Database Fundamentals

Cybersecurity Department

Course Code: ***CBS213***

Lecture 1 : Introduction to Databases

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Lecture Outlines

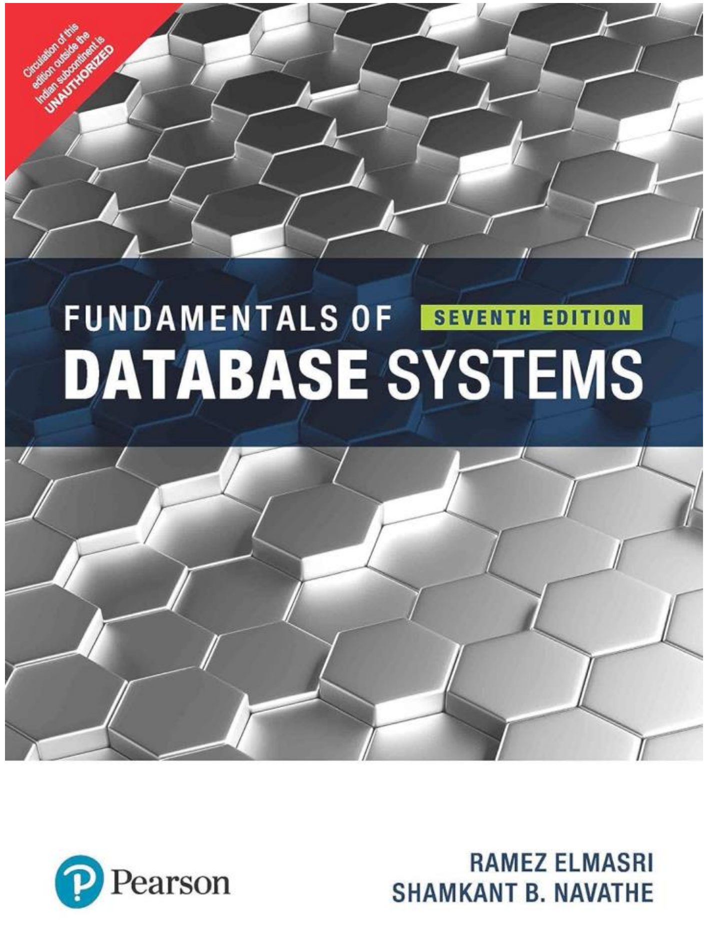
- Data and Information
- File-Based Systems vs Databases
- What is DBMS
- Why We Need Databases
- Types of Databases
- Database Life Cycle

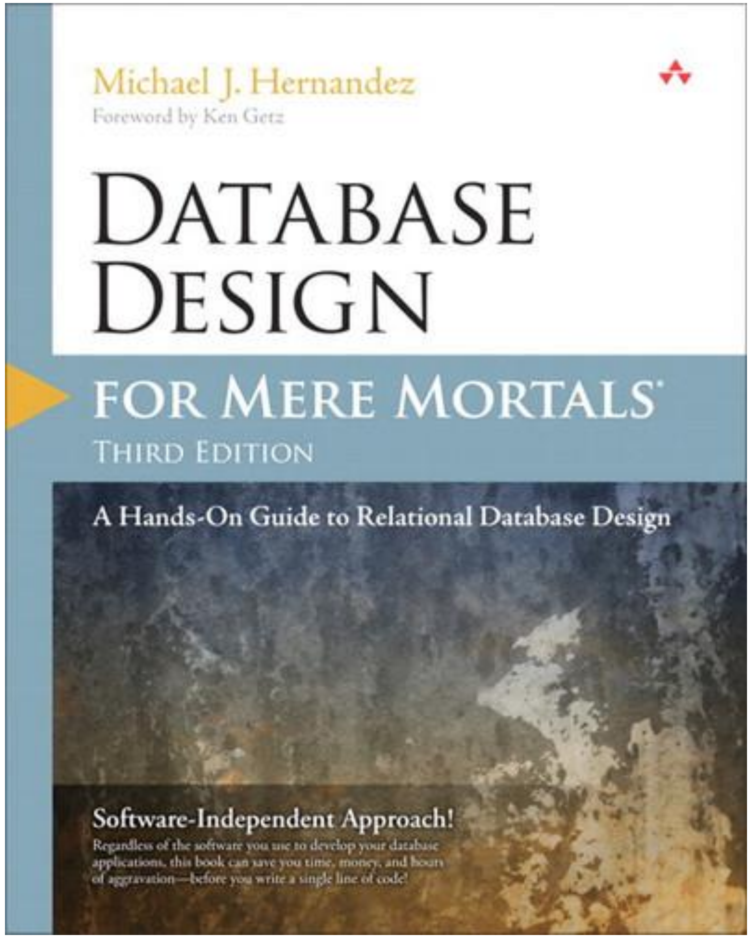
Learning Outcomes

By the end of this lecture, students will be able to:

- Define and differentiate data, information, and metadata.
- Explain the importance of databases in modern information systems.
- Describe the role and functions of a DBMS.
- Identify types of databases and where they are used.
- Illustrate the stages of the database life cycle and key professional roles.

