



College of Information Studies

University of Maryland Hornbake Library Building College Park, MD 20742-4345

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# Relational Databases

Week 9

INFM 603

# Agenda

- Questions
- Relational database design
- Microsoft Access
- MySQL
- Scalability

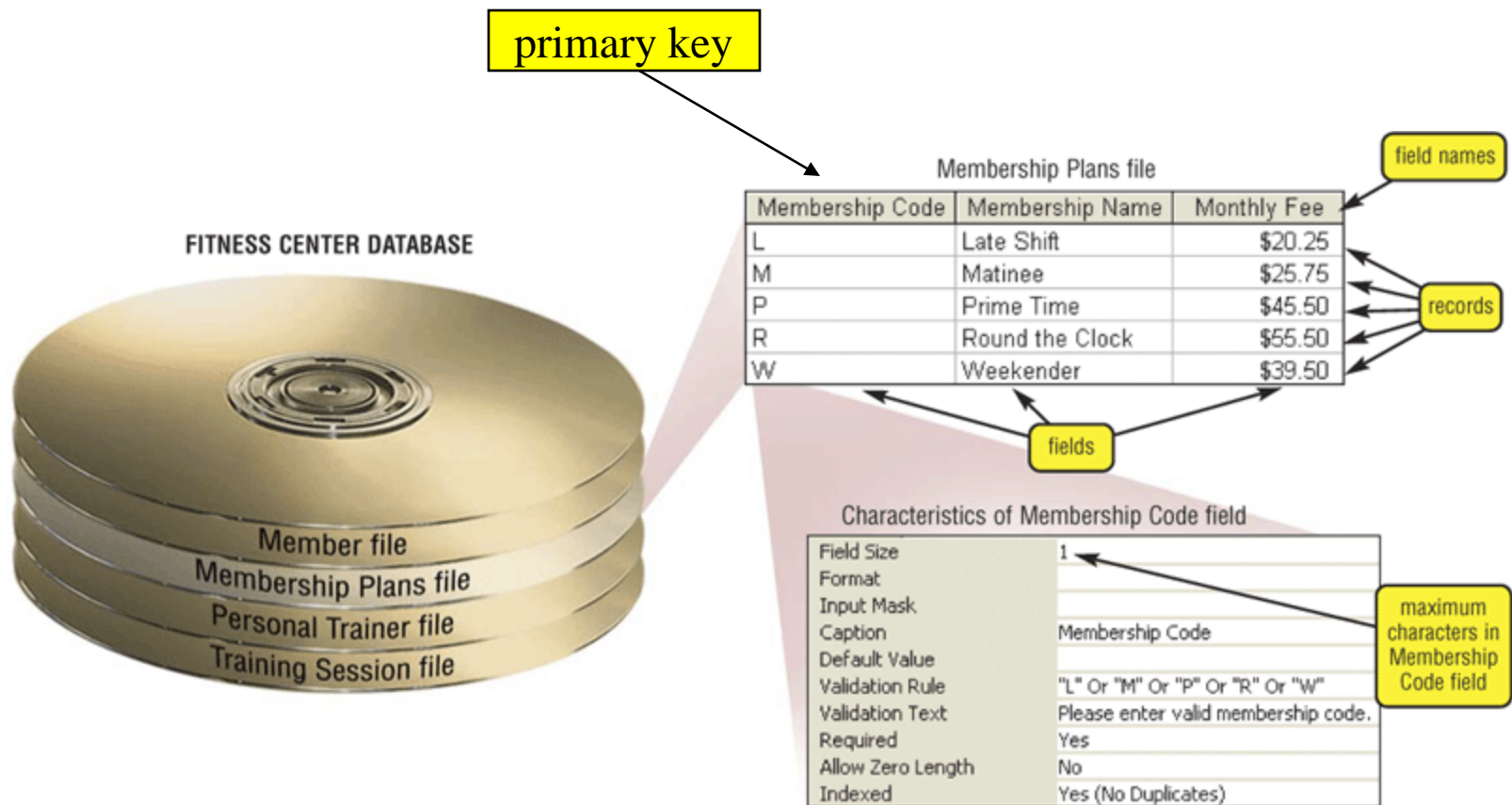
# Databases

- Database
  - Collection of data, organized to support access
  - Models some aspects of reality
- DataBase Management System (DBMS)
  - Software to create and access databases
- Relational Algebra
  - Special-purpose programming language

# Structured Information

- Field                      An “atomic” unit of data
  - number, string, true/false, ...
- Record                    A collection of related fields
- Table                      A collection of related records
  - Each record is one row in the table
  - Each field is one column in the table
- Primary Key              The field that identifies a record
  - Values of a primary key must be unique
- Database                  A collection of tables

# A Simple Example



# Registrar Example

- Which students are in which courses?
- What do we need to know about the students?
  - first name, last name, email, department
- What do we need to know about the courses?
  - course ID, description, enrolled students, grades

