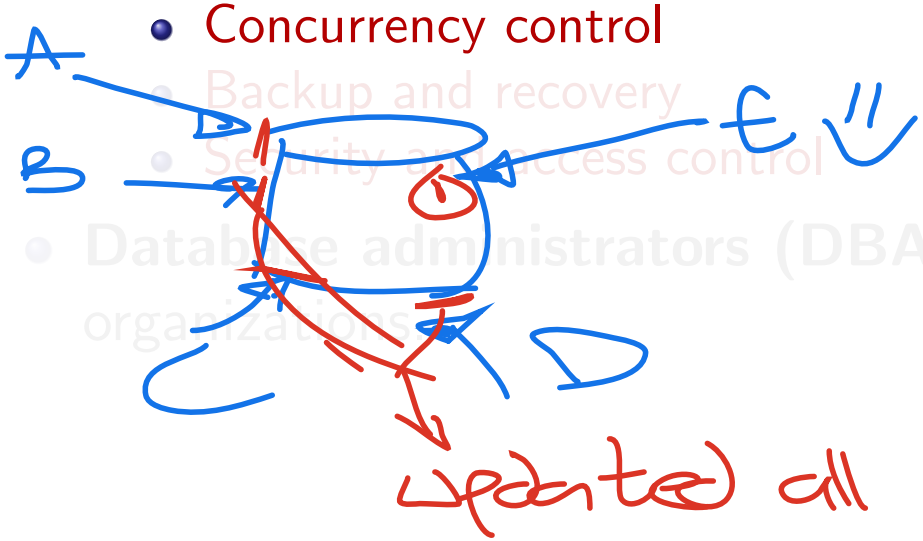

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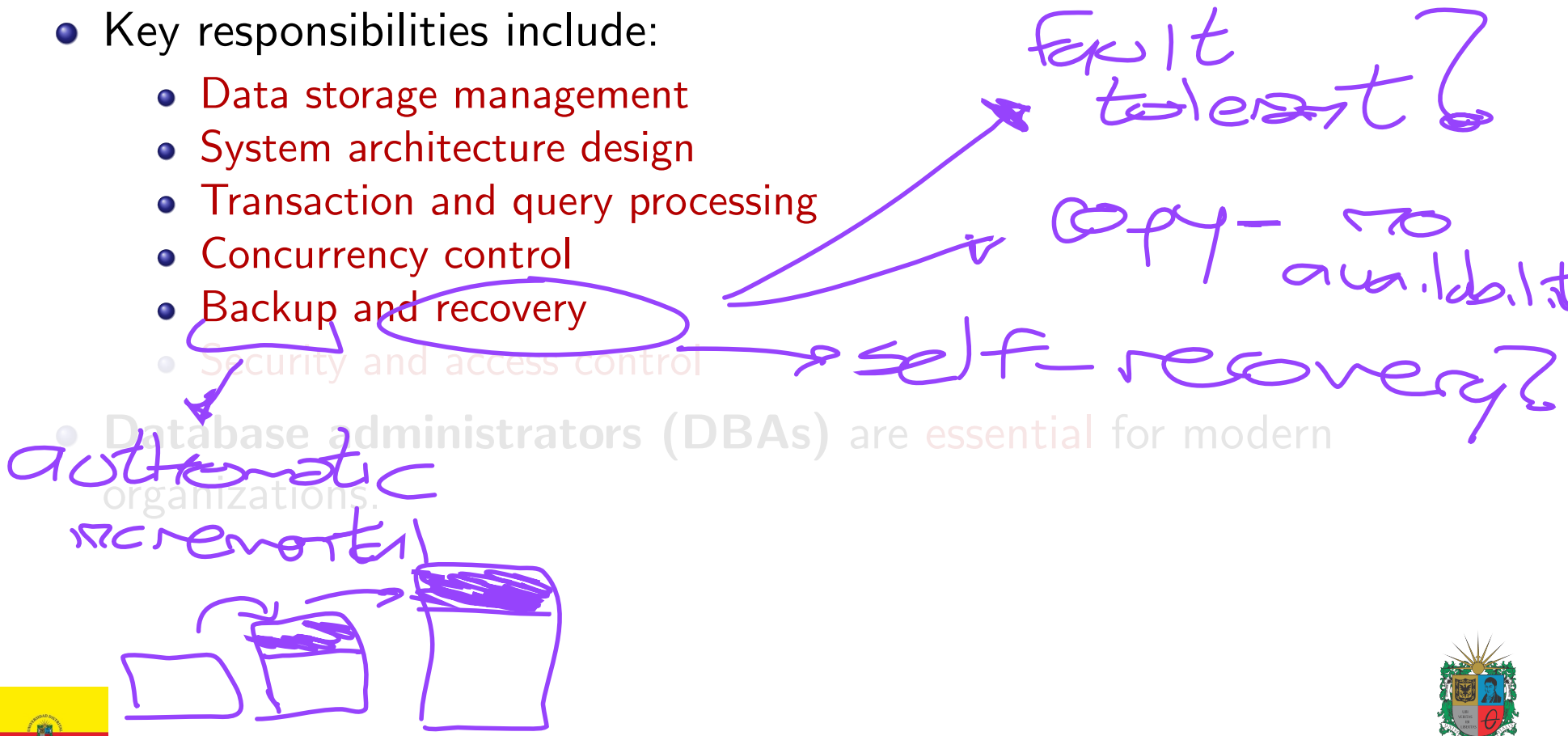

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Grants?

SSH

2FA → auth 2 autenticator

protocols

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Record Storage Concepts

- A **record** (or `row`/`tuple`) is the basic unit of data storage in a *database table*.

- **Efficient record storage** is crucial for fast data retrieval and update.
- Storage techniques:
  - Heap storage: Simple, but slow for queries.
  - Sequential storage: Ordered, fast for range queries.
  - Indexed storage: Uses indexes for fast lookups.

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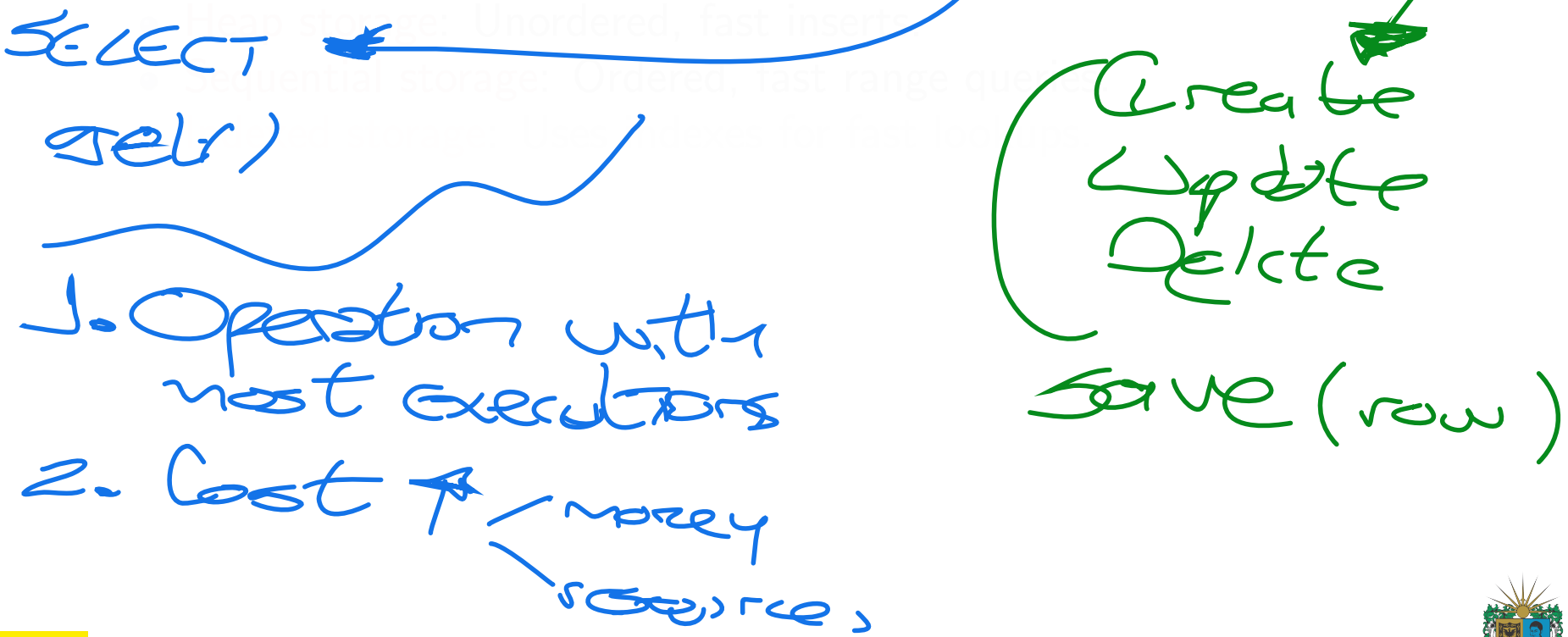

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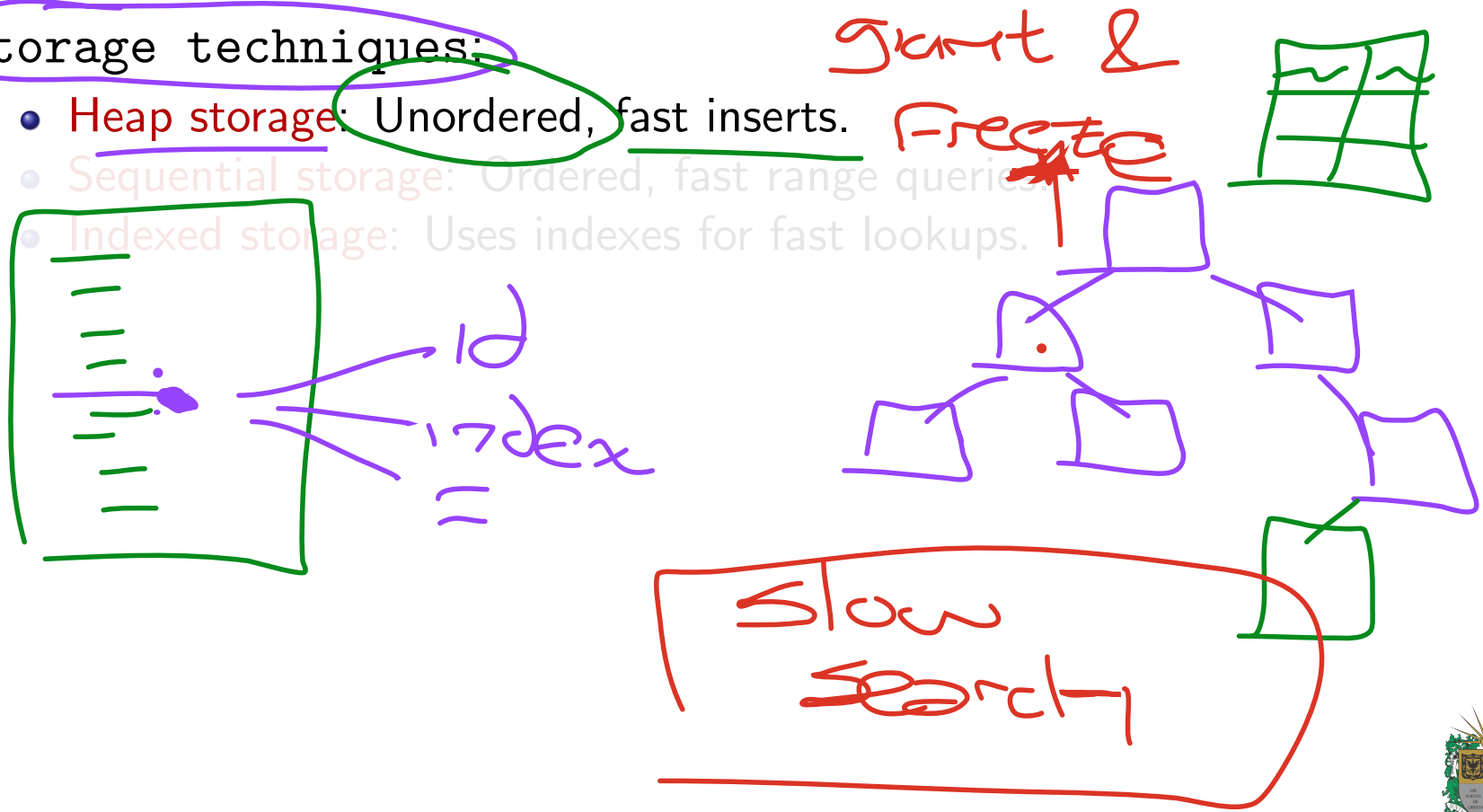

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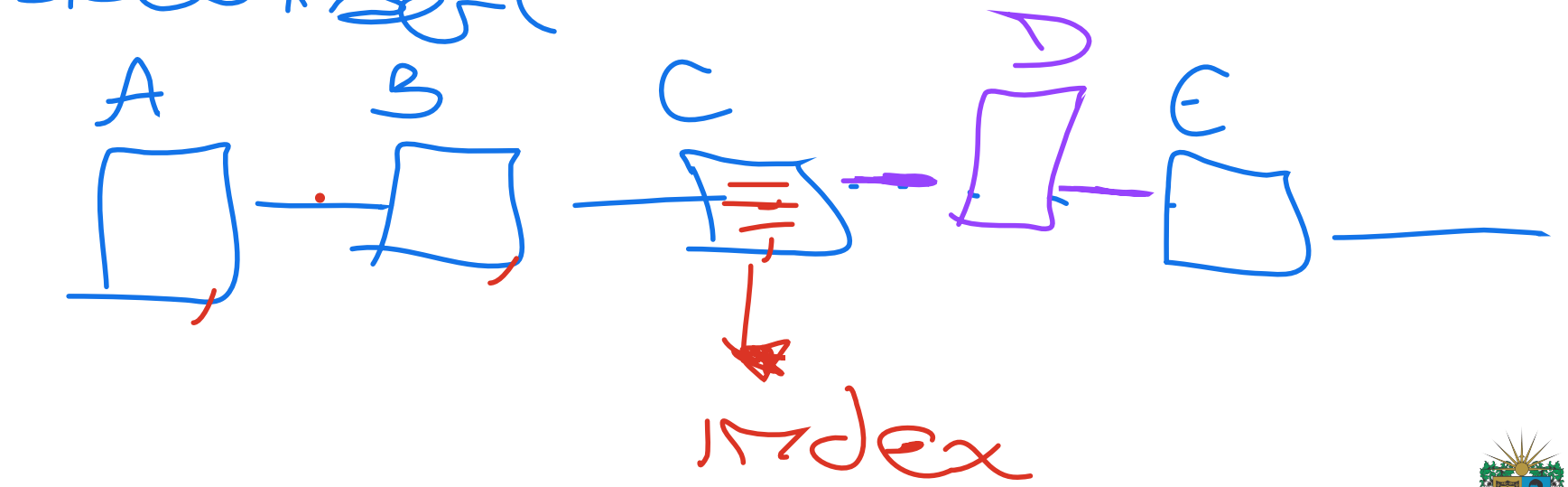

