DataBase Systems Architecture

Databases III

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Outline

1. DataBases Infrastructure
2. DBMS Architecture
3. Database System Administration
4. Transactional System
5. Query Execution
6. Concurrency Control
7. Failure Recovery

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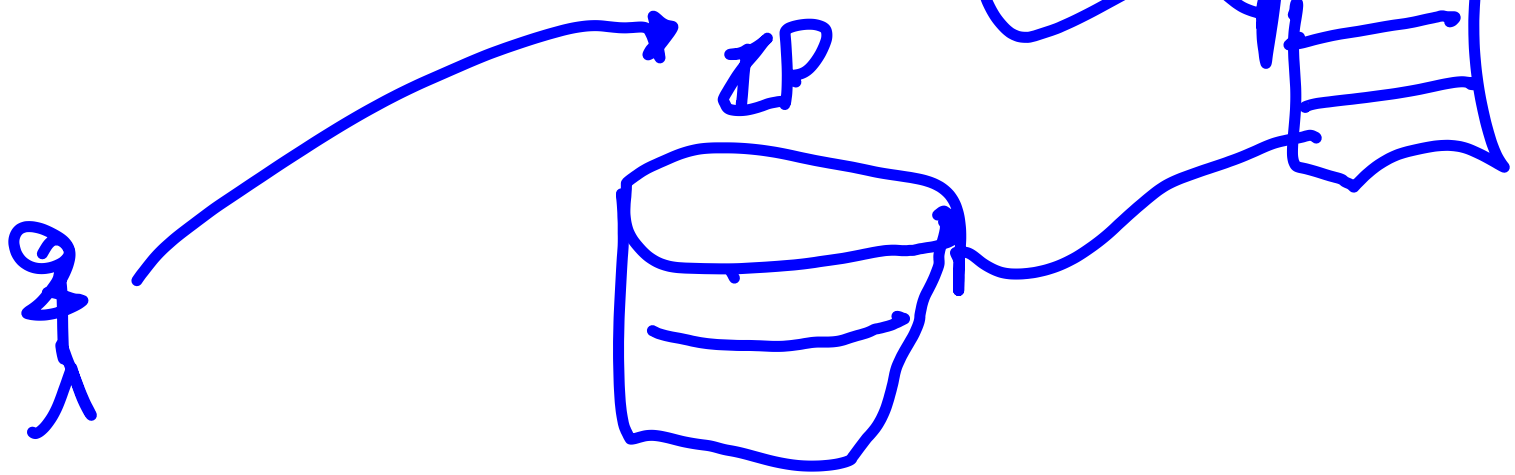
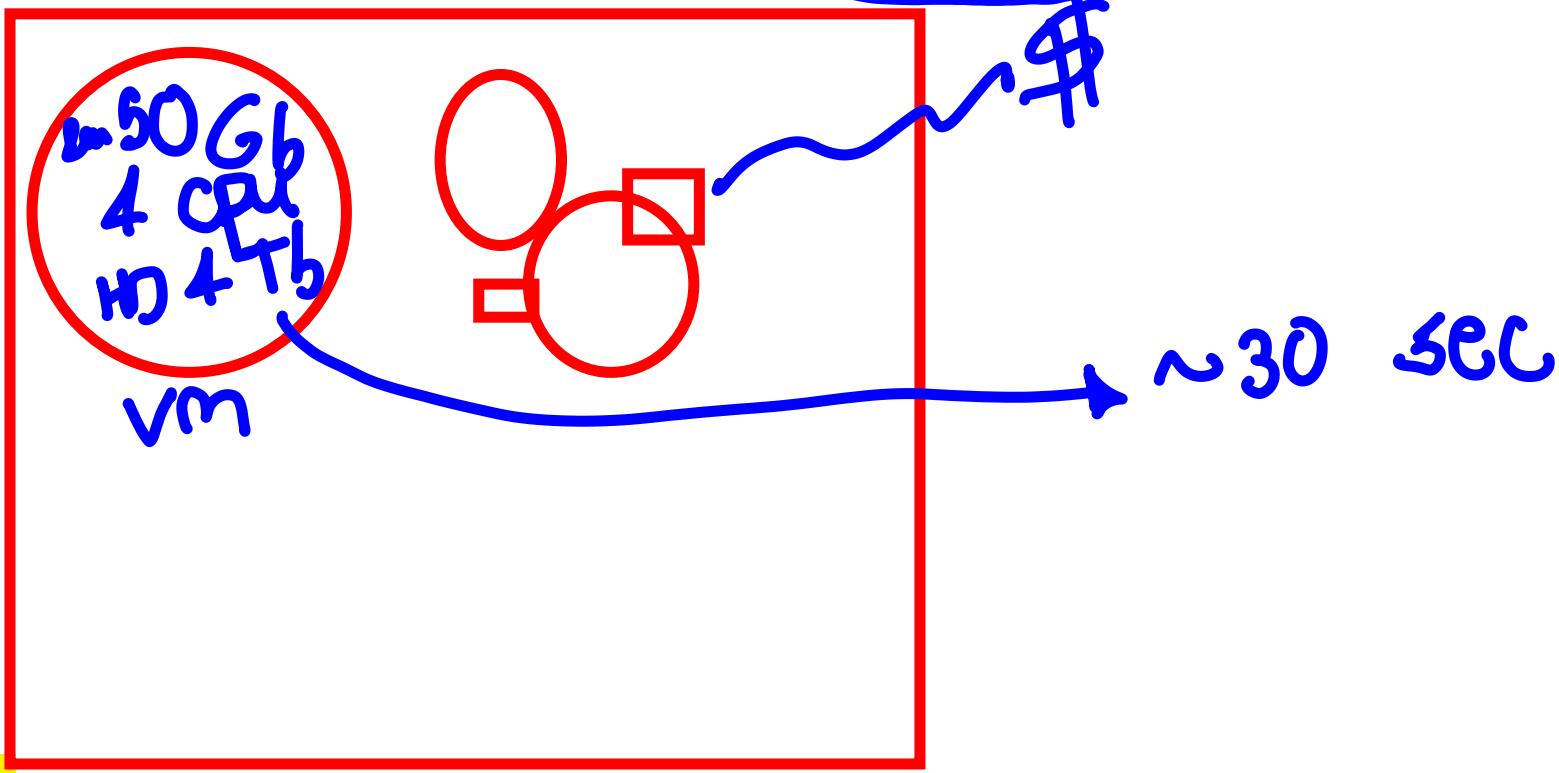
What is On-Premises Computing?

- **On-premises computing** is the traditional way of accessing computing resources.
- **On-premises computing** requires users to purchase and maintain their own computing resources such as servers, storage, and databases.



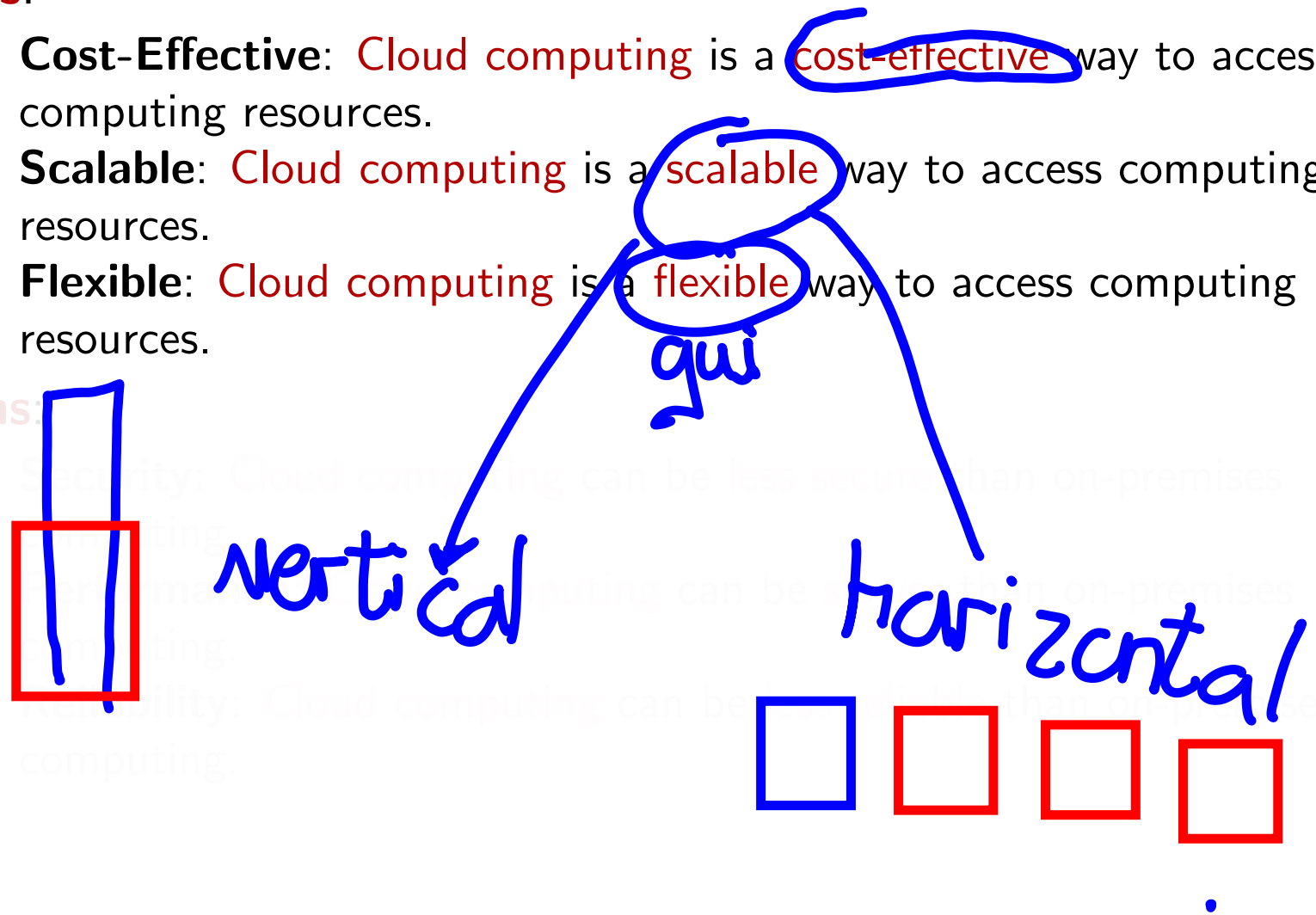
What is the Cloud Computing?

- **Cloud computing** is the delivery of computing services over the internet.
- **Cloud computing** allows users to access computing resources such as servers, storage, and databases **on demand**.



Pros & Cons of Cloud Computing

- **Pros**:
  - **Cost-Effective**: Cloud computing is a cost-effective way to access computing resources.
  - **Scalable**: Cloud computing is a scalable way to access computing resources.
  - **Flexible**: Cloud computing is a flexible way to access computing resources.
- **Cons**:
  - **Security**: Cloud computing can be less secure than on-premises computing.
  - **Performance**: Cloud computing can be slower than on-premises computing.
  - **Reliability**: Cloud computing can be less reliable than on-premises computing.



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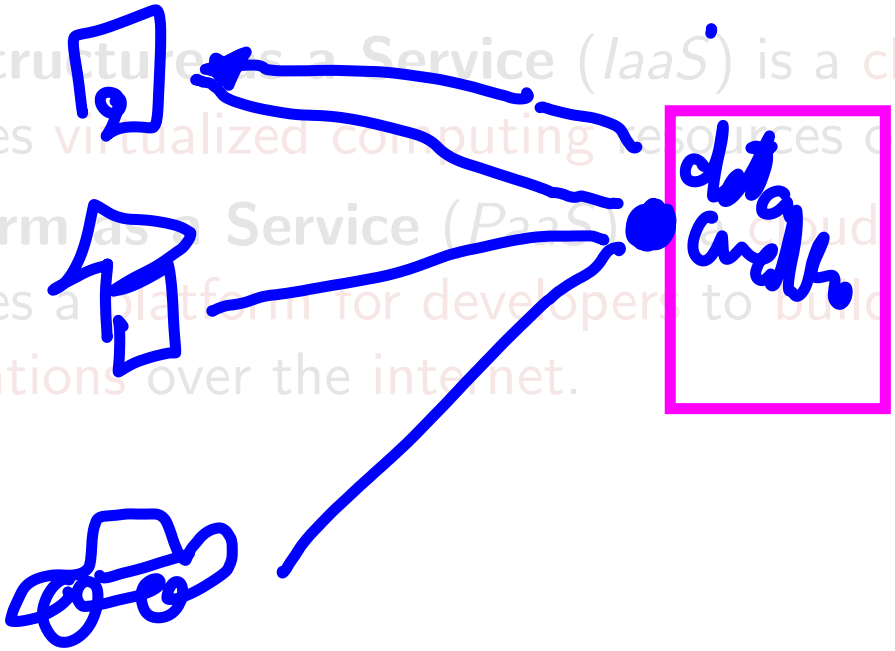
SaaS Vs. IaaS Vs. PaaS

- **Software as a Service** (*SaaS*) is a software distribution model in which a third-party provider hosts applications and makes them available to customers over the internet.



- **Infrastructure as a Service** (*IaaS*) is a cloud computing model that provides virtualized computing resources over the internet.
- **Platform as a Service** (*PaaS*) is a cloud computing model that provides a platform for developers to build, deploy, and manage applications over the internet.