# A “Flat File” Solution

Student ID	Last Name	First Name	Department ID	Department	Course ID	Course description	Grades	email
1	Arrows	John	EE	EE	lbsc690	Information Technology	90	<a href="mailto:jarrows@wam">jarrows@wam</a>
1	Arrows	John	EE	Elec Engin	ee750	Communication	95	<a href="mailto:ja_2002@yahoo">ja_2002@yahoo</a>
2	Peters	Kathy	HIST	HIST	lbsc690	Informatino Technology	95	<a href="mailto:kpeters2@wam">kpeters2@wam</a>
2	Peters	Kathy	HIST	history	hist405	American History	80	<a href="mailto:kpeters2@wma">kpeters2@wma</a>
3	Smith	Chris	HIST	history	hist405	American History	90	<a href="mailto:smith2002@glue">smith2002@glue</a>
4	Smith	John	CLIS	Info Sci	lbsc690	Information Technology	98	<a href="mailto:js03@wam">js03@wam</a>

Discussion Topic

Why is this a bad approach?

# Goals of “Normalization”

- Save space
  - Save each fact only once
- More rapid updates
  - Every fact only needs to be updated once
- More rapid search
  - Finding something once is good enough
- Avoid inconsistency
  - Changing data once changes it everywhere



# Relational Algebra

- Tables represent “relations”
  - Course, course description
  - Name, email address, department
- Named fields represent “attributes”
- Each row in the table is called a “tuple”
  - The order of the rows is not important
- Queries specify desired conditions
  - The DBMS then finds data that satisfies them

# A Normalized Relational Database

## Student Table

Student ID	Last Name	First Name	Department ID	email
1	Arrows	John	EE	jarrows@wam
2	Peters	Kathy	HIST	kpeters2@wam
3	Smith	Chris	HIST	<a href="mailto:smith2002@glue">smith2002@glue</a>
4	Smith	John	CLIS	js03@wam

## Department Table

Department ID	Department
EE	Electronic Engineering
HIST	History
CLIS	Information Stuides

## Course Table

Course ID	Course Description
lbsc690	Information Technology
ee750	Communication
hist405	American History

## Enrollment Table

Student ID	Course ID	Grades
1	lbsc690	90
1	ee750	95
2	lbsc690	95
2	hist405	80
3	hist405	90
4	lbsc690	98

# Approaches to Normalization

- For simple problems
  - Start with “binary relationships”
    - Pairs of fields that are related
  - Group together wherever possible
  - Add keys where necessary
- For more complicated problems
  - Entity relationship modeling

# Example of Join

Student Table

Student ID	Last Name	First Name	Department ID	email
1	Arrows	John	EE	jarrows@wam
2	Peters	Kathy	HIST	kpeters2@wam
3	Smith	Chris	HIST	<a href="mailto:smith2002@glue">smith2002@glue</a>
4	Smith	John	CLIS	js03@wam

Department Table

Department ID	Department
EE	Electronic Engineering
HIST	History
CLIS	Information Stuides

“Joined” Table

Student ID	Last Name	First Name	Department ID	Department	email
1	Arrows	John	EE	Electronic Engineering	<a href="mailto:jarrows@wam">jarrows@wam</a>
2	Peters	Kathy	HIST	History	<a href="mailto:kpeters2@wam">kpeters2@wam</a>
3	Smith	Chris	HIST	History	<a href="mailto:smith2002@glue">smith2002@glue</a>
4	Smith	John	CLIS	Information Stuides	<a href="mailto:js03@wam">js03@wam</a>

# Problems with Join

- Data modeling for join is complex
  - Useful to start with E-R modeling
- Join are expensive to compute
  - Both in time and storage space
- But it's joins that make databases relational
  - Projection and restriction also used in flat files

# Some Lingo

- “Primary Key” uniquely identifies a record
  - e.g. student ID in the student table
- “Compound” primary key
  - Synthesize a primary key with a combination of fields
  - e.g., Student ID + Course ID in the enrollment table
- “Foreign Key” is primary key in the other table
  - Note: it need not be unique in this table

# Project

## New Table

Student ID	Last Name	First Name	Department ID	Department	email
1	Arrows	John	EE	Electronic Engineering	<a href="mailto:jarrows@wam">jarrows@wam</a>
2	Peters	Kathy	HIST	History	<a href="mailto:kpeters2@wam">kpeters2@wam</a>
3	Smith	Chris	HIST	History	<a href="mailto:smith2002@glue">smith2002@glue</a>
4	Smith	John	CLIS	Information Stuides	<a href="mailto:js03@wam">js03@wam</a>



SELECT **Student ID**, Department

Student ID	Department
1	Electronic Engineering
2	History
3	History
4	Information Stuides

# Restrict

## New Table

Student ID	Last Name	First Name	Department ID	Department	email
1	Arrows	John	EE	Electronic Engineering	<a href="mailto:jarrows@wam">jarrows@wam</a>
2	Peters	Kathy	HIST	History	<a href="mailto:kpeters2@wam">kpeters2@wam</a>
3	Smith	Chris	HIST	History	<a href="mailto:smith2002@glue">smith2002@glue</a>
4	Smith	John	CLIS	Information Stuides	<a href="mailto:js03@wam">js03@wam</a>