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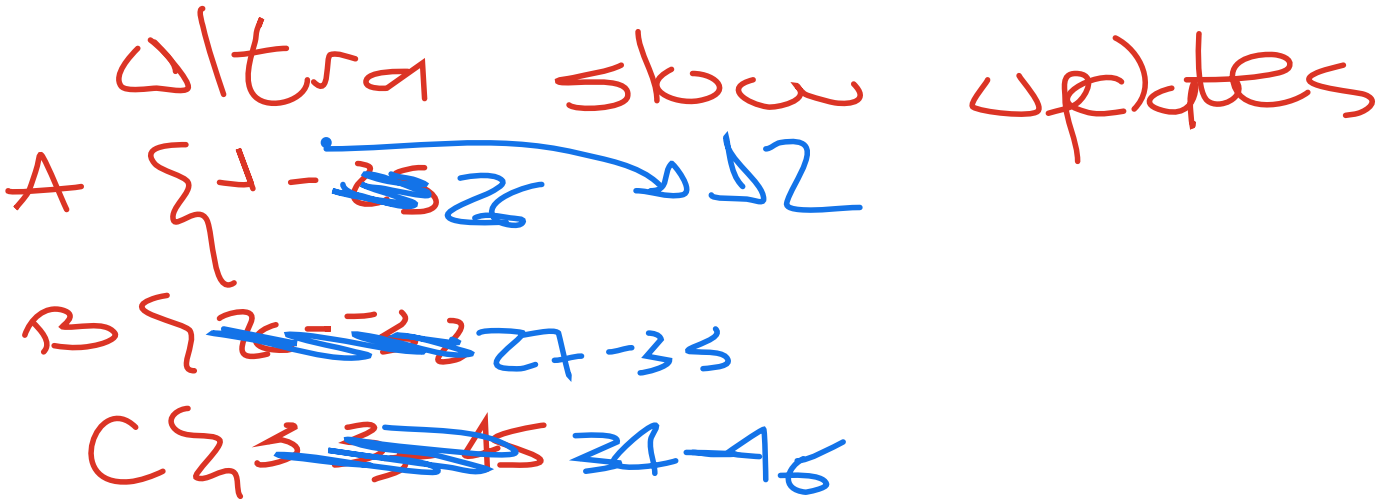
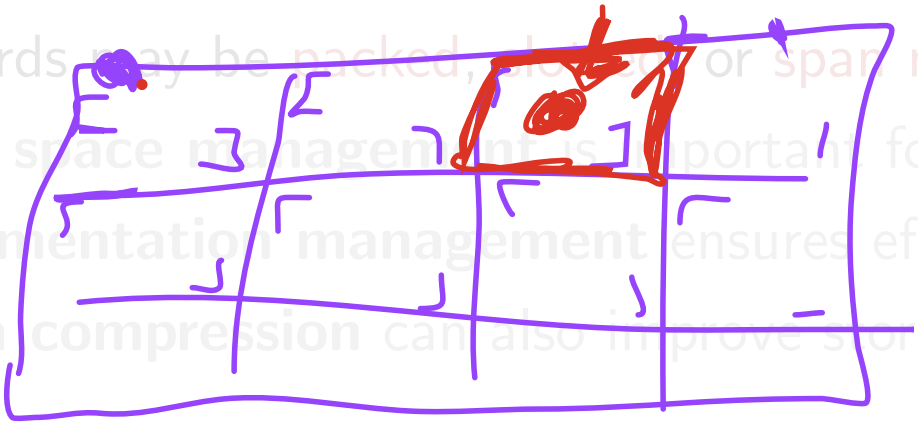


Block and Page Organization

- Data is stored in **blocks** (pages) on disk.
- Block size and layout affect **I/O performance**.
- Records may be packed, blocked, or span multiple blocks.
- **Free space management** is important for updates and inserts.
- **Fragmentation management** ensures efficient use of space.
- **Data compression** can also improve storage efficiency.



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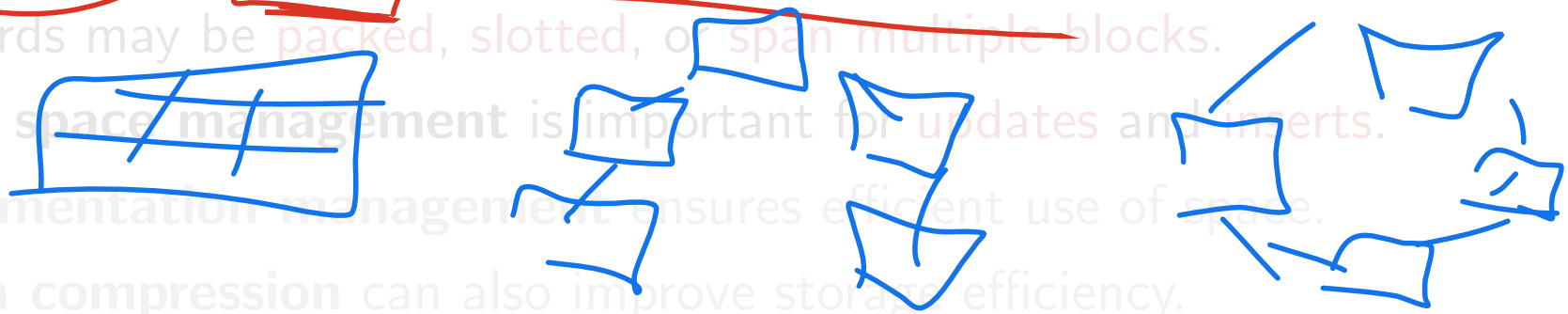

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+ performance
+ storage
+ hard to migrate

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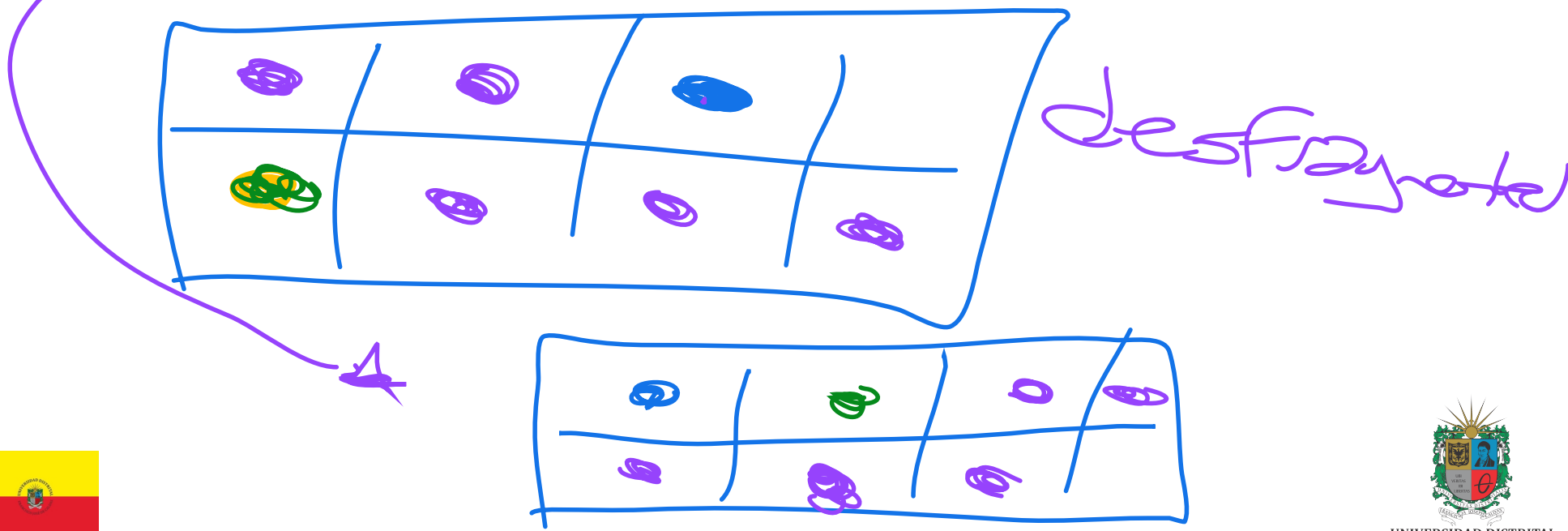

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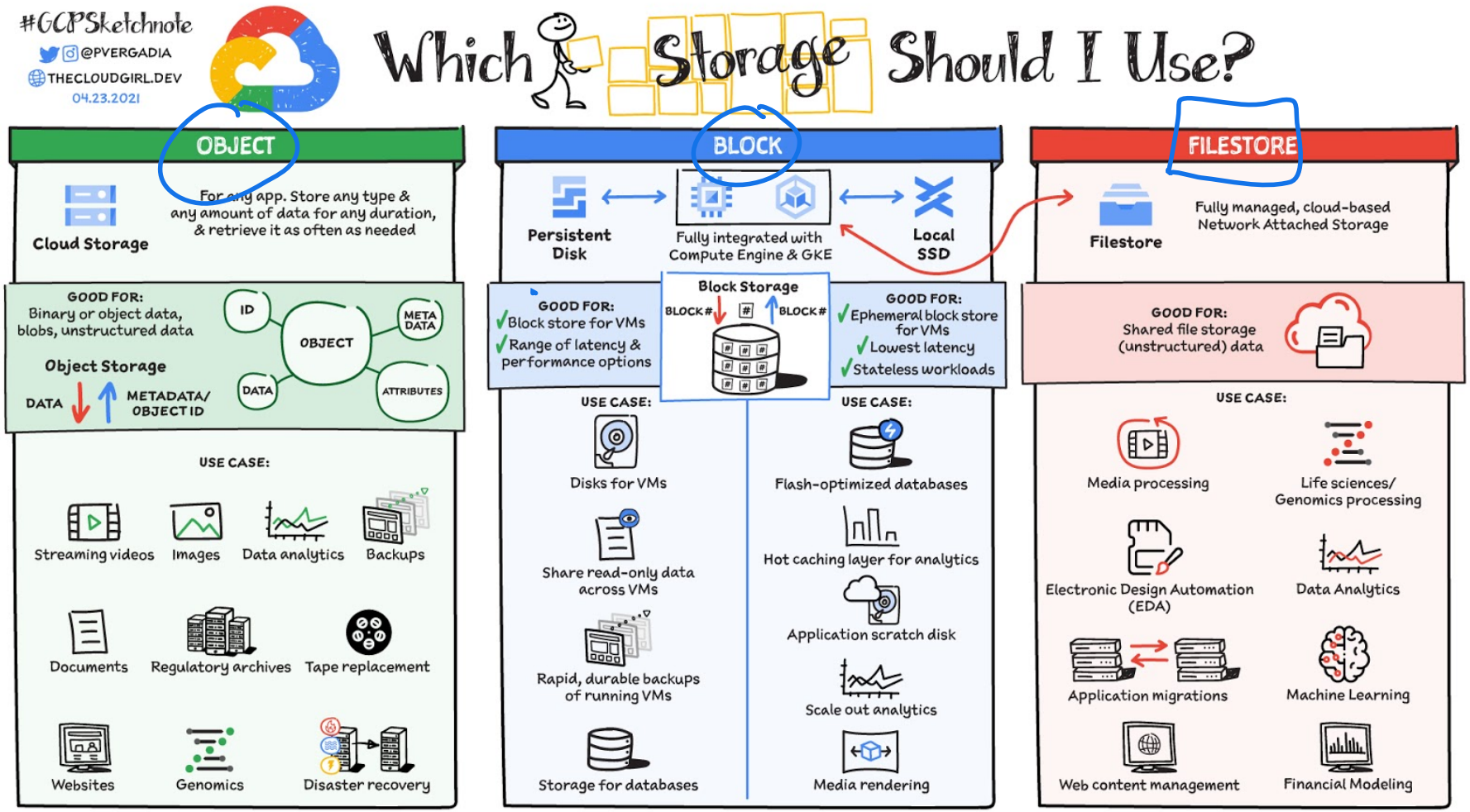