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IaC → terraform

SaaS Vs. IaaS Vs. PaaS

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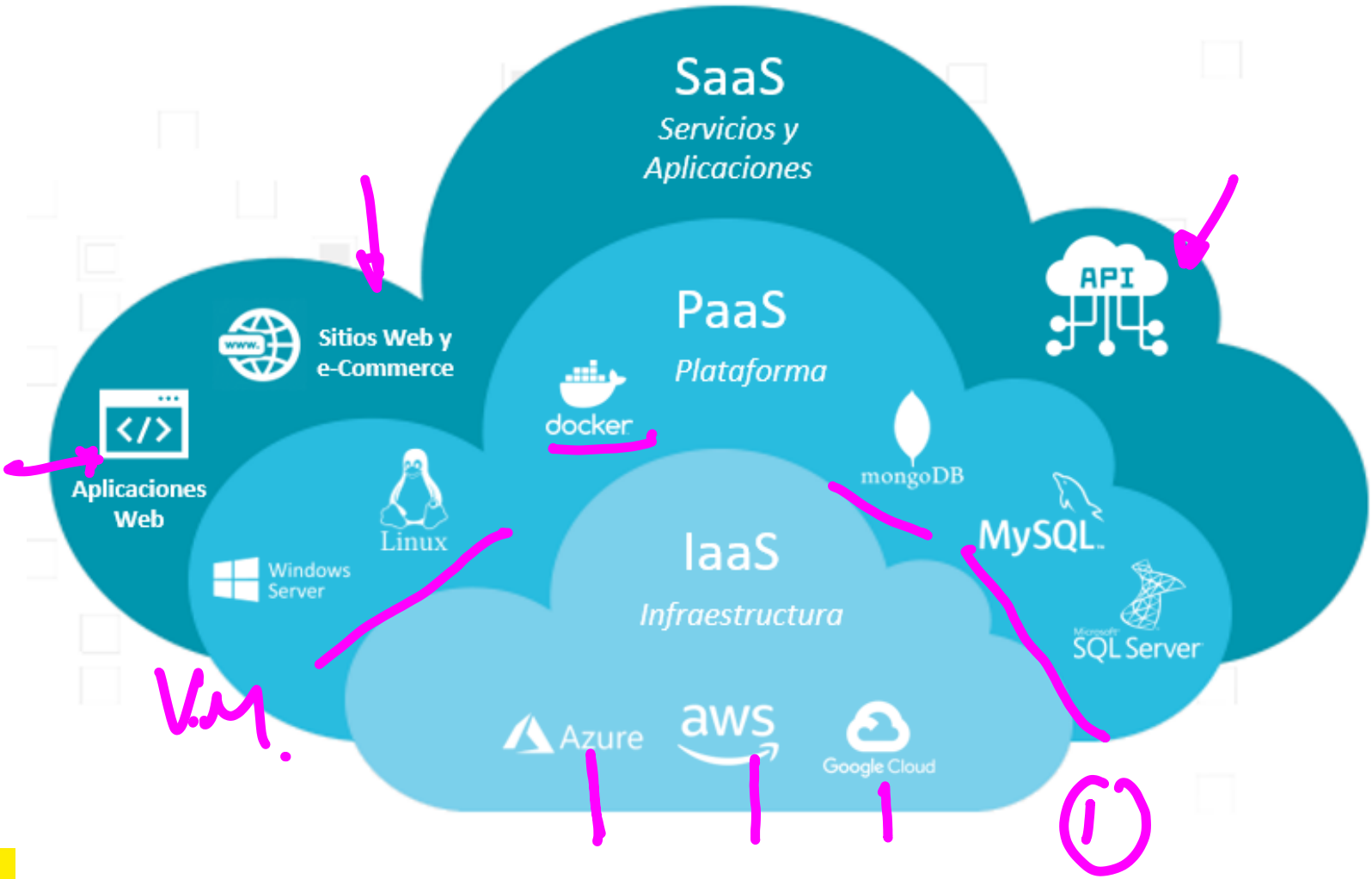
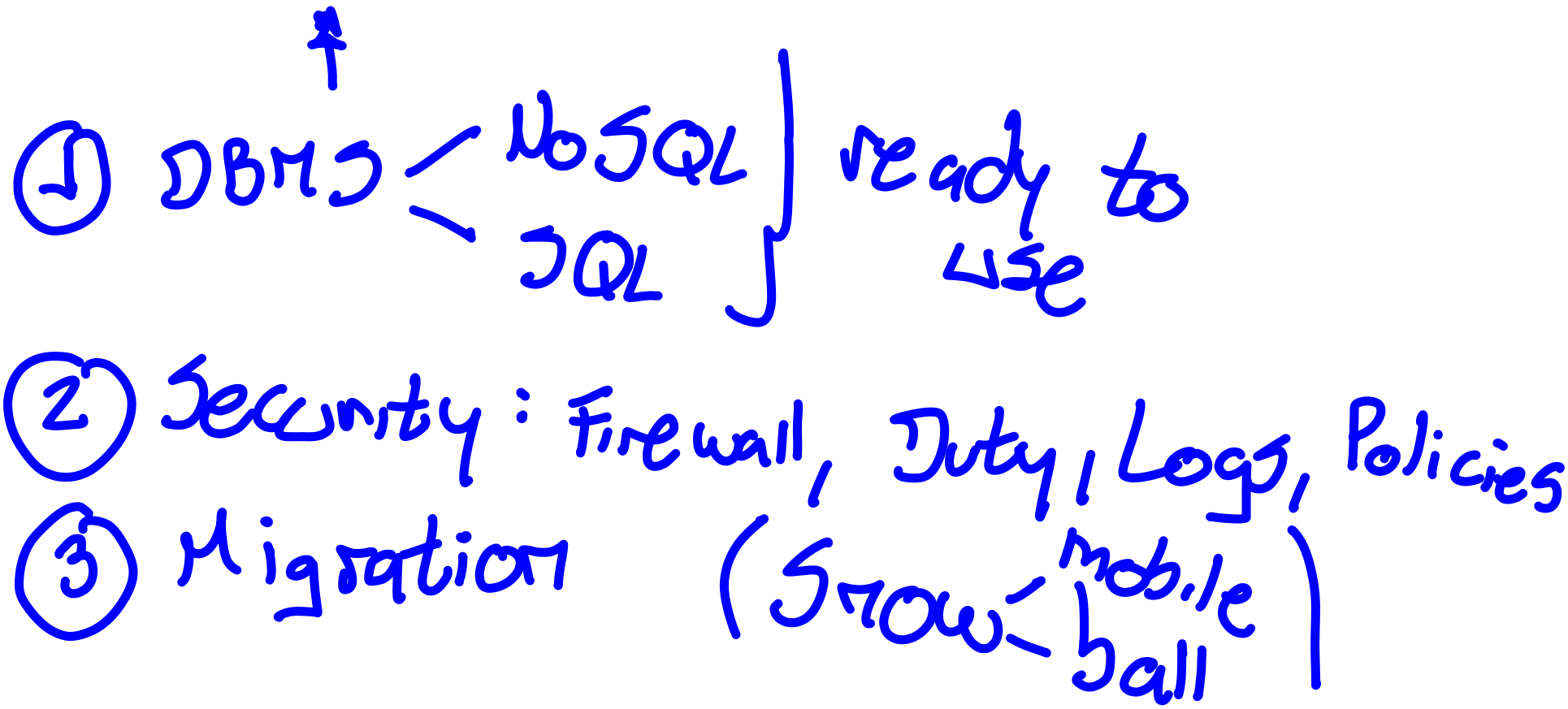
Cloud Levels



DataBases as a Service

Database as a Service (DBaaS) is a cloud computing model that provides database services over the internet.



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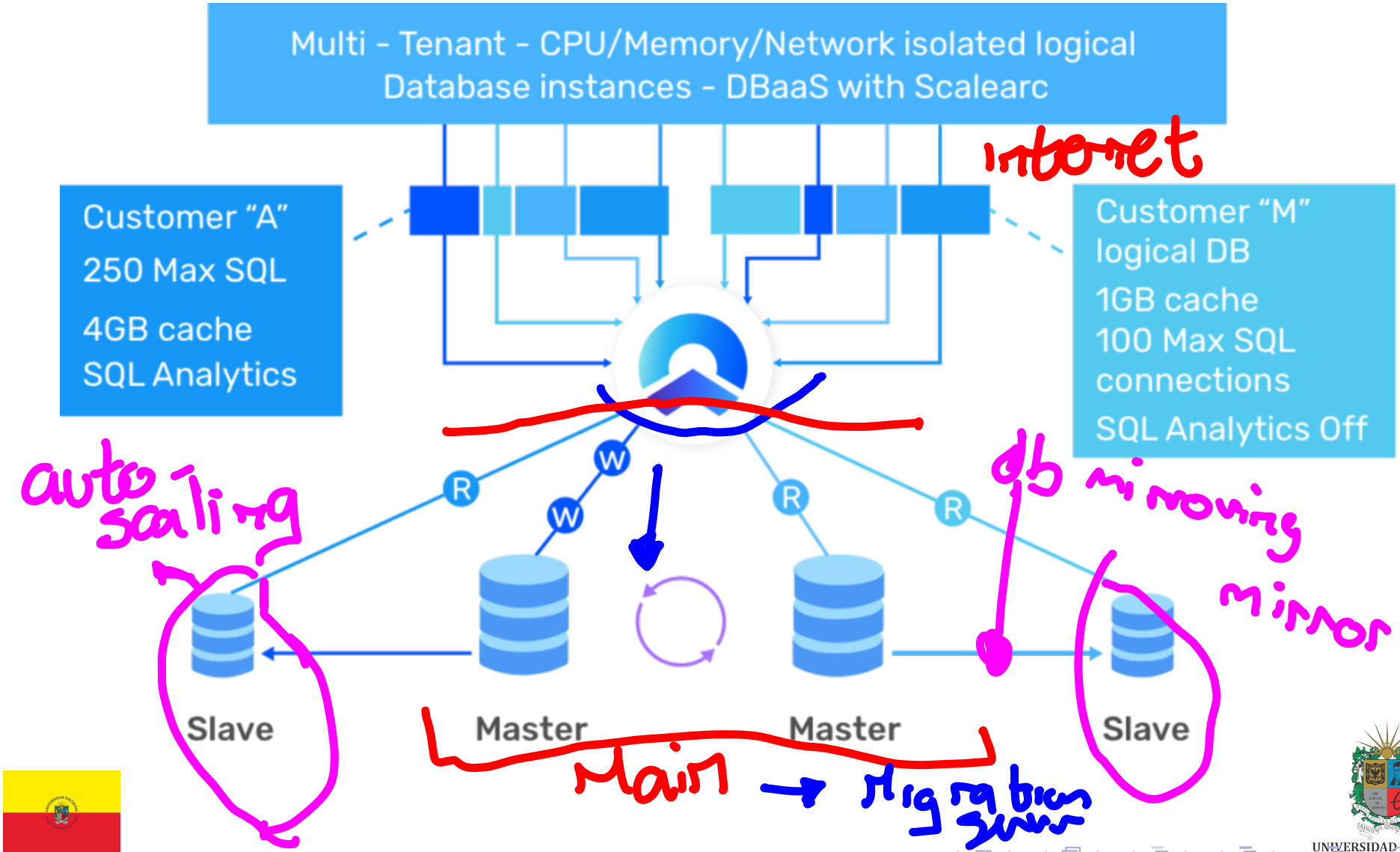
Case Study: DBaaS Custom for Clients



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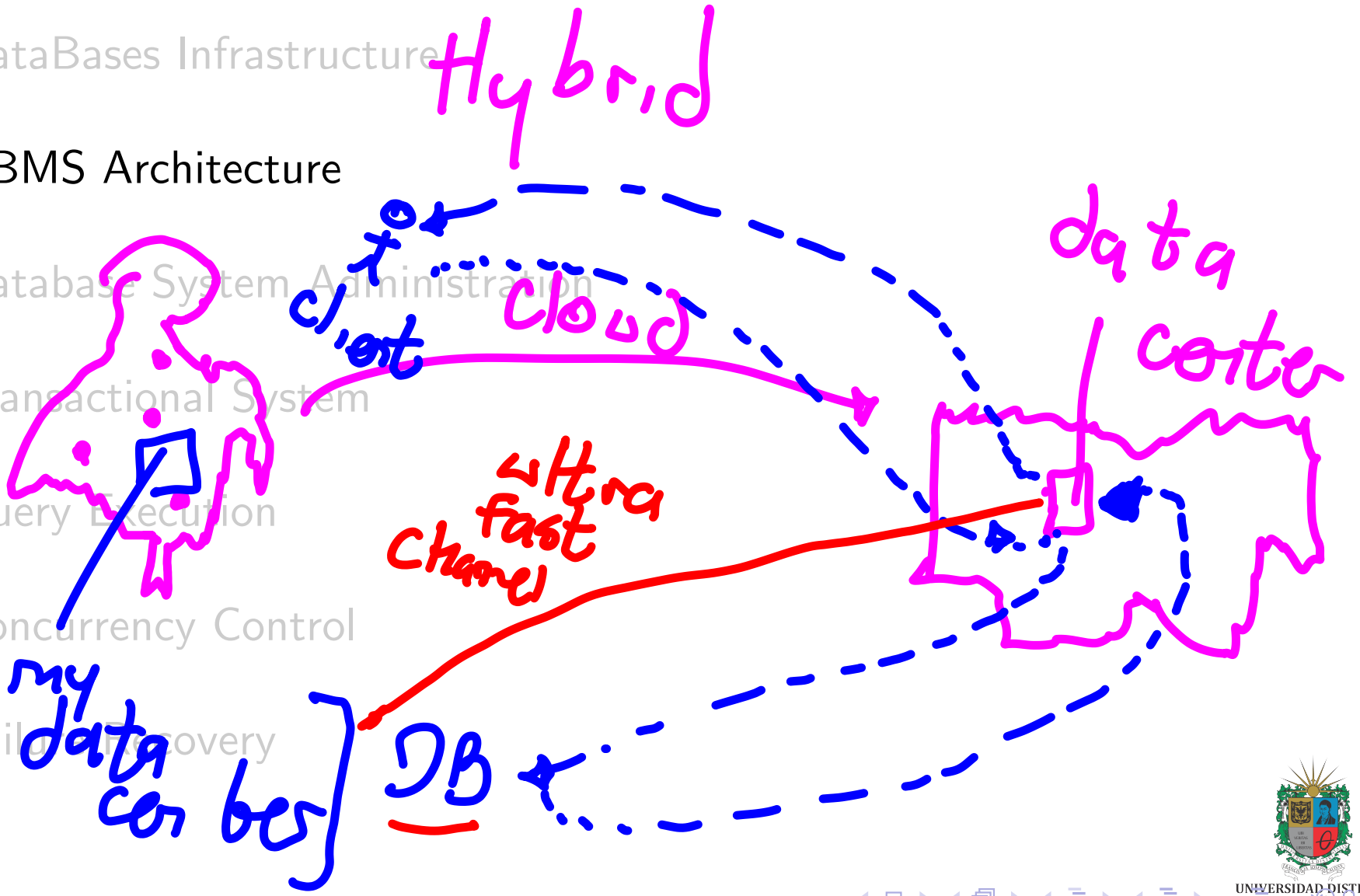
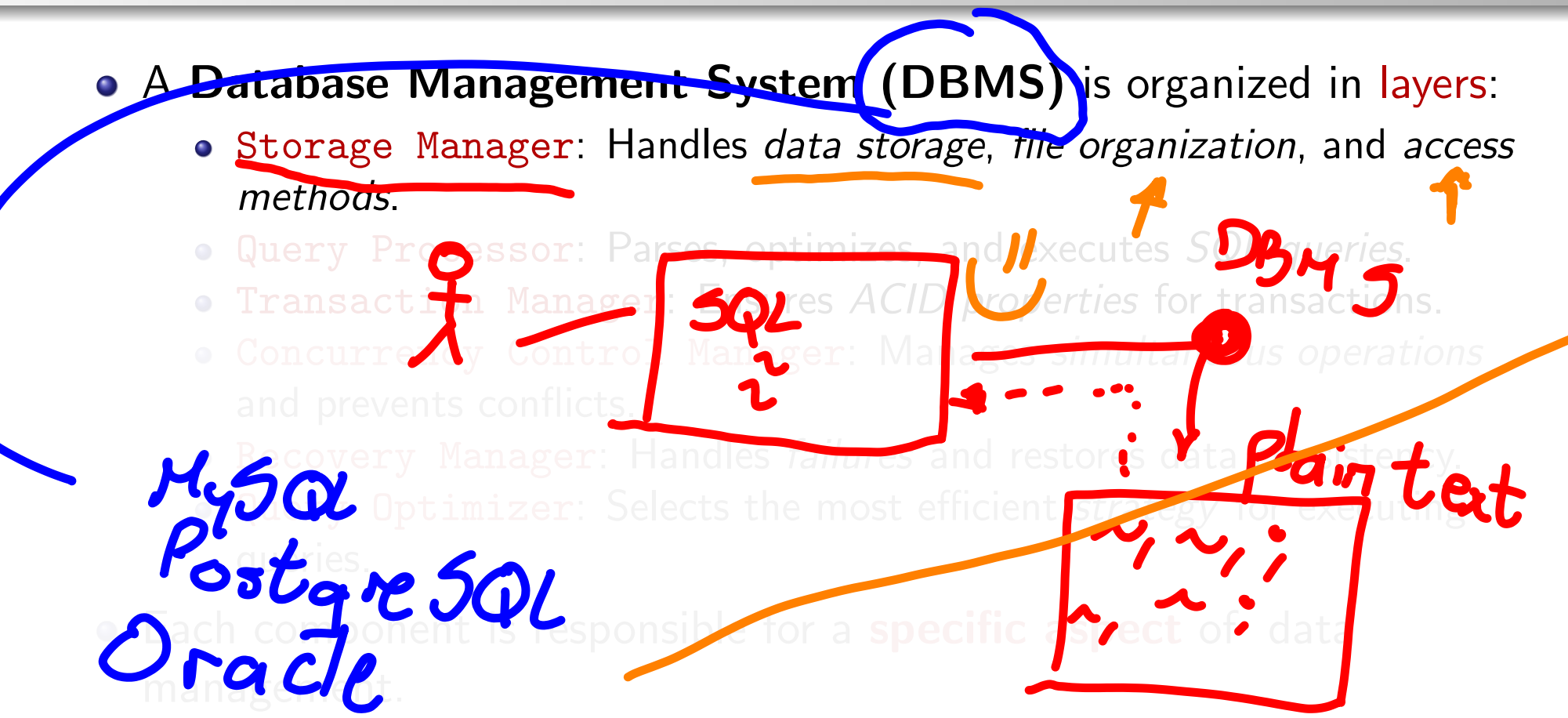


DBMS Architecture Overview

- 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.
  - `Recovery Manager`: Handles *failures* and restores data consistency.
  - `Query Optimizer`: Selects the most efficient *strategy* for executing queries.
- Each component is responsible for a **specific aspect** of data management.