WHERE **Department ID** = “HIST”

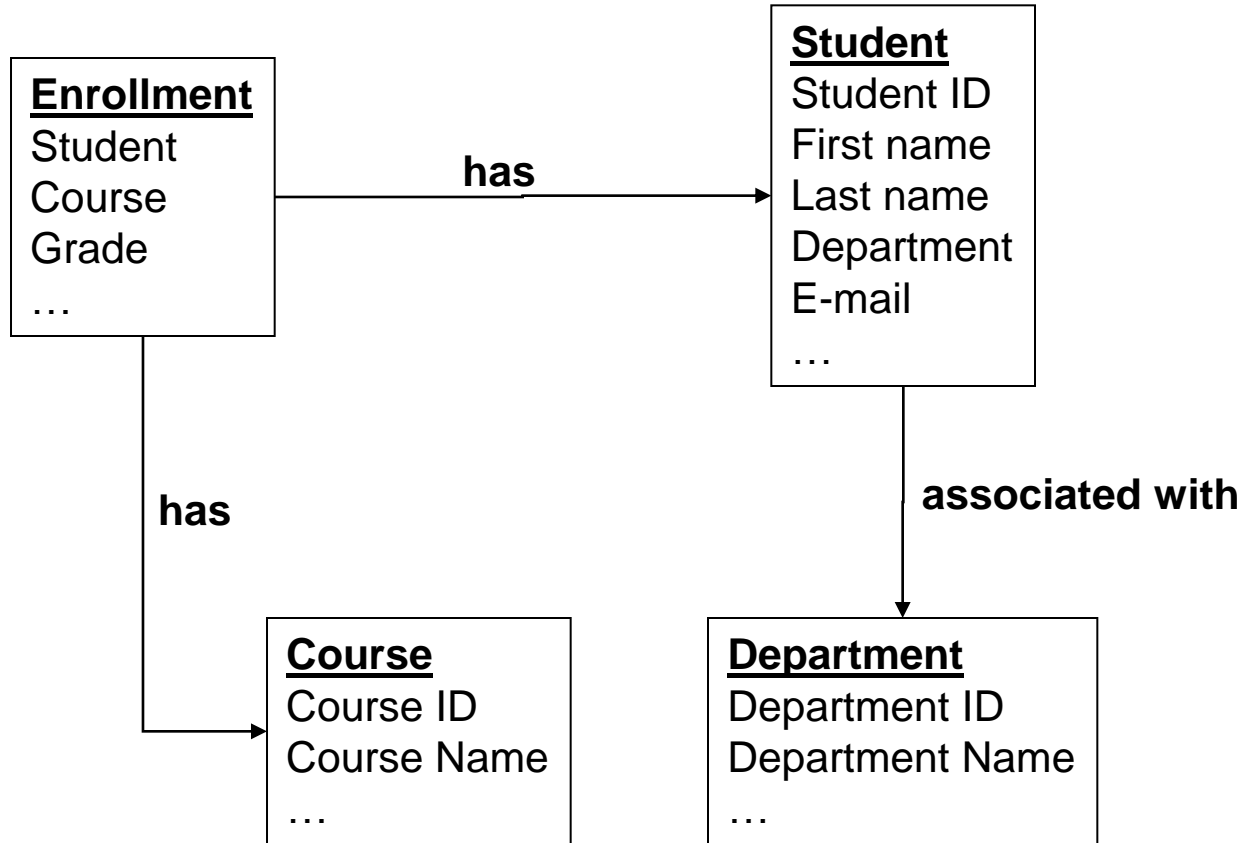
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# Entity-Relationship Diagrams

- Graphical visualization of the data model
- Entities are captured in boxes
- Relationships are captured using arrows