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DBMS Architecture Overview

- A **Database Management System (DBMS)** is organized in layers:
  - `Storage Manager`: Handles *data storage*, *file organization*, and *access methods*.
  - `Query Processor`: Parses, optimizes, and executes *SQL queries*.
  - `Transaction Manager`: Ensures *ACID properties* for transactions.
  - `Concurrency Control Manager`: Manages *simultaneous operations* and prevents conflicts.
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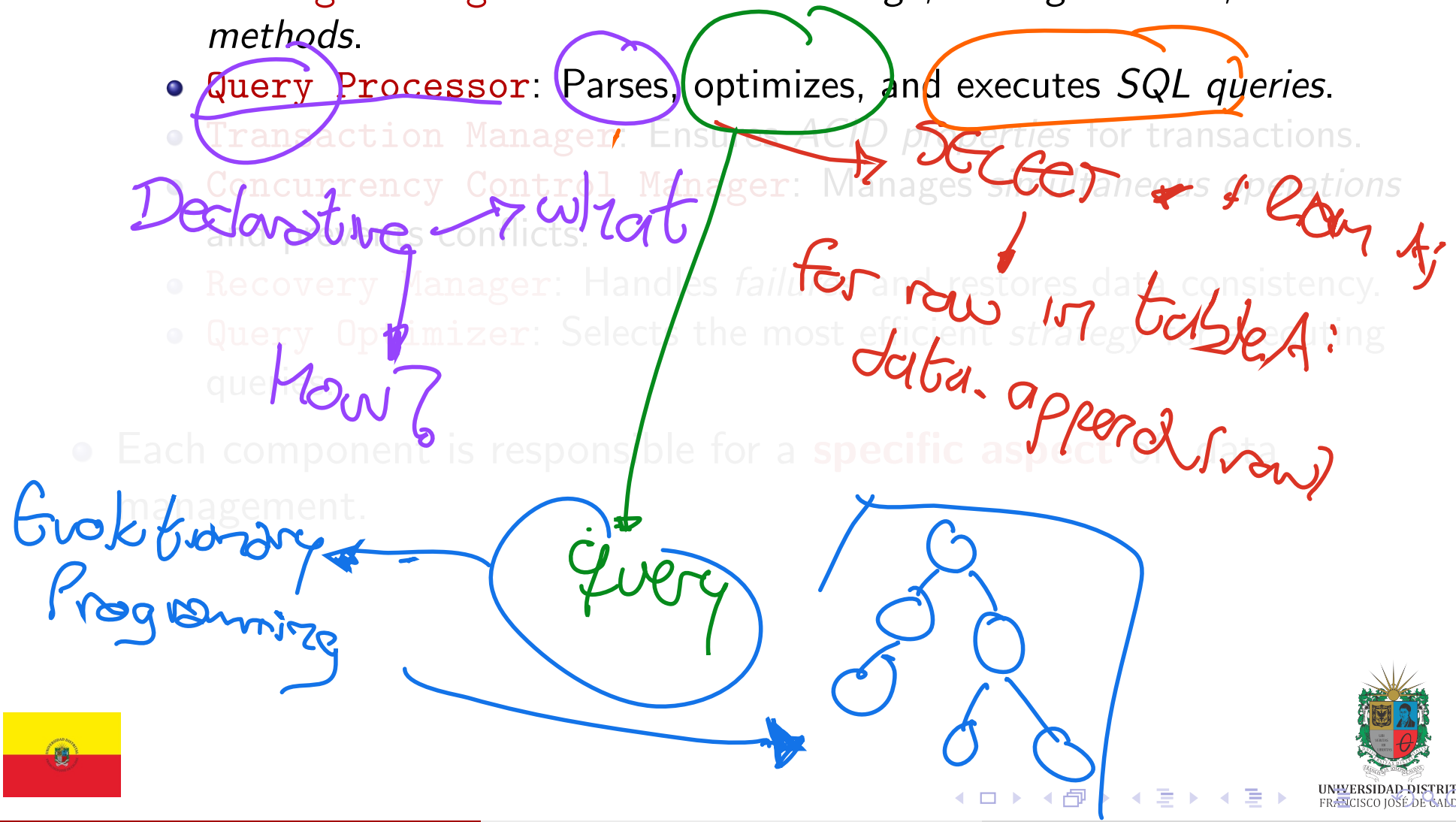

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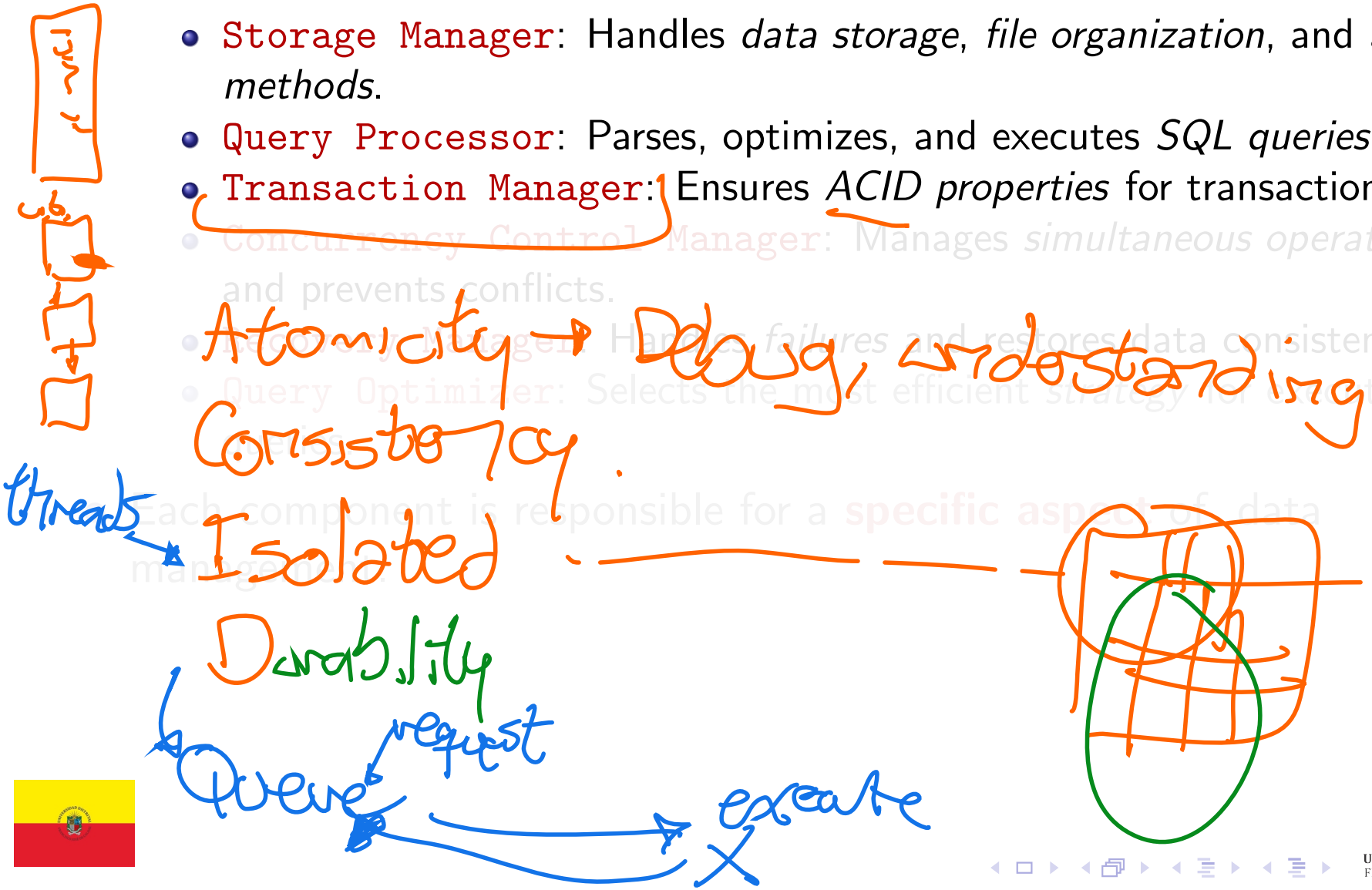

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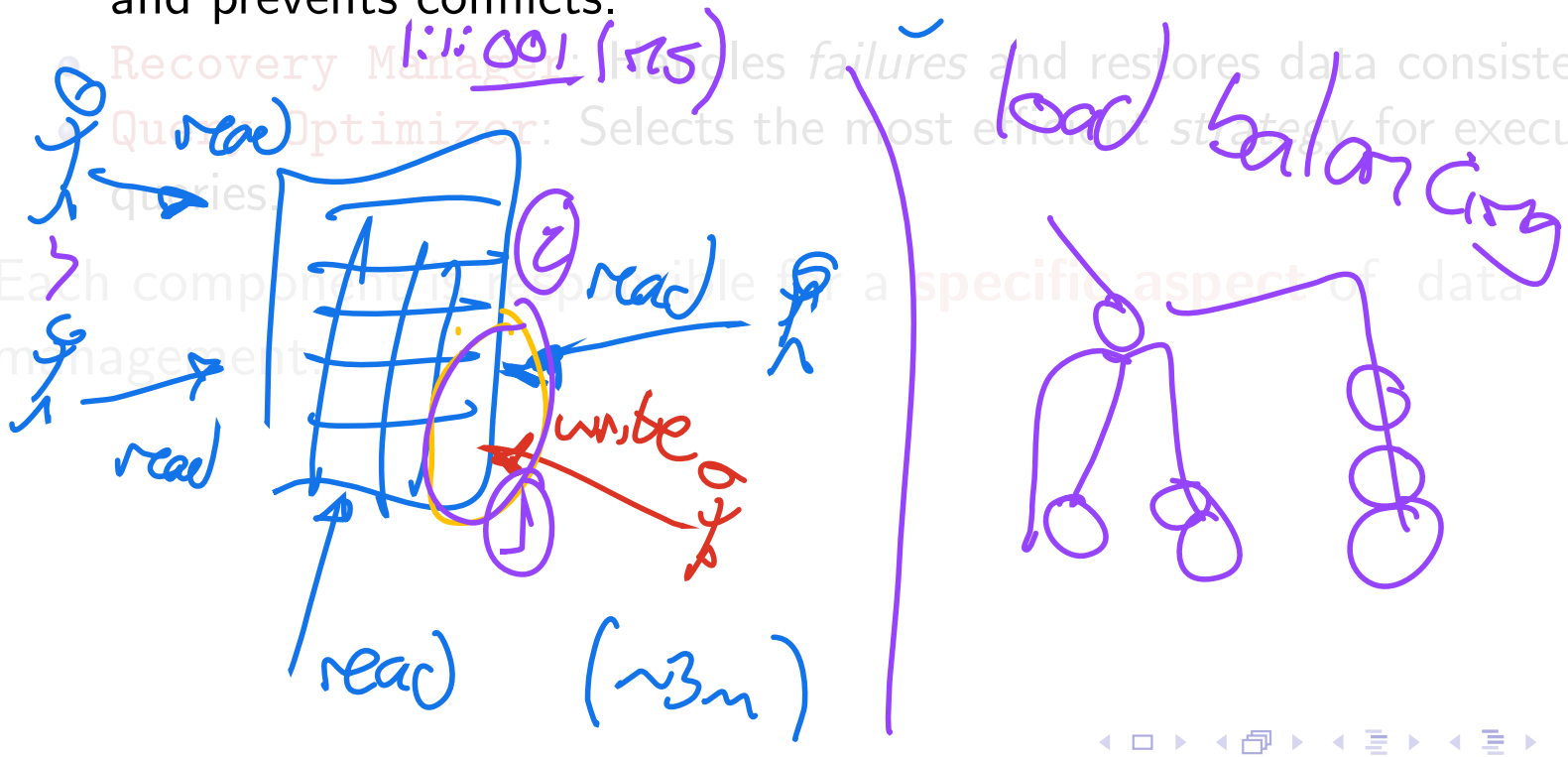

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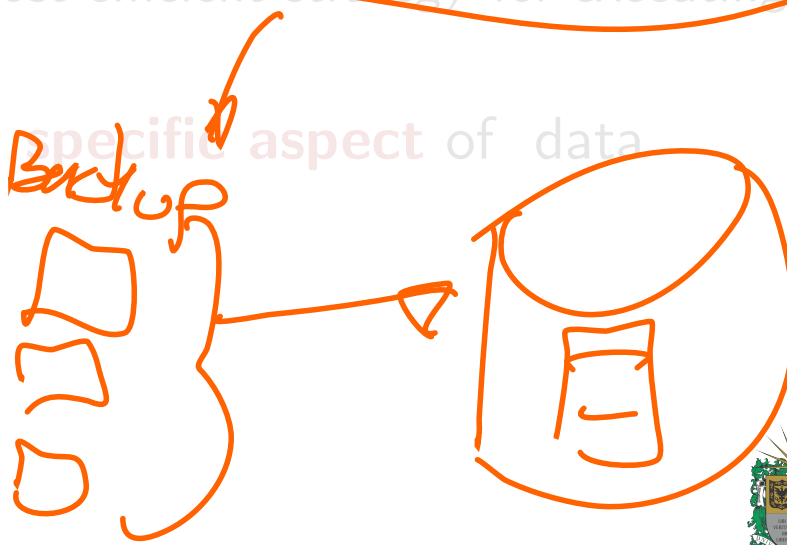

