⭐ DAY 5 — DATABASES

🔷 PART A — INTRO TO DATABASES

By the end of this part, students should **clearly understand WHY databases exist** and **why files are not enough**.

🧠 1️⃣ WHAT IS A DATABASE?

📌 Definition

A **database** is a **place to store data permanently** so that:

- Data does not disappear
- Data can be searched easily
- Data can be updated safely
- Many users can use it at the same time

🗣️

“A database is like a **smart digital cupboard** for your data.”

🧠 Real-Life Analogy

Imagine:

- You write student details on paper
- You keep papers in a bag

Problems:

❌ Papers can tear

❌ Hard to find one student

❌ No backup
❌ Multiple people can't edit

📌 **Database solves all these problems.**

📂 2️⃣ WHY FILES (TXT, JSON, CSV) ARE NOT ENOUGH

🤔 Question:

"Why can't we just use files to store data?"

❌ Problems with Files

Problem	Example
Data loss	File deleted accidentally
No structure	Everyone writes differently
Slow search	Reading entire file
No security	Anyone can open
No multi-user	Two people overwrite data
No relationships	Hard to connect data

🗣️:

"Files are okay for practice, but **real apps will break** if we use files."

💾 3️⃣ WHAT PROBLEM DATABASES SOLVE

Databases give us:

✓ Permanent storage
✓ Fast search
✓ Organized data
✓ Safe updates

✓ Multiple users at once
✓ Security
✓ Backup & recovery

📌 Example:

Instagram:

- Millions of users
- Millions of posts
- Likes, comments, messages

👉 **Impossible without a database**

🧱 🔌 PERSISTENT STORAGE (VERY IMPORTANT)

❓ What does "Persistent" mean?

Persistent = **Data stays even after app/server is stopped**

Example:

- Backend stopped ❌
- Laptop restarted 🔁
- Data still exists ✅

🗣️:

“If data disappears after refresh, it’s not a database.”

🔁 Example Comparison

Storage Type	Data after restart
Variable	❌ Lost

Array	❌ Lost
File	⚠️ Risky
Database	✅ Safe

🧩 5️⃣ TYPES OF DATA (STRUCTURED vs UNSTRUCTURED)

🟦 Structured Data

Data with **fixed format**

Example:

id	name	age
1	Alex	21

✓ Easy to search
✓ Fixed columns

Used in:

- Banks
- Schools
- Finance apps

🟦 Unstructured Data

Data with **no fixed format**

Examples:

- Images
- Videos
- Messages
- JSON documents

Used in:

- Social media
- Chat apps
- Logs

🗣️:

“Not all data fits in tables.”

🗂️ 6️⃣ TYPES OF DATABASES (HIGH LEVEL)

Two Main Types (IMPORTANT)

Type	Name
SQL	Relational Database
NoSQL	Non-Relational Database

We will learn:
✓ **PostgreSQL (SQL)**
✓ **MongoDB (NoSQL)**

📊 7️⃣ SQL DATABASES (RELATIONAL)

Key Idea:

Data is stored in **tables**

Example:

Students Table

id	name	email

Features:

✓ Fixed structure
✓ Strong rules
✓ Relationships between tables

Used when:

- Data is structured
- Rules are strict
- Financial accuracy is needed

🗣️ Example Apps:

- Banking apps
- College systems
- Payroll

📦 🗄️ NOSQL DATABASES (MONGODB)

Key Idea:

Data is stored as **documents**

Example (JSON-like):

```
{
  "name": "Alex",
  "email": "alex@mail.com",
  "skills": ["React", "FastAPI"]
}
```

Features:

✓ Flexible structure
✓ Easy to scale
✓ Faster for large apps

Used when:

- Data changes often
- App grows fast
- Flexible data is needed

🗣️ Example Apps:

- Instagram
- Netflix
- Uber

⚖️ 9️⃣ SQL vs NoSQL (VERY IMPORTANT)

Feature	SQL	NoSQL
Structure	Fixed	Flexible
Schema	Required	Optional
Scaling	Vertical	Horizontal
Best for	Accuracy	Speed & scale
Example	PostgreSQL	MongoDB

🗣️ Tell students:

“There is NO best database — only best choice for the problem.”

🔐 🔟 ACID vs FLEXIBILITY (SIMPLE LANGUAGE)

ACID (SQL Databases)

ACID = **Rules to protect data**

✓ Data is always correct
✓ Transactions are safe
✓ No partial updates

Example:

- Money transfer
- Exam results

Flexibility (NoSQL)

✓ Faster writes
✓ Flexible structure
✓ Handles large data

Example:

- Social posts
- Chat messages

🗣️ Simple line:

“SQL = Safety first
NoSQL = Speed first”

📈 1️⃣1️⃣ SCALING IDEA (BASIC)

Vertical Scaling

Add more power to one machine

🧠 Example:

- More RAM
- Better CPU

❌ Expensive
❌ Limited

Horizontal Scaling

Add more machines

🧠 Example:

- Multiple servers
- Load sharing

✓ Cheap
✓ Unlimited growth

📌 MongoDB is great at this.

📓 MINI CHEAT SHEET — PART A

Concept	Meaning
Database	Permanent data storage
Persistent	Data survives restart
SQL	Table-based, strict

NoSQL	Document-based, flexible
ACID	Data safety rules
Vertical scaling	Bigger machine
Horizontal scaling	More machines

🧠 FINAL MINDSET (VERY IMPORTANT)

Tell students:

“Backend without database is incomplete.
Database is the memory of your application.”

◇ PART-B — MongoDB Setup & Verification

🎯 Goal:
By the end of this part:

- MongoDB is installed correctly
- MongoDB is running
- They can talk to MongoDB
- They understand *what is happening*, not just commands

🧠 1️⃣ Before We Touch MongoDB

🗣️ :

“MongoDB is NOT a programming language.
MongoDB is a **database server** that runs in the background.”

Think of it like:

- WhatsApp app → frontend
- WhatsApp servers → backend
- **MongoDB → place where data is stored permanently**

📋 2️⃣ What Needs to Be Installed (Checklist)

On **Mac**, for MongoDB work we need:

Item	Why needed
MongoDB Server	To store data
MongoDB Shell (mongosh)	To talk to MongoDB
Terminal	To run commands
VS Code	To write backend code
Python	For FastAPI (already done)

👉 We will **VERIFY**

☑️ 3️⃣ Step 1 — Check if MongoDB is Installed

📍 Open Terminal and run:

```
mongod --version
```

☑️ If MongoDB is installed, you'll see:

Something like:

```
db version v7.0.x
```

✓ This means **MongoDB Server exists**

❌ If command not found:

MongoDB server is **NOT installed**

☑ 4️⃣ Step 2 — Check MongoDB Shell

MongoDB is useless if we can't talk to it.

Run:

```
mongosh
```

☑ Expected output:

You'll see something like:

```
Current Mongosh Log ID: ...
Connecting to: mongodb://127.0.0.1:27017
>
```

That > symbol means:

🎉 **You are inside MongoDB**

🗣️ :

"This is like opening Python REPL or Node console —
now we are talking directly to MongoDB."

❌ If mongosh not found:

Shell missing → install required

🧠 5️⃣ What is Running Right Now?

Let's clarify **confusion students always have**:

Thing	Meaning
mongod	MongoDB server (background)
mongosh	MongoDB shell (your chat window)
Port 27017	Default MongoDB door

🧠 Visualization:

```
Your Mac
 ├── MongoDB Server (mongod)  ← running silently
 └── Terminal (mongosh)       ← you typing commands
```

🔎 6️⃣ Verify MongoDB is Actually Running

Inside mongosh, type:

```
db
```

Output:

```
test
```

This means:

- MongoDB is alive
- You are connected

- Default database is test

✓ Good sign

🧪 7️⃣ Create a Test Database (NO DATA YET)

Run:

```
use school
```

Output:

```
switched to db school
```

🧠 Explain:

"MongoDB creates databases **lazily**.
Database exists only when we insert data."

📦 8️⃣ What is a Database? (MongoDB Style)

Term	Meaning
Database	Big container
Collection	Like a table
Document	Like a row (JSON)

🧠 Visualization:

```
Database: school
└── Collection: students
    └── Document: { name, age, email }
```

🧪 9️⃣ Create First Collection + Document

Insert one student 👇

```
db.students.insertOne({
  name: "Alex",

  age: 20,
  email: "alex@mail.com"
})
```

Output:

```
acknowledged: true
insertedId: ObjectId(...)
```

🎉 MongoDB is WORKING

🔍 🔟 Read Data (Important)

```
db.students.find()
```

You will see:

```
[
  {
    _id: ObjectId("..."),
    name: "Alex",
    age: 20,
    email: "alex@mail.com"
  }
]
```

🧠 Explain:

- _id is auto-generated
- MongoDB stores **JSON-like documents**
- No schema forced

📓 1️⃣1️⃣ MINI CHEAT SHEET — MongoDB Basics

Command	Meaning
mongosh	Open MongoDB shell
use dbName	Switch DB
db	Current DB
show dbs	List databases
db.collection.insertOne()	Insert
db.collection.find()	Read

⚠️ 1️⃣2️⃣ Important MongoDB Characteristics (Explain Slowly)

❌ No fixed schema

```
{ name: "Alex" }
{ name: "Sam", age: 22 }
```

✓ Both valid

❌ No tables

✓ Collections instead

❌ No joins by default

✓ Designed for flexibility + speed

🧠 1️⃣3️⃣ MongoDB vs SQL (Student Friendly)

MongoDB	SQL
Flexible	Strict
JSON documents	Tables
Schema-less	Schema-based
Scales horizontally	Mostly vertical

🗣️ :

“MongoDB is like a flexible notebook
SQL is like a ruled register.”

Let’s Practise some MongoDB

🧠 LAYER 1 — MongoDB MENTAL MODEL

Read this slowly.

❓ What MongoDB REALLY is

MongoDB is:

- a **JSON document storage engine**
- running as a **background service**
- optimized for **real-world app data**

It is **NOT**:

- Excel
- SQL tables
- rows & columns thinking

📦 MongoDB Structure (Burn this into your brain)

```
MongoDB Server
└── Database
    └── Collection
        └── Document
```

Real-life analogy:

```
Library
└── Section (Database)
    └── Shelf (Collection)
        └── Book (Document)
```

👉 MongoDB doesn't care:

- what fields a book has
- how many pages
- what order

That's the **power and danger**.

📄 What is a DOCUMENT really?

A MongoDB document is just:

```
{
 name: "Rahul",
 age: 21,
```

```
  skills: ["Python", "MongoDB"]
}
```

It’s:

- NOT a class
- NOT a table row
- Just **stored JSON**

MongoDB **does not ask permission**.

🧠 KEY DIFFERENCE THAT BLOCKS CONFIDENCE

SQL mindset ❌

“First define structure, then insert data”

MongoDB mindset ☑

“Insert data first, structure evolves naturally”

This shift takes time — **you’re normal**.

✍ LAYER 2 — CORE COMMANDS (DEEP COMFORT)

We will now go **very slow** and explain *why*, not just *how*.

◇ 1. Switching Databases

```
use college
```

🧠 Meaning:

“Hey MongoDB, from now on, keep my data in a box called college.”

⚠️ Database is NOT created yet.

◇ 2. Collections Are Created Automatically

```
db.students.insertOne({
  name: "Ananya",
  age: 22
})
```

🧠 What MongoDB did:

1. Created college database
2. Created students collection
3. Inserted document
4. Added _id

SQL people find this scary — MongoDB people love it.

◇ 3. Why _id Exists (Important)

Every document has:

```
_id: ObjectId("...")
```

Why?

- MongoDB needs **unique identity**
- Like Aadhaar for documents

You don’t manage it → MongoDB does.

◇ 4. Reading Data Slowly

```
db.students.find()
```

Means:

“Give me **all documents** from students collection”

MongoDB does **not** care about column order.

◇ 5. Filtering (THIS BUILDS CONFIDENCE)

```
db.students.find({ age: 22 })
```

Meaning:

“Only give documents where age is 22”

Multiple conditions:

```
db.students.find({
  age: 22,
  name: "Ananya"
})
```

This is **AND** by default.

◇ 6. Projection (Selective Fields)

```
db.students.find(
 { age: 22 },
 { name: 1, _id: 0 }
)
```

🧠 Meaning:

- 1 → include
- 0 → exclude

MongoDB forces _id unless you hide it.

◇ 7. Update (THIS IS WHERE FEAR COMES)

Update ONE document:

```
db.students.updateOne(
 { name: "Ananya" },
 { $set: { age: 23 } }
)
```

🧠 $set means:

“Only update this field — don’t destroy others”

⚠️ Without $set, MongoDB **replaces the entire document**.

This single rule causes most beginner disasters.

◇ 8. Delete (Safe First)

```
db.students.deleteOne({ name: "Ananya" })
```

One match → delete one.

◇ 9. Schema Flexibility (See the Magic)

```
db.students.insertOne({
  name: "Rohit",
  skills: ["Java", "Node"],

active: true
})
```

Same collection.
Different structure.
Still valid.

🧪 LAYER 2 PRACTICE (MANDATORY)

Before Part-C, you must be able to do this **without thinking**:

✓ Create DB
✓ Insert different shaped documents
✓ Find with filter
✓ Update using $set
✓ Delete safely

◇ PART-C — CONNECT FASTAPI WITH MONGODB

🎯 Goal:

You should clearly understand **how FastAPI talks to MongoDB**, how data flows, and how real APIs store data permanently.

🧠 1️⃣ THEORY — WHAT ARE WE DOING?

Real-World Story (IMPORTANT)

Think like this 👇

```
React  →  FastAPI  →  MongoDB
(UI)       (Brain)     (Memory)
```

- React: asks for data
- FastAPI: processes request
- MongoDB: stores & returns data permanently

📌 **FastAPI itself does NOT store data**
If server restarts → memory is gone
So we need **MongoDB = permanent storage**

❓ Why we cannot use MongoDB shell directly in backend?

Mongo shell is for:

- humans
- manual testing

Backend needs:

- automatic
- async
- non-blocking
- production-safe access

👉 So we use a **MongoDB DRIVER**

🧠 2️⃣ IMPORTANT CONCEPT — DRIVER & ASYNC

MongoDB + FastAPI uses:

Motor (Async MongoDB Driver)

Why async?