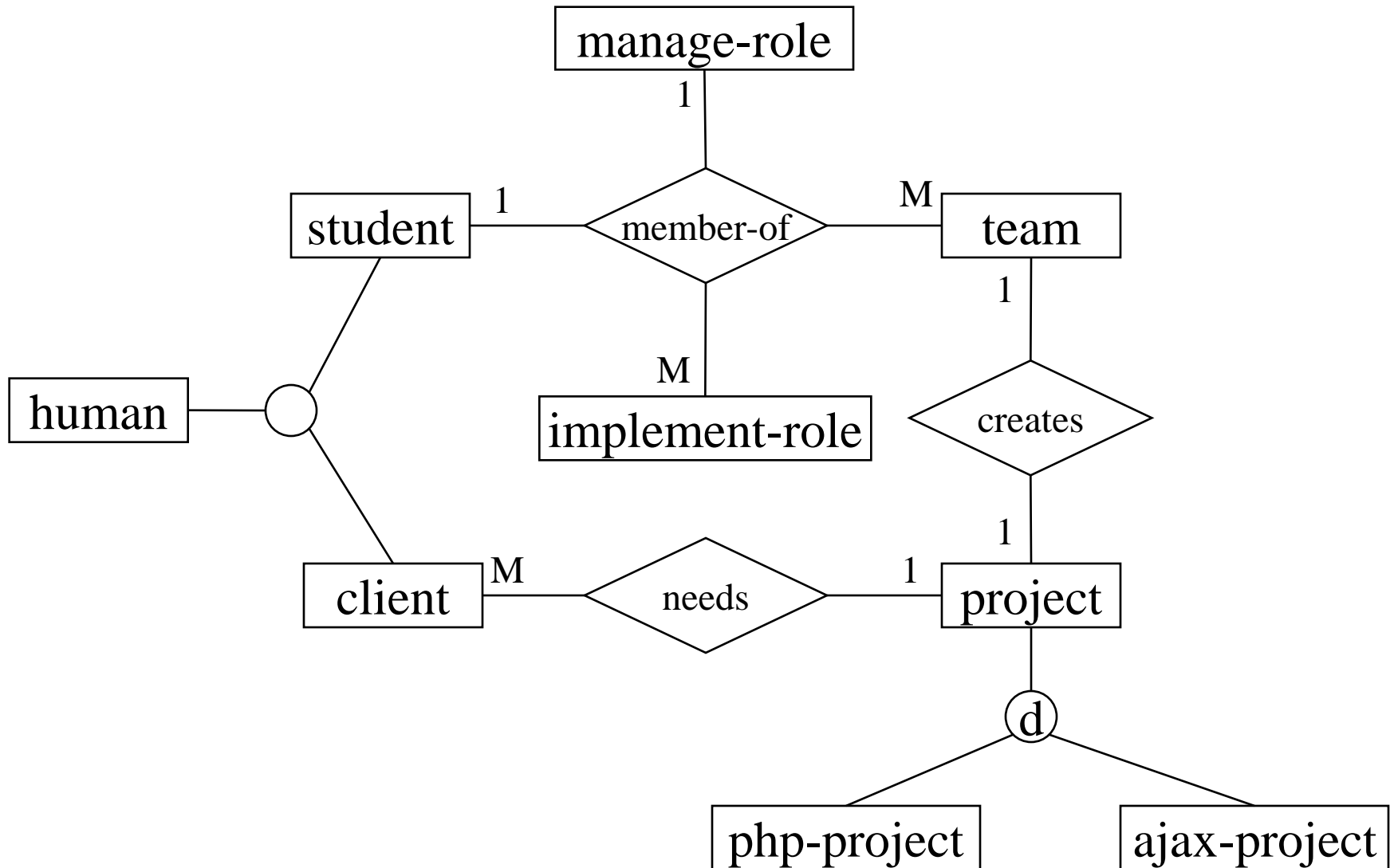
# Registrar ER Diagram



# Getting Started with E-R Modeling

- What **questions** must you answer?
- What **data** is needed to generate the answers?
  - Entities
    - Attributes of those entities
  - Relationships
    - Nature of those relationships
- How will the user interact with the system?
  - Relating the question to the available data
  - Expressing the answer in a useful form

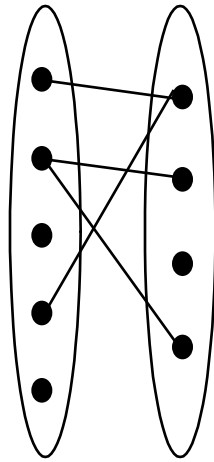
# “Project Team” E-R Example



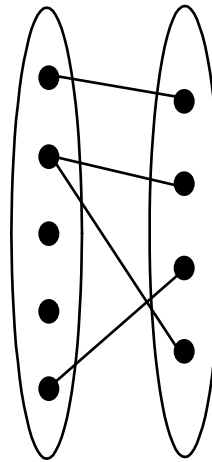
# Components of E-R Diagrams

- Entities
  - Types
    - Subtypes (disjoint / overlapping)
  - Attributes
    - Mandatory / optional
  - Identifier
- Relationships
  - Cardinality
  - Existence
  - Degree

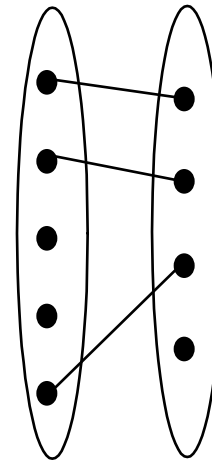
# Types of Relationships



**Many-to-Many**



**1-to-Many**



**1-to-1**

# Making Tables from E-R Diagrams

- Pick a primary key for each entity
- Build the tables
  - One per entity
  - Plus one per M:M relationship
  - Choose terse but memorable table and field names
- Check for parsimonious representation
  - Relational “normalization”
  - Redundant storage of computable values
- Implement using a DBMS