Course Materials (Theoretical)




Michael J. Hernandez
Foreword by Ken Getz
DATABASE DESIGN
FOR MERE MORTALS®
THIRD EDITION
A Hands-On Guide to Relational Database Design
Software-Independent Approach!
Regardless of the software you use to develop your database applications, this book can save you time, money, and hours of aggravation—before you write a single line of code!

Warm-Up Question

How do we store student grades at a university?

Papers → files → Excel → Databases

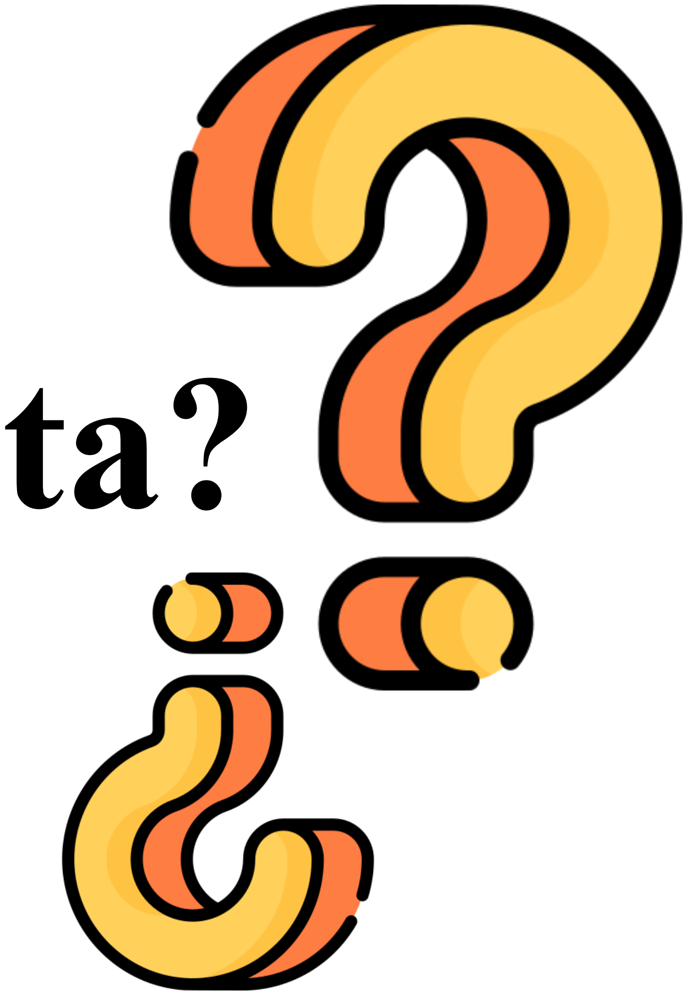
WARM UP

Watch & Note

Watch & Note

- Watch the video: *“***Database Tutorial for Beginners***”*.
- While watching, **take notes** on any important points.
- After the video, **write down at least 5 keywords** that you think are related to databases.
- **Submit your notes and keywords on a paper.**

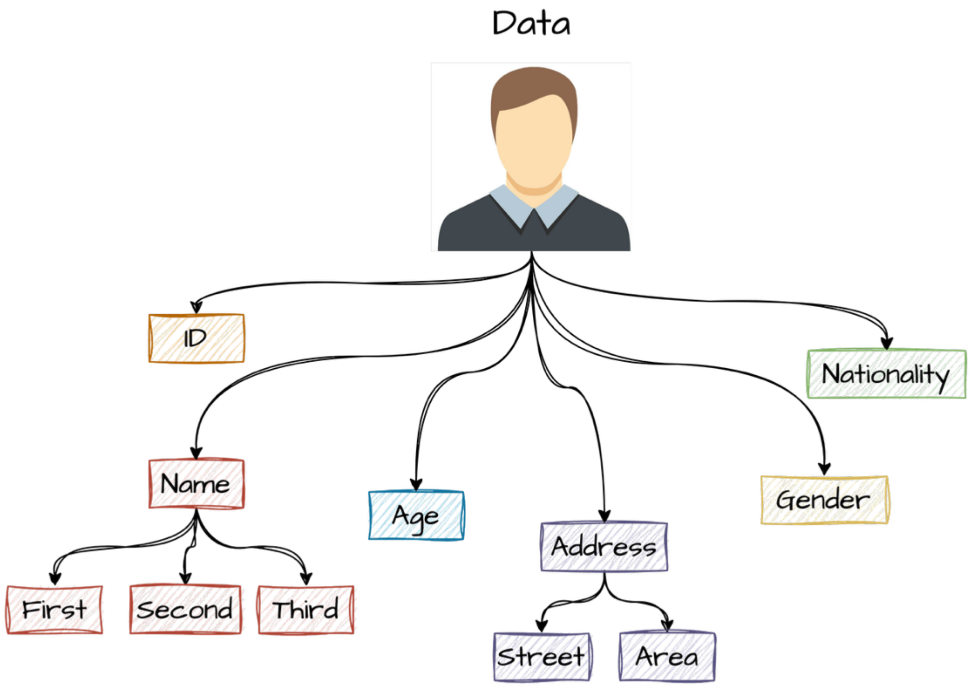
What is a Data?



