THE GEORGE WASHINGTON UNIVERSITY

WASHINGTON, DC

1b. Course Overview

CSCI 2541 Database Systems & Team Projects

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Slides adapted from ones by Prof. Bhagi Narahari & Wood

A DBMS should provide…

Structure that is **independent** of the underlying file formats

Queries to flexibly read, update, and delete information

Transactions that provide guarantees about **multi-user consistency**

DBMS: How to structure the data?

Structure that is **independent** of the underlying file formats

What **data** is needed?

- Eg: What do we need to store to uniquely identify a restaurant customer?

How to **store & organize** the data?

- How many attributes are really needed about a student/course/faculty
- What is an efficient way to organize the data?
  - This is why we will need to study schema design and Normal forms

Data Models and Representation

Structure that is **independent** of the underlying file formats

A **data model** is a formal framework for describing data.

- Data objects, relationships, constraints (business rules)
- Provides primitives for data manipulation and data definition
- Provides us with the mathematical basis to prove/assert properties and show correctness of algorithms

The **relational model** is one of the main models of data that is **independent** of its data structures and implementation

- Data organized as **relations** (“tables”)

Not the only way!

- NoSQL databases model unstructured and big data without requiring strict relations
- Other data models: network, hierarchical, Object Oriented…
- Relational model can be inefficient for many such applications

DBMS: How to provide abstraction?

Structure that is **independent** of the underlying file formats

The major problem with developing applications based on files is that the application is **dependent** on the file structure.

There is no **program-data independence** separating the application from the data it is manipulating.

- If the data file changes, the code that accesses the file may require changes to the application.

A major advantages of DBMS is they provide **data abstraction**.

Data abstraction allows the *internal definition of an object* to change without *affecting programs that use the object* through an external definition.

Database Schema

Structure that is **independent** of the underlying file formats

Similar to **types** and **variables** in programming languages

Schema – **structure** of the database

- Ex: database contains information about Students and Courses and the relationships between them
- Defines columns and the type of data that can be stored in them

Occurs at multiple levels:

- **Logical Level**: Database design, definition of structure and relations
- **Physical Level**: Implementation of how data is stored on disk

Customers Relation (Table)

first_name	last_name	email	phone	reservation	birthday
Kelli	Perris	kperris0@nifty.com	963-930-8531	1/6/2020	9/12/1958
Goddart	Braams	gbraams1@ted.com	534-300-7372	1/26/2020	1/18/1979
Merrel	Clere	mclere2@blogger.com	194-430-7153	1/25/2020	2/12/1957
Towney	Bratcher	tbratcher3@narod.ru	304-227-0235	1/5/2020	7/10/1977
Latia	Peete	lpeete4@w3.org	448-368-1546	1/28/2020	3/6/1964
Hadria	Rann	hrann5@cbsnews.com	206-421-4913	1/24/2020	1/5/1976
Bastian	Clother	bclother6@microsoft.com	104-598-7586	1/25/2020	9/15/1965
Corene	Attoe	cattoe7@soup.io	819-616-3261	1/20/2020	3/7/1946
Sara-ann	Creeboe	screeboe8@theatlantic.com	831-348-1941	1/13/2020	4/15/1998

Levels of Data Modeling

Structure that is **independent** of the underlying file formats

Logical Level: describes data stored in the database and the relationship between them

```
ex:  type customer {
         name: string
         email: string
         birthday: date
     }
```

Physical Level: describes how a record is stored (i.e., how is data organized on the disk)

- Ex: sorting, page alignment, index

Big Idea: Logical and Physical level independence

- Can change one without changing the other!!