- 1NF: Single-valued indivisible (atomic) attributes
  - Split “Doug Oard” to two attributes as (“Doug”, “Oard”)
  - Model M:M implement-role relationship with a table
- 2NF: Attributes depend on complete primary key
  - (id, impl-role, name)  $\rightarrow$  (id, name) + (id, impl-role)
- 3NF: Attributes depend directly on primary key
  - (id, addr, city, state, zip)  $\rightarrow$  (id, addr, zip) + (zip, city, state)
- 4NF: Divide independent M:M tables
  - (id, role, courses)  $\rightarrow$  (id, role) + (id, courses)
- 5NF: Don't enumerate derivable combinations



# Normalized Table Structure

- Persons: id, fname, lname, userid, password
- Contacts: id, ctype, cstring
- Ctlabels: ctype, string
- Students: id, team, mrole
- Iroles: id, irole
- Rlabels: role, string
- Projects: team, client, pstring

# Making Tables from E-R Diagrams

- Pick a primary key for each entity
- Build the tables
  - One per entity
  - Plus one per M:M relationship
  - Choose terse but memorable table and field names
- Check for parsimonious representation
  - Relational “normalization”
  - Redundant storage of computable values
- Implement using a DBMS

# Database Integrity

- Registrar database must be internally consistent
  - Enrolled students must have an entry in student table
  - Courses must have a name
- What happens:
  - When a student withdraws from the university?
  - When a course is taken off the books?

# Integrity Constraints

- Conditions that must always be true
  - Specified when the database is designed
  - Checked when the database is modified
- RDBMS ensures integrity constraints are respected
  - So database contents remain faithful to real world
  - Helps avoid data entry errors

# Referential Integrity

- Foreign key values must exist in other table
  - If not, those records cannot be joined
- Can be enforced when data is added
  - Associate a primary key with each foreign key
- Helps avoid erroneous data
  - Only need to ensure data quality for primary keys

# Database “Programming”

- Natural language
  - Goal is ease of use
    - e.g., Show me the last names of students in CLIS
  - Ambiguity sometimes results in errors
- Structured Query Language (SQL)
  - Consistent, unambiguous interface to any DBMS
  - Simple command structure:
    - e.g., `SELECT Last name FROM Students WHERE Dept=CLIS`
  - Useful standard for inter-process communications
- Visual programming (e.g., Microsoft Access)
  - Unambiguous, and easier to learn than SQL

# Using Microsoft Access

- Create a database called M:\rides.mdb
  - File->New->Blank Database
- Specify the fields (columns)
  - “Create a Table in Design View”
- Fill in the records (rows)
  - Double-click on the icon for the table

# Creating Fields

- Enter field name
  - Must be unique, but only within the same table
- Select field type from a menu
  - Use date/time for times
  - Use text for phone numbers
- Designate primary key (right mouse button)
- Save the table
  - That's when you get to assign a table name



# Entering Data

- Open the table
  - Double-click on the icon
- Enter new data in the bottom row
  - A new (blank) bottom row will appear
- Close the table
  - No need to “save” – data is stored automatically

# Building Queries

- Copy ride.mdb to your C:\ drive
- “Create Query in Design View”
  - In “Queries”
- Choose two tables, Flight and Company
- Pick each field you need using the menus
  - Unclick “show” to not project
  - Enter a criterion to “restrict”
- Save, exit, and reselect to run the query

# Fun Facts about Queries

- Joins are automatic if field names are same
  - Otherwise, drag a line between the fields
- Sort order is easy to specify
  - Use the menu

# The SQL SELECT Command

- Project chooses columns
  - Based on their label
- Restrict chooses rows
  - Based on their contents
    - e.g. department ID = “HIST”
- These can be specified together
  - SELECT **Student ID, Dept** WHERE **Dept = “History”**

# Restrict Operators

- Each SELECT contains a single WHERE
- Numeric comparison
  - <, >, =, <>, ...
    - e.g., grade<80
- Boolean operations
  - e.g., Name = “John” AND Dept <> “HIST”

# Structured Query Language

DESCRIBE Flight;

Flight : Table		
	Field Name	Data Type
🔑	Flight Number	Text
	Origin	Text
	Destination	Text
	Departure Time	Date/Time
	Arrival Time	Date/Time
	Available Seats	Number
	Company Name	Text
	Price	Currency