- FastAPI is async
- MongoDB queries can be slow
- Async = server doesn't freeze

📌 **Motor = bridge between FastAPI and MongoDB**

🏗️ 3️⃣ BACKEND PROJECT STRUCTURE (VERY IMPORTANT)

We now slightly upgrade backend structure 👇

```
backend/
 ├─ main.py
 ├─ database.py        👈 NEW (MongoDB connection)
 ├─ routers/
 │   └─ students.py
 ├─ models/
 │   └─ student.py     👈 NEW (data structure)
```

👉 This is **industry-standard**, not random.

🧩 4️⃣ DATABASE CONNECTION (CORE FILE)

📁 backend/database.py

```
from motor.motor_asyncio import AsyncIOMotorClient

MONGO_URL = "mongodb://localhost:27017"

client = AsyncIOMotorClient(MONGO_URL)

database = client.college

student_collection = database.students
```

🧠 Understand this properly:

- AsyncIOMotorClient → connects to MongoDB service
- college → database name
- students → collection name

⚠️ MongoDB creates DB & collection **automatically**

🧠 Why separate database.py?

✓ Clean code
✓ Reusable
✓ Easy to change DB later
✓ Professional backend practice

🧩 5️⃣ DATA MODEL (HOW DATA SHOULD LOOK)

📁 backend/models/student.py

```
from pydantic import BaseModel, EmailStr
from typing import Optional

class Student(BaseModel):
    name: str
    email: EmailStr
    age: int
```

🧠 IMPORTANT CLARITY

This model:

- does NOT create DB
- does NOT insert data
- only **validates incoming data**

👉 MongoDB stores JSON

👉 Pydantic ensures correctness

🧩 6️⃣ ROUTER — REAL CRUD WITH MONGODB

📁 backend/routers/students.py

```
from fastapi import APIRouter, HTTPException
from models.student import Student
from database import student_collection

router = APIRouter(prefix="/students", tags=["Students"])


@router.post("/")
async def create_student(student: Student):
    student_dict = student.dict()
    result = await student_collection.insert_one(student_dict)
    return {
        "message": "Student created",
        "id": str(result.inserted_id)
    }


@router.get("/")
async def get_students():
    students = []
    cursor = student_collection.find()


async for student in cursor:
        student["_id"] = str(student["_id"])
```

```
    students.append(student)

return students
```

🧠 LET'S UNDERSTAND THE FLOW (VERY IMPORTANT)

POST /students

1️⃣ React sends JSON
2️⃣ FastAPI validates using Student
3️⃣ Converted to dict
4️⃣ Inserted into MongoDB
5️⃣ MongoDB returns _id

📌 **Permanent storage achieved**

GET /students

1️⃣ MongoDB returns cursor
2️⃣ Cursor iterated asynchronously
3️⃣ _id converted to string
4️⃣ JSON returned to frontend

⚠️ MongoDB _id is not JSON-serializable → must convert

🧩 7️⃣ MAIN ENTRY FILE (YOU WARNED ME — SO HERE IT IS)

📁 backend/main.py

```
from fastapi import FastAPI
from routers import students

app = FastAPI(title="Student API")

app.include_router(students.router)
```

✓ Router connected
✓ Backend complete
✓ Clean startup

🧪 8️⃣ TEST FLOW (YOU MUST DO THIS)

Step 1 — Start MongoDB

```
mongod
```

Step 2 — Start FastAPI

```
uvicorn main:app --reload
```

Step 3 — Open Swagger

http://localhost:8000/docs

✓ Create student
✓ Fetch students
✓ Check MongoDB shell

🧠 9️⃣ MINI CHEAT SHEET (MEMORIZE THIS)

Concept	Meaning
Motor	Async MongoDB driver
Collection	Like table (but flexible)
Document	JSON object
Pydantic	Validation layer
Async	Non-blocking
Cursor	MongoDB iterator
_id	Unique identifier

⚠️ 1️⃣0️⃣ COMMON BEGINNER MISTAKES (READ CAREFULLY)

❌ Forgetting async/await
❌ Returning ObjectId directly
❌ Mixing shell syntax in Python
❌ Writing DB logic inside main.py
❌ Skipping data validation

You avoided all of them 👏

☑ WHERE YOU ARE NOW (IMPORTANT)

You can now confidently say:

✓ “I know MongoDB shell”
✓ “I know how FastAPI stores data”
✓ “I understand backend → DB flow”
✓ “I’m not scared of MongoDB anymore”

.

🚀 MINI ASSIGNMENT — USER REGISTRATION SYSTEM (MongoDB + FastAPI)

🎯 What we are building

A **real backend flow** that every company uses:

✓ Register user
✓ Prevent duplicate emails
✓ Hash password
✓ Store user in MongoDB
✓ List users (without password)

🧠 MENTAL MODEL (VERY IMPORTANT)

Flow in simple words:

Client (Swagger / React)
↓
FastAPI Endpoint
↓
Pydantic Validation
↓
Password Hashing
↓
MongoDB (users collection)
↓
Response (safe data)

MongoDB stores **raw data**, FastAPI controls **logic & safety**.

🗂 PROJECT STRUCTURE

```
backend/
│
├── main.py
├── database.py
├── models/
│   └── user_model.py
├── routers/
│   └── users.py
├── requirements.txt
```

1️⃣ INSTALL REQUIRED PACKAGES

Run this once:

pip install fastapi uvicorn motor python-dotenv passlib[bcrypt]

Why each?

- motor → async MongoDB
- passlib → password hashing
- dotenv → environment variables later

2️⃣ database.py (MongoDB Connection)

```
# database.py

from motor.motor_asyncio import AsyncIOMotorClient

MONGO_URL = "mongodb://localhost:27017"

client = AsyncIOMotorClient(MONGO_URL)

db = client["user_db"]

user_collection = db["users"]
```

🧠 Notes:

- Database name = user_db
- Collection = users
- MongoDB auto-creates both

3️⃣ User Model (Validation Layer)

📄 models/user_model.py

```
from pydantic import BaseModel, EmailStr
from typing import Optional

class UserCreate(BaseModel):
    name: str
    email: EmailStr
    password: str

class UserResponse(BaseModel):
    id: str
    name: str
    email: EmailStr
```

🧠 Why this matters:

- UserCreate → input
- UserResponse → output (NO password)

4️⃣ Password Hashing Logic (SECURITY)

📄 routers/users.py

```
from passlib.context import CryptContext

pwd_context = CryptContext(schemes=["bcrypt"], deprecated="auto")
def hash_password(password: str) -> str:
    return pwd_context.hash(password)
```

🧠 Rule:

Never store raw passwords. EVER.

MongoDB will store:

$2b$12$K9kE... (hashed)

5 User Router (FULL CRUD LOGIC)

routers/users.py

```
from fastapi import APIRouter, HTTPException
from database import user_collection
from models.user_model import UserCreate, UserResponse
from bson import ObjectId
from passlib.context import CryptContext

router = APIRouter()

pwd_context = CryptContext(schemes=["bcrypt"], deprecated="auto")

def hash_password(password: str):
    return pwd_context.hash(password)

def user_serializer(user) -> dict:
    return {
        "id": str(user["_id"]),
        "name": user["name"],
        "email": user["email"]
    }

# REGISTER USER
@router.post("/register", response_model=UserResponse)
async def register_user(user: UserCreate):

    existing_user = await user_collection.find_one(
```

```
    {"email": user.email}
  )

  if existing_user:
    raise HTTPException(
      status_code=400,
      detail="Email already registered"
    )

  user_dict = user.dict()
  user_dict["password"] = hash_password(user.password)

  result = await user_collection.insert_one(user_dict)

  new_user = await user_collection.find_one(
    {"_id": result.inserted_id}
  )

  return user_serializer(new_user)

# LIST USERS
@router.get("/users")
async def list_users():
  users = []
  async for user in user_collection.find():
    users.append(user_serializer(user))
  return users
```

🧠 WHAT YOU LEARNED HERE:

- Duplicate email check
- Password hashing
- MongoDB insert
- MongoDB find
- Safe response

6️⃣ main.py (APP ENTRY POINT — IMPORTANT)

```
from fastapi import FastAPI
from routers import users

app = FastAPI()

app.include_router(users.router, prefix="/api")
```

📌 You previously noticed when this was missing — good instinct.

7️⃣ TEST FLOW (DO THIS STEP-BY-STEP)

Step 1 — MongoDB (already running ✓)

```
brew services list
```

Step 2 — Start FastAPI

```
uvicorn main:app --reload
```

Step 3 — Swagger

Open:

```
http://127.0.0.1:8000/docs
```

🧪 Test APIs

◇ Register User

```
POST /api/register
{
 "name": "Yashas",
 "email": "yashas@mail.com",
 "password": "secret123"
}
```

◇ List Users

GET /api/users

✓ Password NOT visible
✓ Email unique
✓ Clean response

8️⃣ VERIFY IN MONGODB SHELL

```
mongosh
use user_db
db.users.find().pretty()
```

You will see:

- _id
- name
- email
- hashed password

🧠 MINI CHEAT SHEET (SAVE THIS)

MongoDB

```
db.users.find()
db.users.findOne({email: "x@mail.com"})
db.users.deleteMany({})
```

Motor

```
insert_one()
find_one()
find()
```

Security Rule

❌ Plain password
✅ Hashed password

PostgreSQL: SQL Basics (Theory + CLI)

🎯 **Goal of Day 5**
By the end of today, students should:

- Understand **how SQL databases think**
- Be comfortable using **PostgreSQL CLI**
- Write **basic SQL queries confidently**
- Clearly see the difference between **MongoDB vs SQL**

🧠 1. SQL Mental Model (VERY IMPORTANT)

MongoDB vs PostgreSQL (Quick Comparison)

MongoDB	PostgreSQL
Database	Database
Collection	Table
Document	Row
Field	Column
Schema-less	Fixed Schema
JSON-like	Structured (Rows & Columns)

👉 **PostgreSQL is like an Excel sheet with rules**

🟫 2. Core SQL Concepts (Theory)

📦 Table

A **table** stores data in a structured format.

Example: students table

id	name	age	email

📄 Row

A **row** = one complete record

(1, "Rahul", 21, "rahul@gmail.com")

📊 Column

A **column** = one type of data

name → only names
age → only numbers

🟧 3. Primary Key (PK)

What is a Primary Key?

- Uniquely identifies each row
- Cannot be NULL
- Cannot be duplicated

Example:

id SERIAL PRIMARY KEY

✓ SERIAL → auto-increment
✓ PRIMARY KEY → unique identity

🟧 4. Foreign Key (FK)

What is a Foreign Key?

- Creates a **relationship** between tables
- Points to another table's primary key

Example:

- One **department**
- Many **students**

department_id INT REFERENCES departments(id)

👉 This enforces **data integrity**

🟩 5. PostgreSQL CLI (Hands-On)

Step 1: Enter PostgreSQL

```
psql postgres


--or

psql -U postgres
```

Step 2: Create a Database

```
CREATE DATABASE college;
```

Step 3: Use the Database

```
\c college
```

Step 4: List Databases

```
\l
```

Step 5: List Tables

```
\dt
```

▧ 6. CREATE TABLE

Create students table

```
CREATE TABLE students (
  id SERIAL PRIMARY KEY,
  name VARCHAR(100),
  age INT,
  email VARCHAR(150)
);
```

📌 Explanation:

- VARCHAR(100) → string with max 100 chars
- INT → integer
- SERIAL → auto increment

▧ 7. INSERT (Add Data)

Insert one row

```
INSERT INTO students (name, age, email)
VALUES ('Aman', 20, 'aman@gmail.com');
```

Insert multiple rows

```
INSERT INTO students (name, age, email) VALUES
('Riya', 21, 'riya@gmail.com'),
```

```
('Kunal', 22, 'kunal@gmail.com'),
('Neha', 19, 'neha@gmail.com');
```

8. SELECT (Read Data)

Get all data

```
SELECT * FROM students;
```

Get specific columns

```
SELECT name, age FROM students;
```

9. WHERE (Filter Data)

Students older than 20

```
SELECT * FROM students
WHERE age > 20;
```

Student with specific name

```
SELECT * FROM students
WHERE name = 'Riya';
```

Combine conditions

```
SELECT * FROM students
WHERE age >= 20 AND age <= 22;
```

🟧 10. ORDER BY (Sorting)

Sort by age (ascending)

```
SELECT * FROM students
ORDER BY age;
```

Sort by age (descending)

```
SELECT * FROM students
ORDER BY age DESC;
```

🟧 11. LIMIT (Restrict Results)

Get only first 2 students

```
SELECT * FROM students
LIMIT 2;
```

Top 2 oldest students

```
SELECT * FROM students
ORDER BY age DESC
LIMIT 2;
```

🟧 12. Foreign Key Example (Mini)

🧠 First: Forget SQL for 1 minute

Think about a **college in real life**.

🏫 Real-life rules:

- A **college has departments**
  → CSE, ECE, MECH
- A **student must belong to ONE department**
- A student **cannot belong to a department that doesn't exist**

👉 This rule is what **Foreign Key** enforces.

🧱 Step 1: Departments table (Parent table)

```
CREATE TABLE departments (
  id SERIAL PRIMARY KEY,
  dept_name VARCHAR(100)
);
```

What this means:

Column	Meaning
id	Unique ID for each department
dept_name	Department name

Example data:

```
INSERT INTO departments (dept_name)
VALUES ('CSE'), ('ECE');
```

Now the table looks like:

id	dept_name
1	CSE
2	ECE

📌 **Important**

- PostgreSQL automatically creates id

- id is the **identity** of the department

🧱 Step 2: Students table (Child table)

```
CREATE TABLE college_students (
  id SERIAL PRIMARY KEY,
  name VARCHAR(100),
  department_id INT REFERENCES departments(id)
);
```

What is department_id?

👉 It **points to** departments.id

This is the **Foreign Key**.

🔗 How tables are connected

```
departments
+----+-----------+
| id | dept_name |
+----+-----------+
| 1  | CSE       |
| 2  | ECE       |
+----+-----------+

college_students
+----+------+---------------+
| id | name | department_id |
+----+------+---------------+
```

Meaning:

- department_id = 1 → CSE
- department_id = 2 → ECE

☑ Insert VALID student (Allowed)

```
INSERT INTO college_students (name, department_id)
VALUES ('Aman', 1);
```

Why allowed?

✓ Department with id = 1 exists (CSE)

```
INSERT INTO college_students (name, department_id)
VALUES ('Riya', 2);
```

✓ ECE exists → allowed

❌ Insert INVALID student (Blocked by PostgreSQL)

```
INSERT INTO college_students (name, department_id)
VALUES ('Kunal', 5);
```

What happens?