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graph

compiler

tree

language to interact with storage

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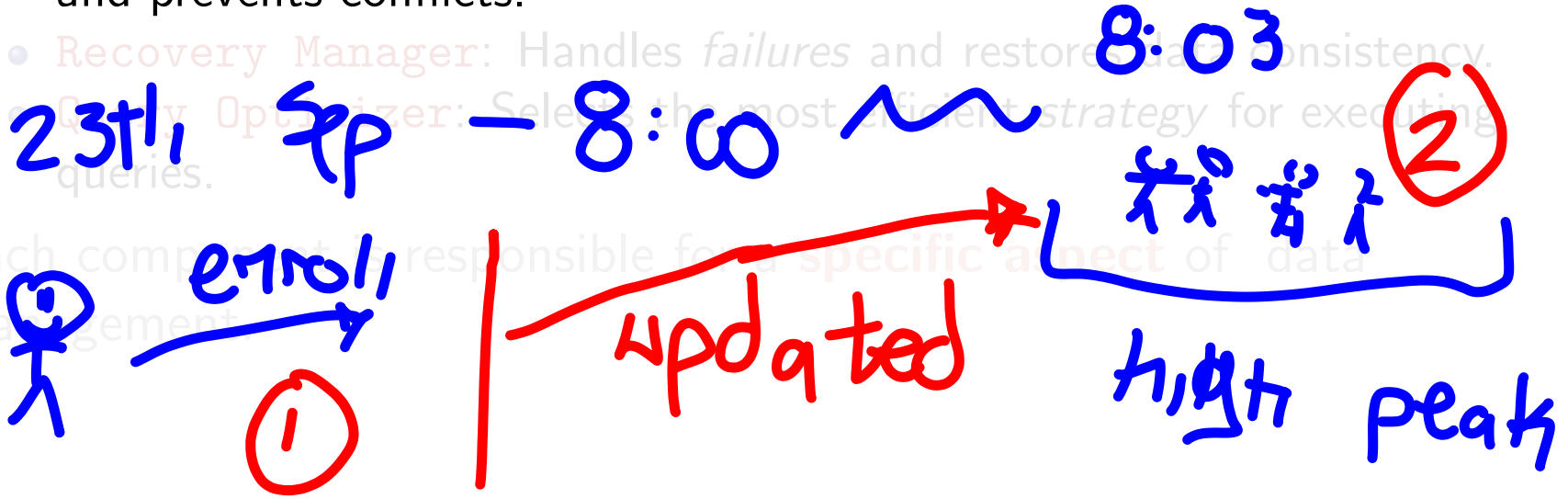

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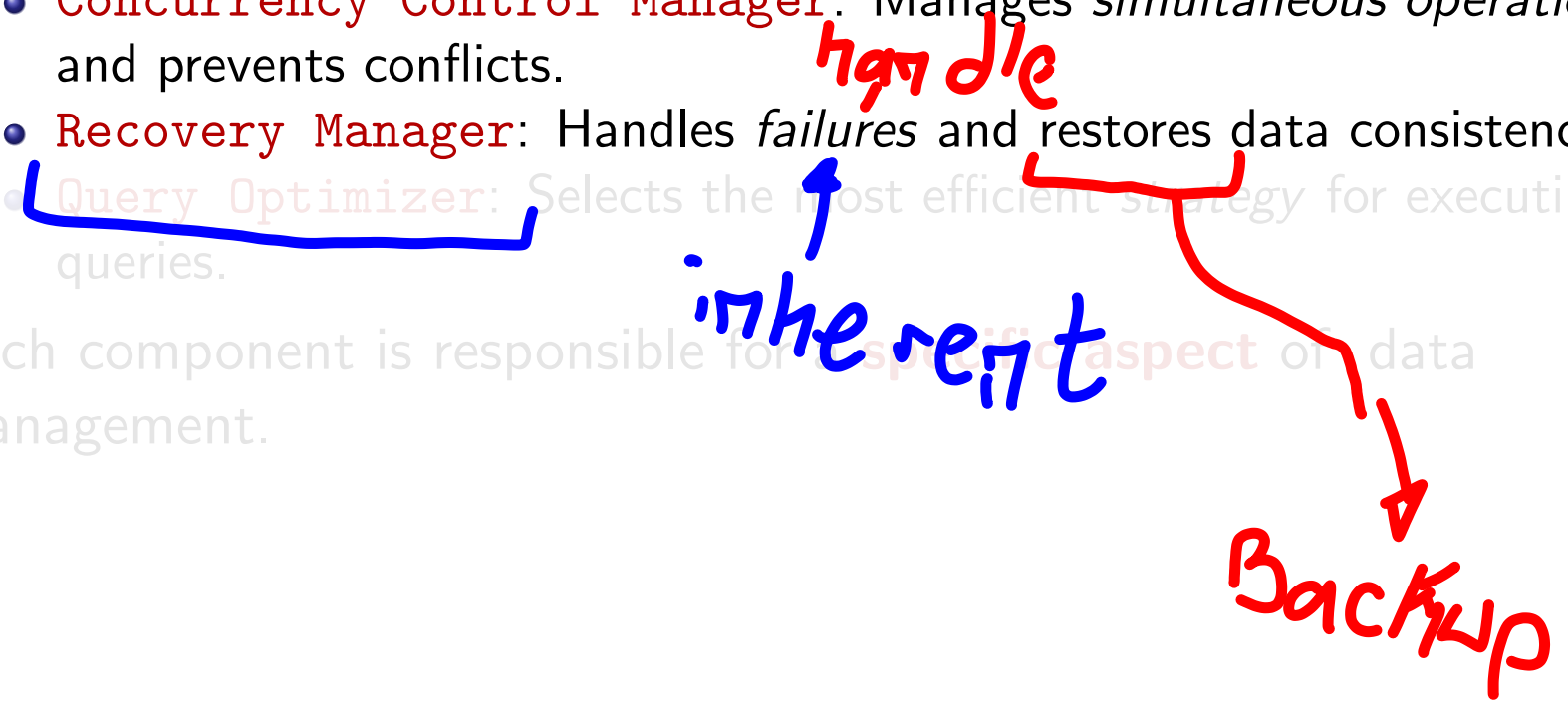

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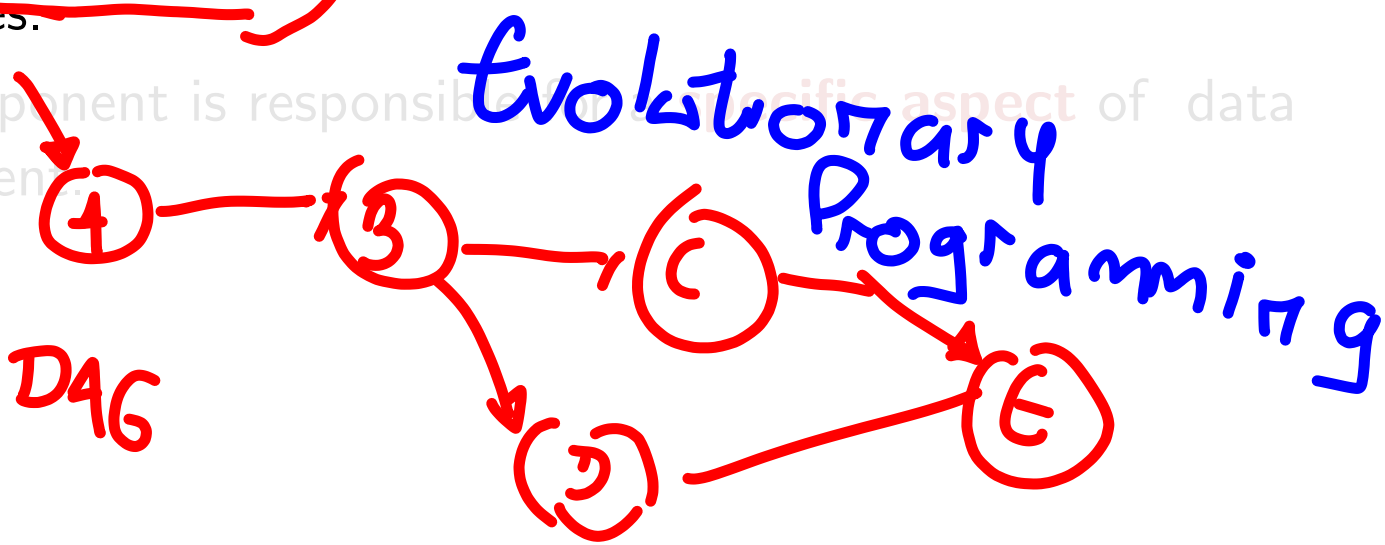

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all

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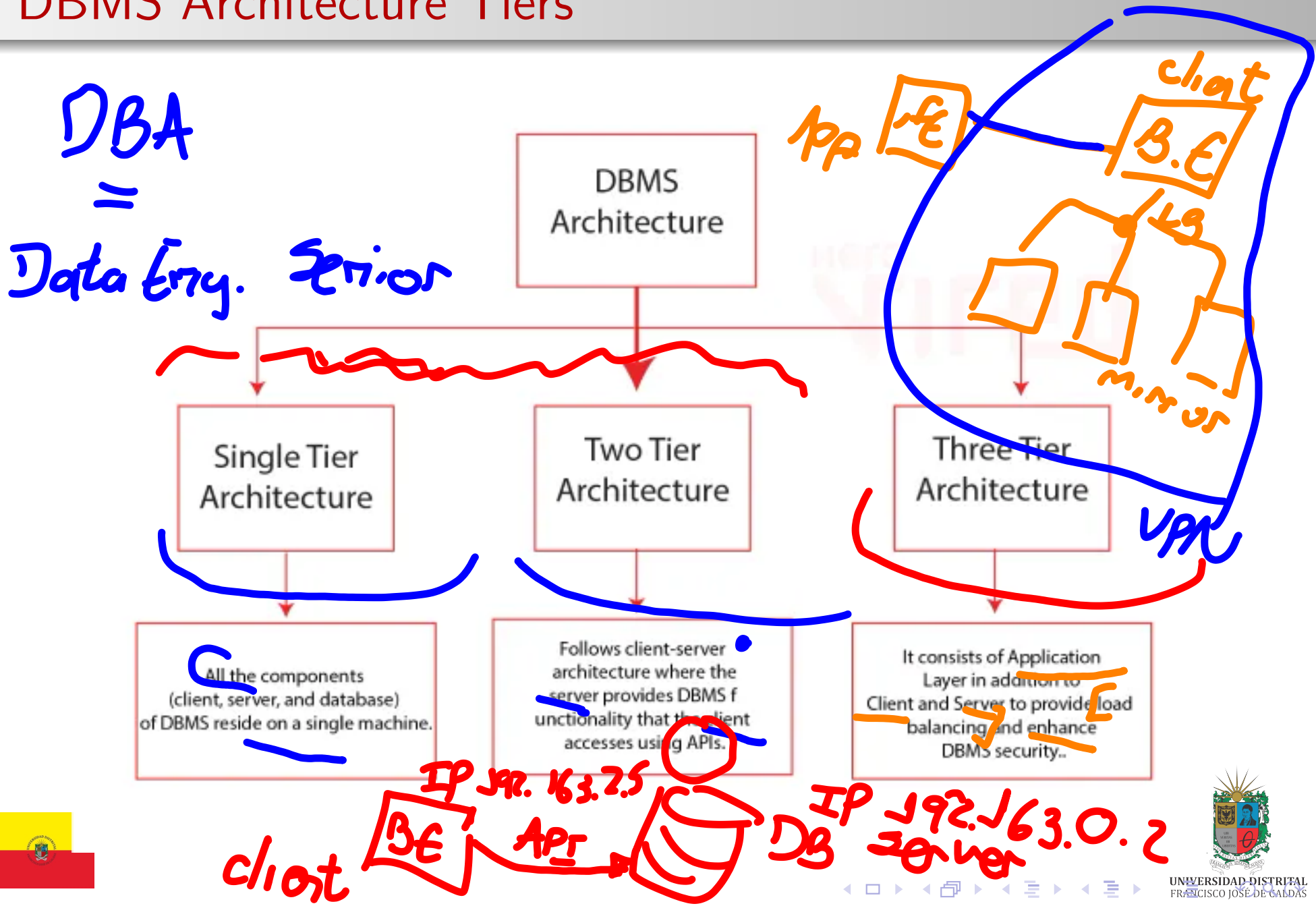
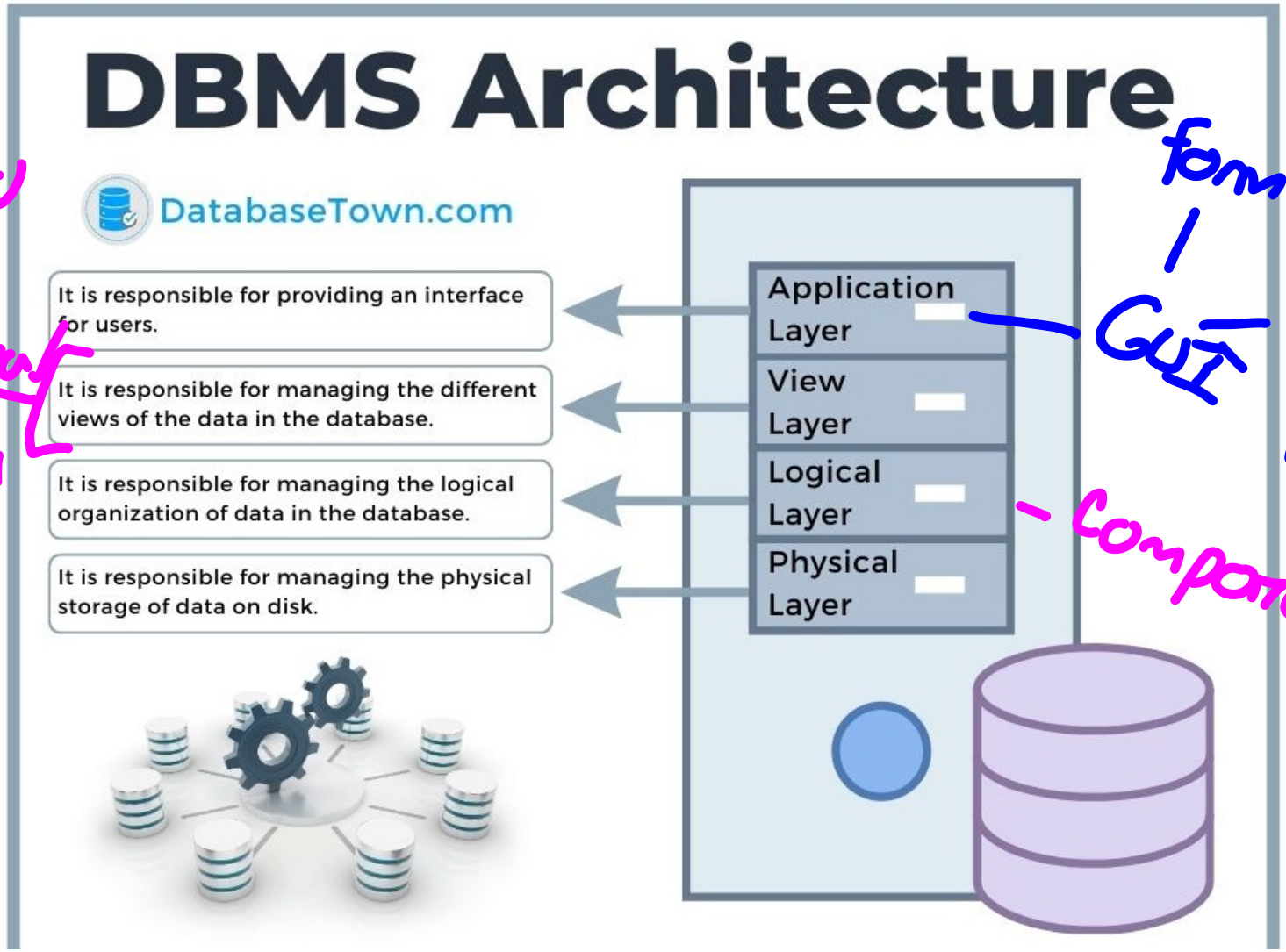
DBMS Architecture Tiers



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**: Combine 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.