Data Independence

Structure that is **independent** of the underlying file formats

Logical data independence

- Protects the user from changes in the logical structure of the data
- Lets us reorganize the customer “schema” without changing how we query/store it

Physical data independence

- Protects the user from changes in the physical structure of data
- Lets us change how student data is stored in memory/disk without changing how the user would write the query

Additional Views:

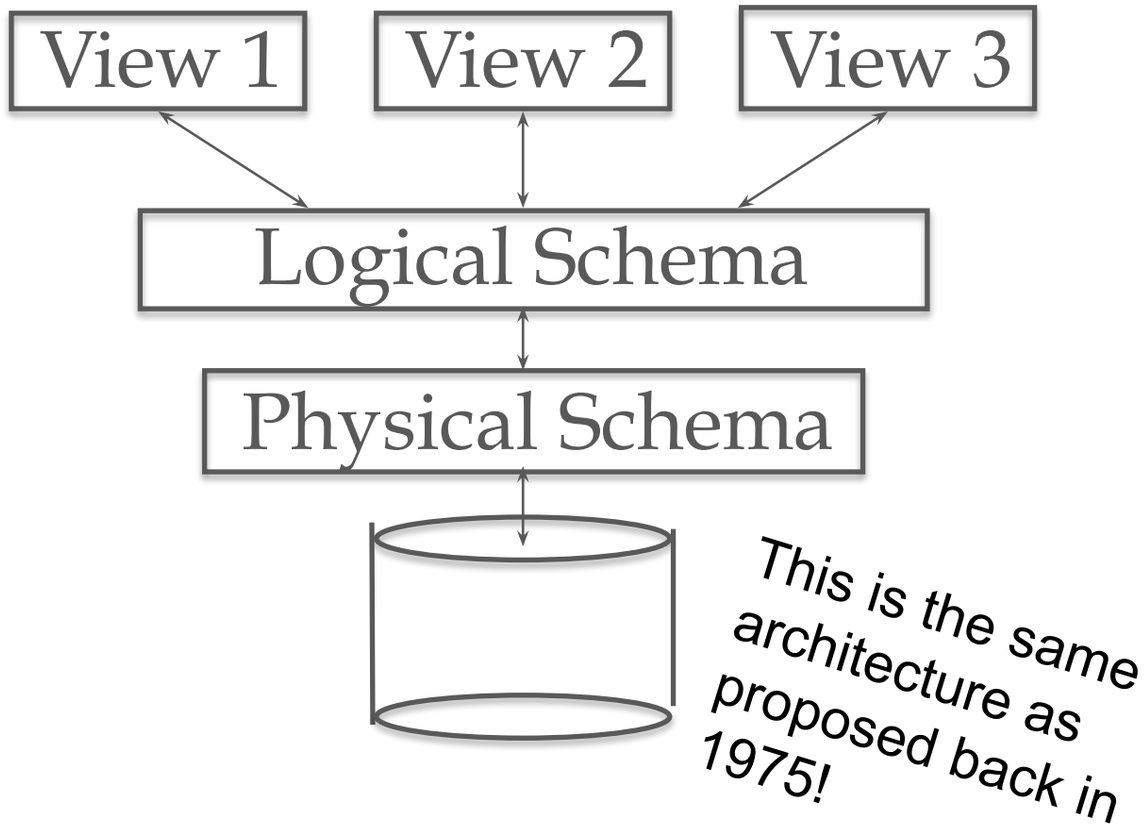
- DB applications hide details of data types and can also hide some information (salary?) for security & privacy purposes

Summary- Levels of Abstraction

Structure that is **independent** of the underlying file formats

Many views, single conceptual (logical) schema and physical schema

- Views describe how users see the data
- Conceptual/Logical schema defines logical structure
- Physical schema describes the files and indexes used



Schemas are defined using DDL; data is modified/queried using DML

Confusing? Curious?

ust covered…

Structure that is **independent** of the underlying file formats

Queries to flexibly read, update, and delete information

Transactions that provide guarantees about **multi-user consistency**

…marching on!

Queries & Data Independence

Queries to flexibly read, update, and delete information

What this means….

A user of a relational database system should be able to use the database without knowing precisely how data is stored, e.g.

```
SELECT Name, Reservation
FROM Customers
WHERE Name= 'Alan Turing'
```

The above "query" does not need to know how the data in Customers is stored. Why should you need to worry about that?!