❌ ERROR:

insert or update on table "college_students"
violates foreign key constraint

Why?

🚫 There is **NO department with id = 5**

👉 PostgreSQL says:

“You cannot assign a student to a department that doesn’t exist.”

🧠 One-to-Many (Very Important)

One department → many students

Example:

Student	department_id
Aman	1
Neha	1
Riya	2

- CSE (1) → Aman, Neha
- ECE (2) → Riya

✓ ONE department
✓ MANY students

This is called:

ONE → MANY relationship

🔒 What Foreign Key REALLY enforces

Rule	Who enforces it
Student must belong to a valid department	PostgreSQL
No fake department IDs allowed	PostgreSQL
Data consistency	PostgreSQL

Without Foreign Key ❌:

- Students can point to random numbers

- Data becomes dirty

With Foreign Key ✅:

- Clean data
- Real-world logic enforced

🧠 One Line Definition (Exam / Interview)

A **Foreign Key** is a column that **references the Primary Key of another table** to maintain data integrity.

🧪 Mini Test (Check your understanding)

Answer mentally:

1️⃣ Can two students have same department_id?
✓ YES

2️⃣ Can one student have two departments here?
❌ NO

3️⃣ Can a student belong to non-existing department?
❌ NO

🎯 Why this matters later

You'll use this in:

- SQLAlchemy relationships
- Backend APIs
- Authentication (users → roles)

- Real projects

🧪 Mini Practice

Ask to write:

1. Create a teachers table
2. Insert 3 teachers
3. Fetch teachers older than 30
4. Sort teachers by name
5. Get only top 1 result

🧠 COMPLETE SQL ROADMAP (A → Z)

🟢 LEVEL 1 — EASY (FOUNDATION)

👉 Goal:
✓ Be confident in PostgreSQL CLI
✓ Read & write basic queries without fear

1️⃣ Database & CLI Basics

- psql login
- \l – list databases
- \c database_name – connect database
- \dt – list tables
- \d table_name – describe table
- \q – exit

2️⃣ Data Types

- INT, SERIAL

- VARCHAR, TEXT
- BOOLEAN
- DATE, TIMESTAMP
- FLOAT, NUMERIC

3 Table Operations (DDL)

- CREATE TABLE
- DROP TABLE
- ALTER TABLE
- RENAME TABLE
- ADD COLUMN
- DROP COLUMN

4 Basic CRUD Queries

- INSERT
- SELECT
- UPDATE
- DELETE

5 Filtering Data

- WHERE
- AND, OR, NOT
- Comparison operators: =, !=, >, <, >=, <=
- IN
- BETWEEN
- LIKE
- ILIKE
- IS NULL

6 Sorting & Limiting

- ORDER BY
- ASC, DESC
- LIMIT

- OFFSET

🟠 LEVEL 2 — INTERMEDIATE (REAL BACKEND SQL)

👉 Goal:
✓ Think like a backend developer
✓ Write meaningful business queries

7️⃣ Constraints

- PRIMARY KEY
- FOREIGN KEY
- UNIQUE
- NOT NULL
- DEFAULT
- CHECK

8️⃣ Relationships

- One-to-Many
- REFERENCES
- Foreign key behavior

9️⃣ Joins (VERY IMPORTANT)

- INNER JOIN
- LEFT JOIN
- RIGHT JOIN
- FULL JOIN
- JOIN ... ON

🔟 Aggregate Functions

- COUNT()
- SUM()

- AVG()
- MIN()
- MAX()

1️⃣1️⃣ Grouping Data

- GROUP BY
- HAVING

1️⃣2️⃣ Subqueries

- Subquery in SELECT
- Subquery in WHERE
- IN (SELECT …)

1️⃣3️⃣ Indexes

- CREATE INDEX
- DROP INDEX
- Why indexes exist (performance)

🟤 LEVEL 3 — ADVANCED

👉 Goal:
✓ Handle complex data
✓ Think like DB designer

1️⃣4️⃣ Transactions

- BEGIN
- COMMIT
- ROLLBACK

- ACID properties

1️⃣5️⃣ Views

- CREATE VIEW
- DROP VIEW
- Why views are useful

1️⃣6️⃣ Functions

- Built-in functions
- NOW(), CURRENT_DATE
- String functions
- Date functions

1️⃣7️⃣ Case Statements

- CASE WHEN THEN ELSE END

1️⃣8️⃣ Advanced Joins & Logic

- Self join
- Conditional joins

1️⃣9️⃣ Performance Basics

- Query planning (conceptual)
- When queries are slow

2️⃣0️⃣ Real-World Patterns

- Pagination (LIMIT + OFFSET)
- Soft delete
- Unique email constraint
- Auditing (created_at)

🟢 LEVEL 1 — SQL FOUNDATIONS

🎯 **Goal after this**
You should be able to:

- Sit in psql comfortably
- Create tables without fear
- Insert, read, update, delete data
- Write basic filters confidently
- Understand *what you're doing*, not memorizing

1️⃣ PostgreSQL CLI BASICS

Enter PostgreSQL

```
psql postgres
```

You see:

```
postgres=#
```

That means:

- You are inside PostgreSQL
- Connected to database: postgres

List databases

```
\l
```

Create database

```
CREATE DATABASE college;
```

Connect to database

```
\c college
```

Now prompt becomes:

```
college=#
```

If you see this → ✅ success

List tables (initially empty)

```
\dt
```

Exit psql

```
\q
```

2 DATA TYPES (YOU MUST KNOW THESE)

These decide **what kind of data a column can store**.

Data Type	Meaning	Example
INT	Whole number	21
SERIAL	Auto-increment ID	1, 2, 3
VARCHAR(100)	Short text	name
TEXT	Long text	description

BOOLEAN	true / false	is_active
DATE	Date only	2026-01-22
TIMESTAMP	Date + time	created_at

👉 Don't overthink. We'll use **INT, SERIAL, VARCHAR, BOOLEAN** mostly.

3️⃣ CREATE TABLE (DDL — STRUCTURE)

Create students table

```
CREATE TABLE students (
  id SERIAL PRIMARY KEY,
  name VARCHAR(100),
  age INT,
  email VARCHAR(100)
);
```

📌 Meaning:

- id → auto number (1,2,3…)
- PRIMARY KEY → unique identity
- Columns define **shape of data**

Verify table

```
\dt
```

Describe table

```
\d students
```

4️⃣ INSERT DATA (CREATE ROWS)

Insert one row

```
INSERT INTO students (name, age, email)
VALUES ('Aman', 21, 'aman@gmail.com');
```

Insert multiple rows

```
INSERT INTO students (name, age, email) VALUES
('Riya', 20, 'riya@gmail.com'),
('Kunal', 22, 'kunal@gmail.com'),
('Neha', 19, 'neha@gmail.com');
```

📌 Every row = one student

5️⃣ SELECT DATA (MOST IMPORTANT)

Get everything

```
SELECT * FROM students;
```

Select specific columns

```
SELECT name, email FROM students;
```

Select single row

```
SELECT * FROM students WHERE id = 1;
```

6 WHERE CLAUSE (FILTERING DATA)

Equality

```
SELECT * FROM students WHERE age = 21;
```

Greater / Less

```
SELECT * FROM students WHERE age > 20;
```

AND

```
SELECT * FROM students
WHERE age > 20 AND name = 'Kunal';
```

OR

```
SELECT * FROM students
WHERE age = 19 OR age = 20;
```

NOT

```
SELECT * FROM students WHERE age != 21;
```

IN

```
SELECT * FROM students WHERE age IN (19, 21);
```

BETWEEN

```
SELECT * FROM students WHERE age BETWEEN 20 AND 22;
```

LIKE (pattern search)

```
SELECT * FROM students WHERE name LIKE 'A%';
```

Starts with A

ILIKE (case-insensitive)

```
SELECT * FROM students WHERE email ILIKE '%gmail%';
```

NULL check

```
SELECT * FROM students WHERE email IS NULL;
```

7 ORDER BY (SORTING)

Ascending (default)

```
SELECT * FROM students ORDER BY age;
```

Descending

```
SELECT * FROM students ORDER BY age DESC;
```

Order by name

```
SELECT * FROM students ORDER BY name;
```

8️⃣ LIMIT & OFFSET (PAGINATION BASICS)

First 2 rows

```
SELECT * FROM students LIMIT 2;
```

Skip first row, get next 2

```
SELECT * FROM students LIMIT 2 OFFSET 1;
```

📌 Used in pagination in backend APIs

9️⃣ UPDATE DATA

Update one row

```
UPDATE students
SET age = 23
WHERE name = 'Kunal';
```

⚠️ **ALWAYS use WHERE**
Without WHERE → all rows update ❌

Verify

```
SELECT * FROM students;
```

🔟 DELETE DATA

Delete one row

```
DELETE FROM students WHERE name = 'Neha';
```

Delete all rows (danger)

```
DELETE FROM students;
```

1️⃣1️⃣ DROP TABLE (DANGEROUS)

```
DROP TABLE students;
```

Deletes structure + data permanently.

☑ LEVEL 1 — FINAL CHECKLIST (ALL DONE)

✓ PostgreSQL CLI
✓ CREATE DATABASE
✓ CREATE TABLE
✓ INSERT
✓ SELECT

✓ WHERE
✓ AND / OR / NOT
✓ IN / BETWEEN
✓ LIKE / ILIKE
✓ ORDER BY
✓ LIMIT / OFFSET
✓ UPDATE
✓ DELETE

🔵 Level 2: SQL INTERMEDIATE LEVEL

🔵 PART 1 — CONSTRAINTS & DATA INTEGRITY

🧠 CONCEPT (VERY SIMPLE)

Constraint = Rule

Database says:

“I will not allow bad data.”

Just like:

- Exam hall rules
- College ID rules

◇ 1. NOT NULL

❓ Why?

Some data is **mandatory**.

Example:

Student **must** have a name.

Create table

```
CREATE TABLE students (
  id SERIAL PRIMARY KEY,
  name VARCHAR(100) NOT NULL,
  age INT,
  email VARCHAR(100)
);
```

Try inserting NULL

```
INSERT INTO students (age, email)
VALUES (20, 'test@gmail.com');
```

❌ Error → GOOD (database saved you)

◇ 2. UNIQUE

❓ Why?

Email should not repeat.

Example

```
CREATE TABLE users (
  id SERIAL PRIMARY KEY,
  email VARCHAR(100) UNIQUE,
  password TEXT
);
```

Test

```
INSERT INTO users (email, password)
VALUES ('a@gmail.com', '123');

INSERT INTO users (email, password)
VALUES ('a@gmail.com', '456');
```

❌ Duplicate blocked

◇ 3. DEFAULT

❓ Why?

If user doesn't give value → database sets it.

Example

```
CREATE TABLE students (
  id SERIAL PRIMARY KEY,
  name VARCHAR(100),
  is_active BOOLEAN DEFAULT true
);
```

Insert:

```
INSERT INTO students (name)
VALUES ('Riya');
```

is_active → true automatically

◇ 4. CHECK

❓ Why?

Ensure logical values.

Example:

Age cannot be negative.

```
CREATE TABLE students (
  id SERIAL PRIMARY KEY,
  name VARCHAR(100),
  age INT CHECK (age >= 0)
);
```

Try:

```
INSERT INTO students (name, age)
VALUES ('Test', -5);
```

❌ Rejected

◇ 5. PRIMARY KEY (Quick Reminder)

- Unique
- Not NULL
- Identifies row

```
id SERIAL PRIMARY KEY
```

◇ 6. FOREIGN KEY (EASY EXPLANATION)

🧠 Story

- One **Department**
- Many **Students**

Student belongs to **one department**.

Create departments

```
CREATE TABLE departments (

id SERIAL PRIMARY KEY,
   dept_name VARCHAR(100)
);
```

Insert:

```
INSERT INTO departments (dept_name)
VALUES ('CSE'), ('ECE');
```

Create students with department_id

```
CREATE TABLE college_students (
   id SERIAL PRIMARY KEY,
   name VARCHAR(100),
   department_id INT REFERENCES departments(id)
);
```

📌 Meaning:

- department_id must exist in departments table

- No invalid department allowed

Try invalid insert

```
INSERT INTO college_students (name, department_id)
VALUES ('Aman', 99);
```

❌ Blocked → database protecting data

📝 MINI CHEAT SHEET — PART 1

Constraint	Purpose
NOT NULL	Value required
UNIQUE	No duplicates
DEFAULT	Auto value
CHECK	Condition
PRIMARY KEY	Row identity
FOREIGN KEY	Table relation

🟢 PART 2 — AGGREGATE FUNCTIONS

This is where SQL stops being "just data storage"
and starts becoming **analytics + reporting**.

🧠 MENTAL MODEL

Think like this 👇

👉 **Rows = raw data**
👉 **Aggregate functions = summary of data**

Example:

- 100 students →
- “How many students?”
- “Average age?”
- “Youngest student?”

That’s **aggregate functions**.

◇ WHAT ARE AGGREGATE FUNCTIONS?

Aggregate functions:

- Take **many rows**
- Return **ONE value**

🔘 AGGREGATE FUNCTIONS WE WILL COVER

Function	Meaning
COUNT	How many rows
SUM	Total
AVG	Average
MIN	Smallest value
MAX	Largest value

🔧 SETUP (USE THIS TABLE)

Make sure you have a table like this 👇

```
CREATE TABLE students (
  id SERIAL PRIMARY KEY,
  name VARCHAR(100),
  age INT,
  department VARCHAR(50)
);
```

Insert data:

```
INSERT INTO students (name, age, department) VALUES
('Aman', 21, 'CSE'),
('Riya', 22, 'CSE'),
('Kunal', 20, 'ECE'),
('Neha', 19, 'ECE'),
('Rahul', 23, 'CSE');
```

◇ 1. COUNT()

❓ What does COUNT do?

Counts **number of rows**

Count all students

```
SELECT COUNT(*) FROM students;
```

✓ Output: total students

Count students with age

```
SELECT COUNT(age) FROM students;
```

📌 Ignores NULL values

Count CSE students

```
SELECT COUNT(*)
FROM students
WHERE department = 'CSE';
```

◇ 2. SUM()

❓ What does SUM do?

Adds numeric values

Total age of all students

```
SELECT SUM(age) FROM students;
```

Total age of CSE students

```
SELECT SUM(age)
FROM students
WHERE department = 'CSE';
```

📌 Only works on **numbers**

◇ 3. AVG()

❓ What does AVG do?