1-tier

developers

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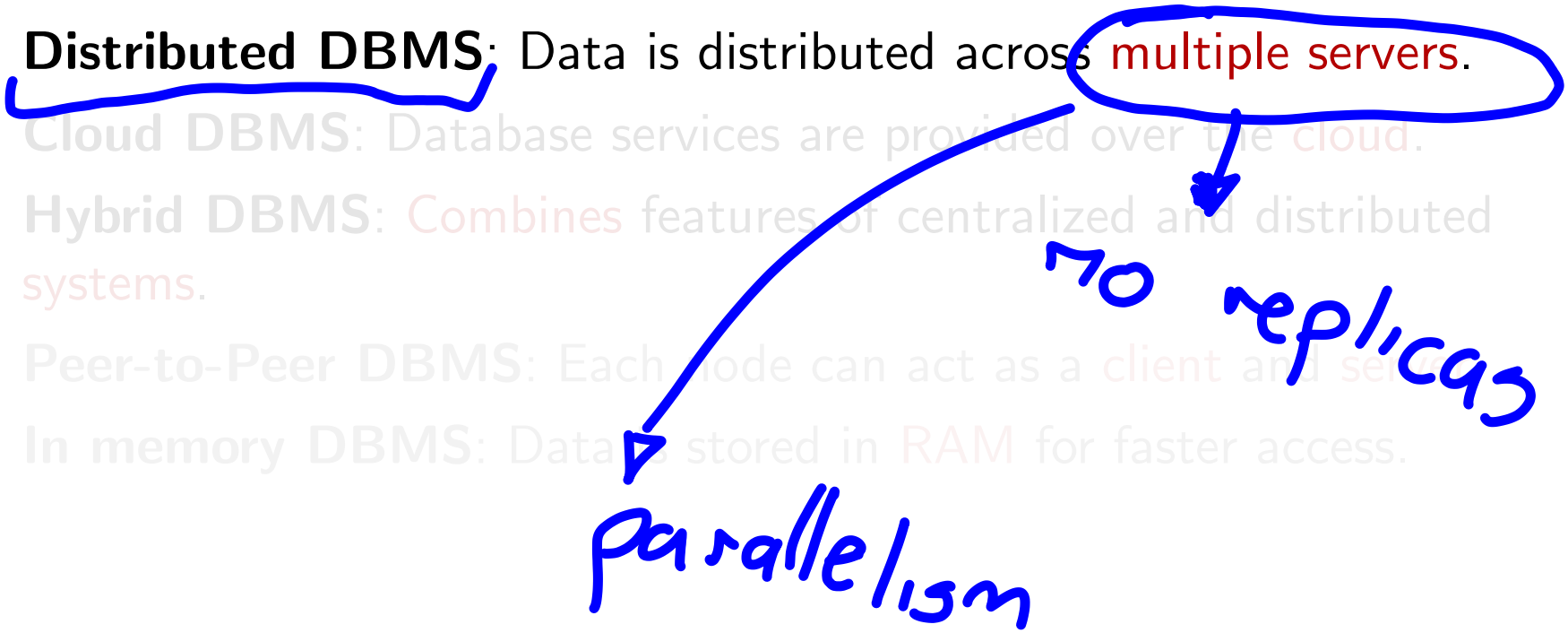

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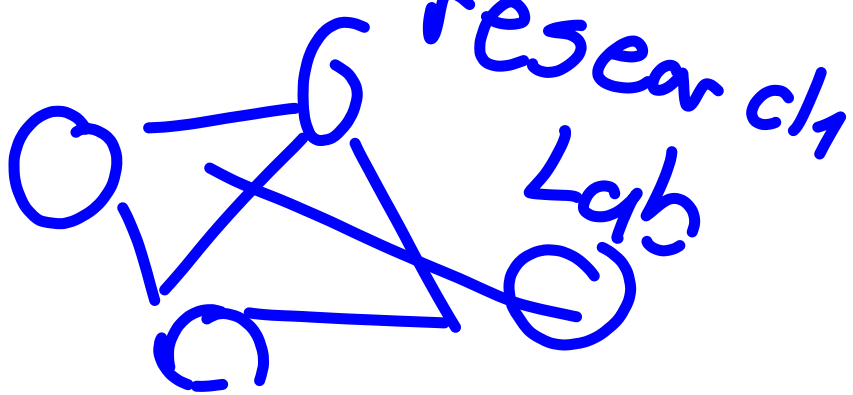

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DB- 100-200ms

Cache - 5-10 ms

Cache

lifetime (sec-min)

Max 30 hours

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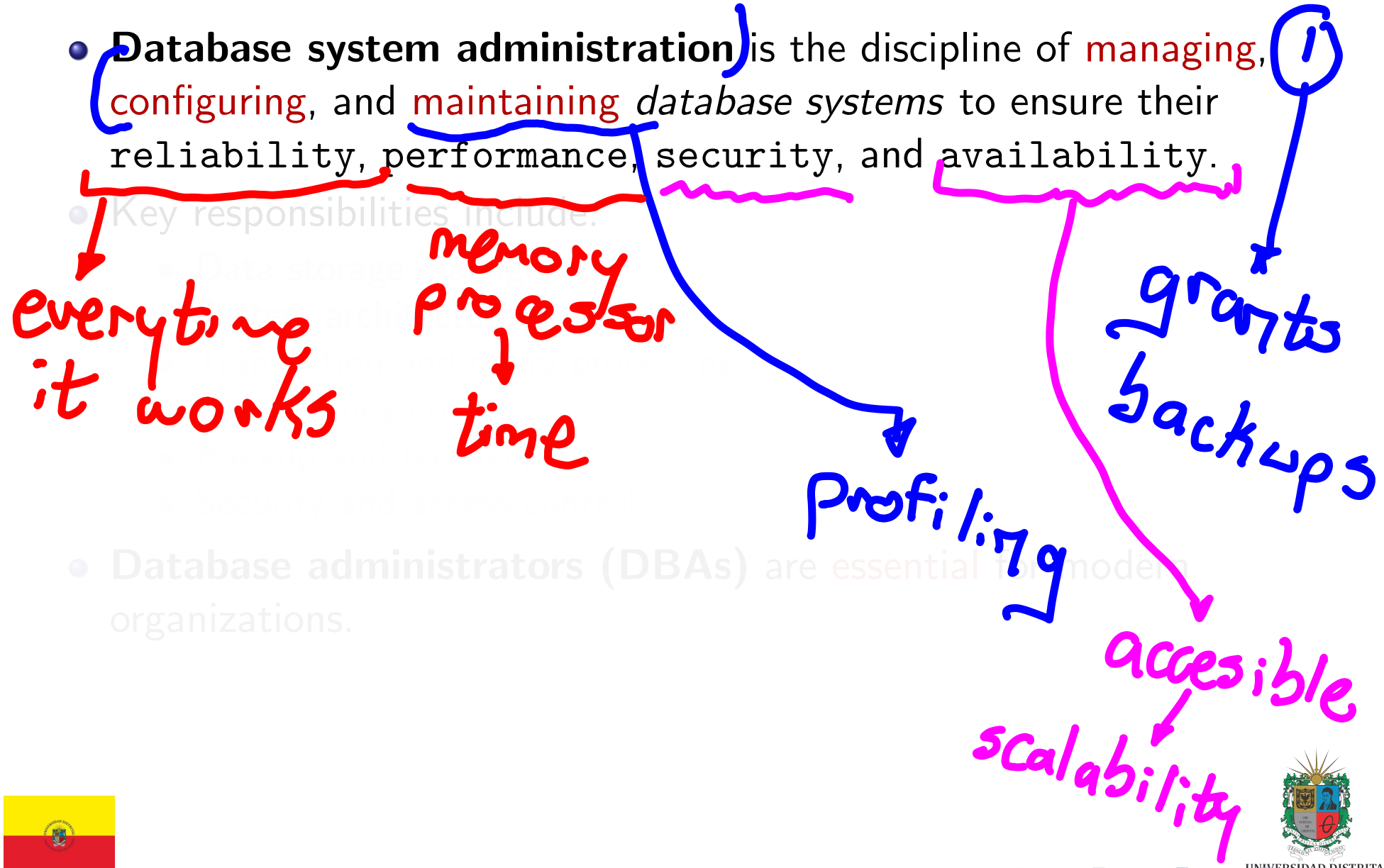
- **Database system administration** is the discipline of managing, configuring, and maintaining *database systems* to ensure their `reliability`, `performance`, `security`, and `availability`.
- Key responsibilities include:
  - Data storage management
  - Backup and recovery planning
  - Performance tuning
  - Security enforcement
- **Database administrators (DBAs)** are essential in modern organizations.



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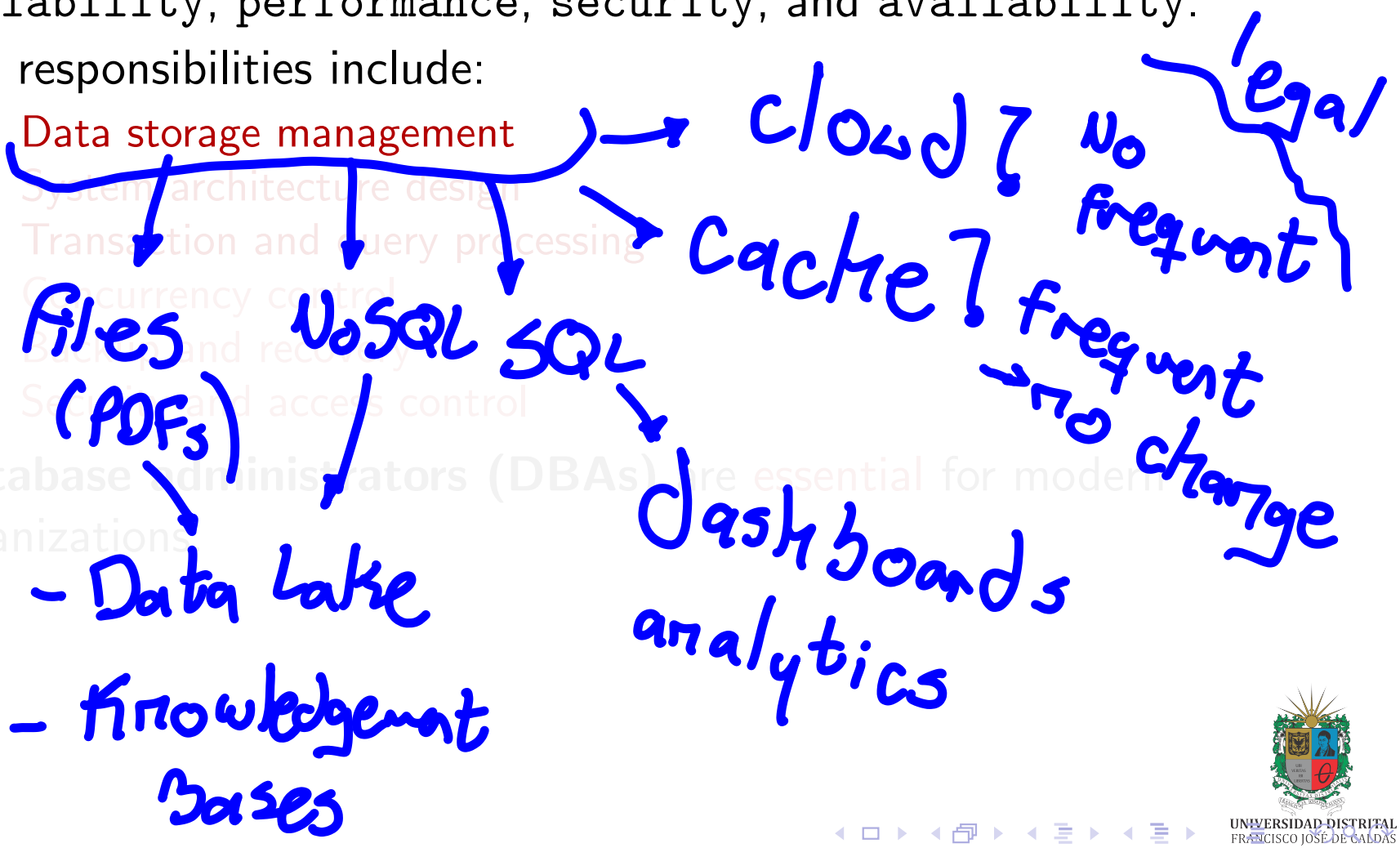