What is a Data?

Data refers to raw, unorganized facts and figures, such as numbers, text, images, or symbols, that can be processed and analyzed to extract meaningful information.

- Data can exist in a raw form (unorganized) or processed form (organized and meaningful).



Unlocking the Power of Databases

Ever wondered what truly powers our digital world?

- Every social media post, bank transfer, or map search relies on a database.
- Databases are the **core of data storage and management** in almost all systems.
- Understanding them is essential for **developers, IT professionals, and cybersecurity experts.**

Why We Study Databases

- Databases power:
    - Facebook – user profiles & posts
    - Google Maps – locations & routes
    - Banks – secure transactions
    - Hospitals – patient histories
    - E-commerce – products & orders
- Without databases, **data would be lost, duplicated, or insecure.** Databases are the *heart* of nearly every application today.

Data Storage as a Necessity

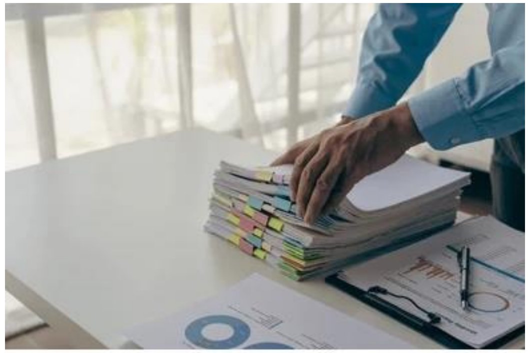
- Every invention starts with a problem.
- The problem: how to **store and manage** growing data safely.

Manual methods failed because of:

- Slow processes
- Errors
- No sharing or security

Life Before Databases

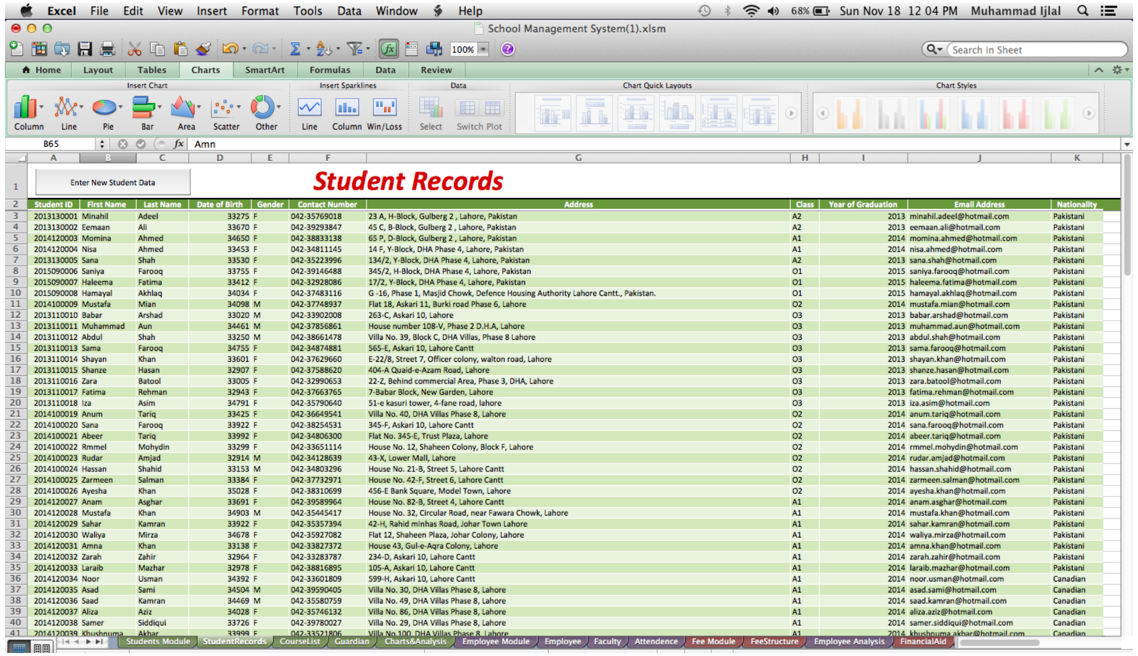
- People used **paper files, registers, and cabinets** to store information.