Average (mean)

Average age of students

```
SELECT AVG(age) FROM students;
```

📌 Result is **decimal**

Average age of ECE students

```
SELECT AVG(age)
FROM students
WHERE department = 'ECE';
```

◇ 4. MIN()

❓ What does MIN do?

Finds smallest value

Youngest student age

```
SELECT MIN(age) FROM students;
```

Youngest CSE student

```
SELECT MIN(age)
FROM students
WHERE department = 'CSE';
```

◇ 5. MAX()

❓ What does MAX do?

Finds largest value

Oldest student

```
SELECT MAX(age) FROM students;
```

Oldest ECE student

```
SELECT MAX(age)
FROM students
WHERE department = 'ECE';
```

🧠 IMPORTANT RULES

❗ Aggregate functions:

- Return **one row**
- Ignore NULL values (except COUNT*)

🧪 PRACTICE QUESTIONS (DO THESE)

Try without looking 👇

1️⃣ Total number of students
2️⃣ Average age of all students
3️⃣ Count students in ECE
4️⃣ Youngest student age
5️⃣ Oldest student in CSE

(Answer using COUNT, AVG, MIN, MAX)

📓 MINI CHEAT SHEET — PART 2

Function	Example
COUNT	COUNT(*)
SUM	SUM(age)
AVG	AVG(age)
MIN	MIN(age)
MAX	MAX(age)

🔥 WHY THIS MATTERS

These are used in:

- Dashboards
- Reports
- Analytics
- Admin panels
- Business decisions

🟠 PART 3 — GROUP BY + HAVING

🧠 MENTAL MODEL

Think like this 👇

- **WHERE** → filters **rows**
- **GROUP BY** → creates **groups**
- **AGGREGATE FUNCTIONS** → summarize **each group**
- **HAVING** → filters **groups**

📌 **HAVING = WHERE for groups**

🔧 SAME TABLE (IMPORTANT)

We'll use the same students table:

```
SELECT * FROM students;
```

id	name	age	department
1	Aman	21	CSE
2	Riya	22	CSE
3	Kunal	20	ECE
4	Neha	19	ECE
5	Rahul	23	CSE

◇ 1. GROUP BY (BASICS)

❓ What does GROUP BY do?

It **groups rows** that have the **same value**

Example: Count students per department

```
SELECT department, COUNT(*)
FROM students
GROUP BY department;
```

Output:

department	count
CSE	3
ECE	2

✓ One row **per department**

🧠 RULE

If you use GROUP BY:

👉 **Every selected column must be**

- Either in GROUP BY
- Or inside an aggregate function

❌ WRONG:

```
SELECT name, COUNT(*)
FROM students
GROUP BY department;
```

✓ RIGHT:

```
SELECT department, COUNT(*)
FROM students
GROUP BY department;
```

◇ 2. GROUP BY + AVG()

Average age per department

```
SELECT department, AVG(age)
FROM students
GROUP BY department;
```

◇ 3. GROUP BY + MIN / MAX

Youngest student in each department

```
SELECT department, MIN(age)
FROM students
GROUP BY department;
```

Oldest student in each department

```
SELECT department, MAX(age)
FROM students
GROUP BY department;
```

◇ 4. WHERE + GROUP BY (ORDER MATTERS)

Count students older than 20 per department

```
SELECT department, COUNT(*)
FROM students
WHERE age > 20
GROUP BY department;
```

📌 WHERE filters rows **before grouping**

◇ 5. HAVING (MOST CONFUSING PART)

❓ Why HAVING?

Because WHERE **cannot use aggregate functions**

❌ WRONG:

```
SELECT department, COUNT(*)

FROM students
WHERE COUNT(*) > 2
GROUP BY department;
```

✓ RIGHT:

```
SELECT department, COUNT(*)
FROM students
GROUP BY department
HAVING COUNT(*) > 2;
```

Output:

department	count
CSE	3

◇ 6. WHERE vs HAVING (CLEAR DIFFERENCE)

WHERE	HAVING
Filters rows	Filters groups

Used before GROUP BY	Used after GROUP BY
Cannot use COUNT, AVG	Uses aggregate functions

◇ 7. Combined Example (REAL LIFE)

Departments with average age > 21

```
SELECT department, AVG(age)
FROM students
GROUP BY department
HAVING AVG(age) > 21;
```

🧪 PRACTICE QUESTIONS (IMPORTANT)

Try these 👇

1️⃣ Count students per department
2️⃣ Average age per department
3️⃣ Departments with more than 2 students
4️⃣ Departments where average age > 20
5️⃣ Count students older than 21 per department

📓 MINI CHEAT SHEET — PART 3

```
SELECT column, AGG_FUNC(column)
FROM table
WHERE condition
GROUP BY column
HAVING AGG_FUNC(column) condition;
```

🔥 COMMON INTERVIEW QUESTION

❓ Difference between WHERE and HAVING?

✅ Answer:

- WHERE filters rows before grouping
- HAVING filters groups after aggregation

🟢 PART 4 — JOINS

🧠 MENTAL MODEL

Think like this 👇

- Tables are **separate**
- JOINS are used to **connect tables**
- They connect using a **common column (usually FK → PK)**

📌 **No JOIN = isolated data**
📌 **JOIN = meaningful data**

🧱 TABLE SETUP (USE THIS)

departments

SELECT * FROM departments;

id	dept_name
1	CSE
2	ECE

students

```
SELECT * FROM students;
```

id	name	age	department_id
1	Aman	21	1
2	Riya	22	1
3	Kunal	20	2
4	Neha	19	2
5	Rahul	23	1

◇ 1. INNER JOIN (MOST USED)

❓ What is INNER JOIN?

✓ Returns rows **only when match exists in both tables**

Example: Student name + Department name

```
SELECT students.name, departments.dept_name
FROM students
INNER JOIN departments
ON students.department_id = departments.id;
```

Output:

name	dept_name
Aman	CSE
Riya	CSE
Rahul	CSE
Kunal	ECE
Neha	ECE

🧠 VISUAL

```
students ∩ departments
```

Only common records.

◇ 2. LEFT JOIN

❓ What is LEFT JOIN?

✓ All rows from **left table**
✓ Matching rows from right table
✓ Non-matching → NULL

Example: All students even if no department

```
SELECT students.name, departments.dept_name
FROM students
LEFT JOIN departments
ON students.department_id = departments.id;
```

If a student has no department → dept_name = NULL

◇ 3. RIGHT JOIN

❓ What is RIGHT JOIN?

✓ All rows from **right table**
✓ Matching rows from left table

```
SELECT students.name, departments.dept_name
FROM students
RIGHT JOIN departments
ON students.department_id = departments.id;
```

📌 Rarely used (LEFT JOIN preferred)

◇ 4. FULL OUTER JOIN

❓ What is FULL JOIN?

✓ All rows from both tables

✓ Matching + non-matching

```
SELECT students.name, departments.dept_name
FROM students
FULL OUTER JOIN departments
ON students.department_id = departments.id;
```

NULL appears where no match exists.

◇ 5. JOIN + WHERE

Students from CSE only

```
SELECT students.name
FROM students
JOIN departments
ON students.department_id = departments.id
WHERE departments.dept_name = 'CSE';
```

◇ 6. JOIN + GROUP BY (REAL LIFE)

Count students per department

```
SELECT departments.dept_name, COUNT(students.id)
FROM departments
LEFT JOIN students
ON students.department_id = departments.id
GROUP BY departments.dept_name;
```

✓ Even departments with **zero students appear**

◇ 7. ALIAS (MAKE QUERIES CLEAN)

```
SELECT s.name, d.dept_name
FROM students s
JOIN departments d
ON s.department_id = d.id;
```

📌 Always use aliases in real projects

🧪 PRACTICE QUESTIONS

1. List student names with department names
2. Find students in ECE department
3. Count students per department
4. Show departments even if no students
5. Find students without a department

📓 MINI CHEAT SHEET — PART 4

```
-- INNER JOIN
FROM A
JOIN B ON A.col = B.col

-- LEFT JOIN
FROM A
LEFT JOIN B ON A.col = B.col

-- RIGHT JOIN
FROM A
RIGHT JOIN B ON A.col = B.col

-- FULL JOIN
FROM A
FULL JOIN B ON A.col = B.col
```

🔥 COMMON INTERVIEW QUESTION

❓ Difference between INNER JOIN and LEFT JOIN?

✅ Answer:

- INNER → only matching rows
- LEFT → all left + matching right

🟠 PART 5 — SUBQUERIES & NESTED QUERIES

🧠 FIRST: WHAT IS A SUBQUERY?

Simple definition:

👉 **A query inside another query**

```
SELECT *
FROM students
WHERE age > (
  SELECT AVG(age) FROM students
);
```

📌 Inner query runs **first**

📌 Outer query uses its result

🧠 REAL-LIFE ANALOGY

"Show students older than the **average age**"

You first calculate average → then compare

◇ 1. SUBQUERY IN WHERE

Example: Students older than average age

```
SELECT name, age
FROM students
WHERE age > (
  SELECT AVG(age)
  FROM students
);
```

Example: Students from CSE department

```
SELECT name
FROM students
WHERE department_id = (
  SELECT id
  FROM departments
  WHERE dept_name = 'CSE'
);
```

✓ Very common

✓ Clean logic

◇ 2. SUBQUERY WITH IN

❓ When to use IN?

✓ When subquery returns **multiple rows**

Example: Students in CSE or ECE

```
SELECT name
FROM students
WHERE department_id IN (
  SELECT id
  FROM departments
);
```

Example: Students older than any 22-year-old

```
SELECT name, age
FROM students
WHERE age > ANY (
  SELECT age
```

```
  FROM students
  WHERE age = 22
);
```

◇ 3. SUBQUERY IN SELECT (CALCULATED COLUMN)

Example: Show average age with every student

```
SELECT name, age,
    (SELECT AVG(age) FROM students) AS avg_age
FROM students;
```

📌 Subquery runs once

📌 Result reused

◇ 4. SUBQUERY IN FROM (DERIVED TABLE)

Example: Find students older than 20

```
SELECT *
FROM (
  SELECT name, age
  FROM students
  WHERE age > 20
) AS temp;
```

📌 Subquery behaves like a **temporary table**

◇ 5. EXISTS (VERY IMPORTANT)

❓ What is EXISTS?

✓ Checks **presence**, not value

✓ Faster than IN in large tables

Example: Students with valid department

```
SELECT name
FROM students s
WHERE EXISTS (
   SELECT 1
   FROM departments d
   WHERE d.id = s.department_id
);
```

Example: Departments having students

```
SELECT dept_name
FROM departments d
WHERE EXISTS (
   SELECT 1
   FROM students s
   WHERE s.department_id = d.id
);
```

◇ 6. NOT EXISTS

Departments with NO students

```
SELECT dept_name
FROM departments d
WHERE NOT EXISTS (
   SELECT 1
   FROM students s
   WHERE s.department_id = d.id
);
```

◇ 7. CORRELATED SUBQUERY (ADVANCED INTERMEDIATE)

? What is correlated?

✓ Inner query depends on outer query

✓ Runs **for each row**

Example: Students older than department average

```
SELECT name, age
FROM students s
WHERE age > (
   SELECT AVG(age)
   FROM students
   WHERE department_id = s.department_id
);
```

📌 Powerful
📌 Slower if misused

📏 PRACTICE QUESTIONS

1️⃣ Find students older than average
2️⃣ Departments having more than 2 students
3️⃣ Students belonging to CSE using subquery
4️⃣ Students without department
5️⃣ Students older than their department average

📝 MINI CHEAT SHEET — PART 5

```
-- Single value
WHERE col = (SELECT ...)

-- Multiple values
WHERE col IN (SELECT ...)

-- Check existence
WHERE EXISTS (SELECT 1 ...)

-- Derived table
FROM (SELECT ...) AS alias

-- Correlated
WHERE col > (SELECT ... WHERE t.col = outer.col)
```

🔥 VERY IMPORTANT INTERVIEW TIP

❓ IN vs EXISTS?

✅ Answer:

- IN → compares values
- EXISTS → checks row existence
- EXISTS is faster for large datasets

🟢 PART 6 — INDEXES & PERFORMANCE BASICS

Goal:
Understand **why queries become slow** and **how indexes fix them**

🧠 FIRST: WHY DATABASES BECOME SLOW

Imagine this table:

students (1 million rows)

Query:

```
SELECT * FROM students WHERE email = 'abc@gmail.com';
```

Without index 👇
❌ PostgreSQL checks **every row** (full table scan)

With index 👇
✅ PostgreSQL jumps directly to the row

◇ 1. WHAT IS AN INDEX?

Simple definition:

👉 **An index is like a book's index**

- Table = Book
- Rows = Pages
- Index = Alphabetical index

📌 Faster reads
📌 Slightly slower writes

◇ 2. CREATE INDEX

Index on email

```
CREATE INDEX idx_students_email
ON students(email);
```

Now this becomes fast:

```
SELECT * FROM students WHERE email = 'aman@gmail.com';
```

◇ 3. UNIQUE INDEX

Prevent duplicate values

```
CREATE UNIQUE INDEX idx_students_email_unique
ON students(email);
```

❌ Duplicate emails now fail

◇ 4. WHEN TO USE INDEX (VERY IMPORTANT)

Good candidates:

✓ WHERE
✓ JOIN
✓ ORDER BY
✓ GROUP BY

Bad candidates:

❌ Small tables
❌ Columns with few unique values (gender, status)

◇ 5. MULTI-COLUMN INDEX

Query example:

```
SELECT *
FROM students
WHERE department_id = 1 AND age = 21;
```

Index:

```
CREATE INDEX idx_students_dept_age
ON students(department_id, age);
```

📌 Order matters!

◇ 6. INDEX ORDER MATTERS

Index:

(department_id, age)

✓ Works:

```
WHERE department_id = 1
WHERE department_id = 1 AND age = 21
```

❌ Does NOT work:

WHERE age = 21

◇ 7. DROP INDEX

```
DROP INDEX idx_students_email;
```

◇ 8. CHECK QUERY PERFORMANCE (INTRO)

Explain query plan

```
EXPLAIN SELECT * FROM students WHERE email = 'aman@gmail.com';
```

With index:

Index Scan using idx_students_email

Without index:

Seq Scan on students

📌 Seq Scan = Slow for big tables
📌 Index Scan = Fast

◇ 9. EXPLAIN ANALYZE (REAL EXECUTION)

EXPLAIN ANALYZE

```
SELECT * FROM students WHERE email = 'aman@gmail.com';
```

Shows:
✓ Time taken
✓ Rows scanned
✓ Index used or not

◇ 10. FOREIGN KEY & INDEX (IMPORTANT)

Foreign keys should be indexed!

```
CREATE INDEX idx_students_dept
ON students(department_id);
```

Why?