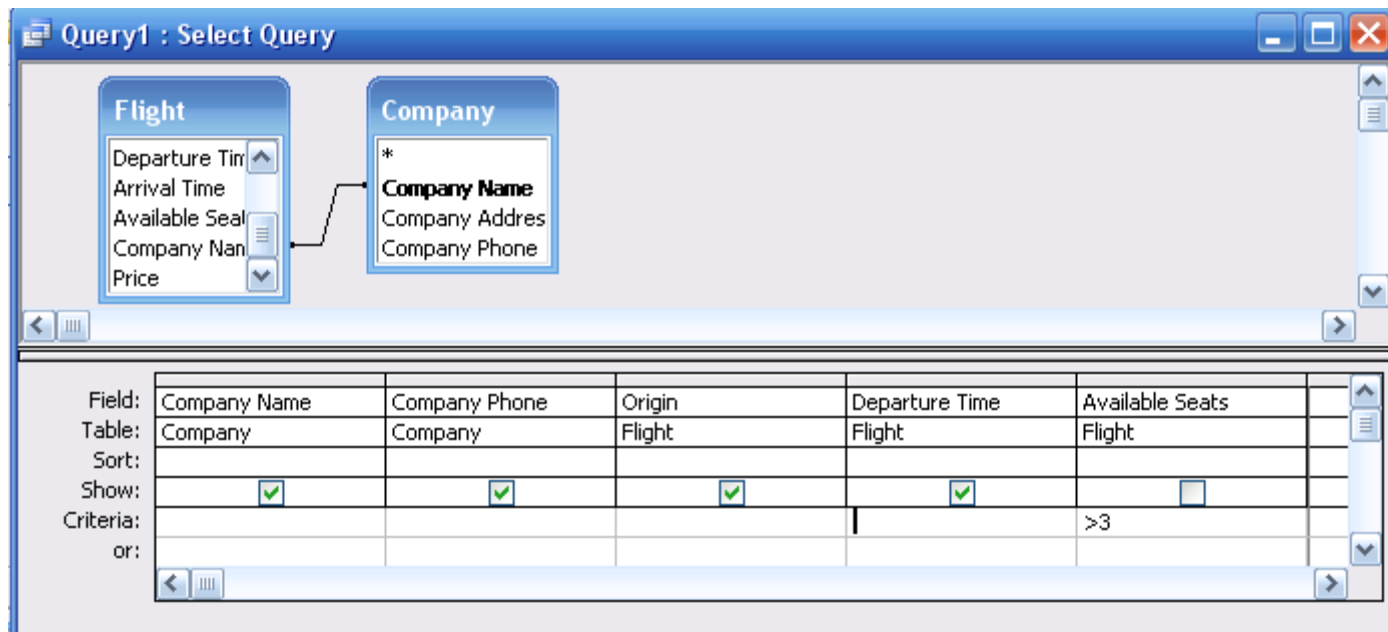
# Structured Query Language

SELECT \* FROM Flight;

Flight : Table								
	Flight Number	Origin	Destination	Departure Time	Arrival Time	Available Seats	Company Name	Price
►	CA210	DC	Austin	6:00:00 AM	11:00:00 AM	0	Cal Air	\$200.00
	CA345	San Jose	San Diego	9:00:00 AM	10:30:00 AM	20	Cal Air	\$100.00
	FT900	Chicago	New York	2:00:00 PM	5:00:00 PM	1	Fancy Trans	\$200.00
	GJ405	DC	San Jose	12:30:00 PM	8:45:00 PM	10	Green Jet	\$340.00
	GJ908	New York	Austin	8:00:00 AM	12:00:00 PM	2	Green Jet	\$250.00
	TP123	New York	San Jose	7:00:00 AM	11:00:00 AM	2	Trans Planet	\$400.00
*						0		\$0.00

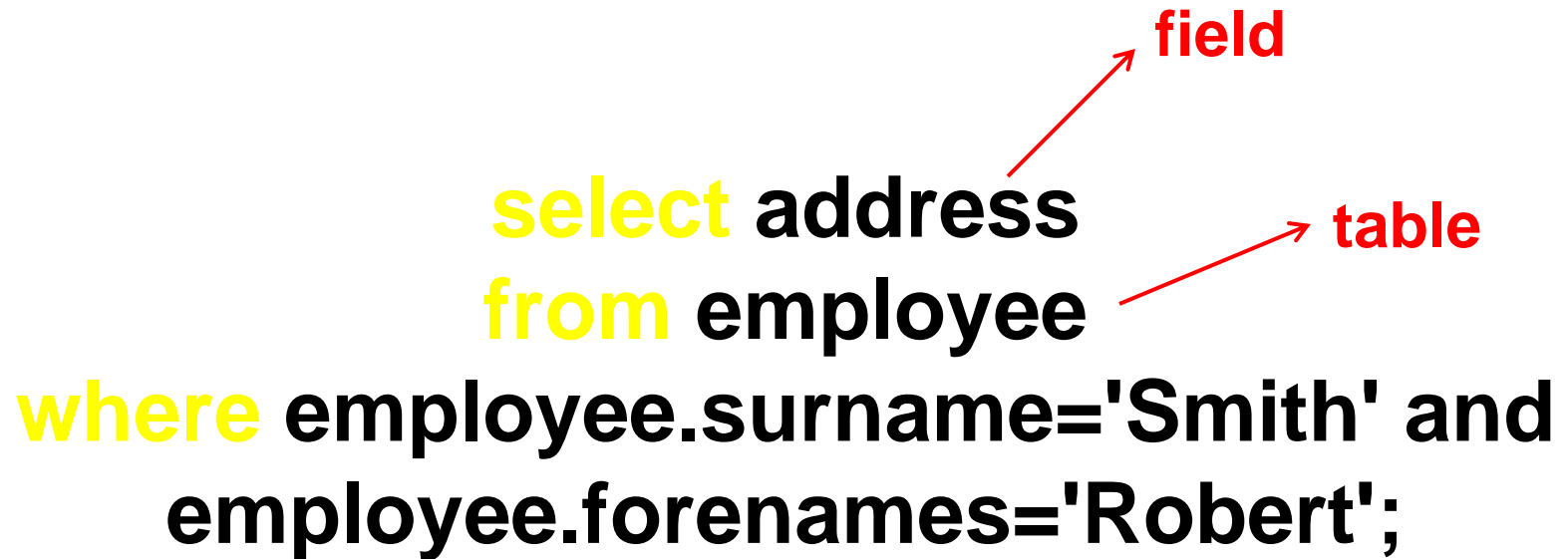
# Structured Query Language

```
SELECT Company.CompanyName, Company.CompanyPhone,  
       Flight.Origin, Flight.DepartureTime  
FROM Flight,Company  
WHERE Flight.CompanyName=Company.CompanyName  
AND Flight.AvailableSeats>3;
```