- This caused problems:
  - **Slow search** → finding one record took a long time.
  - **Mistakes** → human errors were common.
  - **Missing files** → papers could get lost or damaged.
  - Sharing info was difficult – you had to **physically copy** papers.

Databases solved these issues by making storage **faster, safer, and easier**.

Example: of a university keeping student records. Instead of messy papers everywhere, all student info is neatly stored in one place.



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Student Records

Student ID	First Name	Last Name	Date of Birth	Gender	Contact Number	Address	Class	Year of Graduation	Email Address	Nationality
2013130001	Minahil	Adeel	33275	F	042-35769018	23 A, H-Block, Gulberg 2 , Lahore, Pakistan	A2	2013	minahil.adeel@hotmail.com	Pakistani
2013130002	Eemaan	Ali	33670	F	042-39293847	45 C, B-Block, Gulberg 2 , Lahore, Pakistan	A2	2013	eemaan.ali@hotmail.com	Pakistani
2014120003	Momina	Ahmed	34650	F	042-38833138	65 P, D-Block, Gulberg 2 , Lahore, Pakistan	A1	2014	momina.ahmed@hotmail.com	Pakistani
2014120004	Nisa	Ahmed	33453	F	042-34811145	14 F, Y-Block, DHA Phase 4, Lahore, Pakistan	A1	2014	nisa.ahmed@hotmail.com	Pakistani
2013130005	Sana	Shah	33530	F	042-35223996	134/2, Y-Block, DHA Phase 4, Lahore, Pakistan	A2	2013	sana.shah@hotmail.com	Pakistani
2015090006	Saniya	Farooq	33755	F	042-39146488	345/2, H-Block, DHA Phase 4, Lahore, Pakistan	O1	2015	saniya.farooq@hotmail.com	Pakistani
2015090007	Haleema	Fatima	33412	F	042-32928086	17/2, Y-Block, DHA Phase 4, Lahore, Pakistan	O1	2015	haleema.fatima@hotmail.com	Pakistani
2015090008	Hamayal	Akhlaq	34034	F	042-37483116	G -16, Phase 1, Masjid Chowk, Defence Housing Authority Lahore Cantt., Pakistan.	O1	2015	hamayal.akhlaq@hotmail.com	Pakistani
2014100009	Mustafa	Mian	34098	M	042-37748937	Flat 18, Askari 11, Burki road Phase 6, Lahore	O2	2014	mustafa.mian@hotmail.com	Pakistani
2013110010	Babar	Arshad	33020	M	042-33902008	263-C, Askari 10, Lahore	O3	2013	babar.arshad@hotmail.com	Pakistani
2013110011	Muhammad	Aun	34461	M	042-37856861	House number 108-V, Phase 2 D.H.A, Lahore	O3	2013	muhammad.aun@hotmail.com	Pakistani
2013110012	Abdul	Shah	33250	M	042-38661478	Villa No. 39, Block C, DHA Villas, Phase 8 Lahore	O3	2013	abdul.shah@hotmail.com	Pakistani
2013110013	Sama	Farooq	34755	F	042-34874881	565-E, Askari 10, Lahore Cantt	O3	2013	sama.farooq@hotmail.com	Pakistani
2013110014	Shayan	Khan	33601	F	042-37629660	E-22/8, Street 7, Officer colony, walton road, Lahore	O3	2013	shayan.khan@hotmail.com	Pakistani
2013110015	Shanze	Hasan	32907	F	042-37588620	404-A Quaid-e-Azam Road, Lahore	O3	2013	shanze.hasan@hotmail.com	Pakistani
2013110016	Zara	Batool	33005	F	042-32990653	22-Z, Behind commercial Area, Phase 3, DHA, Lahore	O3	2013	zara.batool@hotmail.com	Pakistani