How to define and use a database

Queries to flexibly read, update, and delete information

Data **Definition** Language (**DDL**) to specify database schema

- What data, and how it is organized (**logical level**)

Data **Manipulation** Language (**DML**) allows users to access or manipulate data as organized by data model

- procedural DMLs: require user to specify **what data and how** to get it
- *declarative* DMLs: require user to specify what data is needed **without** specifying how to get it.

Often, one language provides both features (e.g., SQL)

Relational DB Query Languages

Queries to flexibly read, update, and delete information

Formal query languages:

- **Relational algebra,**
- Relational Calculus,
- Why study formal languages?

Commercial query language: **SQL**

SQL: “descendent” of SEQUEL; mostly relational algebra and some aspects of relational calculus

- has procedural and non-procedural aspects
- Has DDL and DML components

What is SQL?

Queries to flexibly read, update, and delete information

SQL is **not** a specific database software

It is a standardized query language

- Defines how to create a database schema and issue read/write queries

DBMS software must implement the SQL **standard**

- Plus some of their own extensions
- None actually follow the official ANSI SQL standard precisely…

Good news: SQL queries are “cross platform” and will work on many different database systems

Confusing? Curious? Similar example?

Just covered…

Structure that is **independent** of the underlying file formats

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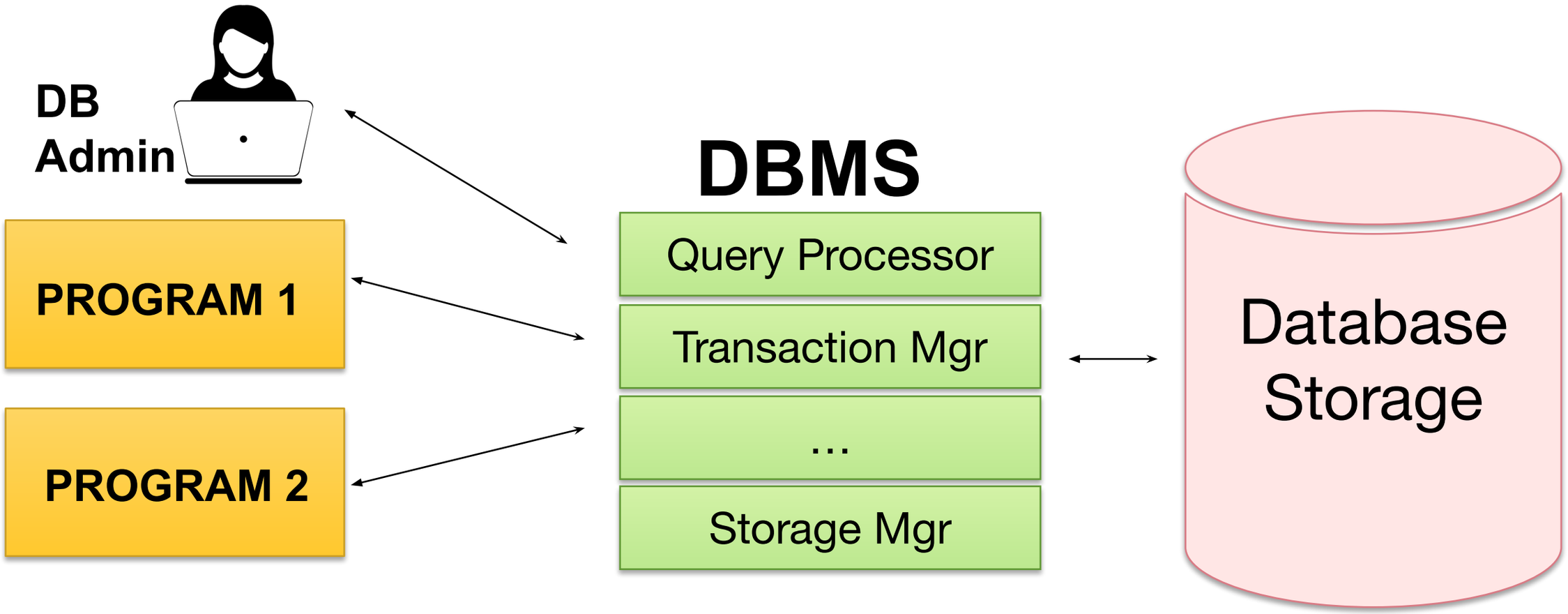
…marching on!