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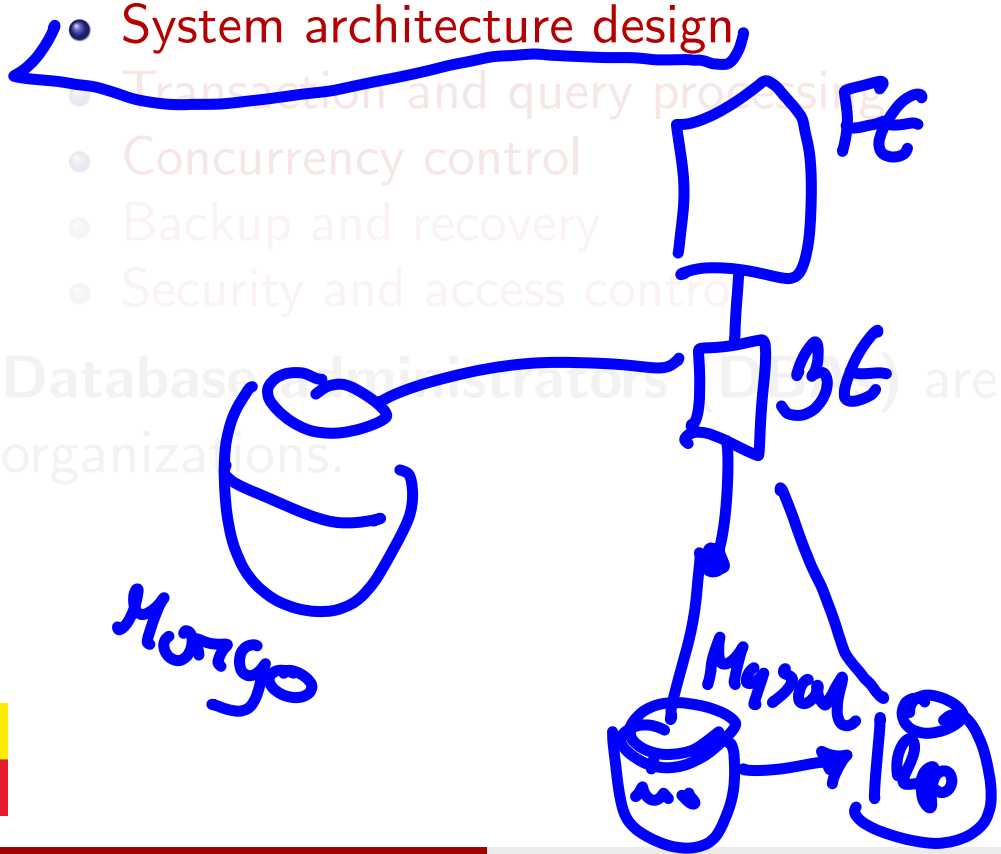

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→ Indexes

→ Improve DB model

→ Internal Optimization

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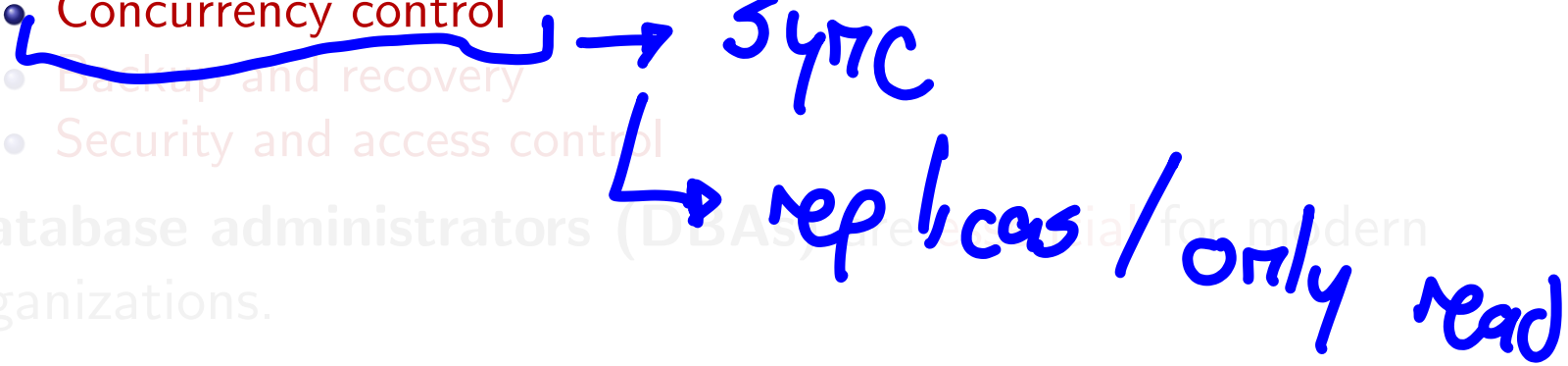

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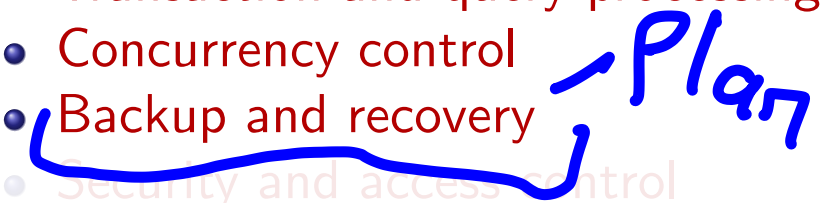

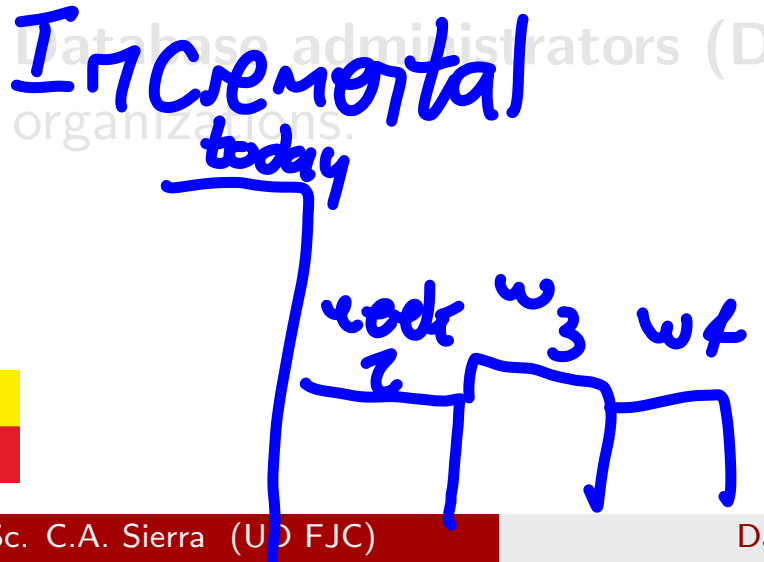

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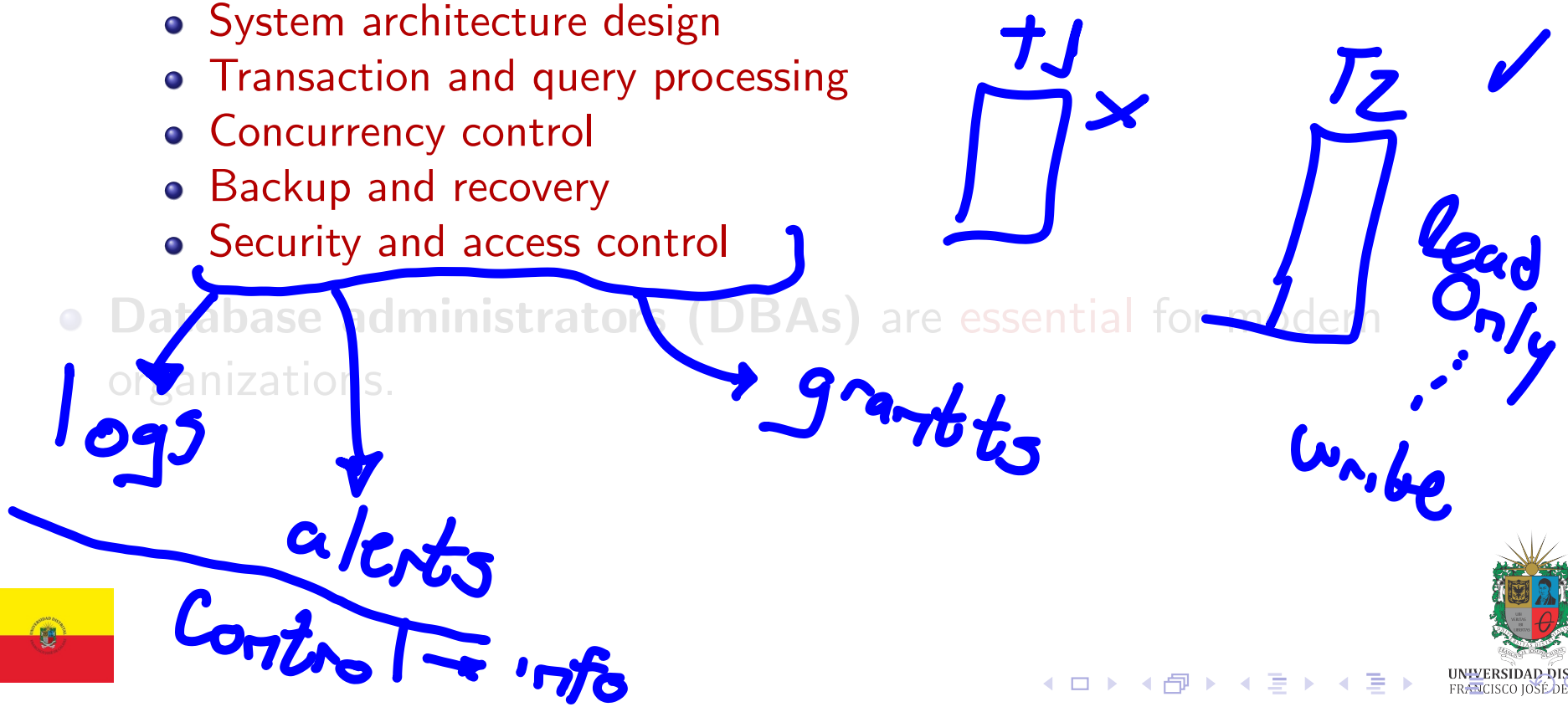

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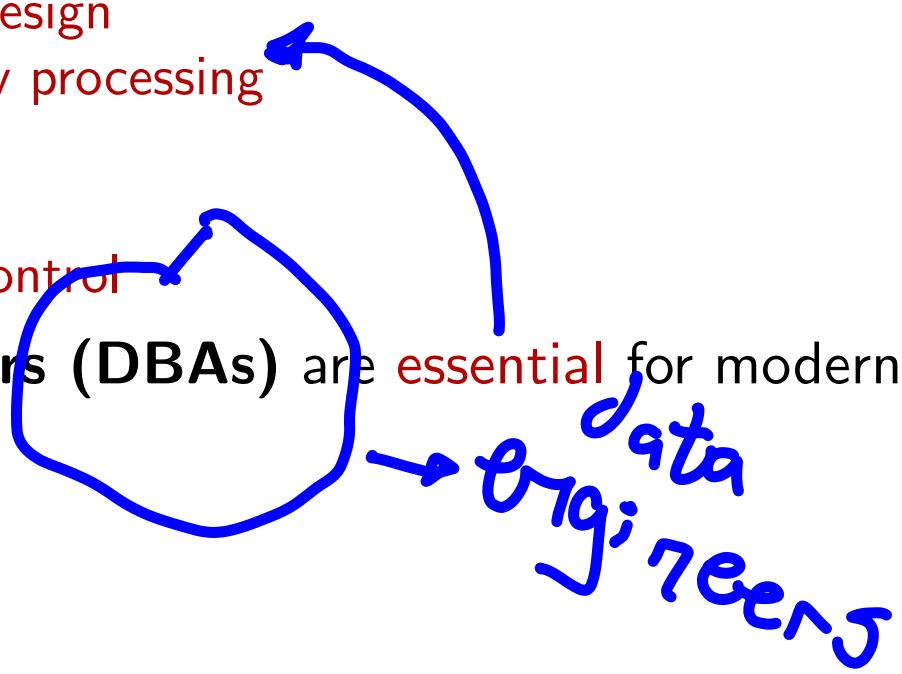

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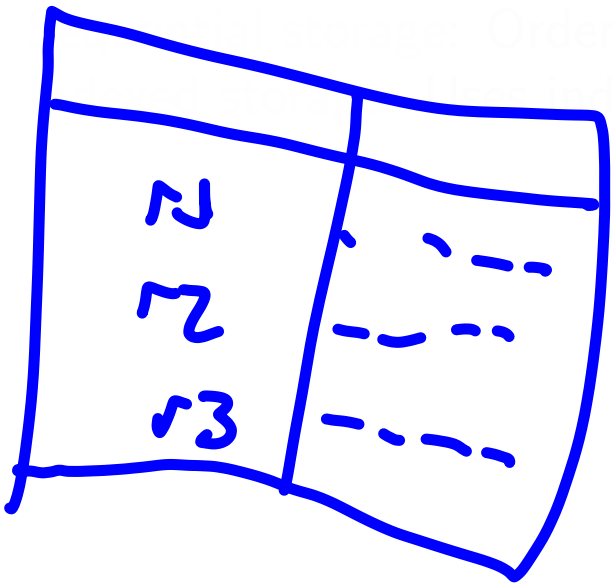
Record Storage Concepts

- 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: Unordered, fast inserts.
  - Sorted storage: Ordered, fast range queries.
  - Hash storage: Use indexes for fast lookups.



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Record Storage Concepts

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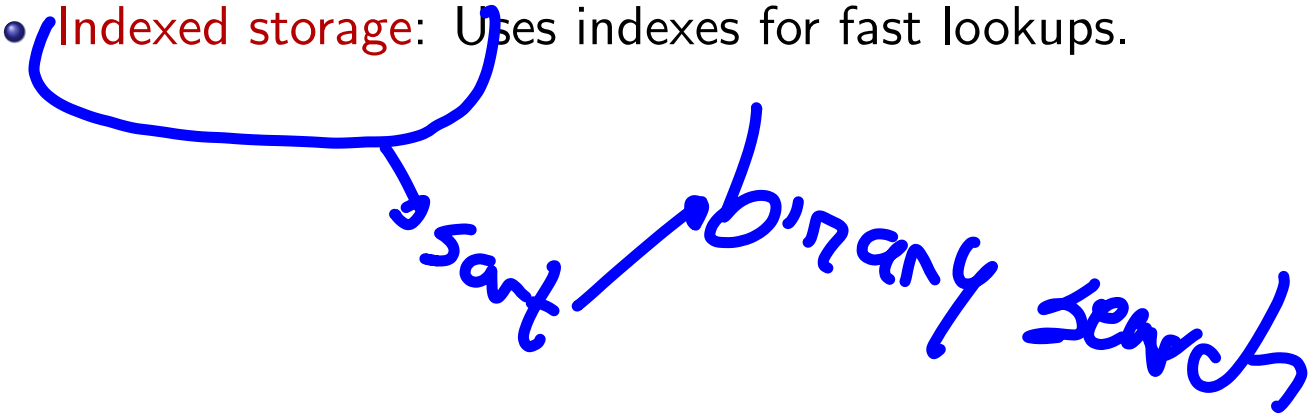

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Block and Page Organization

- Data is stored in **blocks** (pages) on disk.
- Block size and layout affect **I/O performance**.
- Records may be packed, slotted, or may 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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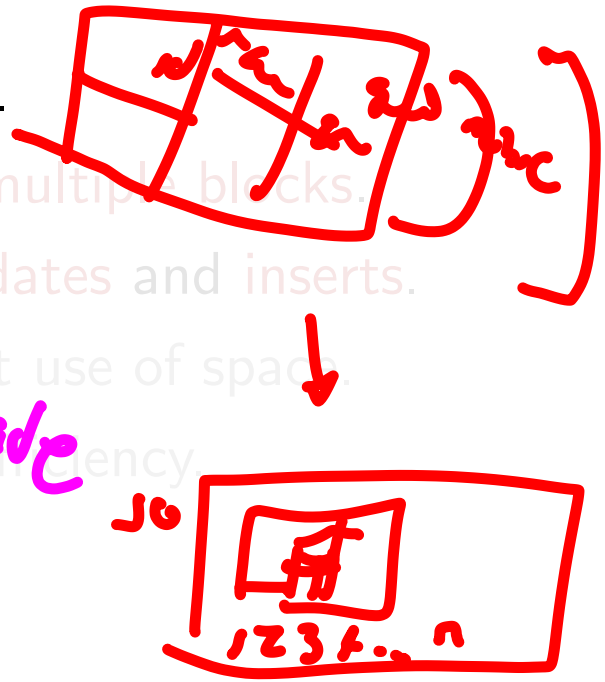


```
SELECT s.name, c.name as career, s.grade
  FROM student AS s
  JOIN career AS c
    ON s.career_fk = c.id
ORDER BY s.grade DESC
OFFSET (n-1)* 10
 LIMIT 10;
```