2013110017	Fatima	Rehman	32943	F	042-37663765	7-Babar Block, New Garden, Lahore	O3	2013	fatima.rehman@hotmail.com	Pakistani
2013110018	Iza	Asim	34791	F	042-35790640	51-e kasuri tower, 4-fane road, lahore	O3	2013	iza.asim@hotmail.com	Pakistani
2014100019	Anum	Tariq	33425	F	042-36649541	Villa No. 40, DHA Villas Phase 8, Lahore	O2	2014	anum.tariq@hotmail.com	Pakistani
2014100020	Sana	Farooq	33922	F	042-38254531	345-F, Askari 10, Lahore Cantt	O2	2014	sana.farooq@hotmail.com	Pakistani
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2014100022	Rmmel	Mohydin	33299	F	042-33651114	House No. 12, Shaheen Colony, Block F, Lahore	O2	2014	rmmel.mohydin@hotmail.com	Pakistani
2014100023	Rudar	Amjad	32914	M	042-34128639	43-X, Lower Mall, Lahore	O2	2014	rudar.amjad@hotmail.com	Pakistani
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2014100025	Zarmeen	Salman	33384	F	042-37732971	House No. 42-F, Street 6, Lahore Cantt	O2	2014	zarmeen.salman@hotmail.com	Pakistani
2014100026	Ayesha	Khan	35028	F	042-38310699	456-E Bank Square, Model Town, Lahore	O2	2014	ayesha.khan@hotmail.com	Pakistani
2014120027	Anam	Asghar	33691	F	042-39589964	House No. 82-B, Street 4, Lahore Cantt	A1	2014	anam.asghar@hotmail.com	Pakistani
2014120028	Mustafa	Khan	34903	M	042-35445417	House No. 32, Circular Road, near Fawara Chowk, Lahore	A1	2014	mustafa.khan@hotmail.com	Pakistani
2014120029	Sahar	Kamran	33922	F	042-35357394	42-H, Rahid mInhas Road, Johar Town Lahore	A1	2014	sahar.kamran@hotmail.com	Pakistani
2014120030	Waliya	Mirza	34678	F	042-35927082	Flat 12, Shaheen Plaza, Johar Colony, Lahore	A1	2014	waliya.mirza@hotmail.com	Pakistani
2014120031	Amna	Khan	33138	F	042-33827372	House 43, Gul-e-Aqra Colony, Lahore	A1	2014	amna.khan@hotmail.com	Pakistani
2014120032	Zarah	Zahir	32964	F	042-33283787	234-D, Askari 10, Lahore Cantt	A1	2014	zarah.zahir@hotmail.com	Pakistani
2014120033	Laraib	Mazhar	32978	F	042-38816895	105-A, Askari 10, Lahore Cantt	A1	2014	laraib.mazhar@hotmail.com	Pakistani
2014120034	Noor	Usman	34392	F	042-33601809	599-H, Askari 10, Lahore Cantt	A1	2014	noor.usman@hotmail.com	Canadian
2014120035	Asad	Sami	34504	M	042-39590405	Villa No. 30, DHA Villas Phase 8, Lahore	A1	2014	asad.sami@hotmail.com	Canadian
2014120036	Saad	Kamran	34469	M	042-35580759	Villa No. 49, DHA Villas Phase 8, Lahore	A1	2014	saad.kamran@hotmail.com	Canadian
2014120037	Aliza	Aziz	34028	F	042-35746132	Villa No. 86, DHA Villas Phase 8, Lahore	A1	2014	aliza.aziz@hotmail.com	Canadian
2014120038	Samer	Siddiqui	33726	F	042-39780027	Villa No. 29, DHA Villas Phase 8, Lahore	A1	2014	samer.siddiqui@hotmail.com	Canadian
2014120039	Khushnuma	Akbar	33999	F	042-33521806	Villa No.100, DHA Villas Phase 8, Lahore	A1	2014	khushnuma.akbar@hotmail.com	Canadian