**select** address  
**from** employee  
**where** employee.surname='Smith' and  
employee.forenames='Robert';



The diagram illustrates the components of an SQL query. Red arrows point from descriptive labels to specific parts of the query: 'field' points to 'address', 'table' points to 'employee', and 'how you want to restrict the rows' points to the 'where' clause.

how you want to restrict the rows

**select** dname  
**from** employee, department  
**where** employee.depno=department.depno  
and surname='Smith' and  
forenames='Robert';

The diagram consists of four red arrows pointing from specific parts of the SQL query to explanatory text. One arrow points from 'dname' to 'field'. Another points from 'employee, department' to 'tables to join'. A third points from 'employee.depno=department.depno' to 'how to join'. A fourth points from 'and surname='Smith' and forenames='Robert';' to 'how you want to restrict the rows'.

field

tables to join

how to join

how you want to restrict the rows

# Create a MySQL Database

- “root” user creates database + grants permissions
  - Using the WAMP console (or `mysql -u root -p`)
    - root has no initial password; just hit <enter> when asked
  - By the system administrator account

```
CREATE DATABASE project;
```

```
GRANT SELECT, INSERT, UPDATE, DELETE, INDEX, ALTER, CREATE, DROP ON  
project.* TO 'foo'@'localhost' IDENTIFIED BY 'bar';
```

```
FLUSH PRIVILEGES;
```

- Start mysql
  - MySQL console for WAMP: `mysql -u foo -p bar`
- Connect to your database

```
USE project;
```

# Creating Tables

```
CREATE TABLE contacts (  
  ckey    MEDIUMINT UNSIGNED NOT NULL AUTO_INCREMENT,  
  id      MEDIUMINT UNSIGNED NOT NULL,  
  ctype   SMALLINT UNSIGNED NOT NULL,  
  cstring VARCHAR(40) NOT NULL,  
  FOREIGN KEY (id) REFERENCES persons(id) ON DELETE CASCADE,  
  FOREIGN KEY (ctype) REFERENCES ctlabels(ctype) ON DELETE RESTRICT,  
  PRIMARY KEY (ckey)  
) ENGINE=INNODB;
```

➤ To delete: **DROP TABLE contacts;**

# Populating Tables

```
INSERT INTO ctlabels
```

```
(string) VALUES
```

```
('primary email'),
```

```
('alternate email'),
```

```
('home phone'),
```

```
('cell phone'),
```

```
('work phone'),
```

```
('AOL IM'),
```

```
('Yahoo Chat'),
```

```
('MSN Messenger'),
```

```
('other');
```