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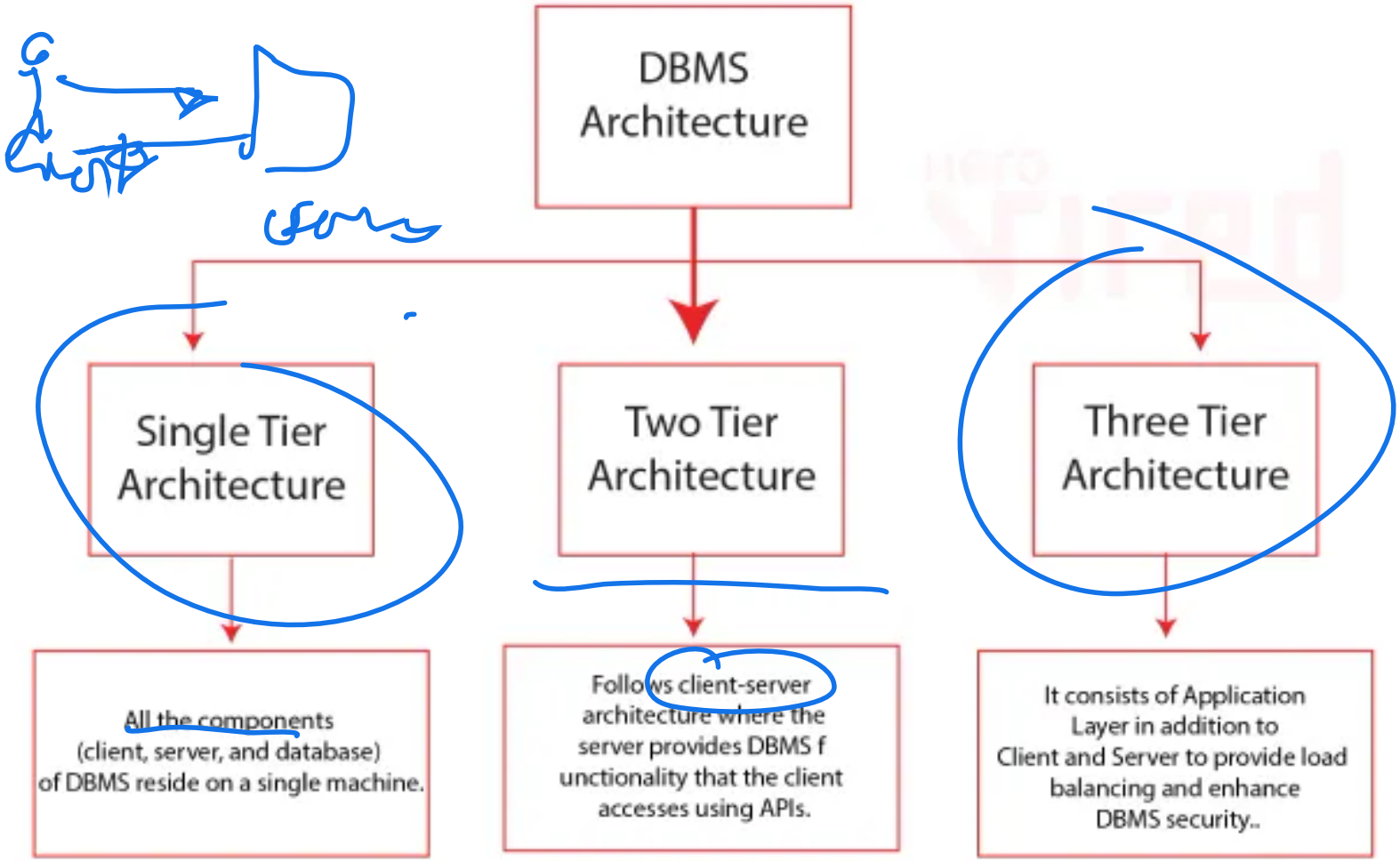
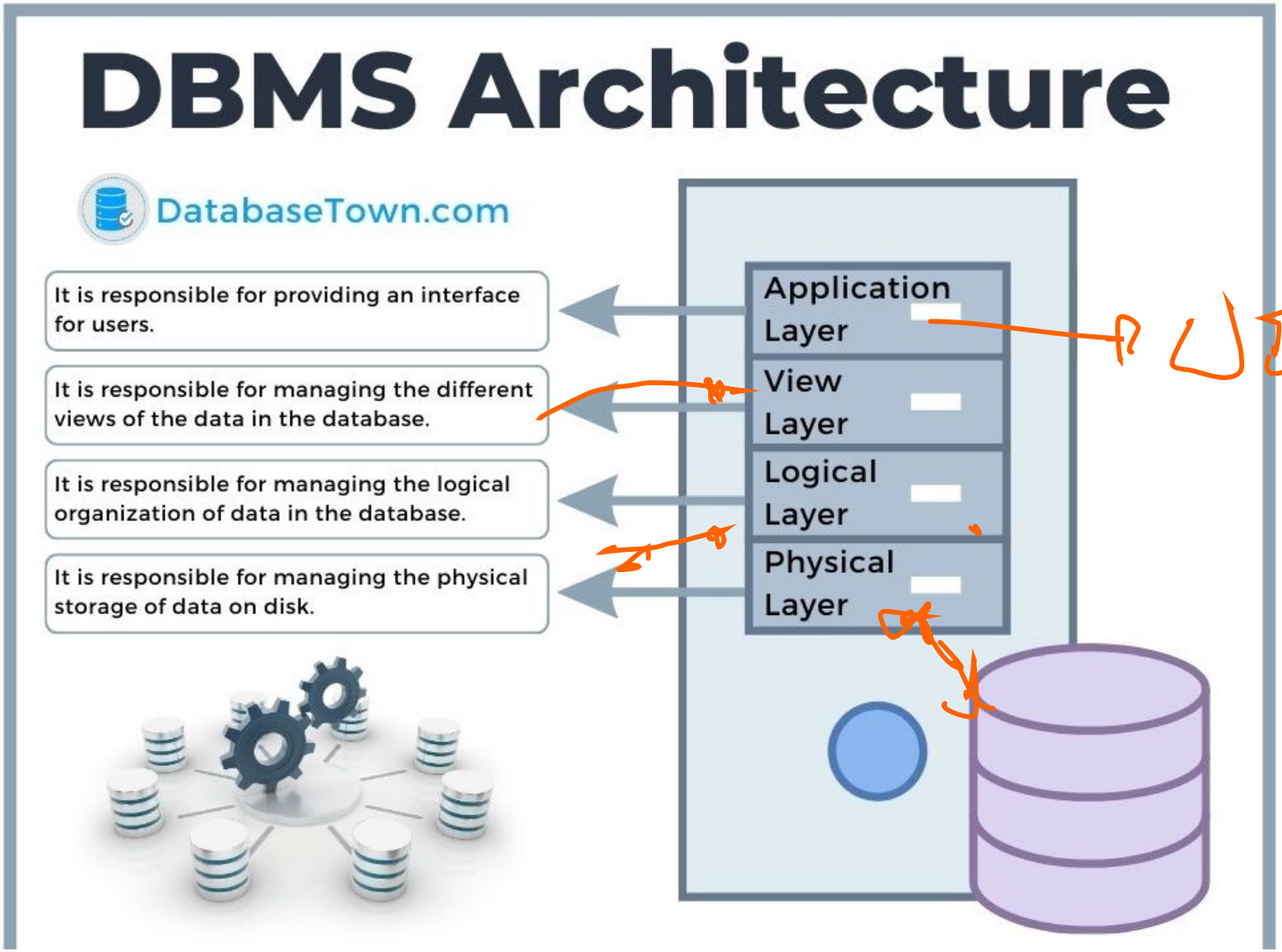
DBMS Architecture Tiers



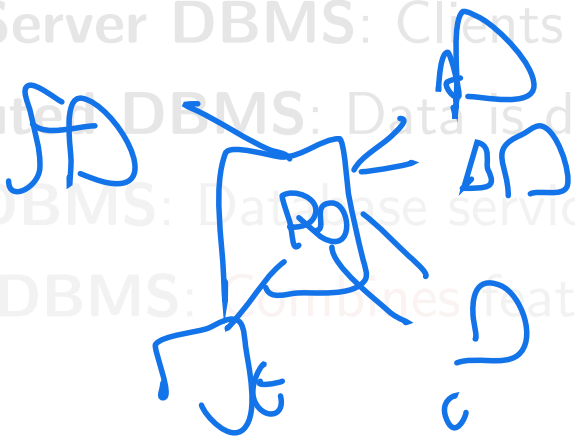
DBMS Architecture N-Tier



Types of DBMS Architecture

There are several types of DBMS architectures:

- **Centralized DBMS**: All components are on a single server.
- **Client-Server DBMS**: Clients access the database through a server.
- **Distributed DBMS**: Data is distributed across multiple servers.
- **Cloud DBMS**: Database services are provided over the cloud.
- **Hybrid DBMS**: Combines features of centralized and distributed systems.
- **Peer-to-Peer DBMS**: Each node can act as a client and server.
- **In memory DBMS**: Data is stored in RAM for faster access.



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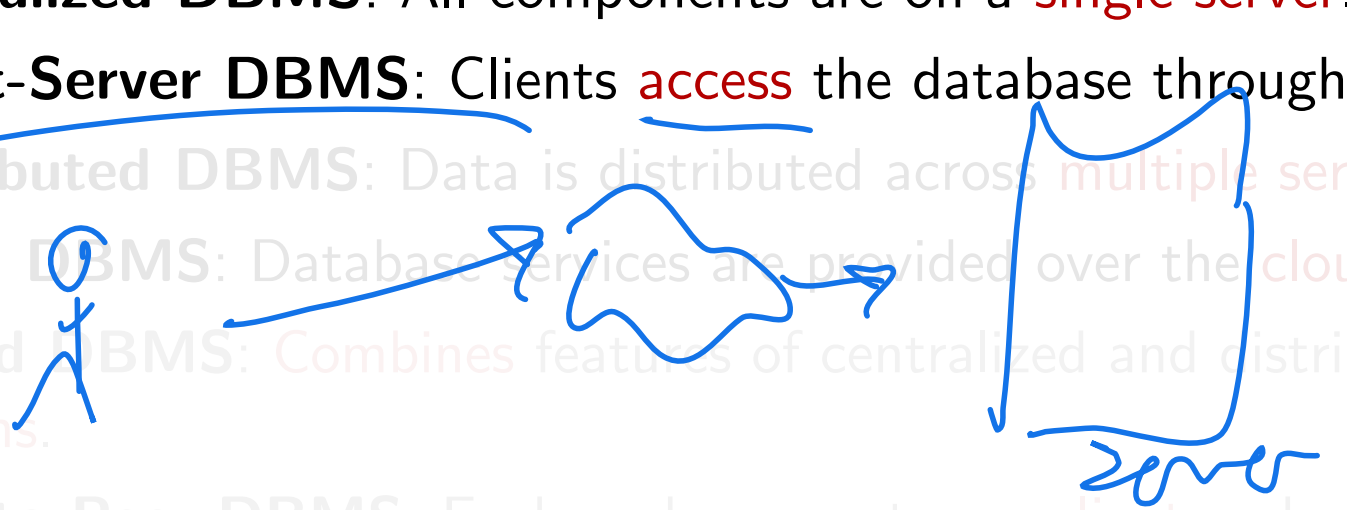

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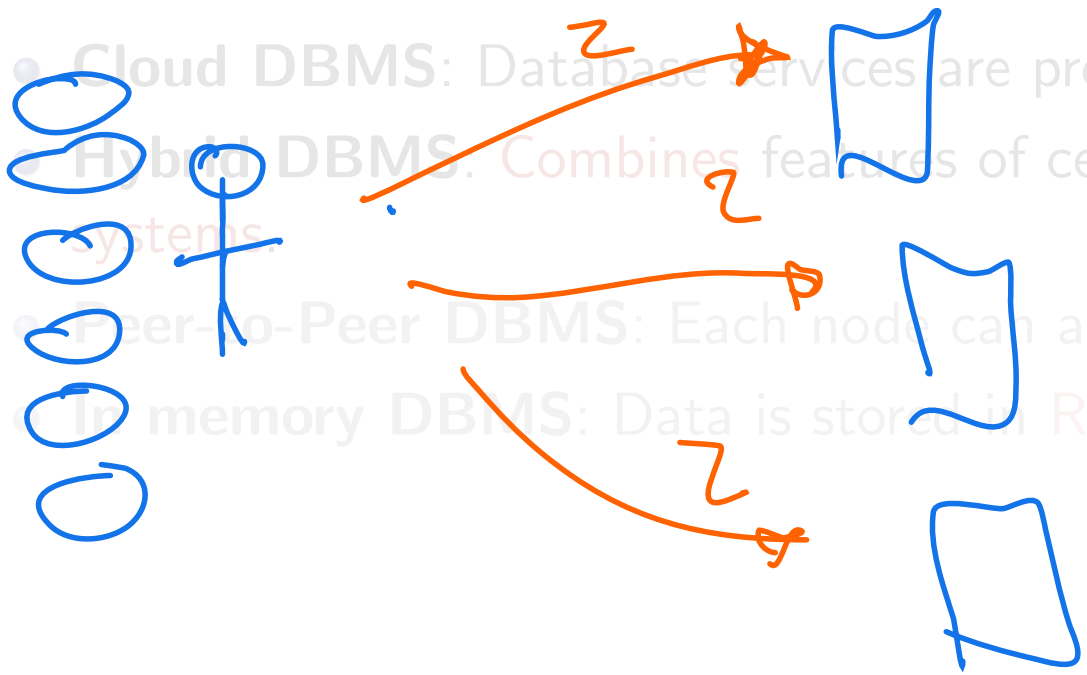

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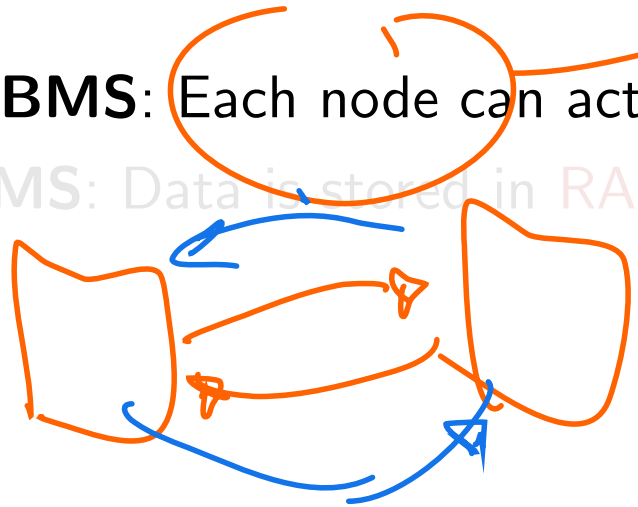