File-Based Systems

- Data stored in **.txt**, .**csv**, or .**xlsx** files.

Easier than paper, but…

- Duplicate data
- No security
- Hard to connect files

File System Limitations

•**Program–Data Dependence:**

Changing the file structure requires modifying all related programs.

•**Data Redundancy:**

The same data is stored in multiple files, wasting space and causing duplication.

•**Inconsistency:**

Different files contain conflicting versions of the same data.

•**Security Problems:**

No proper access control — anyone with file access can view or edit all data.

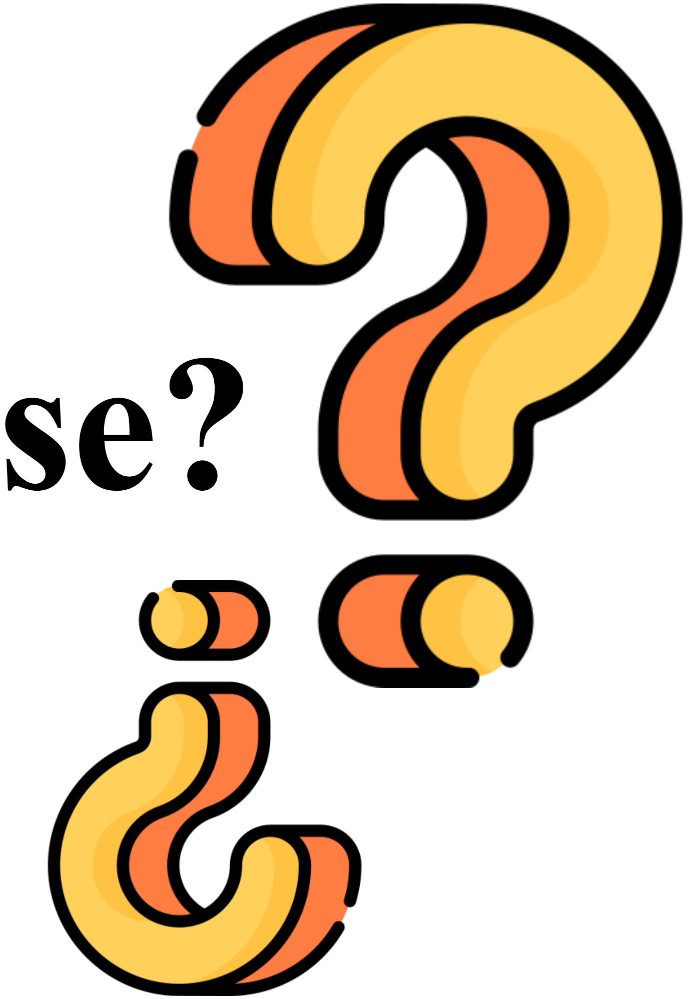
•**Concurrency Issues:**

Multiple users updating the same file at once can corrupt or overwrite data.

Multiple Themes Problem

- One file stored many entities (Student, Department, Advisor).
- Caused data anomalies:
  - Update anomaly
  - Deletion anomaly
  - Insertion anomaly

What is a Database?



What is a Database?

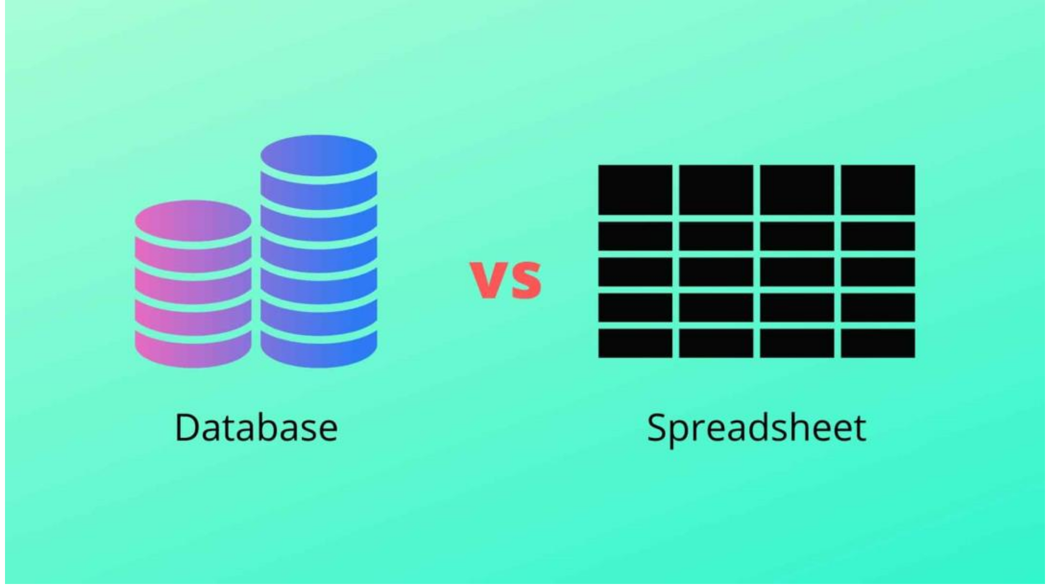
- A database is a digital repository for storing, managing and securing organized collections of data.
- This data is often stored electronically in a computer system called a database management system (DBMS).
- Together, the data and the DBMS, along with the applications that are associated with them, are referred to as a database system, often shortened to just database.

What is a Database?

- Data within the most common types of databases in operation today is typically modeled in rows and columns in a series of tables to make processing and data querying efficient.
- The data can then be easily accessed, managed, modified, updated, controlled, and organized. Most databases use structured query language (SQL) for writing and querying data.

What is a Database?

- Databases are similar to **spreadsheets**, but there are several key differences. In general, databases are much larger than spreadsheets and so can store more data, and they allow for multiple users to access data at the same time.



Why We Need Databases?

- Store large amounts of data safely.
- To **save time** – find information quickly. Easy to search and update.
- To **avoid mistakes** – no lost or duplicate data. Reduce duplication and errors.
- To **share data** – Multi-user access (many people at once).
- To **analyze and make decisions** – like knowing which product sells most.