➤ To empty a table: `DELETE FROM ctlabels;`

# “Looking Around” in MySQL

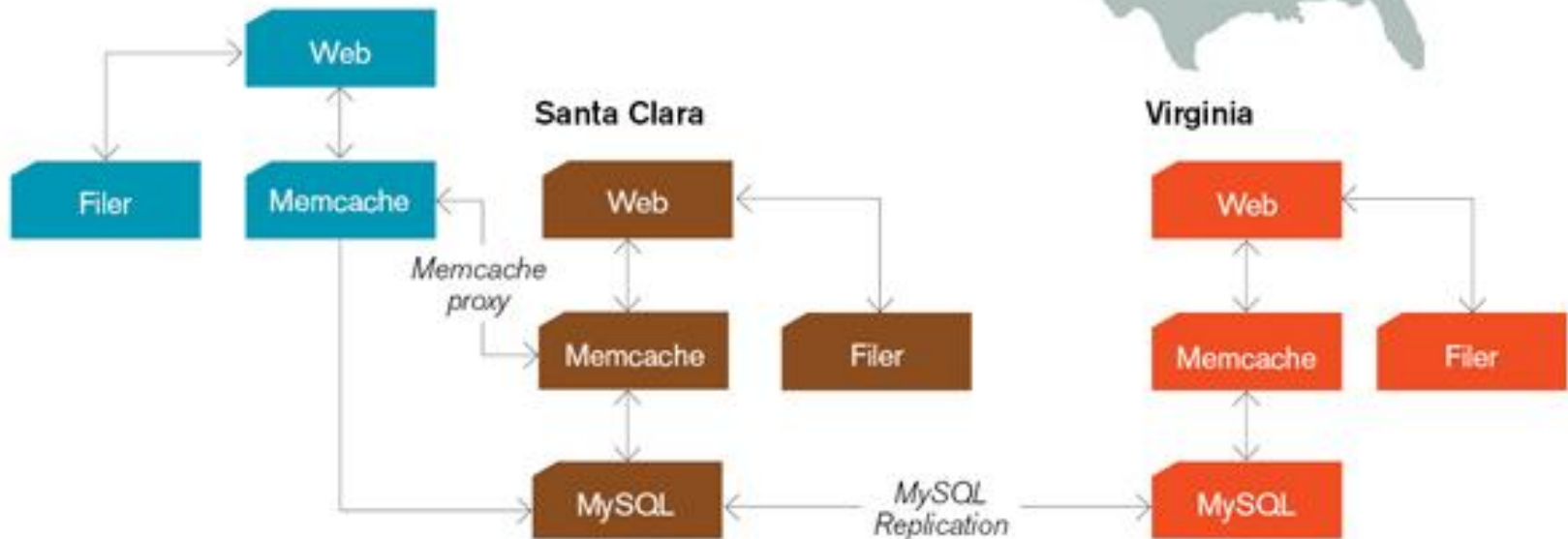
- `SHOW DATABASES;`
- `SHOW TABLES;`
- `DESCRIBE tablename;`
- `SELECT * FROM tablename;`

# Databases in the Real World

- Some typical database applications:
  - Banking (e.g., saving/checking accounts)
  - Trading (e.g., stocks)
  - Airline reservations
- Characteristics:
  - Lots of data
  - Lots of concurrent access
  - Must have fast access
  - “Mission critical”

# FACEBOOK ARCHITECTURE

## San Francisco



**Caching servers:** 15 million requests per second, 95% handled by memcache (15 TB of RAM)

**Database layer:** 800 eight-core Linux servers running MySQL (40 TB user data)



# Concurrency

- Thought experiment: You and your project partner are editing the same file...
  - Scenario 1: you both save it at the same time
  - Scenario 2: you save first, but before it's done saving, your partner saves

**Whose changes survive?**

**A) Yours B) Partner's C) neither D) both E) ???**

# Concurrency Example

- Possible actions on a checking account
  - Deposit check (read balance, write new balance)
  - Cash check (read balance, write new balance)
- Scenario:
  - Current balance: \$500
  - You try to deposit a \$50 check and someone tries to cash a \$100 check at the same time
  - Possible sequences: (what happens in each case?)

**Deposit: read balance**  
**Deposit: write balance**  
Cash: read balance  
Cash: write balance

**Deposit: read balance**  
Cash: read balance  
Cash: write balance  
**Deposit: write balance**

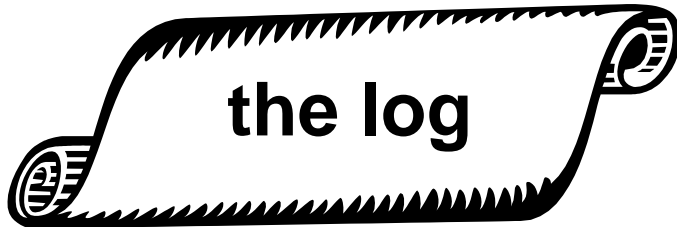
**Deposit: read balance**  
Cash: read balance  
**Deposit: write balance**  
Cash: write balance

# Database Transactions

- Transaction: sequence of grouped database actions
  - e.g., transfer \$500 from checking to savings
- “ACID” properties
  - **Atomicity**
    - All-or-nothing
  - **Consistency**
    - Each transaction must take the DB between consistent states.
  - **Isolation:**
    - Concurrent transactions must appear to run in isolation
  - **Durability**
    - Results of transactions must survive even if systems crash

# Making Transactions

- Idea: keep a log (history) of all actions carried out while executing transactions
  - Before a change is made to the database, the corresponding log entry is forced to a safe location



- Recovering from a crash:
  - Effects of partially executed transactions are undone
  - Effects of committed transactions are redone

# Utility Service Desk Exercise

- Design a database to keep track of service calls for a utility company:
  - Customers call to report problems
  - Call center manages “tickets” to assign workers to jobs
    - Must match skills and service location
    - Must balance number of assignments
  - Workers call in to ask where their next jobs are
- In SQL, you can do the following operations:
  - Count the number of rows in a result set
  - Sort the result set according to a field
  - Find the maximum and minimum value of a field

# Key Ideas

- Databases are a good choice when you have
  - Lots of data
  - A problem that contains inherent relationships
- Join is the most important concept
  - Project and restrict just remove undesired stuff
- Design before you implement
  - Managing complexity is important