Connecting to a DB

Transactions that provide **multi-user consistency**

A typical DB Application design



DBMS

Transactions that provide **multi-user consistency**

The data abstraction is provided by the DBMS

- Separation b/w Logical and Physical, Query language parsing, multi-user, etc.

A database management system provides efficient, convenient, and safe multi-user storage and access to massive amounts of persistent data

- **Efficient & Convenient** - Able to handle large data sets, complex queries without searching all files and data items, easy to write queries
- **Scalability** – Large/huge data
- **Persistence & Safety** - Data exists after program execution completes, handles loss of power
- **Multi-user** - More than one user can access and update data at the same time while preserving consistency….concept of transactions

Components of a DBMS

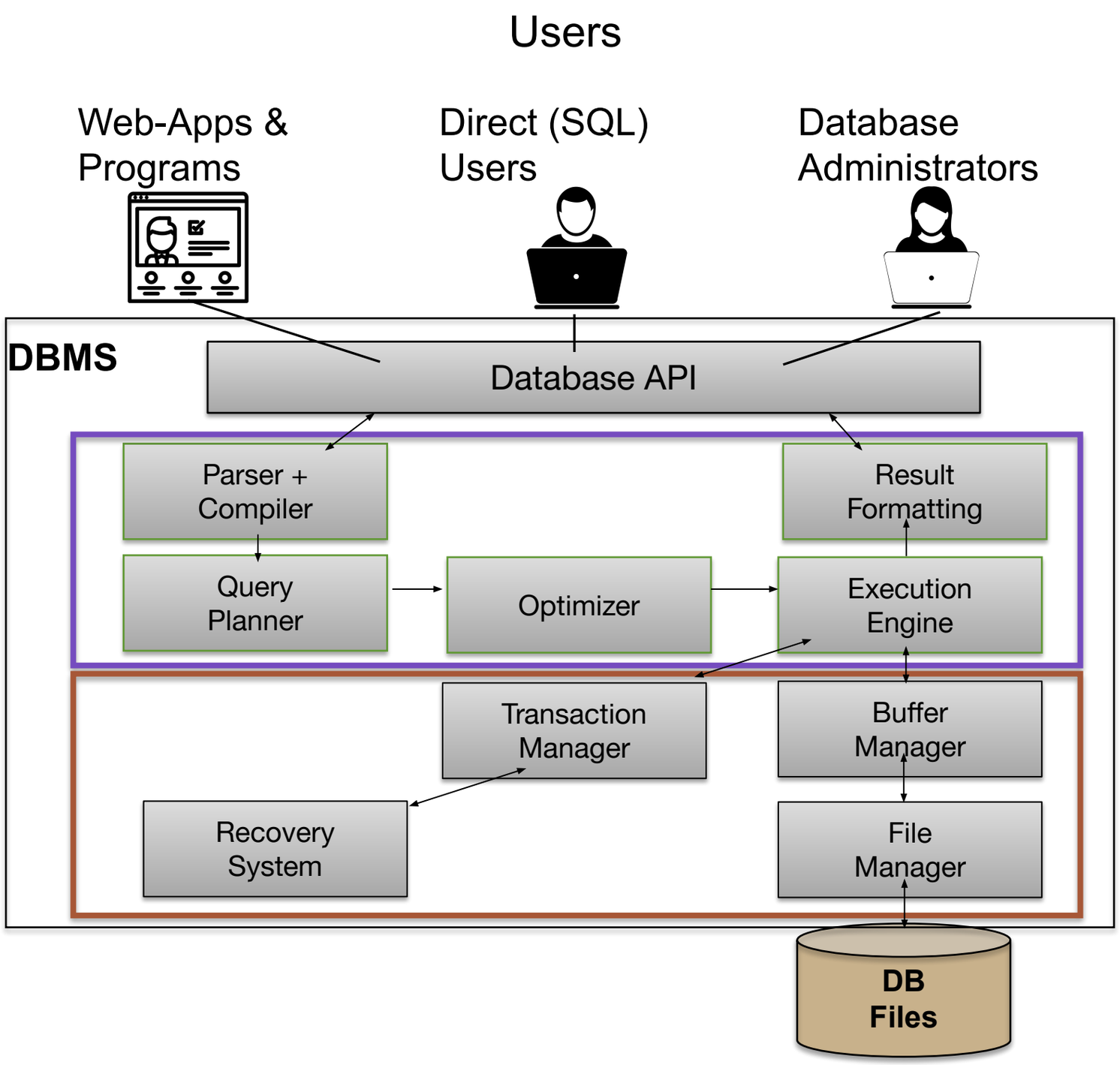
Transactions that provide **multi-user consistency**