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Caché
↳ REDIS

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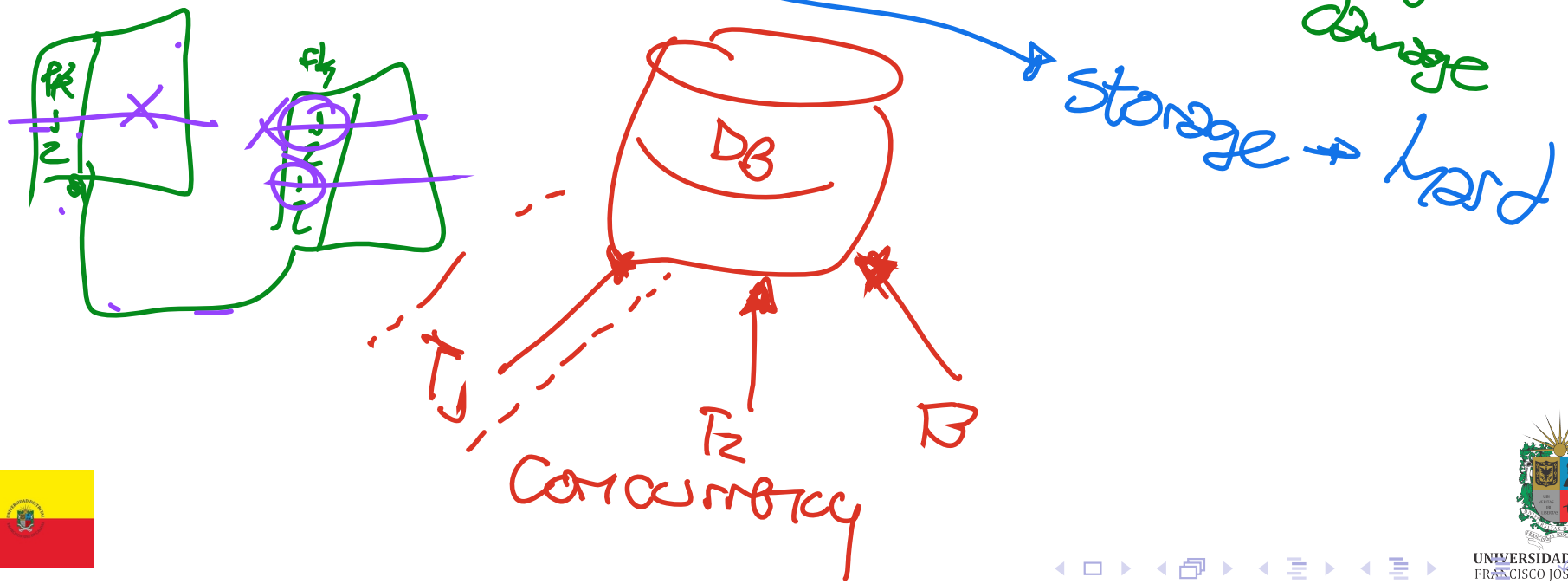
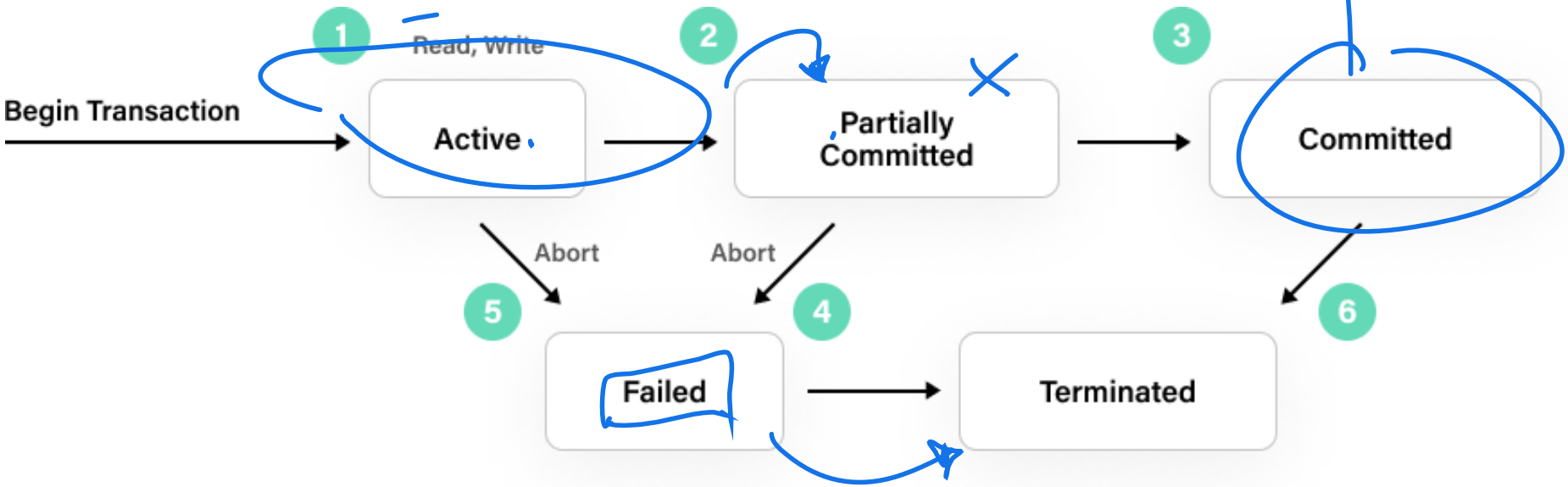
Transactional System Concepts

- A **transaction** is a sequence of operations performed as a single logical unit of work.
- Transactions must satisfy the **ACID** properties:
  - Atomicity: All or nothing.
  - Consistency: Preserves database integrity.
  - Isolation: Transactions do not interfere.
  - Durability: Results persist after completion.



Transaction Lifecycle

- **Begin**: Transaction starts.
- **Read/Write**: Operations are performed.
- **Commit**: Changes are made permanent.
- **Rollback**: Changes are undone if an error occurs.
- Savepoints can be used for partial rollbacks.



Outline

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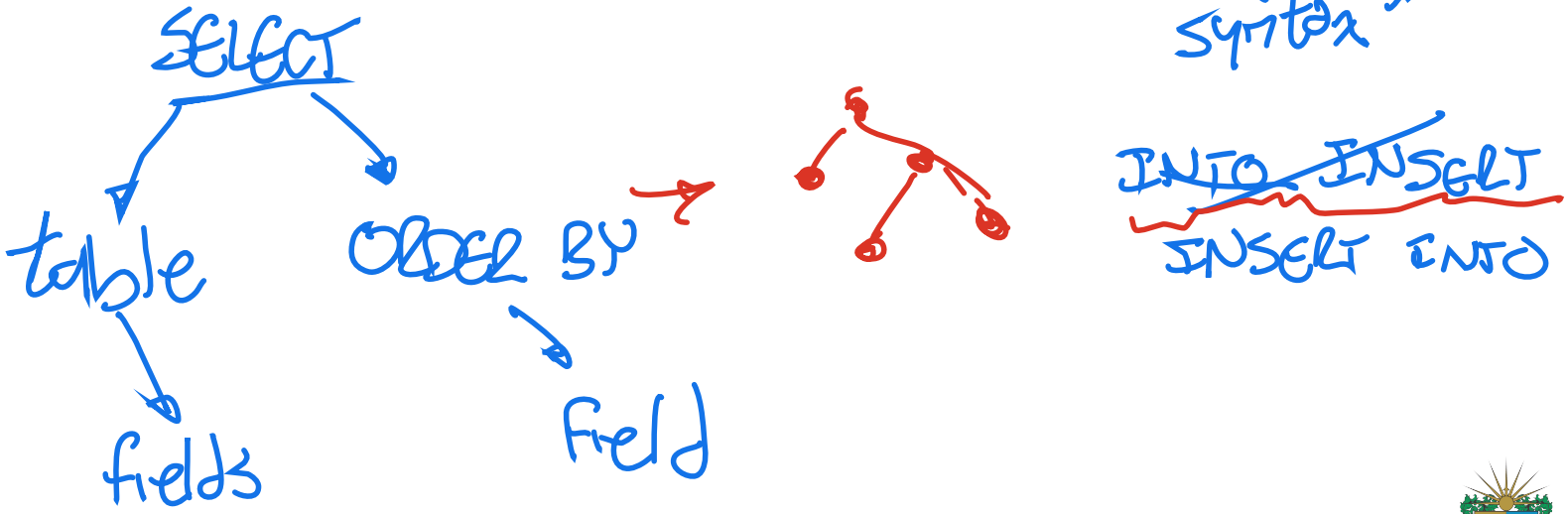
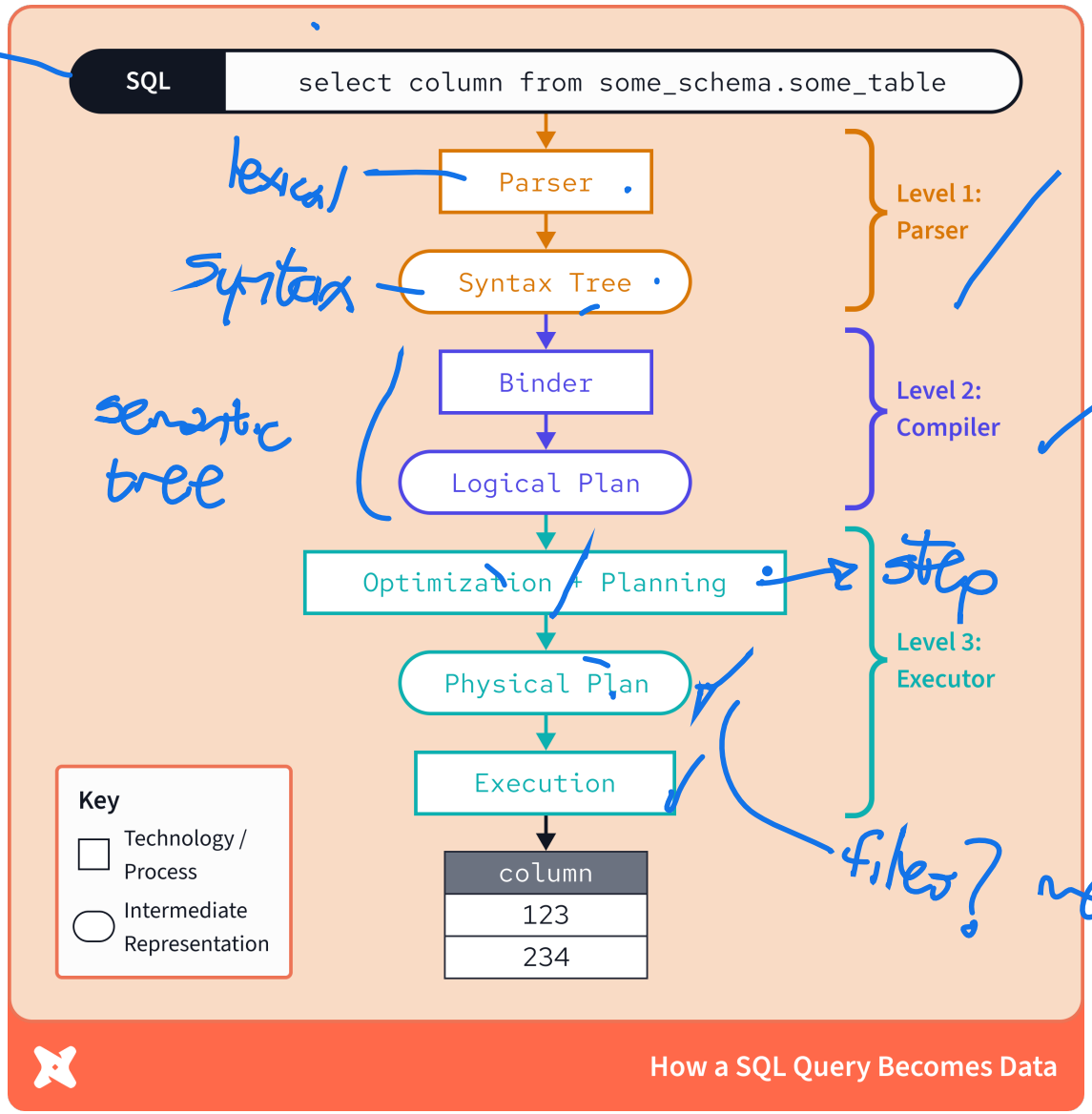
Query Execution Process

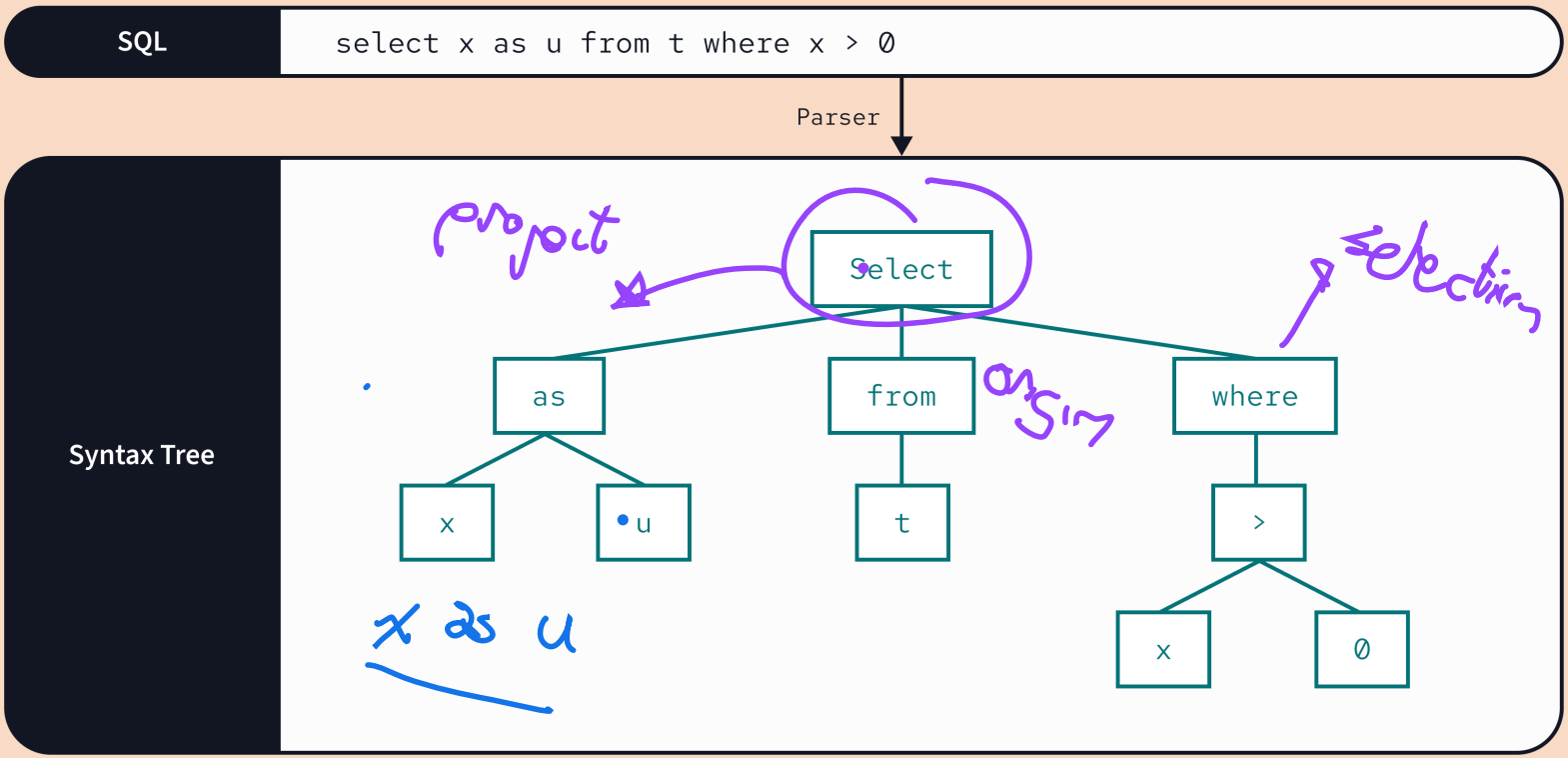
- **Query execution** is the process of interpreting and running database queries.
- Steps:
  - Parsing: Analyzing query syntax.
  - Optimization: Choosing the best execution plan.
  - Execution: Retrieving and processing data.
- **Efficient execution** is critical for performance.