The Power of Relationships

- **Related data connects through keys**

  Keys are special fields that link tables together. A *primary key* uniquely identifies each record, and a *foreign key* connects related tables.

Example: Students ↔ Courses ↔ Enrollments

Each student can take many courses, and each course can have many students. The *Enrollment* table connects them, storing student IDs and course IDs together.

The Power of Relationships

- **Prevents data duplication**

  Instead of repeating student or course information multiple times, data is stored once and referenced through relationships. This saves space and keeps data accurate.

- Relationships make databases organized, consistent, and smart, they connect different pieces of data logically instead of repeating them.

Metadata ("Data About Data")

- **Metadata describes the structure and properties of stored data**

  It contains details like table names, column types, and constraints that define how data should look and behave.

- **Stored inside the Database Catalog**

  Every DBMS has a "catalog" that stores all metadata automatically. The DBMS uses it to understand and manage the database structure.

Metadata (“Data About Data”)

- **Used for validation and security**

  When you run a command, the DBMS checks the metadata to make sure you’re accessing valid data and that you have permission to do so.

Metadata acts like a map or dictionary of the database, it helps the system know what data exists, where it is, and who can use it.

What is a DBMS?

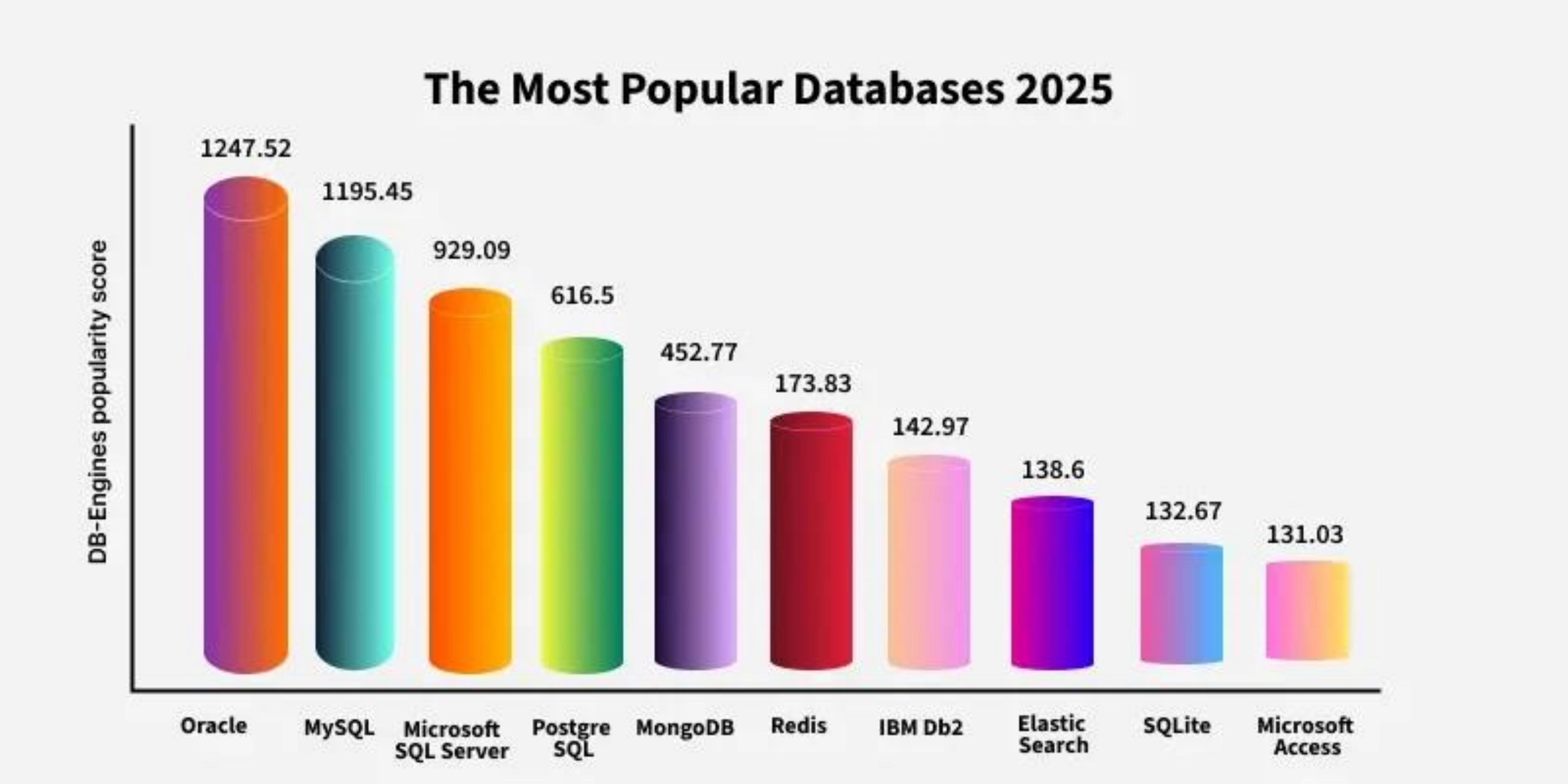
- **DBMS = Software that manages databases**

  It handles all the work of storing, organizing, securing, and accessing data efficiently.