A database management system provides efficient, convenient, and safe multi-user storage and access to massive amounts of persistent data.

A DBMS is a complicated software system containing many components:

- **Query processor** - translates user/application queries into low-level data manipulations
  - Sub-components: query parser, query optimizer
- **Storage manager** - maintains storage information including memory allocation, buffer management, and file storage
  - Sub-components: buffer manager, file manager
- **Transaction manager** - performs scheduling of operations and implements concurrency control algorithms
  - You will learn more about storage management and concurrency in the Operating Systems course… enjoy!

DBMS Architecture: Complete Picture



1. Structure that is **independent** of the underlying file formats

2. Queries to flexibly read, update, and delete information

3. Transactions that provide **multi-user consistency**

Which components provide these properties?

This course is about Database Design…

Focus is on design of databases

- Working at the **logical level**

Internals of DBMS is not the focus in this course

- BUT we will touch upon a few key concepts that make DBMS' work

- DBMS design brings together several key concepts from Computer Science
  - Languages, Compilers/translation, Algorithms, Data structures, Operating systems…

Database System Architectures

There are several different database architectures:

- **Embedded architecture** - DB files and DBMS processing occurs at the client's process (e.g. Microsoft Access or SQLite)

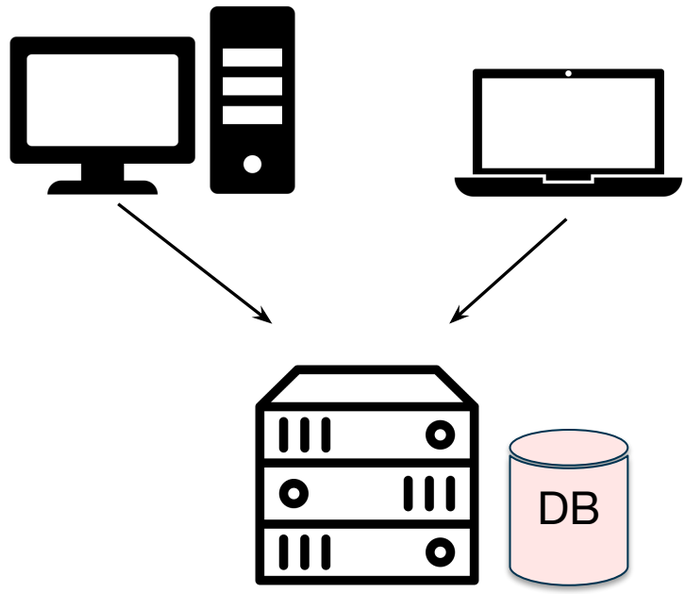
- **DB client-server architecture** - dedicated machine running DBMS accessed by remote clients (e.g. MS SQL Server, MySQL, Postgres)