Query Execution Flow: Full Transaction

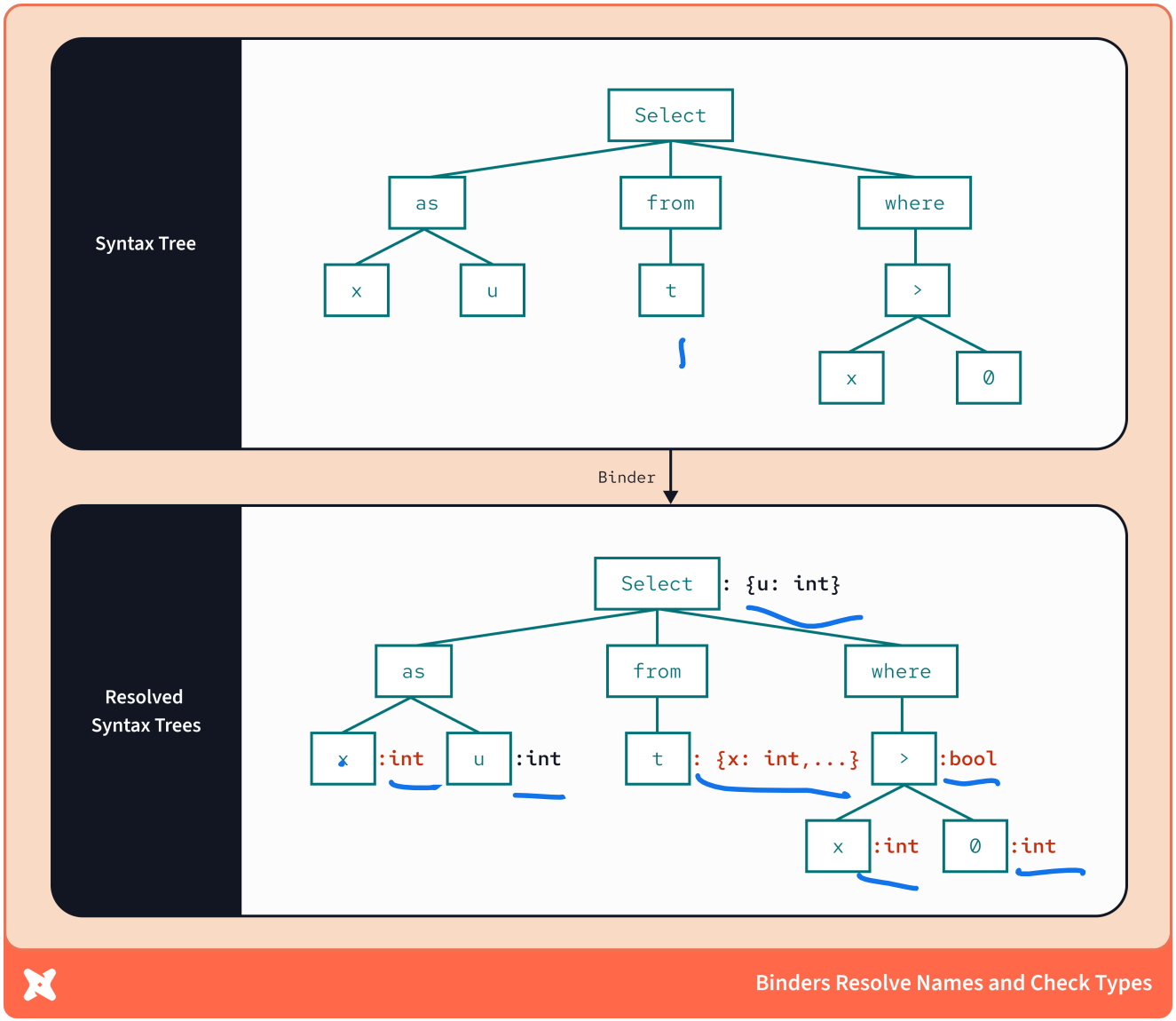


Query Execution Flow: Syntax Tree

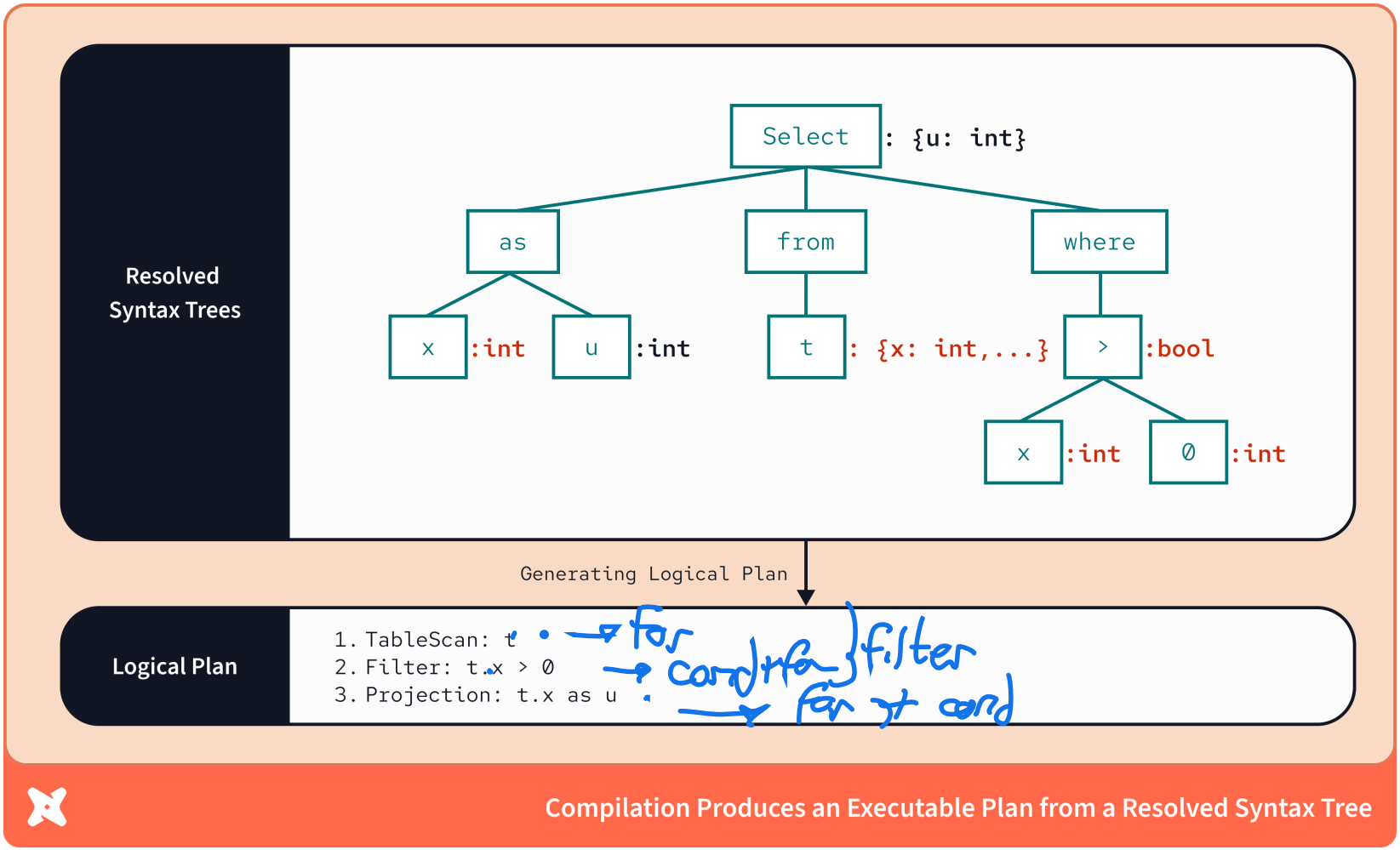


Parsers Recognize the Structure of the Query

Query Execution Flow: Compilation



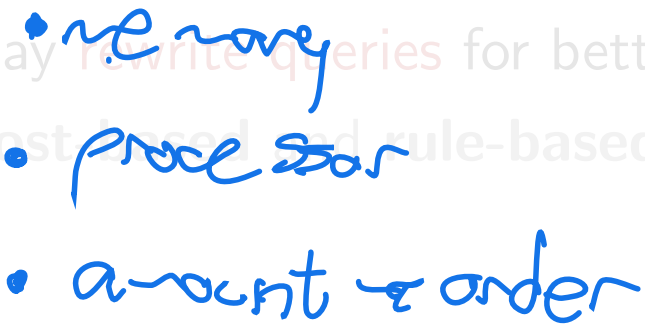
Query Execution Flow: Logical Plan



Compilation Produces an Executable Plan from a Resolved Syntax Tree

Query Optimization

- The **query optimizer** selects the most efficient strategy for executing a query.
- Considers indexes, join methods, and data distribution.
- May rewrite queries for better performance.
- Cost-based and rule-based optimization approaches.



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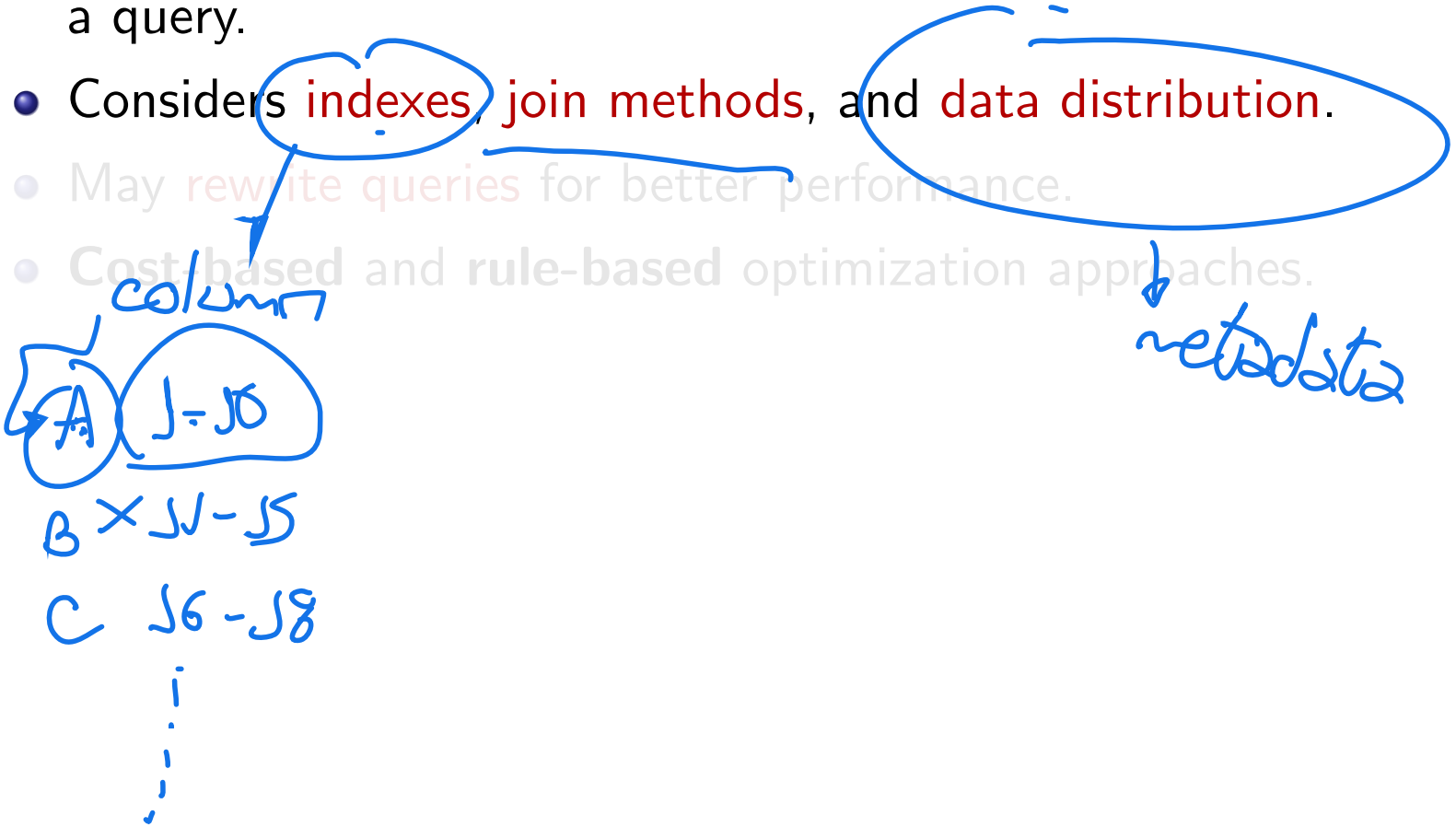