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Distributed Data Systems

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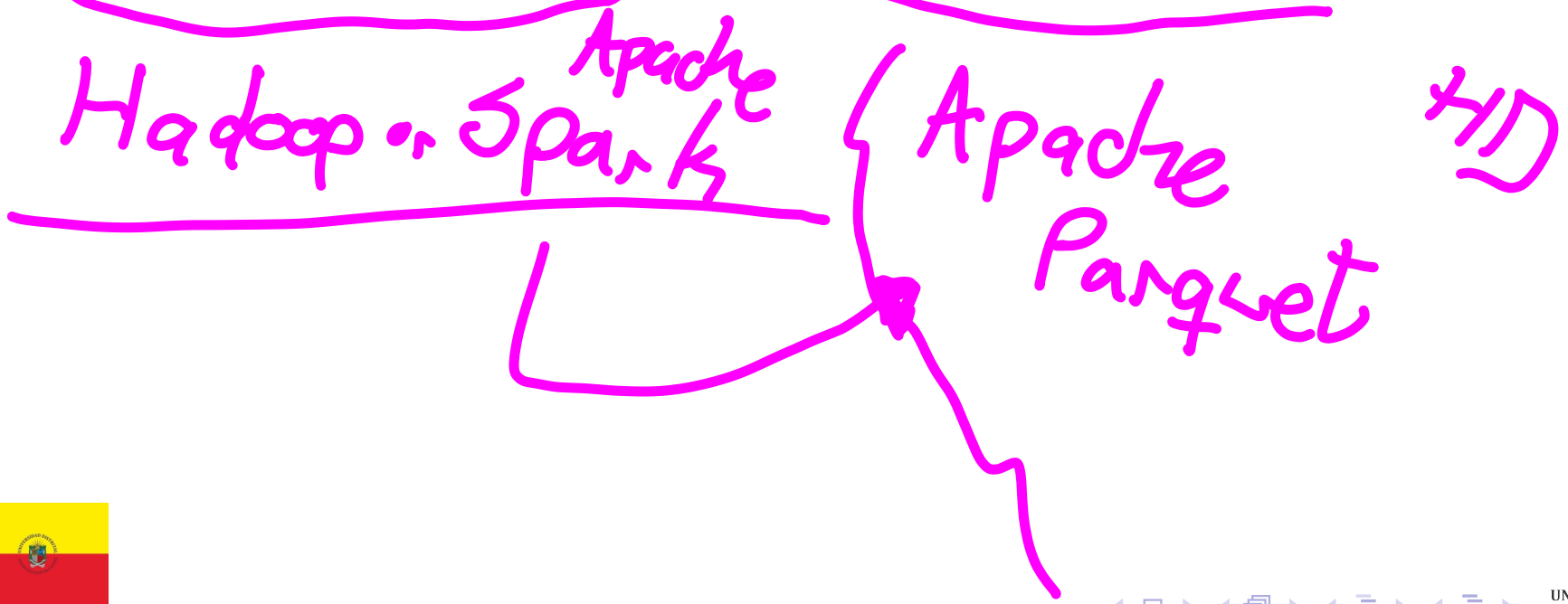
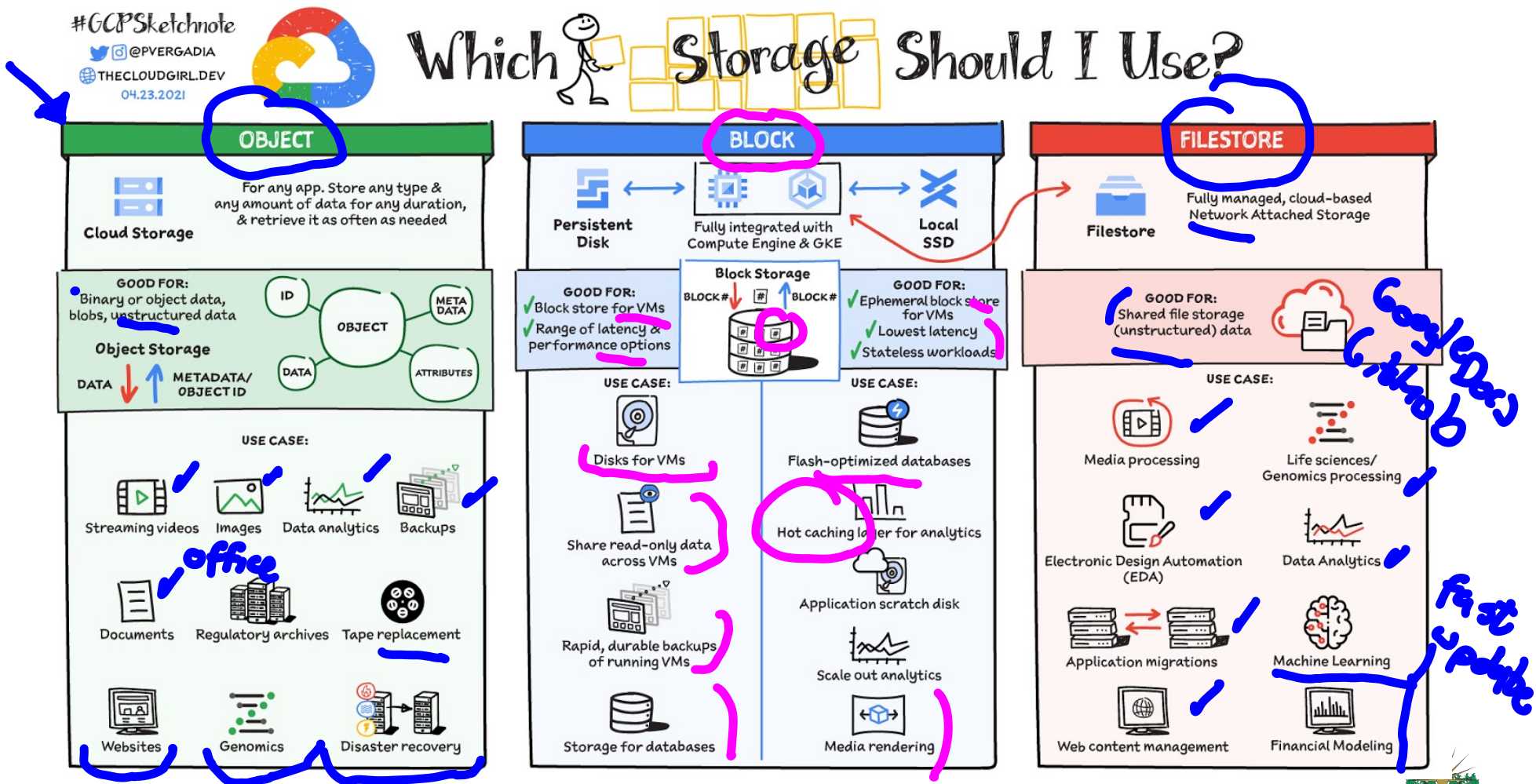


Record Storage: Use Cases



Outline

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2. DBMS Architecture
3. Database System Administration
4. Transactional System
5. Query Execution
6. Concurrency Control
7. Failure Recovery

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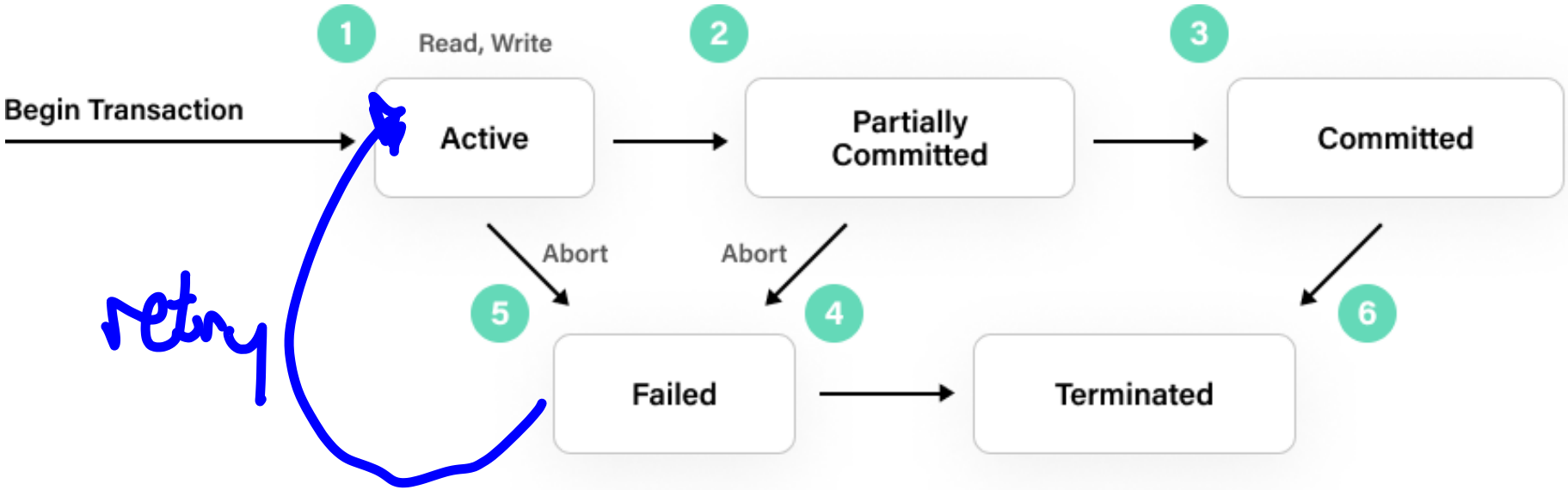
Transactional System Concepts

- 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.



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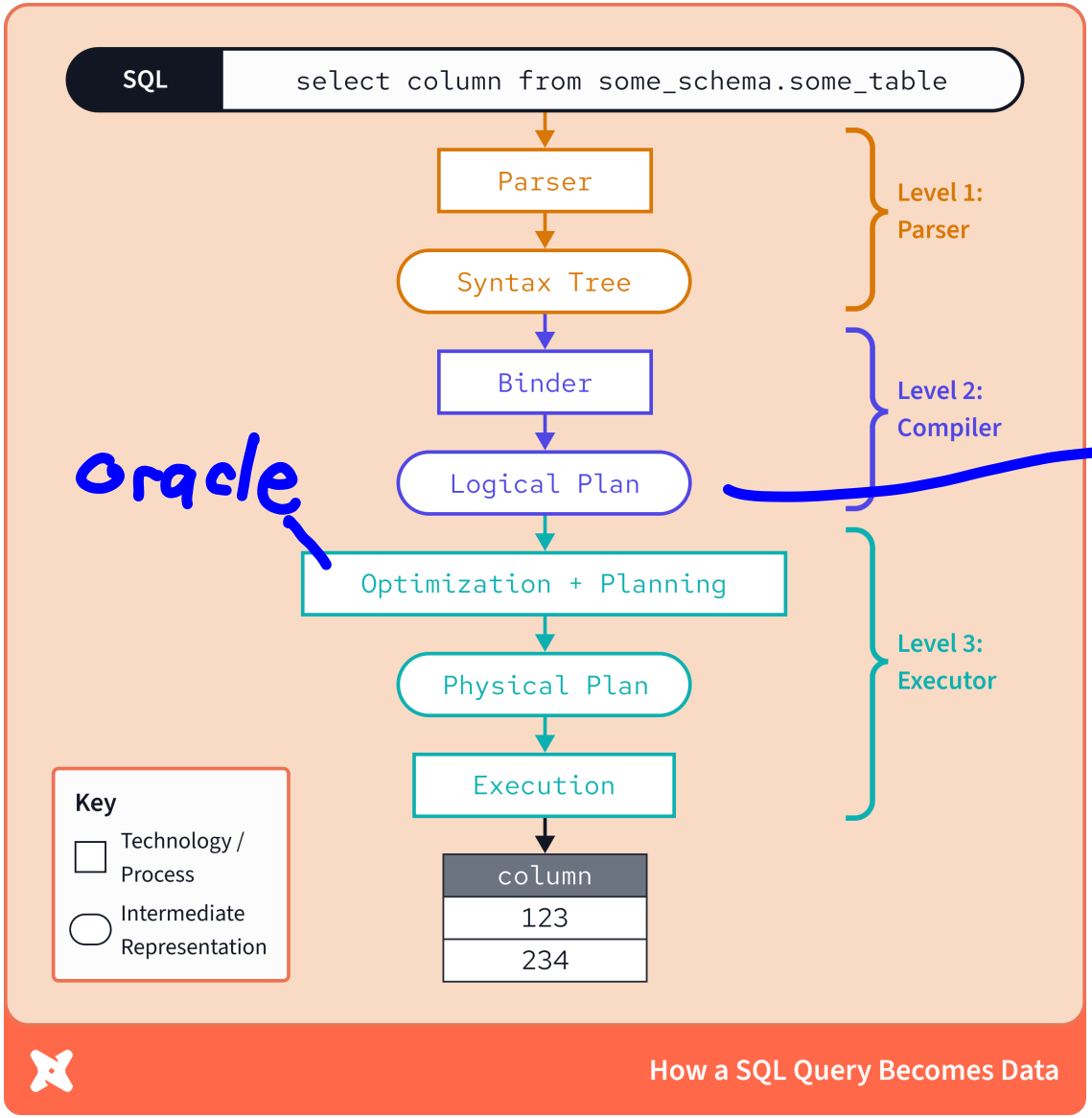
Query Execution Process