- JOINs become fast
- Deletes/updates safer

🧪 PRACTICE TASKS

1️⃣ Create index on email
2️⃣ Create composite index on (department_id, age)
3️⃣ Run EXPLAIN before & after index
4️⃣ Drop index and observe plan
5️⃣ Add index to foreign key column

📓 MINI CHEAT SHEET — PART 6

```
CREATE INDEX idx_name ON table(col);
CREATE UNIQUE INDEX idx_name ON table(col);
CREATE INDEX idx_name ON table(col1, col2);

DROP INDEX idx_name;

EXPLAIN SELECT ...
EXPLAIN ANALYZE SELECT ...
```

🔥 INTERVIEW GOLD ANSWER

❓ Why not index everything?

✅ Answer:

Indexes speed up reads but slow down inserts/updates and consume memory.

🎯 WHERE YOU STAND NOW

You can now:
✓ Write optimized SQL
✓ Understand slow queries
✓ Read execution plans
✓ Design better schemas

🔴 PART 7 — TRANSACTIONS (ACID IN ACTION)

1️⃣ What is a Transaction?

A **transaction** is a **group of SQL operations that must all succeed together**.

👉 Either **everything happens**
👉 Or **nothing happens**

There is **NO half-done state**.

2️⃣ Real-World Example (Bank 💳)

You transfer **₹1000** from **Account A → Account B**

Steps involved:

1. Subtract ₹1000 from A
2. Add ₹1000 to B

❓ What if step 1 succeeds but step 2 fails?
👉 **Money disappears** 😱

💡 **Transactions prevent this.**

3️⃣ ACID Properties (Very Important)

◇ A — Atomicity

All or nothing

If one step fails → everything rolls back.

◇ C — Consistency

Database rules are never broken

Balances can’t go negative (if rule exists).

◇ I — Isolation

Multiple users don’t disturb each other

Two people transferring money at the same time won’t mess balances.

◇ D — Durability

Once committed, data is permanent

Even if the server crashes → data stays.

4️⃣ SQL Commands for Transactions

◇ BEGIN

Start a transaction

◇ COMMIT

Save everything permanently

◇ ROLLBACK

Undo everything

5️⃣ Hands-On Practice (DO THIS IN psql)

Step 1: Create table

```
CREATE TABLE accounts (
  id SERIAL PRIMARY KEY,
  name VARCHAR(50),
  balance INT
);
```

Step 2: Insert data

```
INSERT INTO accounts (name, balance)
VALUES ('Aman', 5000), ('Riya', 3000);
```

Check:

```
SELECT * FROM accounts;
```

6️⃣ Transaction Example (Correct Way)

Transfer ₹1000 from Aman → Riya

```
BEGIN;

UPDATE accounts
SET balance = balance - 1000
WHERE name = 'Aman';

UPDATE accounts
SET balance = balance + 1000
WHERE name = 'Riya';

COMMIT;
```

✅ Both updates succeed
✅ Money is safe

7️⃣ What If Something Goes Wrong?

Example: Mistake happens

```
BEGIN;

UPDATE accounts
SET balance = balance - 1000
WHERE name = 'Aman';

-- Oops! Wrong table / error
UPDATE accountsss
SET balance = balance + 1000
WHERE name = 'Riya';
```

```
ROLLBACK;
```

Result:

✓ Aman’s balance restored
✓ No money lost

8️⃣ WITHOUT Transactions (DANGEROUS ❌)

```
UPDATE accounts
SET balance = balance - 1000
WHERE name = 'Aman';

-- crash happens here 😱
```

❌ Aman lost money
❌ Riya didn’t receive
❌ Database corrupted logically

9️⃣ Where Transactions Are USED (REAL LIFE)

✓ Banking systems
✓ Payments (UPI, cards)
✓ E-commerce orders
✓ Ticket booking
✓ Wallet systems
✓ Stock trading

🚀 MINI CHEAT SHEET (SAVE THIS)

```
BEGIN;      -- start transaction
COMMIT;     -- save changes
ROLLBACK;   -- undo changes
```

Rule:

Multiple dependent queries → ALWAYS use transactions

🟢 PART 8 — VIEWS (VIRTUAL TABLES)

1️⃣ What is a VIEW?

A **VIEW** is a **saved SELECT query**.

💡 Think of it as:

A **window** to see data
NOT a real table
NO data stored separately

Simple analogy 🧩

- **Table** → Actual data stored
- **View** → Filtered / formatted way to look at that data

2️⃣ Why Do We Need Views?

Without view ❌

You write long queries again and again:

```
SELECT name, email
FROM students
WHERE age > 18
ORDER BY name;
```

With view ☑

Write once → reuse forever

3️⃣ Create a Sample Table

```
CREATE TABLE students (
  id SERIAL PRIMARY KEY,
  name VARCHAR(50),
  age INT,
  email VARCHAR(100)
);
```

Insert data:

```
INSERT INTO students (name, age, email)
VALUES
('Aman', 21, 'aman@gmail.com'),
('Riya', 19, 'riya@gmail.com'),
('Neha', 17, 'neha@gmail.com');
```

4️⃣ CREATE VIEW (Core Concept)

Create a view of adult students

```
CREATE VIEW adult_students AS
SELECT name, age, email
```

```
FROM students
WHERE age >= 18;
```

✅ View created
❌ No new table created
❌ No data duplicated

5️⃣ Use the View (Like a Table)

```
SELECT * FROM adult_students;
```

Output:

👉 Looks like a table
👉 Acts like a table
👉 But is NOT a table

6️⃣ Update Data Through View (IMPORTANT)

Can we INSERT/UPDATE using views?

☑️ YES — if view is SIMPLE

This works:

```
UPDATE adult_students
SET age = 20
WHERE name = 'Riya';
```

Because:

✓ Single table

✓ No joins

✓ No group by

❌ NOT allowed in complex views

Example (not updatable):

```
CREATE VIEW student_count AS
SELECT age, COUNT(*)
FROM students
GROUP BY age;
```

Why ❌?

- Aggregation
- Grouping
- PostgreSQL doesn't know which row to update

7️⃣ Why Companies Use Views (REAL WORLD)

◇ Security 🔐

Hide sensitive columns

```
CREATE VIEW public_students AS
SELECT name, age
FROM students;
```

Users can’t see emails/passwords.

◇ Simplicity 🧠

Frontend developers use views instead of writing joins.

◇ Consistency 📏

Everyone uses the same logic → no mistakes.

8️⃣ Read-Only vs Updatable Views

Type	Description
Read-only	Uses joins, group by, aggregate
Updatable	Single table, simple SELECT

9️⃣ DROP VIEW

```
DROP VIEW adult_students;
```

🚀 MINI CHEAT SHEET

```
CREATE VIEW view_name AS SELECT ...
SELECT * FROM view_name
DROP VIEW view_name
```

Rule:

Views store **queries**, not **data**

🟢 PART 9 — CONSTRAINTS IN REAL SYSTEMS

We'll focus on:

✓ ON DELETE CASCADE
✓ ON UPDATE CASCADE
✓ RESTRICT
✓ Why companies care

1️⃣ First: What is a Constraint? (Simple)

A **constraint** is a **rule** that protects your data.

💡 Think:

"Database police 👮 "

2️⃣ Base Tables (We'll Reuse This Everywhere)

Departments table (Parent)

```
CREATE TABLE departments (
   id SERIAL PRIMARY KEY,
   dept_name VARCHAR(50)
);
```

Insert:

```
INSERT INTO departments (dept_name)
VALUES ('CSE'), ('ECE');
```

Students table (Child)

```
CREATE TABLE students (
  id SERIAL PRIMARY KEY,
  name VARCHAR(50),
  department_id INT REFERENCES departments(id)
);
```

Insert students:

```
INSERT INTO students (name, department_id)
VALUES
('Aman', 1),
('Riya', 1),
('Neha', 2);
```

3️⃣ Problem Without Rules (WHY constraints exist)

If we delete a department:

```
DELETE FROM departments WHERE id = 1;
```

❌ What about students of CSE?

- They still exist
- But their department doesn't
- **Broken data**

This is called:

👉 **Orphan records**

4️⃣ ON DELETE CASCADE 🔥

Meaning:

“If parent is deleted → delete children automatically”

Create tables with CASCADE

```
CREATE TABLE students (
  id SERIAL PRIMARY KEY,
  name VARCHAR(50),
  department_id INT
  REFERENCES departments(id)
  ON DELETE CASCADE
);
```

What happens now?

```
DELETE FROM departments WHERE id = 1;
```

✓ Department CSE deleted

✓ All CSE students deleted automatically

💡 PostgreSQL does the cleanup for you

5️⃣ ON UPDATE CASCADE

Meaning:

“If parent key changes → update child automatically”

Example (rare but important):

```
REFERENCES departments(id)
ON UPDATE CASCADE
```

If department ID changes:

```
UPDATE departments SET id = 10 WHERE id = 2;
```

✓ Students' department_id updates automatically

6 RESTRICT (Strict Mode 🚫)

Meaning:

"Don't allow delete/update if children exist"

Example:

```
REFERENCES departments(id)
ON DELETE RESTRICT
```

Now:

```
DELETE FROM departments WHERE id = 2;
```

❌ ERROR:

cannot delete department — students exist

✓ Forces admin to handle students first

7️⃣ Comparison Table (VERY IMPORTANT)

Rule	What it does
CASCADE	Auto delete/update child
RESTRICT	Block delete/update
NO ACTION	Similar to RESTRICT
SET NULL	Set FK to NULL

8️⃣ Real-World Usage 🏢

Banking

- Delete account → delete transactions? ❌
- Use **RESTRICT**

E-commerce

- Delete order → delete order_items ✅
- Use **CASCADE**

College System

- Delete department → delete students? ❌
- Usually **RESTRICT**

9️⃣ When to Use What?

Situation	Best choice
Temporary child data	CASCADE

Critical historical data	RESTRICT
Optional relation	SET NULL

🚀 MINI CHEAT SHEET

```
REFERENCES table(id)
ON DELETE CASCADE
ON UPDATE CASCADE

ON DELETE RESTRICT
```

🟢 PART 10 — CASE & CONDITIONAL LOGIC (SQL IF–ELSE)

Think of **CASE** as:

SQL's **decision-making tool**

Just like:

```
if condition:
   do this
else:
   do that
```

1️⃣ Why CASE Exists (Intuition First)

SQL can:

- Store data

- Filter data

But SQL **cannot think** unless we use **CASE**.

CASE allows SQL to:

- Categorize data
- Assign labels
- Apply business rules
- Make decisions per row

2 Basic CASE Syntax (Must Memorize)

```
CASE
  WHEN condition THEN result
  WHEN condition THEN result
  ELSE result
END
```

✓ Evaluated **row by row**
✓ Returns **one value**

3 Sample Table (Mental Model)

students

id	name	age	marks
1	Aman	21	85
2	Riya	17	92
3	Neha	19	55

4️⃣ CASE in SELECT (Most Common)

Example: Adult or Minor

```
SELECT name, age,
CASE
  WHEN age >= 18 THEN 'Adult'
  ELSE 'Minor'
END AS status
FROM students;
```

Output:

name	age	status
Aman	21	Adult
Riya	17	Minor
Neha	19	Adult

✓ No table modification

✓ Dynamic column

5️⃣ Multiple Conditions (Grades Example 🎓)

```
SELECT name, marks,
CASE
  WHEN marks >= 90 THEN 'A'
  WHEN marks >= 75 THEN 'B'
  WHEN marks >= 60 THEN 'C'
  ELSE 'Fail'
END AS grade
FROM students;
```

📌 **Important rule**

SQL checks **top to bottom**, first match wins.

6️⃣ CASE in UPDATE (Real Systems Use This 🔥)

Scenario:

Give scholarship based on marks.

ALTER TABLE students ADD COLUMN scholarship VARCHAR(10);

```
UPDATE students
SET scholarship =
CASE
  WHEN marks >= 80 THEN 'YES'
  ELSE 'NO'
END;
```

✓ Updates all rows in one query

✓ Used heavily in production systems

7️⃣ CASE in ORDER BY (Very Powerful)

Example: Adults first, minors later

```
SELECT name, age
FROM students
ORDER BY
CASE
  WHEN age >= 18 THEN 1
  ELSE 2
END;
```

✓ Custom sorting logic

✓ Frequently asked in interviews

8️⃣ CASE in WHERE (Rare but Valid)

```
SELECT *
FROM students
WHERE
CASE
  WHEN marks >= 60 THEN true
  ELSE false
END;
```

⚠ Usually better to use normal WHERE
CASE shines most in **SELECT & UPDATE**

9️⃣ Real-World Applications 🌍

Area	Use
Reports	Pass/Fail, Grades
Dashboards	Status labels
APIs	Flags & categories
Analytics	Bucketing data
Finance	Risk levels

🚀 MINI CHEAT SHEET (Save This)

```
CASE
  WHEN condition THEN value
```

```
 ELSE value
END
```

Can be used in:

- ✅ SELECT
- ✅ UPDATE
- ✅ ORDER BY
- ⚠ WHERE

🟢 LEVEL 3 — ADVANCED SQL

📌 LEVEL 3 ROADMAP (What we'll cover)

🟢 PART 1 — Subqueries (Nested Queries)

- Subquery in WHERE
- Subquery in SELECT
- Subquery in FROM
- Correlated subqueries

🟢 PART 2 — Common Table Expressions (CTEs)

- WITH clause
- Why CTEs > subqueries
- Multiple CTEs
- Recursive CTE (intro)

🟢 PART 3 — Window Functions (MOST IMPORTANT 🔥)

- OVER()
- ROW_NUMBER
- RANK, DENSE_RANK
- SUM() OVER

- PARTITION BY
- ORDER BY in windows

🟤 PART 4 — Indexes & Performance

- What indexes really are
- When indexes help
- When indexes hurt
- EXPLAIN

🟤 PART 5 — Advanced Joins & Data Analysis

- Self join
- Anti join
- Semi join
- Finding duplicates
- Gaps & islands problems

🟤 PART 6 — Real Interview & Production Patterns

- Nth highest salary
- Top-N per group
- Running totals
- Time-based queries

🚨 VERY IMPORTANT NOTE

Level 3 concepts:

- Are **heavily tested in interviews**
- Are used **daily by backend engineers**
- Separate juniors from strong developers