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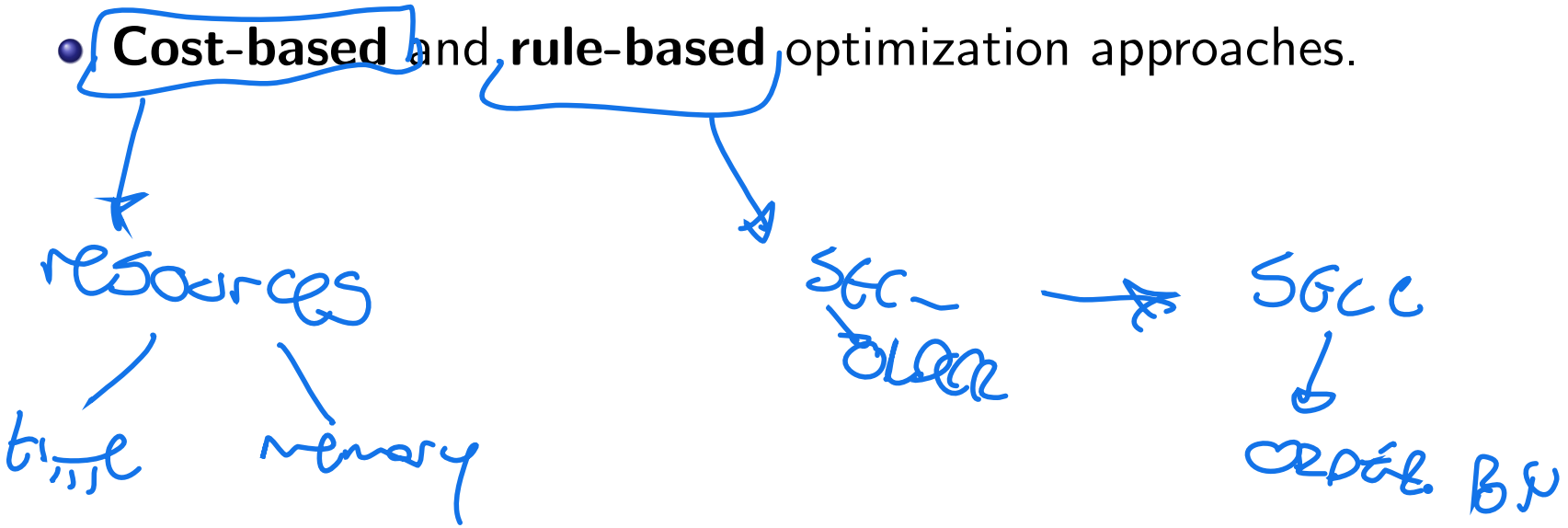
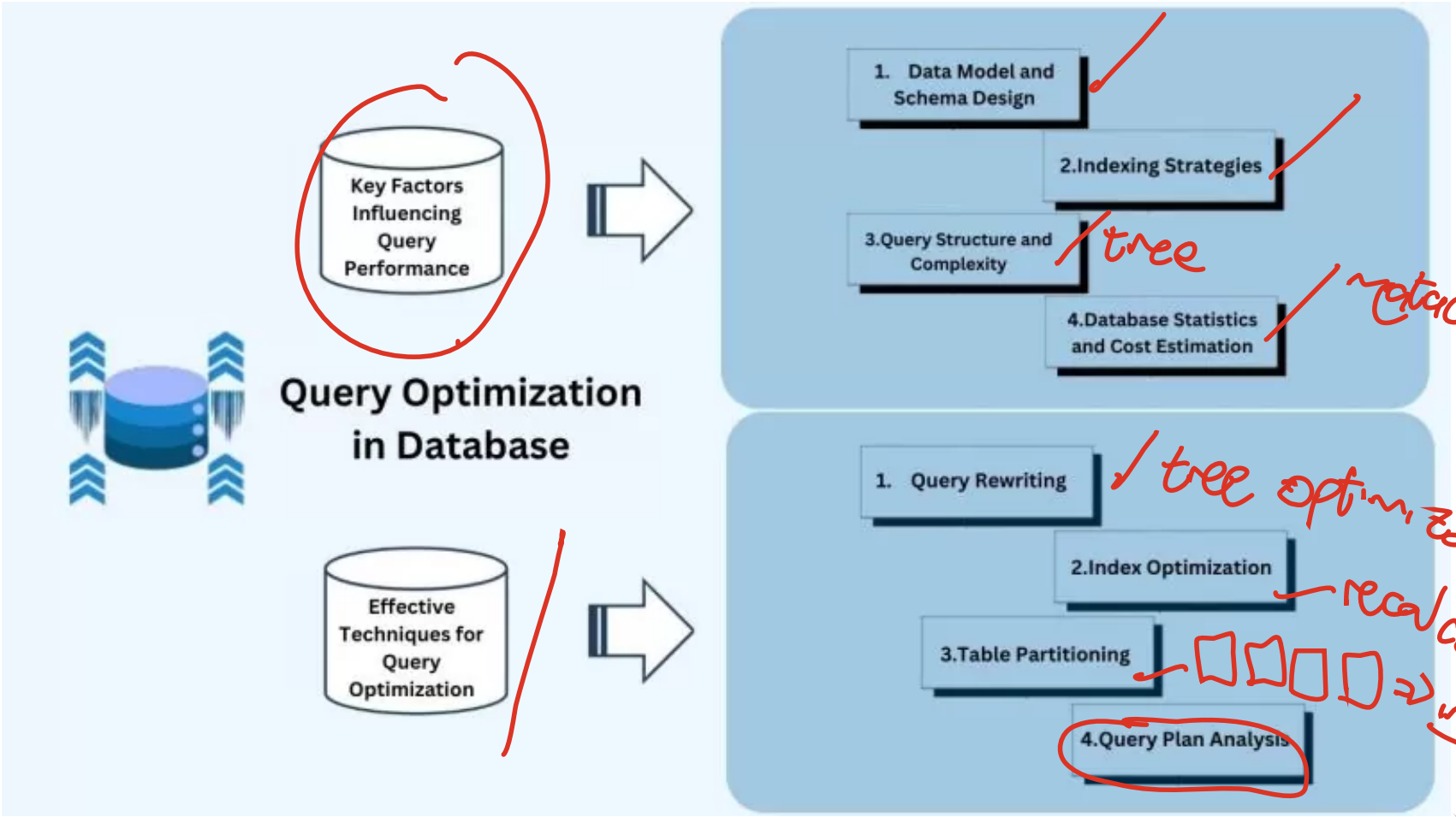


Query Optimization Factors



Outline

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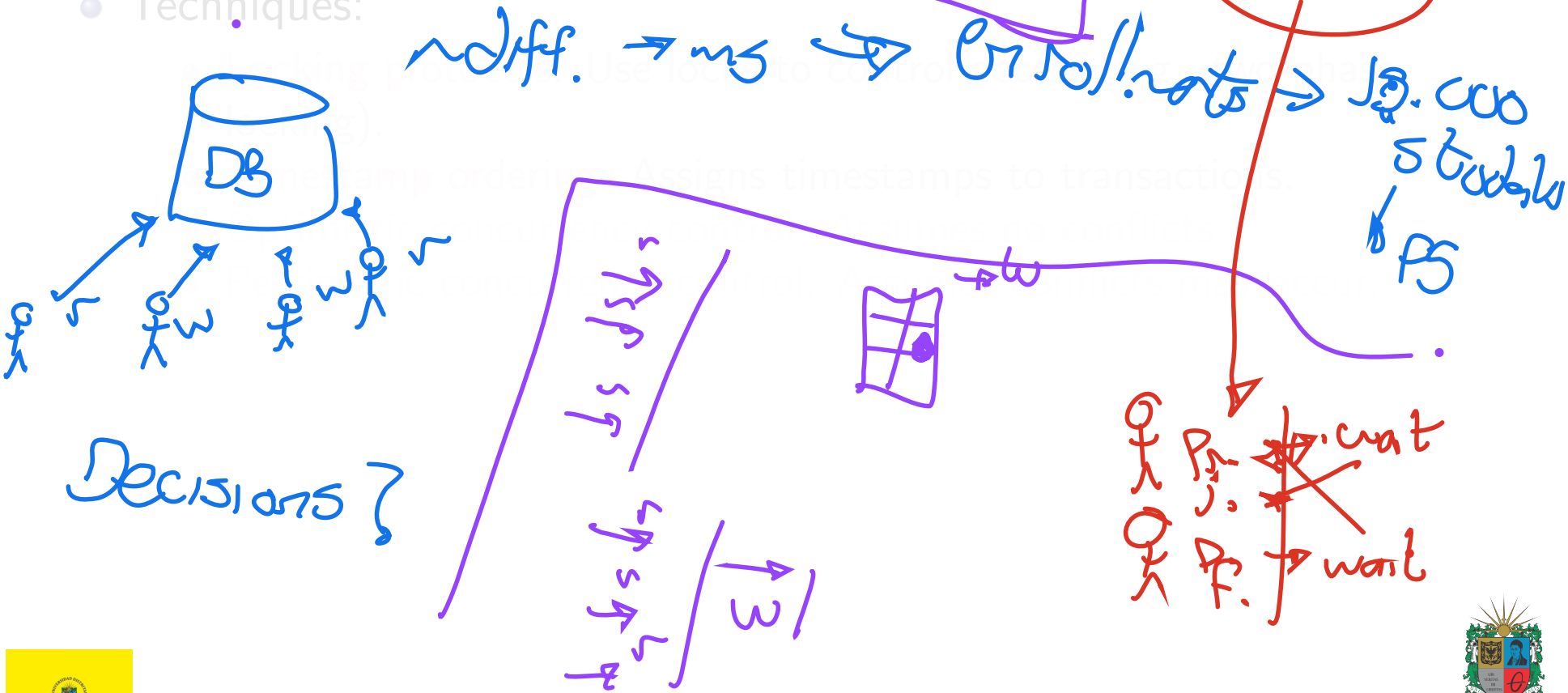
Concurrency Control Concepts

- **Concurrency control** ensures correct results when multiple transactions execute simultaneously.
- Prevents problems like lost updates, dirty reads, and deadlocks.
- Techniques:



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- Techniques:
  - Locking protocols: Use locks to control access (e.g., two-phase locking).
  - Timestamp ordering: Assigns timestamps to transactions.
  - Optimistic concurrency control: Assumes no conflicts.
  - Pessimistic concurrency control: Assumes conflicts may occur.

Consistency + Integrity

write → lock read
read → lock write

- waiting time increase
- memory due queues

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OCC

→ Parallel without locks
↳ reduce queues
↳ memory

High response time

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→ locking + timestamp

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Locking and Deadlocks

- **Locks** prevent conflicting operations on the same data.
- **Deadlocks** occur when transactions wait indefinitely for each other.
- DBMS uses deadlock detection and resolution strategies.
- **Isolation levels** (e.g., Read Committed, Serializable) control visibility of changes.

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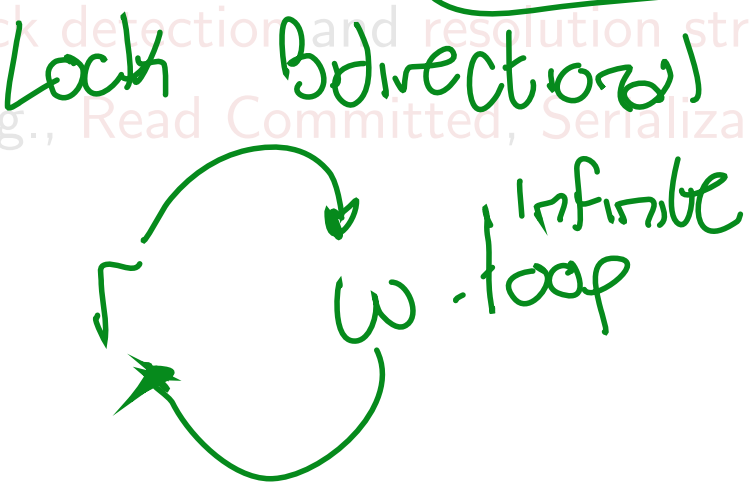

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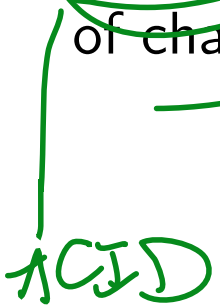

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Outline

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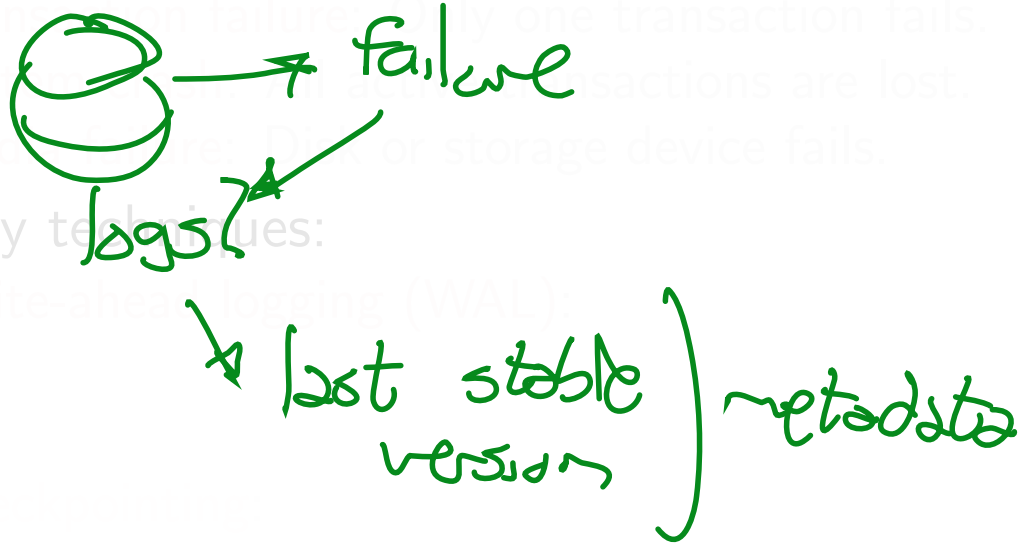
Failure Recovery Concepts

- **Failure recovery** restores the database to a consistent state after a failure.
- Types of failures:
  - Transaction failure: Only one transaction fails.
  - System crash: All active transactions are lost.
  - Media failure: Disk or storage device fails.
- Recovery techniques:
  - Write-ahead logging (WAL):
    - Undo-only logging
    - Redo-only logging



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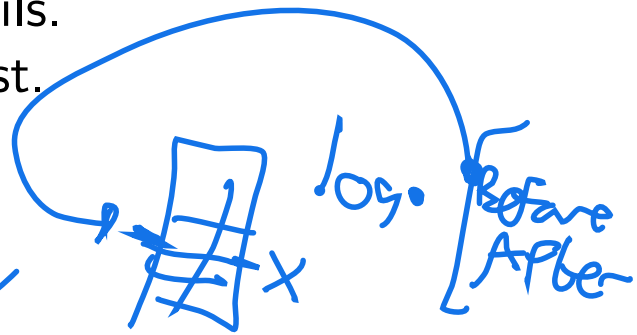
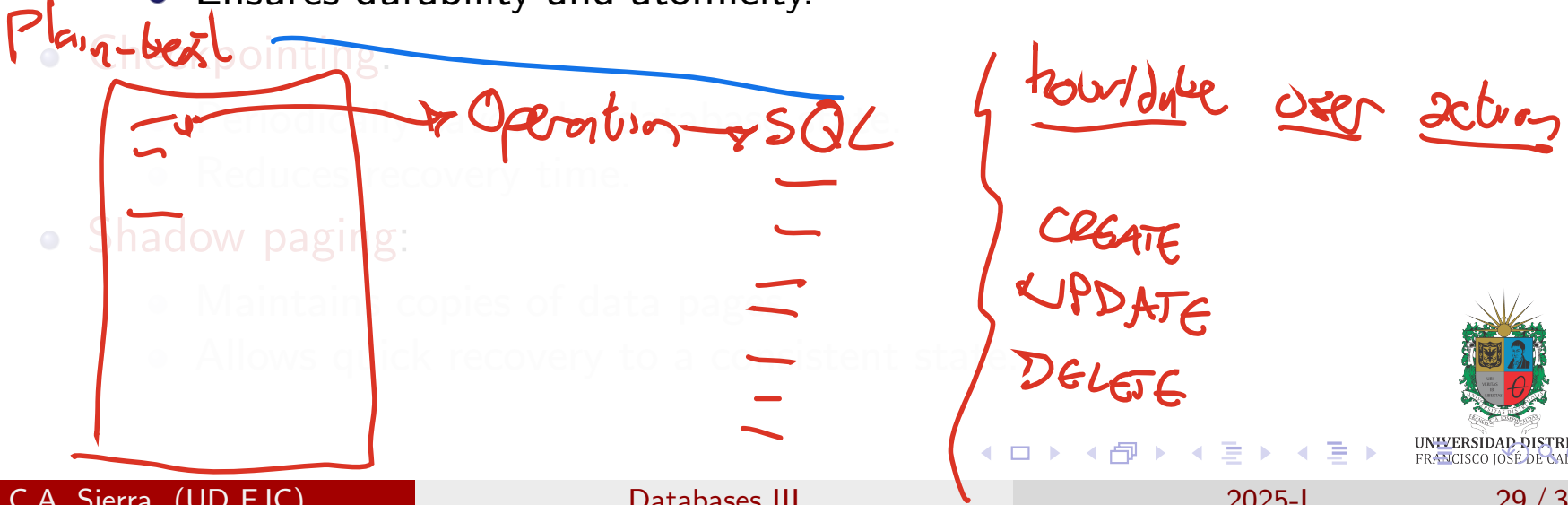
    - Ensures durability and atomicity.
  - Checkpointing:
    - Periodically saves the state of the database.
    - Reduces recovery time.
  - Shadow paging:
    - Maintains copies of data pages.
    - Allows quick recovery to a consistent state.