- **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



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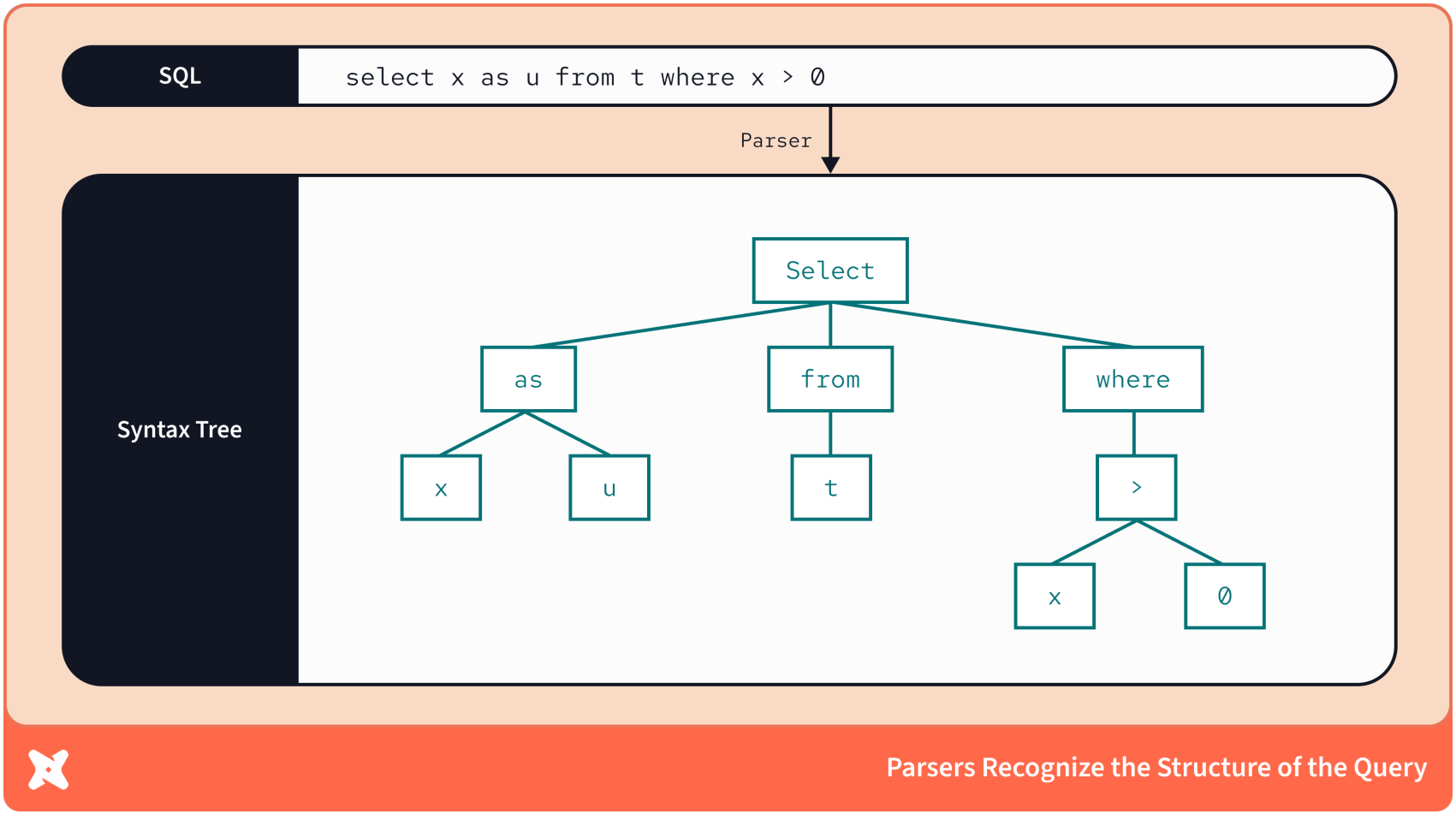
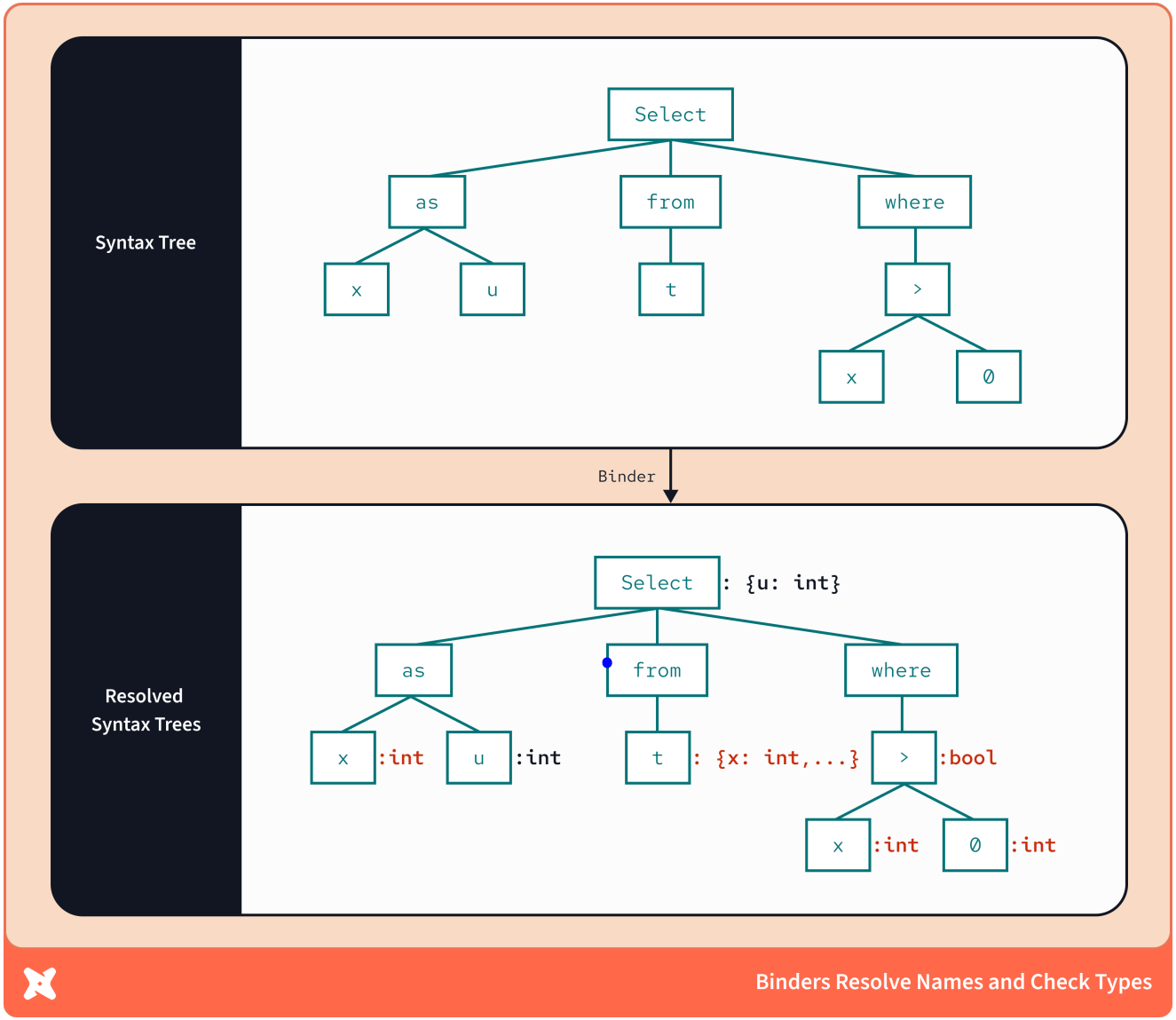
Query Execution Flow: Syntax Tree

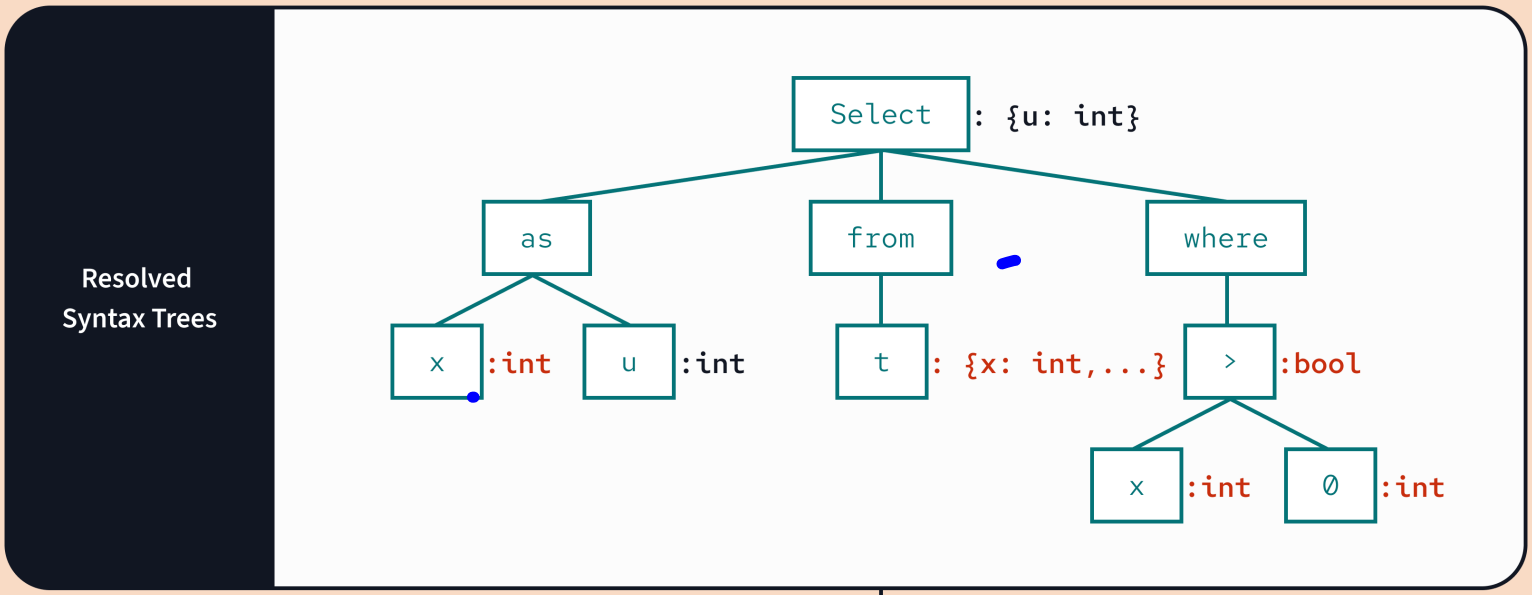


Parsers Recognize the Structure of the Query

Query Execution Flow: Compilation



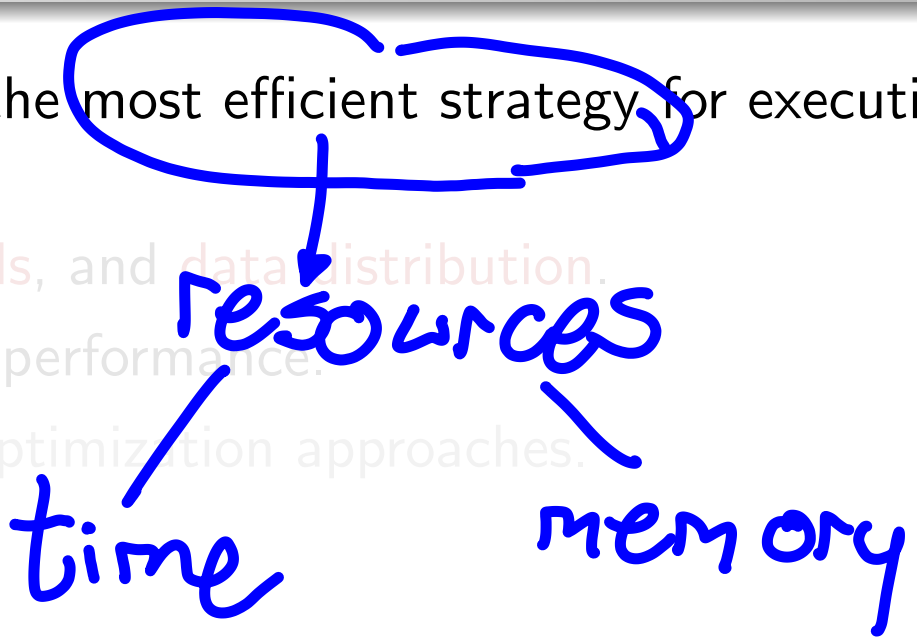
Query Execution Flow: Logical Plan



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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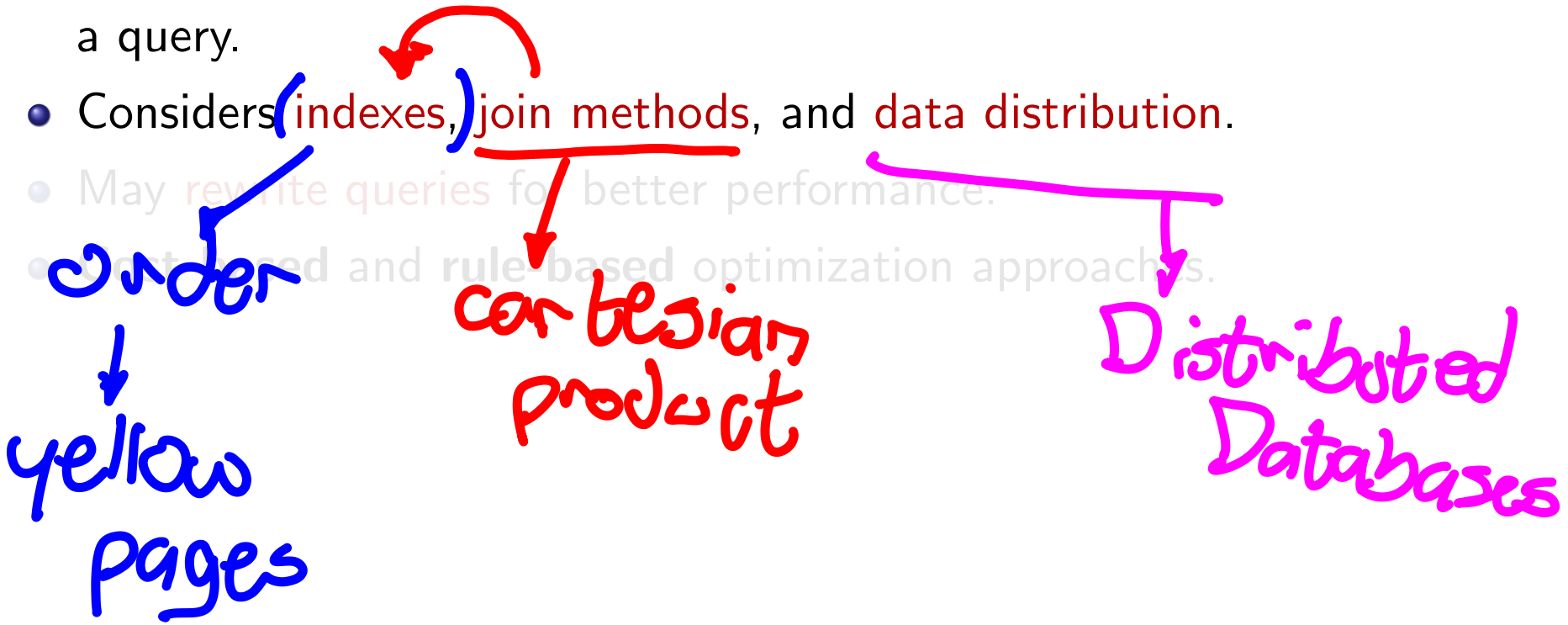