🟢 PART 1 — SUBQUERIES (START HERE)

1️⃣ What is a Subquery? (Easy words)

A **subquery** is:

A query inside another query

Think like:

“First find something → then use it”

2️⃣ Basic Subquery Example

Question:

Find students who scored **more than average marks**

```
SELECT *
FROM students
WHERE marks > (
  SELECT AVG(marks)
  FROM students
);
```

📌 Execution order:

1. Inner query runs first → average marks
2. Outer query uses that value

3️⃣ Subquery in SELECT

```
SELECT name,
    (SELECT AVG(marks) FROM students) AS avg_marks
FROM students;
```

✓ Same value shown for every row

✓ Useful for reports

4️⃣ Subquery in FROM (Derived Table)

```
SELECT *
FROM (
  SELECT name, marks
  FROM students
  WHERE marks >= 60
) AS passed_students;
```

📌 Inner query behaves like a **temporary table**

5️⃣ Correlated Subquery (Important 🔥)

Runs **once per row**

Example:

Students who scored more than **their department average**

```
SELECT s1.*
FROM students s1
WHERE marks > (
  SELECT AVG(s2.marks)
```

```
  FROM students s2
  WHERE s2.department_id = s1.department_id
);
```

📌 Used in analytics & business logic

📌 Slower than joins (important later)

🚀 PART 1 MINI CHEAT SHEET

```
-- WHERE
WHERE column > (SELECT ...)

-- SELECT
SELECT col, (SELECT ...)

-- FROM
FROM (SELECT ...) alias
```

🟢 PART 2 — CTEs (Common Table Expressions)

1️⃣ What is a CTE? (Very simple words)

A **CTE** is:

A named temporary result that exists **only for one query**

Think of it as:

“Create a readable temporary table → use it below”

📌 Syntax keyword: WITH

2️⃣ Why CTEs exist (Problem they solve)

❌ Without CTE (ugly subquery)

```
SELECT *
FROM (
  SELECT department_id, AVG(marks) AS avg_marks
  FROM students
  GROUP BY department_id
) t
WHERE avg_marks > 70;
```

Hard to read ❌

☑️ With CTE (clean & readable)

```
WITH dept_avg AS (
  SELECT department_id, AVG(marks) AS avg_marks
  FROM students
  GROUP BY department_id
)
SELECT *
FROM dept_avg
WHERE avg_marks > 70;
```

✓ Clear
✓ Reusable
✓ Interview-friendly

3️⃣ CTE vs Subquery (Important)

Feature	Subquery	CTE

Readability	❌ Hard	✅ Clean
Reusability	❌ No	✅ Yes
Debugging	❌ Pain	✅ Easy
Complex logic	❌ Messy	✅ Best

📌 **Rule**:

If query is more than 1 subquery → use CTE

4️⃣ Multiple CTEs in one query

```
WITH dept_avg AS (
   SELECT department_id, AVG(marks) AS avg_marks
   FROM students
   GROUP BY department_id
),
top_students AS (
   SELECT *
   FROM students
   WHERE marks > 80
)
SELECT t.name, d.avg_marks
FROM top_students t
JOIN dept_avg d
ON t.department_id = d.department_id;
```

📌 Each CTE builds on logic

📌 Used heavily in analytics

5️⃣ CTE with INSERT / UPDATE / DELETE

Insert using CTE

```
WITH new_students AS (
   SELECT 'Rahul' AS name, 20 AS age
)
INSERT INTO students (name, age)
SELECT name, age FROM new_students;
```

Update using CTE

```
WITH low_scorers AS (
   SELECT id FROM students WHERE marks < 40
)
UPDATE students
SET status = 'FAIL'
WHERE id IN (SELECT id FROM low_scorers);
```

6️⃣ Recursive CTE (Intro — Powerful 🔥)

Used for:

- Trees
- Hierarchies
- Org charts
- Folder structures

Example: Employee → Manager hierarchy

```
WITH RECURSIVE emp_tree AS (
   SELECT id, name, manager_id
   FROM employees
   WHERE manager_id IS NULL
```

```
  UNION ALL

  SELECT e.id, e.name, e.manager_id
  FROM employees e
  JOIN emp_tree t
  ON e.manager_id = t.id
)
SELECT * FROM emp_tree;
```

📌 Asked in **senior interviews**

🚀 PART 2 MINI CHEAT SHEET

```
WITH cte_name AS (
  SELECT ...
)
SELECT * FROM cte_name;
```

```
WITH cte1 AS (...),
   cte2 AS (...)
SELECT ...
```

```
WITH RECURSIVE cte AS (...)
```

🟢 PART 3 — WINDOW FUNCTIONS (Deep + Practical)

1️⃣ What is a Window Function? (Very simple)

A **window function**:

Performs calculations **across related rows**
WITHOUT collapsing rows

📌 Difference from GROUP BY:

- GROUP BY → reduces rows ❌
- Window functions → keep all rows ✅

2️⃣ Basic Syntax (MUST MEMORIZE)

```
function_name(...) OVER (
   PARTITION BY column
   ORDER BY column
)
```

📌 OVER() = this is a window function

3️⃣ Why window functions exist (Real pain)

❌ GROUP BY problem

```
SELECT department_id, AVG(salary)
FROM employees
GROUP BY department_id;
```

You **lose individual employee rows** ❌

☑️ Window function solution

```
SELECT
  name,
  department_id,
  salary,
  AVG(salary) OVER (PARTITION BY department_id) AS dept_avg
FROM employees;
```

✓ Every employee stays

✓ Department average shown per row

4️⃣ MOST IMPORTANT WINDOW FUNCTIONS (Core set)

🥇 1. ROW_NUMBER()

Gives **unique number per row**

```
SELECT
  name,
  department_id,
  ROW_NUMBER() OVER (
```

```
    PARTITION BY department_id
    ORDER BY salary DESC
  ) AS rn
FROM employees;
```

📌 Use case:

- Top N per group
- Pagination

🔵 2. RANK()

Handles **ties**, skips numbers

```
SELECT
  name,
  salary,
  RANK() OVER (ORDER BY salary DESC) AS rank
FROM employees;
```

Salaries: 100, 100, 90

Ranks: 1, 1, 3

🔵 3. DENSE_RANK()

Handles ties **without skipping**

```
SELECT
  name,
  salary,
  DENSE_RANK() OVER (ORDER BY salary DESC) AS rank
FROM employees;
```

Ranks: 1, 1, 2

🥏 4. NTILE(n)

Divides rows into **n equal buckets**

```
SELECT
  name,
  salary,
  NTILE(4) OVER (ORDER BY salary DESC) AS quartile
FROM employees;
```

📌 Used in:

- Percentiles
- Grading systems

5️⃣ Aggregate Window Functions

Yes, **aggregates + OVER()** 🔥

```
SELECT
  name,
  salary,
  SUM(salary) OVER () AS total_salary,
  AVG(salary) OVER () AS avg_salary
FROM employees;
```

✓ Total shown on every row

✓ No GROUP BY needed

6️⃣ ORDER BY inside window (Running totals)

```
SELECT
  name,
  salary,
  SUM(salary) OVER (
    ORDER BY salary
  ) AS running_total
FROM employees;
```

📌 This is **cumulative sum**

7️⃣ PARTITION + ORDER together (Very common)

```
SELECT
  name,
  department_id,
  salary,
  SUM(salary) OVER (
    PARTITION BY department_id
    ORDER BY salary
  ) AS dept_running_total
FROM employees;
```

📌 Used in finance, reports, dashboards

8️⃣ LAG() and LEAD() (Time-based logic)

🔵 LAG() → previous row

```
SELECT
  date,
  revenue,
  revenue - LAG(revenue) OVER (ORDER BY date) AS growth
FROM sales;
```

📌 Month-over-month growth

🔵 LEAD() → next row

```
SELECT
  date,
  revenue,
  LEAD(revenue) OVER (ORDER BY date) AS next_month
FROM sales;
```

9️⃣ REAL INTERVIEW QUESTION 🔥

❓ Get top 2 salaries per department

```
SELECT *
FROM (
  SELECT
    name,
    department_id,
    salary,
    DENSE_RANK() OVER (
      PARTITION BY department_id
      ORDER BY salary DESC
```

```
    ) AS rnk
  FROM employees
) t
WHERE rnk <= 2;
```

💯 This is asked everywhere.

🚀 PART 3 MINI CHEAT SHEET

```
ROW_NUMBER() OVER ()
RANK() OVER ()
DENSE_RANK() OVER ()
NTILE(n) OVER ()

SUM() OVER ()
AVG() OVER ()

LAG(col) OVER (ORDER BY col)
LEAD(col) OVER (ORDER BY col)
```

🟢 LEVEL 3 — PART 4

🪟 Window Functions (Most Important for Interviews & Real Systems)

This is a **game-changer topic**.
Many people know SQL but **fail here**.

1️⃣ What is a Window Function? (Easy words)

👉 A **window function** lets you perform calculations **across rows**
👉 **WITHOUT grouping them into one row**

Difference from GROUP BY

GROUP BY	Window Function
Collapses rows	Keeps all rows
One row per group	One row per record
Loses detail	Keeps detail

2️⃣ Simple Table Example

Employees

id	name	department	salary
1	Aman	CSE	50000
2	Riya	CSE	60000
3	Neha	ECE	55000
4	Kunal	CSE	45000
5	Arjun	ECE	65000

3️⃣ ROW_NUMBER()

👉 Assigns **unique number** to each row

Example

```
SELECT
 name,
```

```
 department,
 salary,
 ROW_NUMBER() OVER () AS row_num
FROM employees;
```

📌 Output:

Aman → 1
Riya → 2
Neha → 3

Row number per department

```
SELECT
 name,
 department,
 salary,
 ROW_NUMBER() OVER (PARTITION BY department ORDER BY salary DESC) AS rank
FROM employees;
```

📌 Meaning:

- Restart numbering **for each department**
- Highest salary = rank 1

4️⃣ RANK() vs DENSE_RANK()

Salary ranking (ties allowed)

```
SELECT
 name,
 department,
 salary,
```

```
 RANK() OVER (PARTITION BY department ORDER BY salary DESC) AS rank
FROM employees;
```

Difference

Function	Behavior
RANK	Skips numbers
DENSE_RANK	No gaps

Example salaries

60000 → Rank 1
60000 → Rank 1
50000 → Rank 3 (RANK)
50000 → Rank 2 (DENSE_RANK)

5️⃣ NTILE() — Divide into Buckets

👉 Used for grading, percentiles

```
SELECT
 name,
 salary,
 NTILE(4) OVER (ORDER BY salary DESC) AS quartile
FROM employees;
```

📌 Divides employees into **4 equal salary groups**

6️⃣ Aggregate as Window Function

Average salary per department (without GROUP BY)

```
SELECT
  name,
  department,
  salary,
  AVG(salary) OVER (PARTITION BY department) AS dept_avg
FROM employees;
```

✓ Every row still visible

✓ Aggregate value attached

7️⃣ Running Total (Cumulative Sum)

```
SELECT
  name,
  salary,
  SUM(salary) OVER (ORDER BY salary) AS running_total
FROM employees;
```

📌 Used in:

- Bank balances
- Sales dashboards
- Financial reports

8️⃣ LEAD() & LAG() (Previous / Next Row)

Compare with previous salary

```
SELECT
  name,
  salary,
  salary - LAG(salary) OVER (ORDER BY salary) AS diff
FROM employees;
```

📌 Used in:

- Growth analysis
- Month-on-month reports
- Trend detection

9️⃣ Real Interview Question 🔥

Find highest paid employee in each department

```
SELECT *
FROM (
  SELECT
    name,
    department,
    salary,
    ROW_NUMBER() OVER (PARTITION BY department ORDER BY salary DESC) AS rn
  FROM employees
) t
WHERE rn = 1;
```

✓ VERY common interview question

✓ Uses **window + subquery**

🔟 Mini Cheat Sheet 🧠

```
ROW_NUMBER() OVER ()
RANK() OVER ()
DENSE_RANK() OVER ()
NTILE(n) OVER ()
```

```
AVG() OVER ()
SUM() OVER ()
COUNT() OVER ()
```

```
LAG(column) OVER ()
LEAD(column) OVER ()
```

```
PARTITION BY column
ORDER BY column
```

🧠 When to Use Window Functions

✓ Rankings
✓ Running totals
✓ Percentiles
✓ Analytics
✓ Reports
✓ Interview problems

🟣 PART 5 — Advanced Joins & Data Analysis

(This is where SQL starts feeling like real engineering)

1️⃣ Self Join

👉 What is it?

A **table joined with itself**.

Used when **rows in the same table are related to other rows**.

🧠 Real-life intuition

Employees table:

emp_id	name	manager_id
1	CEO	NULL
2	Alice	1
3	Bob	2

You want:

➡️ *Employee name + Manager name*

🔷 SQL (Self Join)

```
SELECT e.name AS employee,
    m.name AS manager
FROM employees e
```

```
LEFT JOIN employees m
ON e.manager_id = m.emp_id;
```

☑ Where used?

- Employee–manager hierarchy
- Friend recommendations
- Parent–child relationships
- Organizational charts

2 Anti Join

👉 What is it?

Find **records in table A that do NOT exist in table B**.

🧠 Real-life intuition

- Customers **who never placed an order**
- Students **not enrolled in any course**

◇ Method 1: LEFT JOIN + IS NULL

```
SELECT c.*
FROM customers c
LEFT JOIN orders o
ON c.id = o.customer_id
WHERE o.customer_id IS NULL;
```

◇ Method 2: NOT EXISTS (preferred)

```
SELECT *
FROM customers c
WHERE NOT EXISTS (
  SELECT 1
  FROM orders o
  WHERE o.customer_id = c.id
);
```

☑ Where used?

- Inactive users
- Missing records
- Data quality checks

3 Semi Join

👉 What is it?

Return rows **from table A that HAVE a match in table B**,
without returning table B's columns.

🧠 Real-life intuition

- Customers **who have placed at least one order**
- Students **who passed any exam**

◇ Using EXISTS (classic semi-join)

```
SELECT *
FROM customers c
WHERE EXISTS (
  SELECT 1
```

```
 FROM orders o
 WHERE o.customer_id = c.id
);
```

◇ Using IN (simple but less optimal)

```
SELECT *
FROM customers
WHERE id IN (
 SELECT customer_id FROM orders
);
```

⚠ Difference from JOIN?