Main responsibilities:

- **Storage & Retrieval:** Keeps data organized for fast access.
- **Security:** Controls who can see or change data.
- **Multi-User Access:** Allows many users to use the database at once.
- **Backup & Recovery:** Protects data from loss or crashes.
- **Examples:** MySQL, Oracle, PostgreSQL, SQL Server, MongoDB

According to industry rankings, the most popular databases of 2025 are:



CRUD Operations

CRUD = the four basic actions you can perform on a database.

Action	Meaning	Example
Create	Add new data	Insert a new student record
Read	View or retrieve data	Display all student names
Update	Modify existing data	Change GPA of a student
Delete	Remove data	Delete a student’s record

ACID Transactions

- **A – Atomicity:** All steps of a transaction succeed or none do (no partial updates).
- **C – Consistency:** Ensures data always follows defined rules (no invalid entries).
- **I – Isolation:** Each transaction runs independently, without interfering with others.
- **D – Durability:** Once a transaction is complete, changes remain even after system failure.

Example: In a bank transfer, both "**send**" and "**receive**" must happen or **neither**.

Integrity Constraints

- **NOT NULL:** A value must be entered in this column (no empty cells).
- **UNIQUE:** Prevents duplicate values in a column.
- **CHECK:** Ensures data meets a condition (e.g., age > 0).
- **FOREIGN KEY:** Connects tables, keeping related data consistent.

These rules keep the data accurate and meaningful.

Types of Databases

1. **Relational Databases (SQL)**
2. **Non-Relational Databases (NoSQL)**

Relational Databases (SQL)

- Store data in **tables (rows and columns)**.
- Tables are linked by **relationships** using primary and foreign keys.
- Use **Structured Query Language (SQL)** to manage data.
- Data follows a **fixed schema** (predefined structure).

  Examples: MySQL, Oracle, PostgreSQL.

  Used for: banking systems, universities, ERP systems — where accuracy and relationships are important.

Non-Relational Databases (NoSQL)

- Store data in **flexible formats** like documents, key-value pairs, or JSON.
- No fixed schema which can easily store different kinds of data.
- Designed for **scalability and speed** rather than strict structure.

Examples: MongoDB, Firebase, Cassandra.

Used for: social media, real-time apps, or big data projects where data changes often.

Key Differences

Feature	Relational (SQL)	Non-Relational (NoSQL)
Structure	Tables	Documents / Key-Value / Graph
Schema	Fixed	Flexible
Relationships	Supported	Optional
Query Language	SQL	Varies (JSON, APIs)
Use Case	Structured business data	Unstructured, scalable data

The Database Life Cycle

- **Client Idea:**

The project begins with a client who needs a system (e.g., school management).

- **Requirement Gathering (BA):**

The Business Analyst collects and documents user needs.

- **System Design (ERD):**

The Database Designer creates diagrams and plans the data structure.

- **Implementation (DBA):**

The Database Administrator builds and configures the database.

The Database Life Cycle (Cont.)

- **Application Development:**

Programmers connect the app to the database (front-end + back-end).

- **Testing & Deployment:**

The system is tested, fixed, and released for real users.

- **Maintenance:**

Regular updates, security patches, and backups are done.

ERD (Entity Relationship Diagram)

- **Entities:** The main objects in your system (Student, Course, Department).
- **Attributes:** Properties that describe each entity (Name, ID, GPA).
- **Relationships:** Links between entities (e.g., a student enrolls in many courses).

ERDs are the blueprint of your database before you build it.

Key Roles in Database Projects

Role	Responsibility
Business Analyst (BA)	Gathers system requirements from client.
Database Designer	Creates ERD and plans database structure.
Database Administrator (DBA)	Builds, secures, and maintains the database.
Developer	Connects app to the database using code.
Data Analyst	Extracts and interprets data for decision-making.
End User	Uses the final application to perform daily tasks.

Real-World Example: Banking System

- **Entities:** Customer, Account, Transaction.
- **DBMS Responsibilities:**
    - Ensures only authorized users can access data.
    - Applies ACID properties for safe transactions.
    - Maintains integrity between customer and account tables.

If you withdraw money, the system updates multiple tables correctly and securely.

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Any
Question