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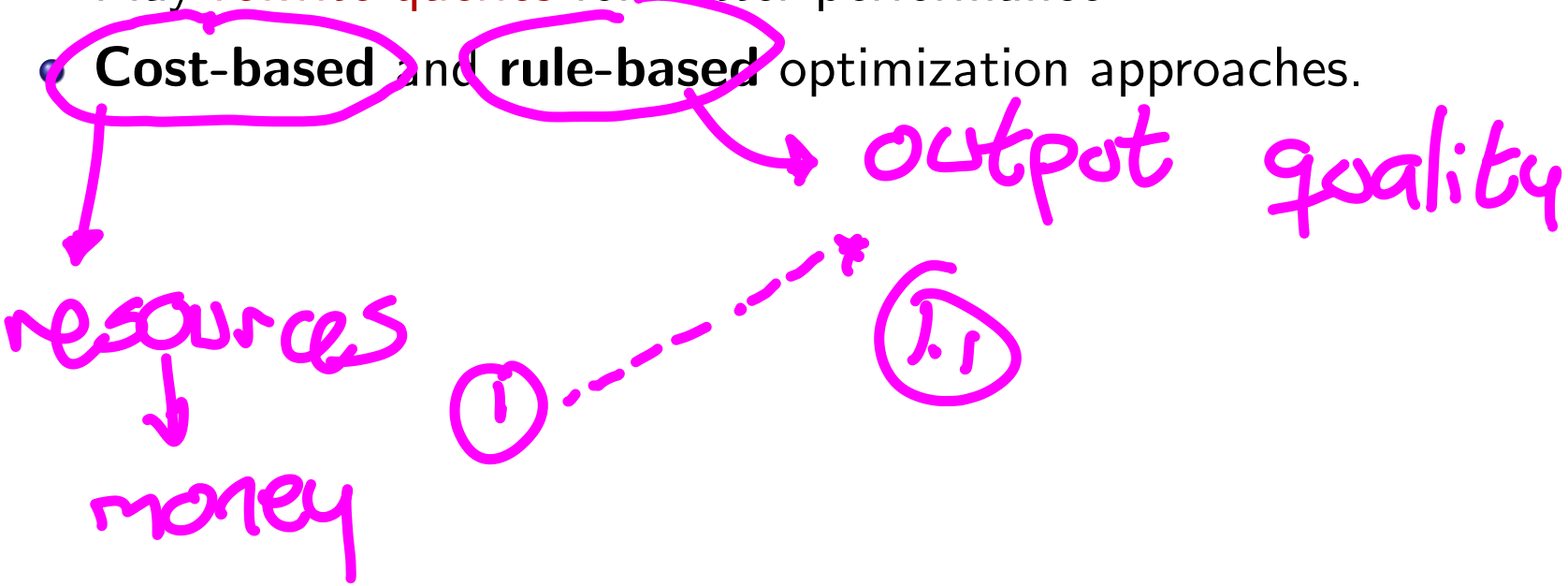

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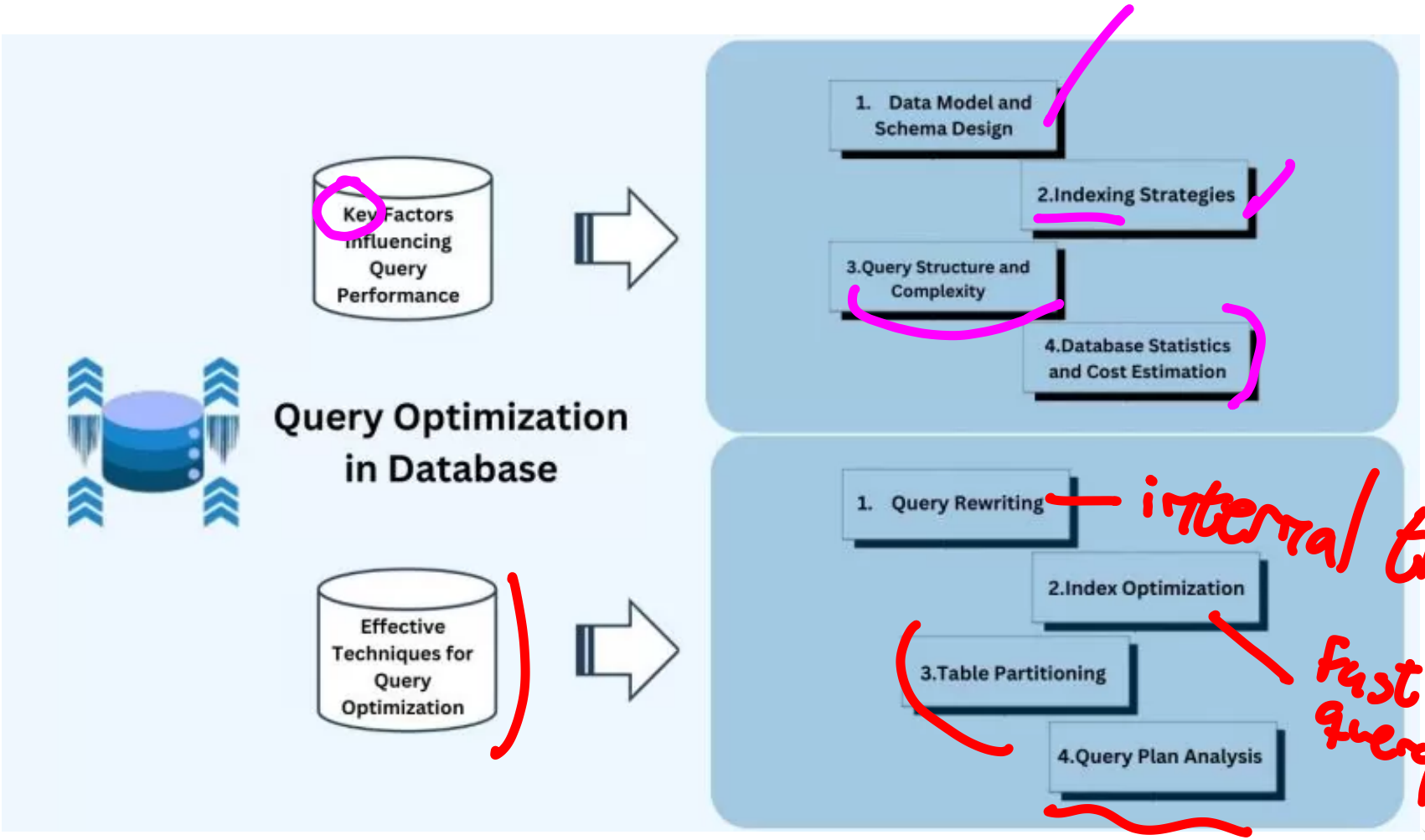
Query Optimization Factors



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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:
  - Locking protocols: Use locks to control access (e.g., two-phase locking).
  - Timestamp ordering: Assigns timestamps to transactions.
  - Optimistic concurrency control: Assumes no conflicts.
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- **Isolation levels** (e.g., Read Committed, Serializable) control visibility of changes.

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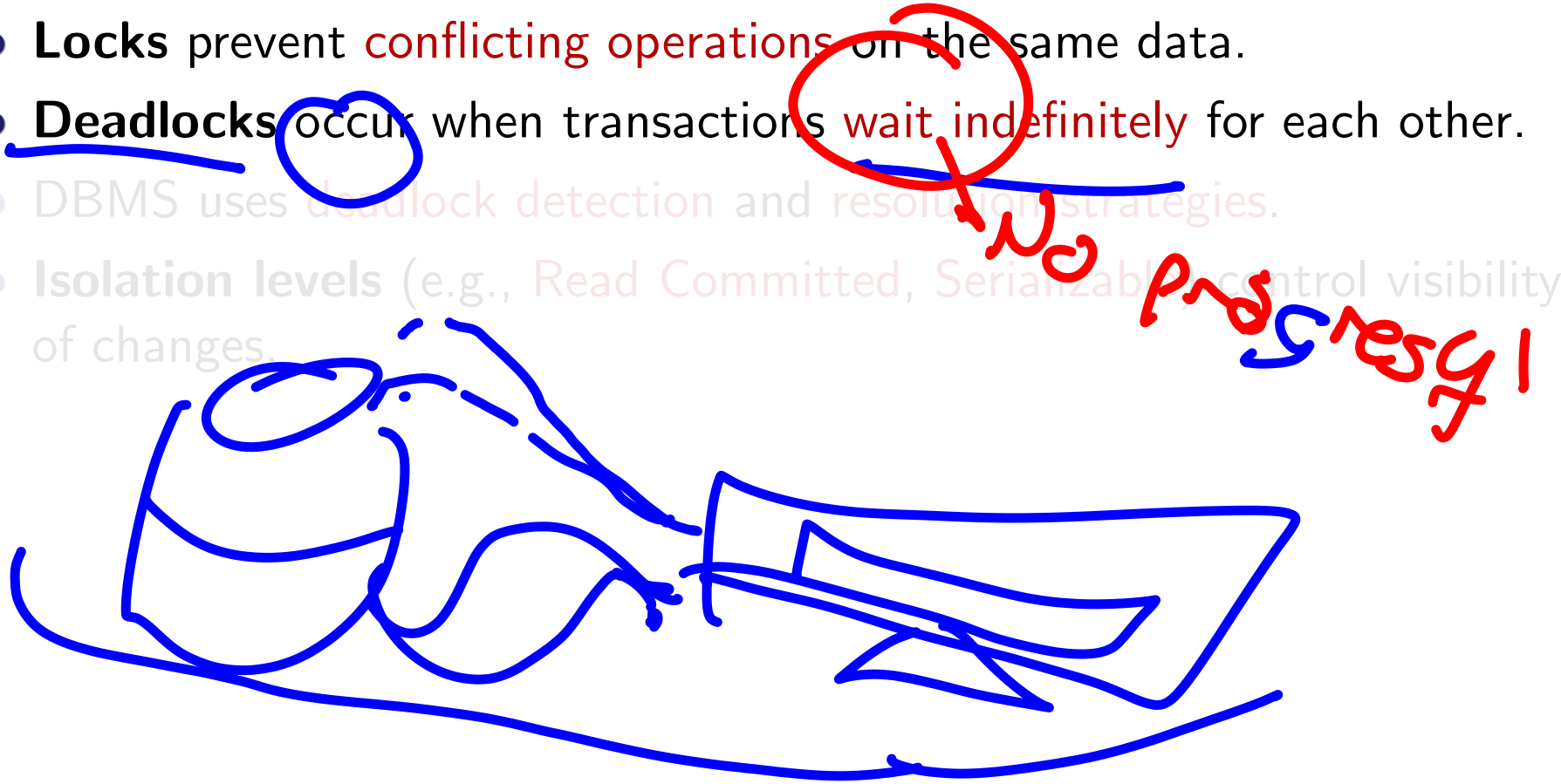

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- Types of failures:
  - Transaction failure: Only one transaction fails.
  - System crash: All active transactions are lost.
  - Media failure: Disk or storage device fails.
- Recovery techniques:
  - Write-ahead logging (WAL):
    - Logs changes before applying them.
    - Ensures durability and atomicity.
  - Checkpointing:
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  - Shadow paging:
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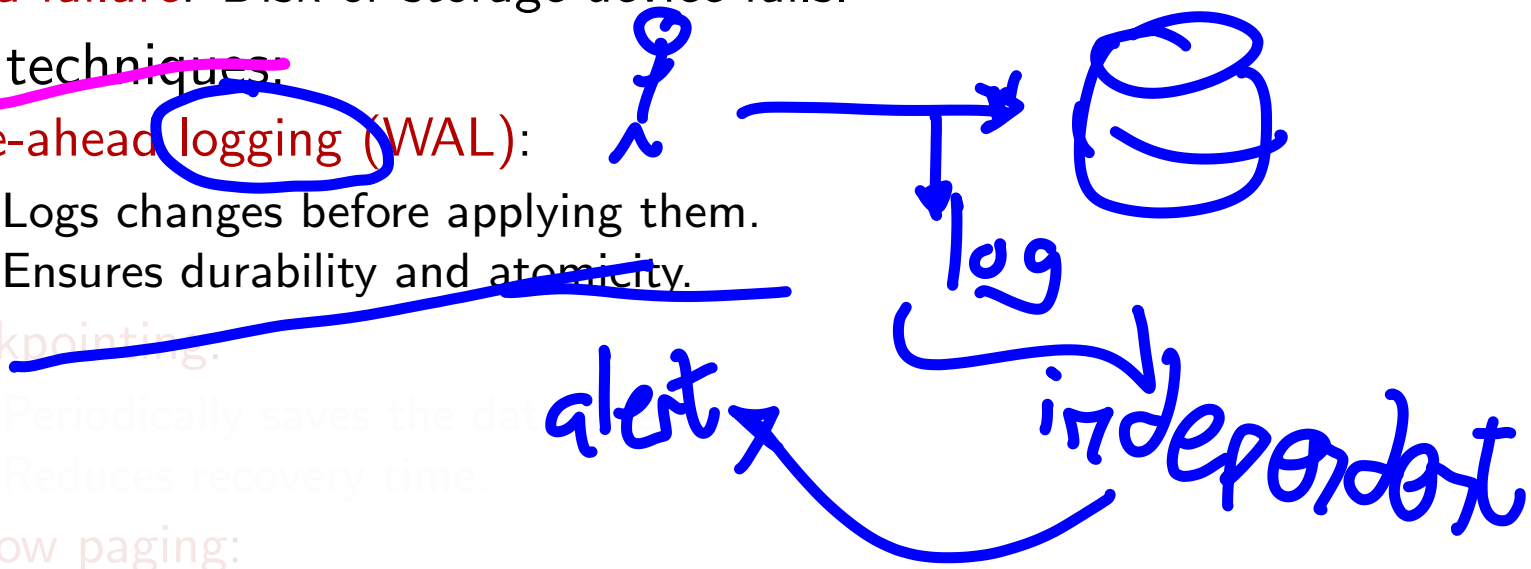

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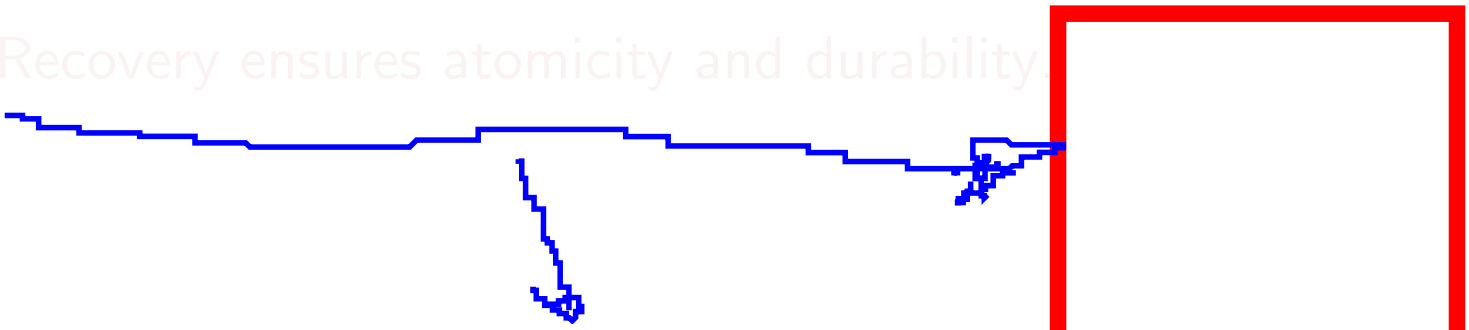

persist into a log

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snapshots

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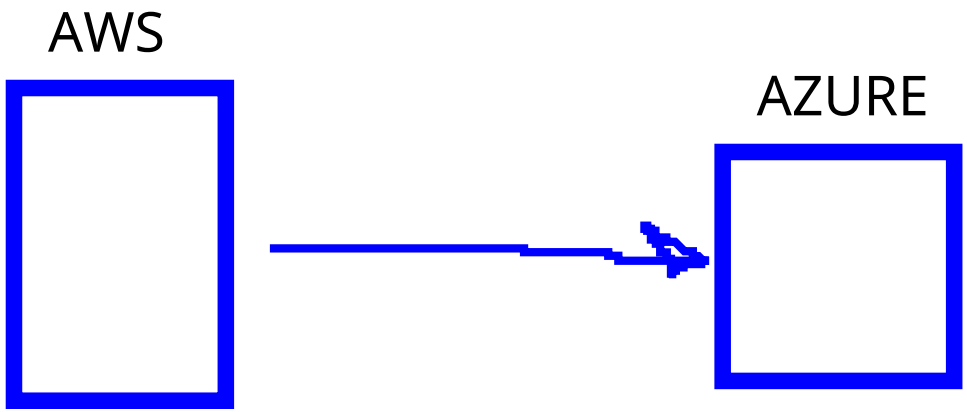

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Thanks!

Questions?

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

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