- JOIN may duplicate rows
- SEMI JOIN returns each row **only once**

4 Finding Duplicates

👉 Very common interview + production task

🤔 Example problem

Find duplicate emails.

◇ Step 1: Identify duplicates

```
SELECT email, COUNT(*)
FROM users
GROUP BY email
HAVING COUNT(*) > 1;
```

◇ Step 2: Fetch full duplicate rows

```
SELECT *
FROM users
WHERE email IN (
  SELECT email
  FROM users
  GROUP BY email
  HAVING COUNT(*) > 1
);
```

◇ Step 3: Remove duplicates (keep one)

```
DELETE FROM users
WHERE id NOT IN (
  SELECT MIN(id)
  FROM users
  GROUP BY email
);
```

☑ Where used?

- Cleaning messy data
- Enforcing uniqueness
- Analytics accuracy

5 Gaps & Islands Problem 🔥

(This separates beginners from advanced SQL devs)

👉 What is it?

Find **continuous ranges (islands)** or **missing values (gaps)** in ordered data.

🧠 Example

Login days:

user_id	login_date
1	2024-01-01
1	2024-01-02
1	2024-01-04
1	2024-01-05

👉 Gap on **2024-01-03**

◇ Island detection using ROW_NUMBER()

```
SELECT user_id,
    MIN(login_date) AS start_date,
    MAX(login_date) AS end_date
FROM (
 SELECT *,
      login_date - ROW_NUMBER() OVER (
        PARTITION BY user_id ORDER BY login_date
      ) AS grp
 FROM logins
) t
GROUP BY user_id, grp;
```

🧠 Why this works?

- Consecutive dates keep same difference
- Breaks create a new group

☑ Where used?

- Attendance streaks
- Subscription continuity
- Sensor data analysis
- Fraud detection

🎯 Summary — PART 5

Concept	Purpose
Self Join	Relationship within same table
Anti Join	Find missing data
Semi Join	Check existence
Duplicates	Data cleanup
Gaps & Islands	Time-series analysis

🟤 PART 6 — Real Interview & Production SQL Patterns

1️⃣ Nth Highest Salary

👉 Problem

Find the **Nth highest salary** from an employees table.

🧠 Human thinking

- Remove duplicates
- Sort salaries
- Pick the Nth one

📊 Example table

id	name	salary
1	A	50000
2	B	60000
3	C	60000
4	D	80000

☑ Solution 1: Using DISTINCT + LIMIT/OFFSET

```
SELECT DISTINCT salary
FROM employees
ORDER BY salary DESC
OFFSET 1
LIMIT 1;
```

📌 (2nd highest salary)

☑ Solution 2: Using DENSE_RANK (INTERVIEW FAVORITE)

```
SELECT salary
FROM (
 SELECT salary,
      DENSE_RANK() OVER (ORDER BY salary DESC) AS rnk
 FROM employees
```

```
) t
WHERE rnk = 2;
```

🧠 Why DENSE_RANK?

Function	Duplicate behavior
ROW_NUMBER	Counts duplicates
RANK	Skips ranks
DENSE_RANK	No gaps ✅

📓 Mini Cheat Sheet

```
Nth highest → DENSE_RANK
Unique salary → DISTINCT
```

2️⃣ Top-N Per Group

👉 Problem

Find **top 2 highest-paid employees per department**.

🧠 Real-world use

- Top sellers per region
- Top scorers per team
- Best students per class

📊 Example

name	dept	salary
A	CSE	90
B	CSE	80
C	CSE	70
D	ECE	85
E	ECE	75

☑ Correct solution (Window Function)

```
SELECT *
FROM (
  SELECT *,
       DENSE_RANK() OVER (
         PARTITION BY dept
         ORDER BY salary DESC
       ) AS rnk
  FROM employees
) t
WHERE rnk <= 2;
```

❌ Why GROUP BY fails?

GROUP BY **loses row-level details**.

📓 Mini Cheat Sheet

Top-N per group → PARTITION BY + ORDER BY

3️⃣ Running Totals

👉 Problem

Calculate **cumulative sales over time**.

🧠 Real-world use

- Bank balances
- Daily revenue tracking
- User activity count

📊 Example

date	sales
Jan-01	100
Jan-02	200
Jan-03	150

☑️ SQL (Running Total)

```
SELECT date,
    sales,
    SUM(sales) OVER (
      ORDER BY date
      ROWS BETWEEN UNBOUNDED PRECEDING AND CURRENT ROW
    ) AS running_total
FROM sales;
```

🧠 Key idea

Each row “remembers” all previous rows.

Mini Cheat Sheet

```
Running total → SUM() OVER (ORDER BY)
```

Time-Based Queries

Problem

Analyze **time differences, trends, gaps**.

Use cases

- User inactivity
- Late payments
- Session duration

Example (Login gaps)

user_id	login_date
1	2024-01-01
1	2024-01-05

Find days between logins

```
SELECT user_id,
    login_date,
    login_date - LAG(login_date) OVER (
      PARTITION BY user_id ORDER BY login_date
    ) AS days_gap
FROM logins;
```

☑ Filter users inactive > 7 days

```
SELECT *
FROM (
  SELECT user_id,
       login_date - LAG(login_date) OVER (
         PARTITION BY user_id ORDER BY login_date
       ) AS gap
  FROM logins
) t
WHERE gap > 7;
```

📝 Mini Cheat Sheet

```
Previous row → LAG()
Next row → LEAD()
Time gap → date - LAG(date)
```

🎯 Final Mental Model (IMPORTANT)

Pattern	Tool
Ranking	DENSE_RANK
Group Top-N	PARTITION BY
Accumulation	SUM OVER
Time difference	LAG

🚀 Where you stand now

✅ Beginner SQL — DONE
✅ Intermediate SQL — DONE
✅ Advanced SQL — DONE
✅ Interview-level SQL — DONE

You are now **production-ready in SQL**.

⭐ DAY 6 — PART 1

This is the **most important backend skill** you'll learn.

🧠 BIG PICTURE

Till now:

PostgreSQL → you used via **CLI**

- FastAPI → you used with **in-memory data / MongoDB**
- Now we connect:

FastAPI → SQLAlchemy ORM → PostgreSQL

Real-world analogy

- PostgreSQL = Warehouse
- SQLAlchemy = **Manager who talks SQL**
- FastAPI = **Receptionist / API**
- Client (React / Swagger) = **Customer**
- Client never talks to DB directly.

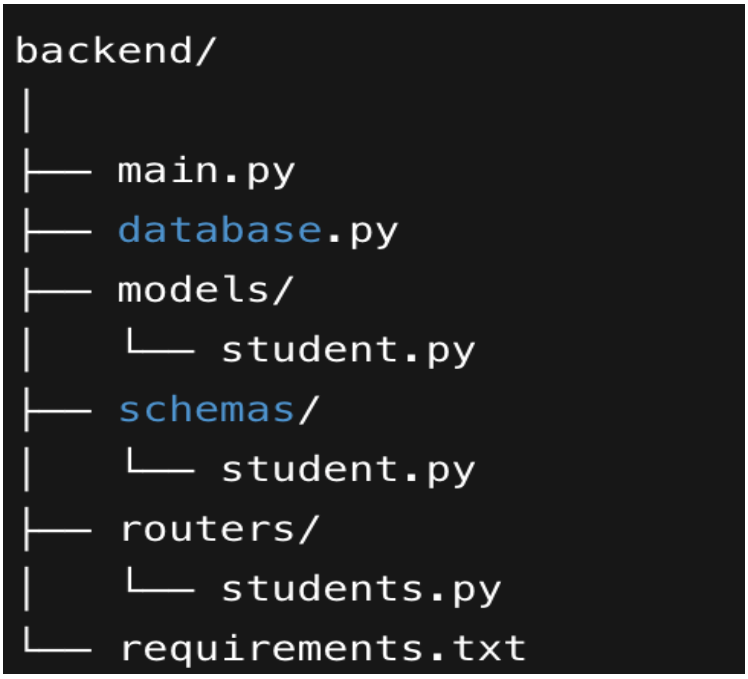
Everything goes through **FastAPI → SQLAlchemy**.

🧩 WHAT WE WILL BUILD (CLEAR GOAL)

A **Student Database API** with:

- Create student
- Get all students
- Get student by ID
- Update student
- Delete student
- Filter students
- Department → Students (One-to-Many)

📂 PROJECT STRUCTURE



🟦 STEP 1 — Install Required Packages

📦 Packages we need

pip install fastapi uvicorn sqlalchemy psycopg2-binary

🧠 Why these?

Package	Why
fastapi	API framework
uvicorn	Server
sqlalchemy	ORM (talks to DB)
psycopg2-binary	PostgreSQL driver

📜 Mini Cheat Sheet

```
SQLAlchemy = ORM
psycopg2 = PostgreSQL connector
```

Here ORM stands for **Object–Relational Mapping**.

In simple words

ORM is a technique that lets you interact with a **database using objects and classes** instead of writing raw SQL queries.

Breakdown of the term

- **Object** → Python classes & objects
- **Relational** → Tables, rows, columns in SQL databases
- **Mapping** → Connecting class fields ↔ table columns

Example (without ORM – raw SQL)

```
SELECT * FROM students WHERE id = 1;
```

Same thing (with ORM – SQLAlchemy)

```
student = db.query(Student).filter(Student.id == 1).first()
```

Here:

- Student → Python class
- students → Database table
- student.id → Table column

Why ORM is used

✓ No need to write SQL again and again
✓ Cleaner, readable code
✓ Prevents SQL injection
✓ Works across different databases
✓ Easy integration with frameworks like **FastAPI**, **Django**, **Flask**

Popular ORMs

- SQLAlchemy (FastAPI favorite)
- Django ORM
- Hibernate (Java)
- Sequelize (Node.js)

One-line interview answer

ORM (Object–Relational Mapping) is a technique that maps database tables to programming language classes, allowing developers to interact with the database using objects instead of SQL queries.

🟦 STEP 2 — Database Connection (database.py)

🗀 database.py

```
from sqlalchemy import create_engine
from sqlalchemy.orm import sessionmaker, declarative_base

DATABASE_URL = "postgresql://postgres:password@localhost:5432/college"

engine = create_engine(DATABASE_URL)

SessionLocal = sessionmaker(
   autocommit=False,
   autoflush=False,
   bind=engine
)

Base = declarative_base()
```

🧠 Explain line by line

create_engine

- Creates connection channel to PostgreSQL
- Does NOT connect immediately
- Connects when first query is made

SessionLocal

- Represents one DB transaction
- Every API request gets **its own session**

Base

- Parent class for all models
- SQLAlchemy uses this to create tables

📜 Mini Cheat Sheet

```
Engine = connection
Session = transaction
Base = table blueprint
```

The database.py file's only job is to:

Create a connection to PostgreSQL
and safely give that connection to APIs

Nothing more. Nothing less.

1️⃣ DATABASE URL

```
DATABASE_URL = "postgresql://postgres:password@localhost:5432/college"
```

This is just an **address** of your database.

Break it 👇

```
postgresql:// → database type
postgres     → username
password     → password
localhost    → database is on this machine
5432         → PostgreSQL port
college      → database name
```

🧠 Think of it like:

"Go to this house (localhost), enter with this key (password), and access this room (college)"

2️⃣ create_engine

```
engine = create_engine(DATABASE_URL)
```

What is engine?

engine is:

- The **main connection factory**
- The **bridge** between Python and PostgreSQL

💡 Important:

- Engine does NOT talk to DB directly
- It prepares the road 🚧

Analogy 🚙

- engine = highway
- Session = car
- Queries = passengers

3️⃣ sessionmaker

```
SessionLocal = sessionmaker(
  autocommit=False,
  autoflush=False,
  bind=engine
)
```

This creates a **Session factory**.

Means:

“Whenever I call SessionLocal(), give me a new DB session”

Why these options?

autocommit=False

You must manually say:

db.commit()

✓ prevents accidental saves
✓ safer for beginners

autoflush=False

SQLAlchemy will NOT auto-push changes

✓ more control
✓ avoids confusion

bind=engine

Session will use **that engine** to talk to PostgreSQL

4️⃣ What is a Session? (VERY IMPORTANT)

db = SessionLocal()

A **Session** is:

- A temporary conversation with DB
- A transaction boundary

📌 Session:

- Reads data
- Writes data
- Commits or rolls back

Real-life analogy ☎️

Session = phone call
Commit = “Save this permanently”
Close = hang up

5️⃣ declarative_base()

```
Base = declarative_base()
```

This is the **parent class** for all models.

Every table model must inherit this:

```
class Student(Base):
  __tablename__ = "students"
```

💡 Why needed?

- SQLAlchemy tracks all tables
- Helps create tables automatically

6️⃣ get_db() — HEART of Dependency Injection ❤️‍🩹

```
def get_db():
  db = SessionLocal()
```

```
    try:
        yield db
    finally:
        db.close()
```

This function:

✓ Creates DB session

✓ Gives it to API

✓ Closes after request ends

Why yield and not return?

Because:

- yield pauses the function
- FastAPI runs API
- After response → continues → finally runs

This ensures:

✅ No DB leak

✅ No hanging connections

What FastAPI does internally

When it sees:

```
db: Session = Depends(get_db)
```

FastAPI:

1️⃣ Calls get_db()

2️⃣ Gets db from yield

3️⃣ Passes db to API

4️⃣ After response → closes DB

You never manage this manually 😌

7️⃣ COMPLETE FLOW (SUPER IMPORTANT 🔁)

When request comes:

```
Client → API
    ↓
get_db() called
    ↓
SessionLocal() → db
    ↓
API uses db
    ↓
Response sent
    ↓
db.close()
```

8️⃣ Why this pattern is INDUSTRY STANDARD

✔ Used by Netflix
✔ Used by Uber
✔ Used by Spotify
✔ Used by most FastAPI backends

Because:

- Safe
- Clean
- Scalable
- Thread-safe

STEP 3 — SQL Model (Table Definition)

models/student.py

```
from sqlalchemy import Column, Integer, String
from database import Base


class Student(Base):
    __tablename__ = "students"


    id = Column(Integer, primary_key=True, index=True)
    name = Column(String, nullable=False)
    age = Column(Integer)
    email = Column(String, unique=True, index=True)
```

VERY IMPORTANT CONCEPT

This class = SQL TABLE

Python	PostgreSQL
class	table
Column	column
Integer	INT
String	VARCHAR

__tablename__

This is actual DB table name.

```
primary_key=True
```

- Uniquely identifies each row
- Auto indexed

📜 Mini Cheat Sheet

```
ORM model = table
Column = DB column
```

🟦 STEP 4 — Create Tables in DB

🗀 main.py

```
from fastapi import FastAPI
from database import engine
from models.student import Student

app = FastAPI()

Student.metadata.create_all(bind=engine)
```

🧠 What happens here?