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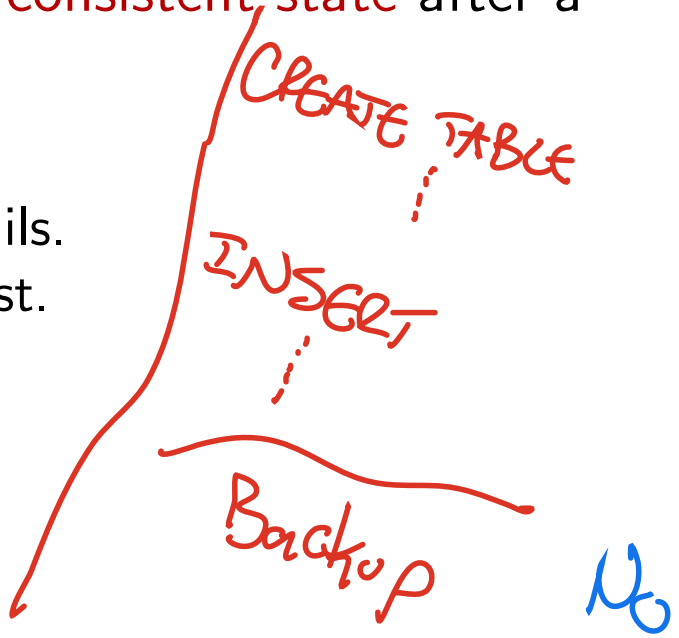
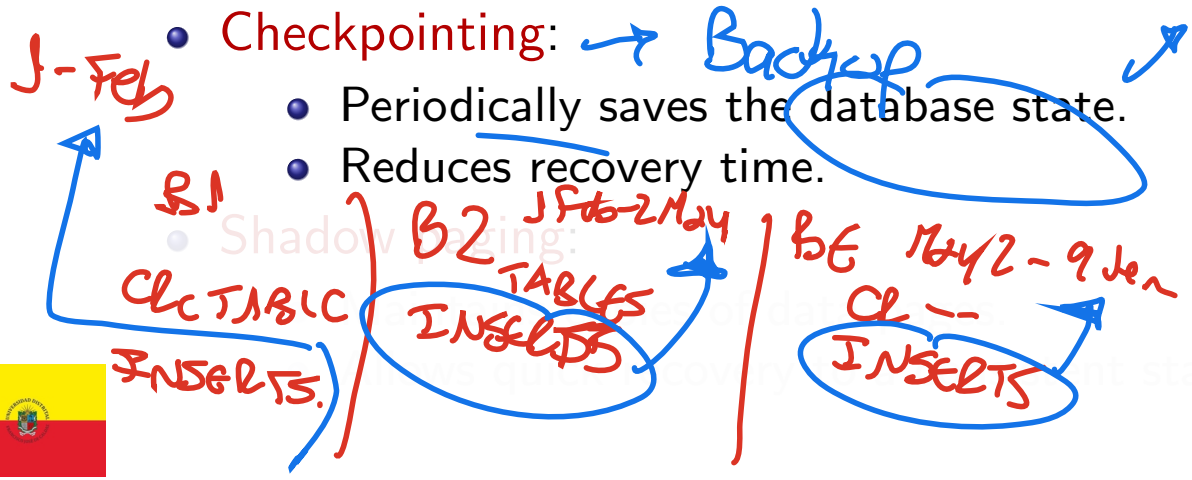
  - Shadow paging:
    - Creates a copy of the database.
    - Switches to the new copy during recovery.





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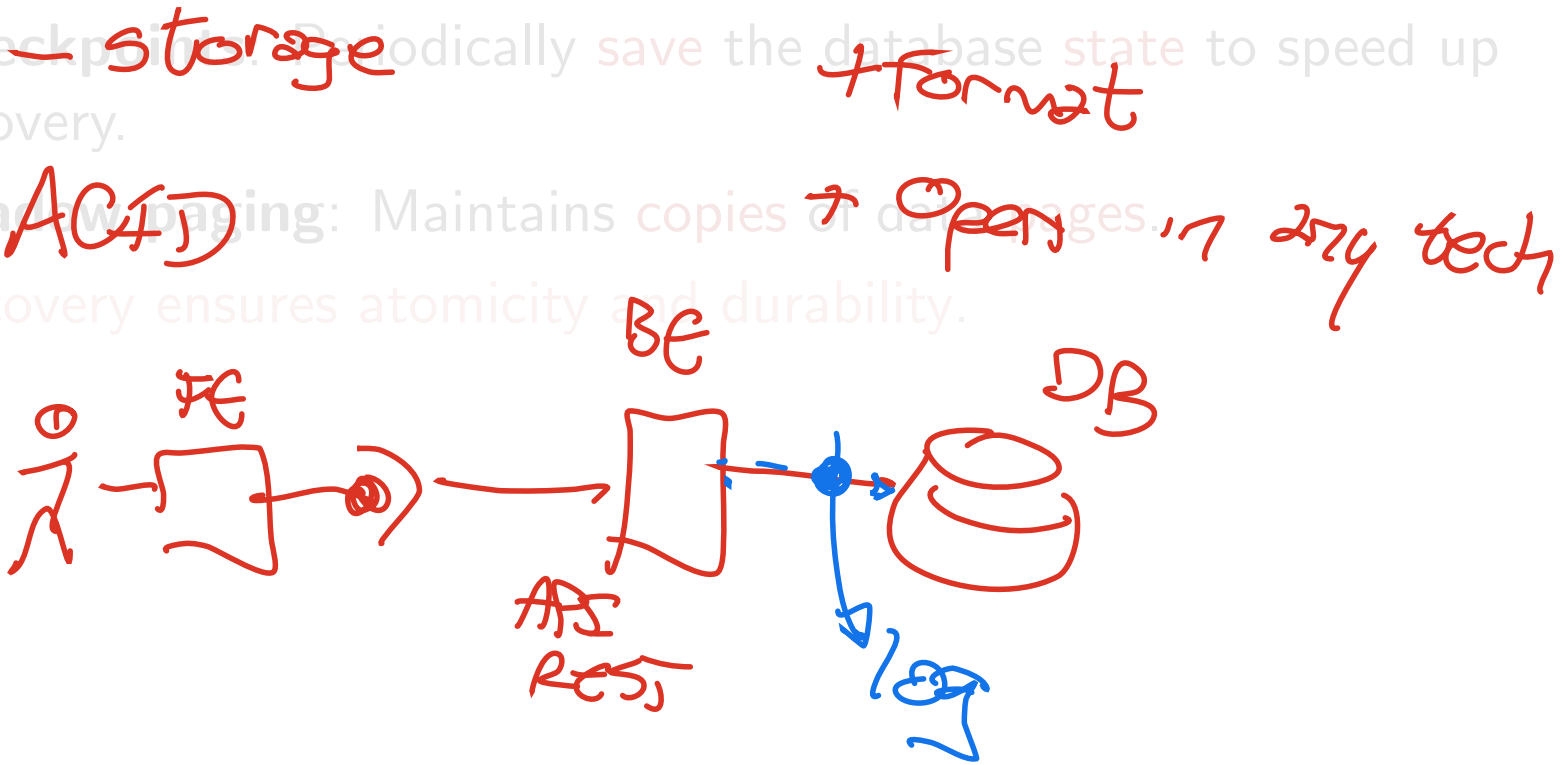

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Automatic — 1 month
1 day - 1 hour
10 minutes

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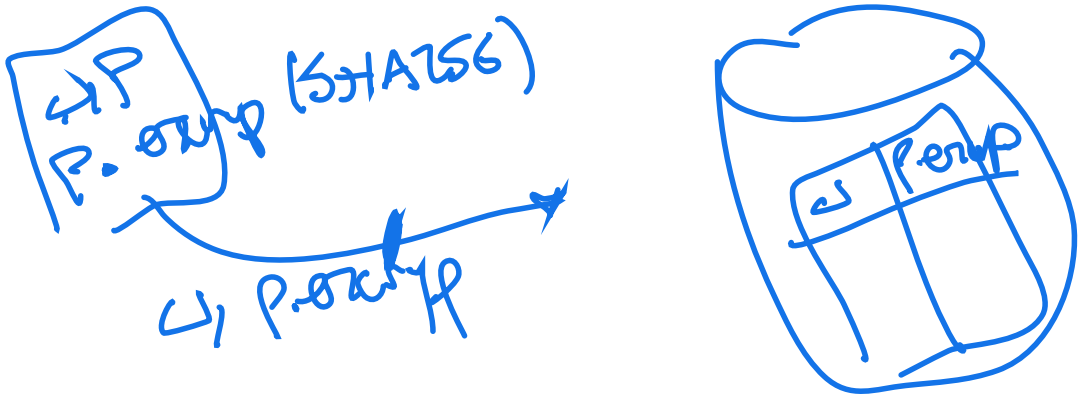
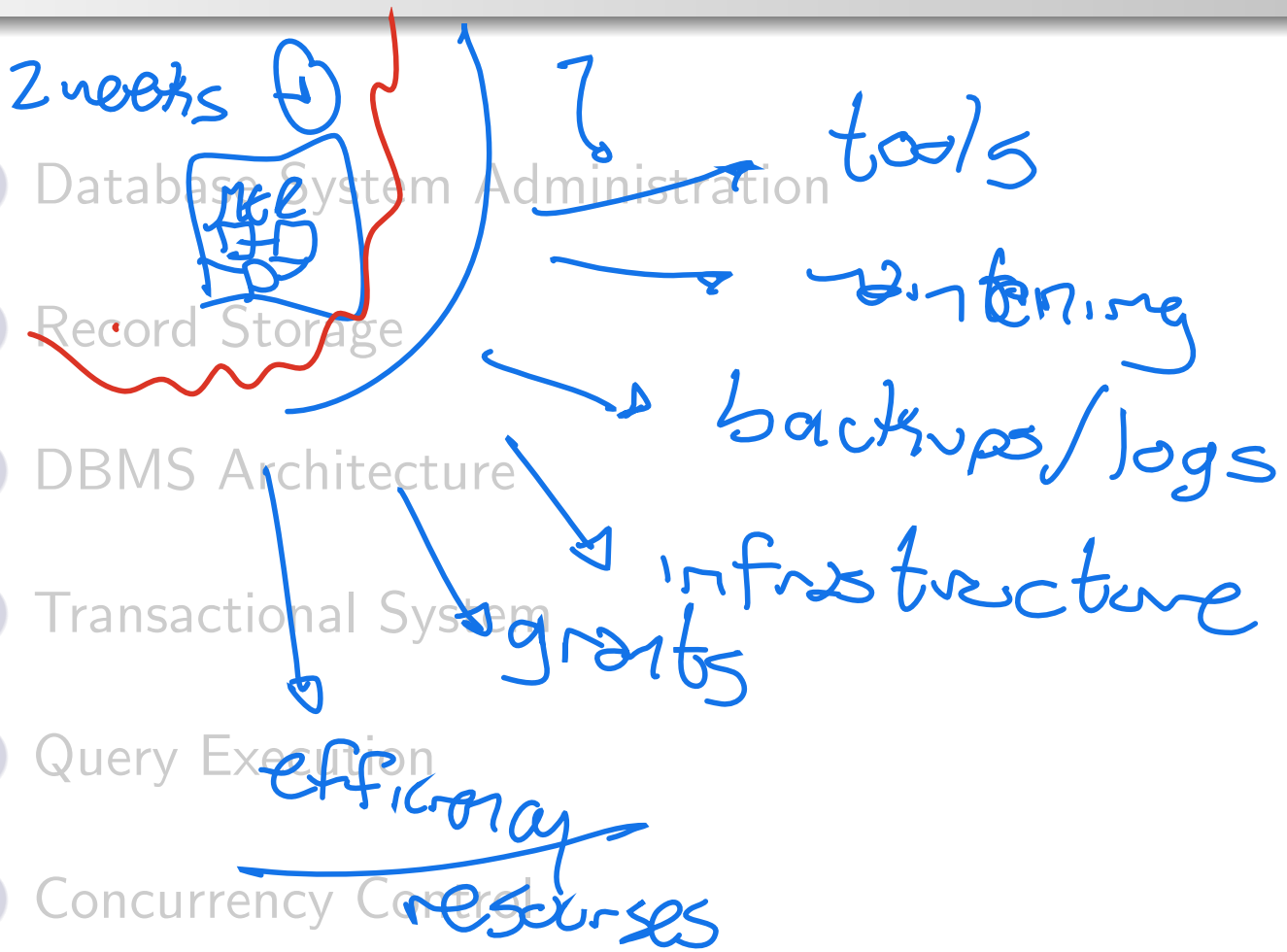


Outline



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Thanks!

Questions?

Repo: `https://github.com/EngAndres/ud-public/tree/main/courses/databases-ii`

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