- **Multi-Tier client-server architecture** - DBMS is bottom tier, second tier is an application server containing business logic, top tier is clients
  Web browser → App Server (Web Server + Business Logic) → Database

DB Client-Server Architecture

Clients

Server



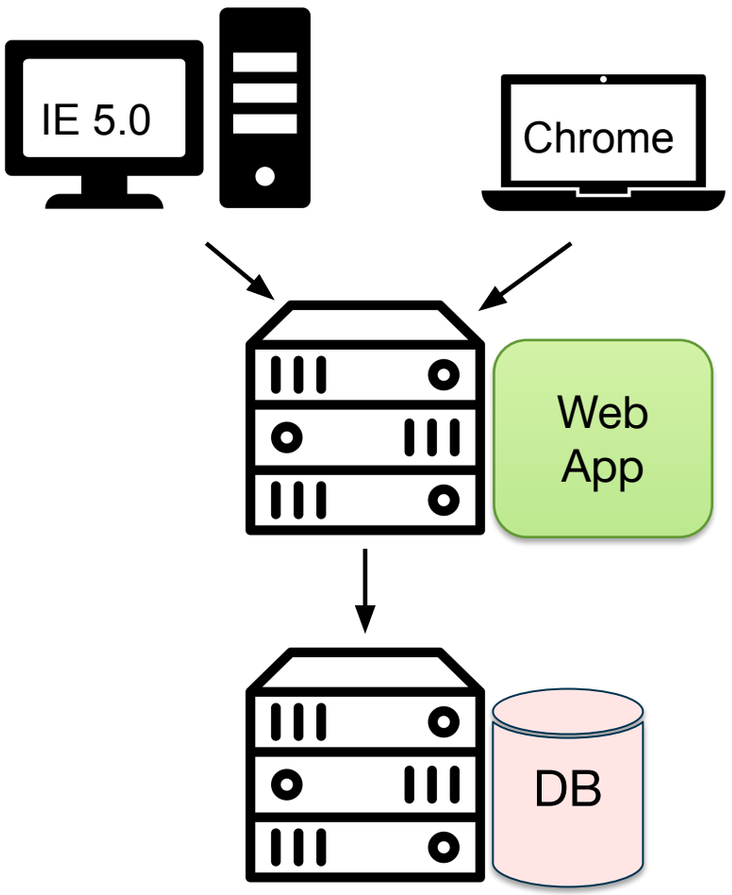
Tier 1: Client Application
- User Interface
- Business and Data Logic

Tier 2: Database Server
- Server-side validation
- Data storage/management

Advantages:

- Only one copy of DBMS software on dedicated machine
- Increased performance
- Easier to maintain consistency and manage concurrency

Three-Tier Client-Server Architecture – our approach



Tier 1: Client (Web/mobile)

- User Interface

HTML/CSS/Javascript

Tier 2: Application Server

- Business logic & data processing

Python+Flask

Tier 3: Database Server

- DBMS and data storage

MySQL

Advantages:

- Reduced client administration and cost using thin web clients.
- Easy to scale architecture and perform load balancing.

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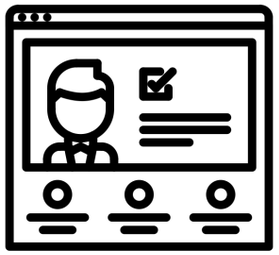

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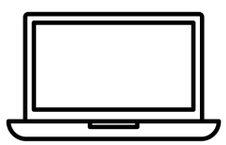

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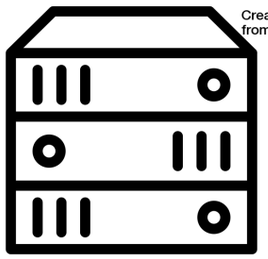

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