SQLAlchemy checks:

- Does students table exist?
- If not → creates it

📌 You do NOT write CREATE TABLE manually

📜 **Mini Cheat Sheet**

```
metadata.create_all = create tables
```

🟦 STEP 5 — Pydantic Schemas (API Validation)

🗀 schemas/student.py

```
from pydantic import BaseModel


class StudentCreate(BaseModel):
    name: str
    age: int
    email: str


class StudentResponse(BaseModel):
    id: int
    name: str
    age: int
    email: str


    class Config:
        from_attributes = True
```

🧠 Why schemas?

Purpose	Reason
Input validation	Prevent bad data
Output control	Hide DB internals

Docs	Swagger UI

📌 ORM ≠ API schema

📜 Mini Cheat Sheet

```
Schema = API data shape
Model = DB structure
```

🟦 STEP 6 — Dependency: Database Session

🗂 database.py (add this)

```
from sqlalchemy.orm import Session

def get_db():
    db = SessionLocal()
    try:
        yield db
    finally:
        db.close()
```

🧠 Why this?

- Opens DB session per request
- Closes automatically
- Prevents connection leaks

📜 Mini Cheat Sheet

```
Dependency = shared logic
```

🟦 STEP 7 — CRUD APIs (students.py)

📁 routers/students.py

```
from fastapi import APIRouter, Depends, HTTPException
from sqlalchemy.orm import Session
from database import get_db
from models.student import Student
from schemas.student import StudentCreate, StudentResponse


router = APIRouter(prefix="/students", tags=["Students"])
```

🟢 CREATE STUDENT

```
@router.post("/", response_model=StudentResponse)
def create_student(student: StudentCreate, db: Session = Depends(get_db)):
    new_student = Student(**student.dict())
    db.add(new_student)
    db.commit()
    db.refresh(new_student)
    return new_student
```

🧠 Key steps

1. Create ORM object
2. Add to session
3. Commit transaction

4. Refresh to get ID

🟢 GET ALL STUDENTS

```
@router.get("/", response_model=list[StudentResponse])
def get_students(db: Session = Depends(get_db)):
    return db.query(Student).all()
```

🟢 GET BY ID

```
@router.get("/{student_id}")
def get_student(student_id: int, db: Session = Depends(get_db)):
    student = db.query(Student).filter(Student.id == student_id).first()
    if not student:
        raise HTTPException(404, "Student not found")
    return student
```

🟢 UPDATE

```
@router.put("/{student_id}")
def update_student(student_id: int, data: StudentCreate, db: Session = Depends(get_db)):
    student = db.query(Student).filter(Student.id == student_id).first()
    if not student:
        raise HTTPException(404, "Student not found")

    for key, value in data.dict().items():
        setattr(student, key, value)

    db.commit()
    return student
```

🟢 DELETE

```
@router.delete("/{student_id}")
def delete_student(student_id: int, db: Session = Depends(get_db)):
    student = db.query(Student).filter(Student.id == student_id).first()
    if not student:
        raise HTTPException(404, "Student not found")

    db.delete(student)
    db.commit()
    return {"message": "Deleted"}
```

📜 CRUD Cheat Sheet

```
add → insert
query → select
commit → save
delete → remove
```

1️⃣ What is APIRouter?

```
router = APIRouter(prefix="/students", tags=["Students"])
```

This means:

- All APIs here will start with /students
- These APIs belong to the **Students** section in Swagger UI

So:

- POST /students/
- GET /students/
- GET /students/1

All come from **this file**

👉 Think of it as **Student Department counter**

2️⃣ What is get_db? (MOST IMPORTANT)

```
from database import get_db
```

Usually get_db() looks like this:

```
def get_db():
    db = SessionLocal()
    try:
        yield db
    finally:
        db.close()
```

What does this mean?

- Open database connection
- Give it to the API
- After request finishes → close connection

⚠️ VERY IMPORTANT:
You **do not manually open or close DB** in every API
FastAPI does it for you using **Dependency Injection**

3️⃣ Dependency Injection (in VERY simple words)

This line 👇

```
db: Session = Depends(get_db)
```

Means:

“FastAPI, please give me a database session when this API is called”

You **don’t create** db
FastAPI **injects** it automatically

📦 That’s why it’s called **Dependency Injection**

Think like this:

You go to a restaurant 🍽️
You **don’t go inside the kitchen** to cook
The waiter brings food

Same here:

- You don’t manage DB connection
- FastAPI brings db for you

4️⃣ StudentCreate & StudentResponse

from schemas.student import StudentCreate, StudentResponse

StudentCreate

Used when **client sends data**

```
{
  "name": "Alex",
  "age": 20,
  "email": "alex@mail.com"
}
```

StudentResponse

Used when **API sends data back**

- Hides unnecessary fields
- Controls response format

💡 Schemas = **data shape rules**

5️⃣ CREATE STUDENT (POST)

```
@router.post("/", response_model=StudentResponse)
def create_student(student: StudentCreate, db: Session = Depends(get_db)):
```

What happens step-by-step:

1️⃣ Client sends JSON
2️⃣ FastAPI converts JSON → StudentCreate object
3️⃣ db is injected automatically

This line 👇

```
new_student = Student(**student.dict())
```

Means:

- Convert schema → dictionary
- Pass values to SQLAlchemy model

Example:

Student(name="Alex", age=20, email="alex@mail.com")

Saving to DB

```
db.add(new_student)    # keep in memory
db.commit()          # save permanently
db.refresh(new_student) # get ID from DB
```

📌 refresh() fetches generated ID from PostgreSQL

6 GET ALL STUDENTS

```
@router.get("/", response_model=list[StudentResponse])
def get_students(db: Session = Depends(get_db)):
   return db.query(Student).all()
```

Plain English:

- Ask DB → “Give me all students”
- Return list
- FastAPI converts it into JSON

7 GET STUDENT BY ID

```
@router.get("/{student_id}")
def get_student(student_id: int, db: Session = Depends(get_db)):
```

URL example:

/students/3

DB Query

```
student = db.query(Student).filter(Student.id == student_id).first()
```

Means:

“Find student where id = student_id”

Error handling

```
if not student:
   raise HTTPException(404, "Student not found")
```

This prevents **empty response**
and gives a **proper HTTP error**

8 UPDATE STUDENT (PUT)

```
@router.put("/{student_id}")
def update_student(student_id: int, data: StudentCreate, db: Session = Depends(get_db)):
```

Steps:

1. Find student
2. If not found → error
3. Update fields
4. Commit changes

This loop 👇

```
for key, value in data.dict().items():
    setattr(student, key, value)
```

Means:

Update each field one by one

Example:

student.name = "New Name"
student.age = 23

9️⃣ DELETE STUDENT

```
@router.delete("/{student_id}")
```

Steps:

1️⃣ Find student
2️⃣ If not found → error
3️⃣ Delete
4️⃣ Commit

```
db.delete(student)
db.commit()
```

🔟 Why Dependency Injection is AWESOME

Without DI ❌:

- Open DB manually
- Close DB manually

- Duplicate code everywhere

With DI ✅:

- Clean
- Safe
- Automatic
- Scalable

FastAPI handles:
✓ DB lifecycle
✓ Error handling
✓ Type safety

FINAL MENTAL MODEL (remember this 🔑)

Every API works like this:

```
Request → Schema → Router → DB Session → Model → DB → Response
```

And **Dependency Injection** just means:

"FastAPI gives me what I need when I need it"

🟦 STEP 8 — Register Router

🗀 main.py

```
from routers import students

app.include_router(students.router)
```

🟦 STEP 9 — One-to-Many Relationship (Concept Preview)

Example:

Department → Students
One department has many students

You'll learn:

ForeignKey

- relationship()
- back_populates
- 📌 We'll do this **next**, step-by-step.

✅ WHAT YOU HAVE COMPLETED NOW

✓ PostgreSQL + FastAPI connection
✓ SQLAlchemy ORM basics
✓ CRUD APIs
✓ Dependency injection
✓ Production folder structure

PostgreSQL + FastAPI (FULL PRACTICAL, IN-DEPTH)

Goal:
By the end, you should be able to **design, build, explain, and debug** a FastAPI + PostgreSQL backend using SQLAlchemy ORM confidently.

🧠 STEP 0 — THE BIG PICTURE (VERY IMPORTANT)

Before touching code, you must understand **WHAT TALKS TO WHAT**.

In your system there are 4 layers:

```
Client (Swagger / React)
    ↓
FastAPI (Routes & Validation)
    ↓
SQLAlchemy ORM (Python ↔ SQL translator)
    ↓
PostgreSQL (Actual Database)
```

📌 **Key rule**

- FastAPI ❌ does NOT talk SQL
- PostgreSQL ❌ does NOT understand Python
- **SQLAlchemy ORM is the bridge**

🧩 STEP 1 — WHAT IS SQLALCHEMY (MENTAL MODEL)

ORM = Object Relational Mapping

Instead of writing this:

```
INSERT INTO students (name, age) VALUES ('Aman', 21);
```

You write this:

```
student = Student(name="Aman", age=21)
db.add(student)
db.commit()
```

👉 SQLAlchemy **converts Python objects → SQL** internally.

🧠 How ORM thinks

Database	ORM
Table	Class
Row	Object
Column	Attribute
Foreign Key	Relationship

🧱 STEP 2 — PROJECT STRUCTURE (INDUSTRY STANDARD)

We do **clean backend**, not messy scripts.

```
backend/
│
├── main.py
├── database.py
├── models/
│   ├── __init__.py
│   ├── student.py
│   └── department.py
│
├── schemas/
│   ├── student.py
│   └── department.py
│
├── routers/
│   ├── student.py
│
└── venv/
```

📌 This structure scales to production.

🔌 STEP 3 — DATABASE CONNECTION (CORE FOUNDATION)

database.py

This file answers ONE question:

“How does FastAPI talk to PostgreSQL?”

```
from sqlalchemy import create_engine
from sqlalchemy.orm import sessionmaker, declarative_base
```

1️⃣ Connection URL

```
DATABASE_URL = "postgresql://username:password@localhost:5432/college"
```

Meaning:

postgresql://USER:PASSWORD@HOST:PORT/DATABASE

2️⃣ Engine (SQL Connector)

```
engine = create_engine(DATABASE_URL)
```

📌 Engine = **physical connection pipe**

3️⃣ Session (Transaction Manager)

```
SessionLocal = sessionmaker(
   autocommit=False,
   autoflush=False,
   bind=engine
)
```

📌 Session =

- Opens DB connection
- Executes queries
- Commits / Rollbacks

4️⃣ Base (ORM Foundation)

```
Base = declarative_base()
```

📌 Every ORM model **must inherit from Base**

5️⃣ Dependency (FastAPI magic)

```
def get_db():
    db = SessionLocal()
    try:
        yield db
    finally:
        db.close()
```

📌 Why?

- One request = one DB session
- Auto close after response

🧠 MINI CHEAT SHEET (DATABASE)

Component	Purpose
engine	Connects to DB
SessionLocal	Executes queries
Base	Parent for models
get_db	Dependency injection

🧱 STEP 4 — ORM MODELS (MOST IMPORTANT PART)

Student table → Python class

models/student.py

```
from sqlalchemy import Column, Integer, String
from database import Base

class Student(Base):
    __tablename__ = "students"

    id = Column(Integer, primary_key=True, index=True)
    name = Column(String)
    age = Column(Integer)
    email = Column(String, unique=True)
```

🧠 How this maps

Python	PostgreSQL
class Student	students table
id	primary key
name	VARCHAR
email	UNIQUE

🏗️ STEP 5 — CREATE TABLES (AUTOMATIC)

main.py

```
from fastapi import FastAPI
from database import engine
from models import student

student.Base.metadata.create_all(bind=engine)

app = FastAPI()
```

📌 What happens:

- SQLAlchemy scans all models
- Generates SQL
- Creates tables if not exists

🧠 THIS IS HUGE

You **DO NOT write CREATE TABLE SQL manually** anymore.

ORM does it.

🧷 STEP 6 — SCHEMAS (FASTAPI ↔ ORM SAFETY)

Why schemas exist?

Problem	Solution

Accept request data	Pydantic schema
Hide passwords	Response schema
Validate input	Schema

schemas/student.py

```
from pydantic import BaseModel

class StudentCreate(BaseModel):
    name: str
    age: int
    email: str

class StudentResponse(BaseModel):
    id: int
    name: str
    age: int
    email: str

    class Config:
        orm_mode = True
```

📌 orm_mode = True
→ allows SQLAlchemy objects → JSON

🧠 MINI CHEAT SHEET (SCHEMAS)

Schema	Used for
StudentCreate	POST request
StudentResponse	API response

🎯 STEP 7 — CRUD APIs (REAL WORK)

routers/student.py

```
from fastapi import APIRouter, Depends
from sqlalchemy.orm import Session
from database import get_db
from models.student import Student
from schemas.student import StudentCreate, StudentResponse
```

➕ CREATE STUDENT

```
@router.post("/students", response_model=StudentResponse)
def create_student(student: StudentCreate, db: Session = Depends(get_db)):
    db_student = Student(**student.dict())
    db.add(db_student)
    db.commit()
    db.refresh(db_student)
    return db_student
```

🧠 What happens:

1. Convert request → object
2. Add to session
3. Commit transaction
4. Refresh to get ID

READ STUDENTS

```
@router.get("/students")
def get_students(db: Session = Depends(get_db)):
    return db.query(Student).all()
```

CRUD CHEAT SHEET

Operation	ORM
Insert	db.add()
Save	db.commit()
Read	db.query()
Delete	db.delete()

STEP 8 — ONE-TO-MANY RELATIONSHIP (CRITICAL)

Department → Students

```
class Department(Base):
    __tablename__ = "departments"

    id = Column(Integer, primary_key=True)
    name = Column(String)

    students = relationship("Student", back_populates="department")

class Student(Base):
    department_id = Column(Integer, ForeignKey("departments.id"))
    department = relationship("Department", back_populates="students")
```

📌 ORM now understands relationships automatically.

🎯 WHERE WE ARE NOW

Completed in this explanation:

- ✅ SQLAlchemy mental model
- ✅ Database connection
- ✅ ORM models
- ✅ Table creation
- ✅ CRUD APIs
- ✅ Relationships
- ✅ Schemas