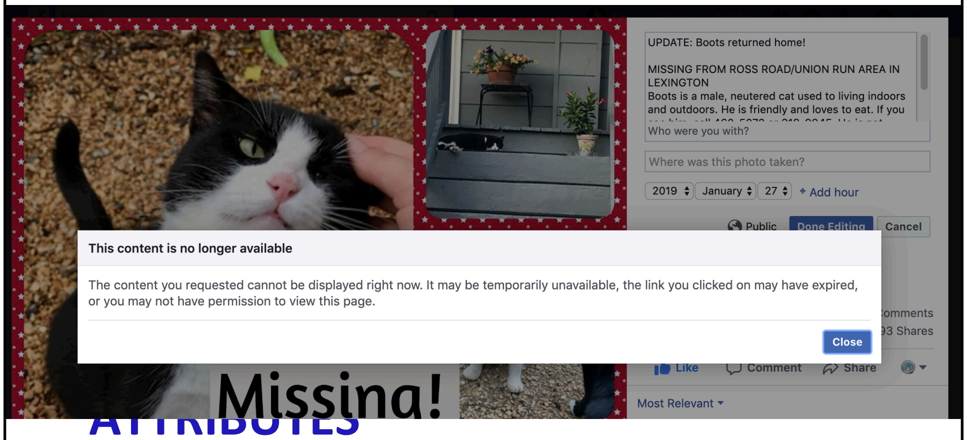
Objectives

- Review: JavaScript
- Quality Attributes of Web Software
- Introduction to Relational Databases, SQL
- JDBC

JavaScript review

- True or False: JavaScript is just like Java
- How do you declare a variable? (2 ways)
- How do you write text to the web page?
- What is the syntax for functions?
- What are some examples of events?
- How do you access a particular element in a document?
  - What are some ways to change that element?



UPDATE: Boots returned home!

MISSING FROM ROSS ROAD/UNION RUN AREA IN LEXINGTON
Boots is a male, neutered cat used to living indoors and outdoors. He is friendly and loves to eat. If you

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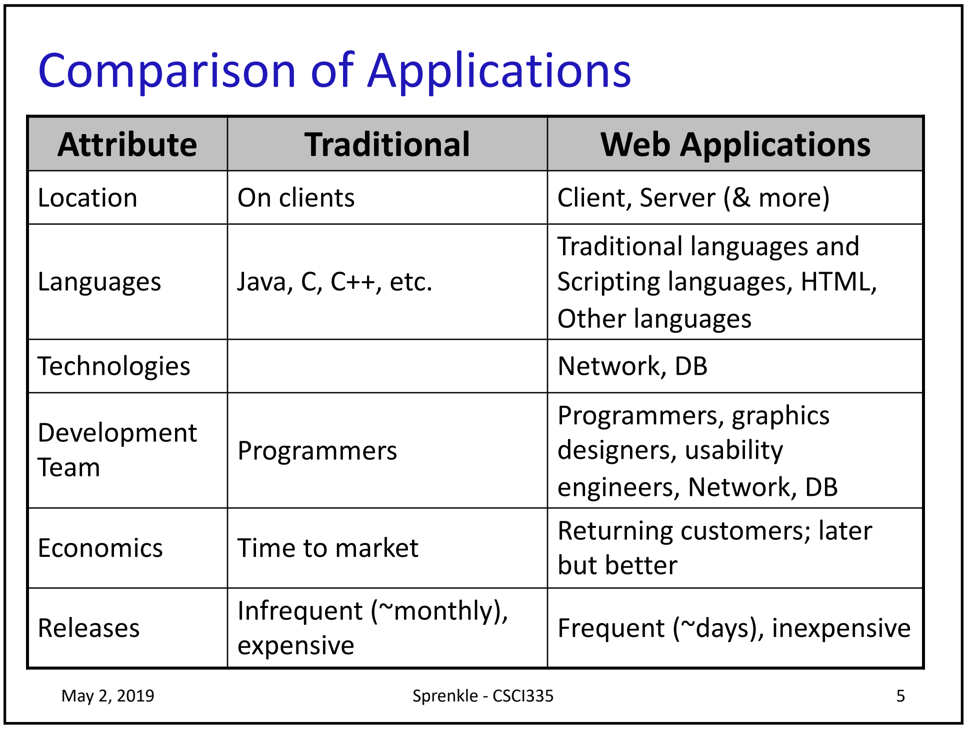
ATTRIBUTES

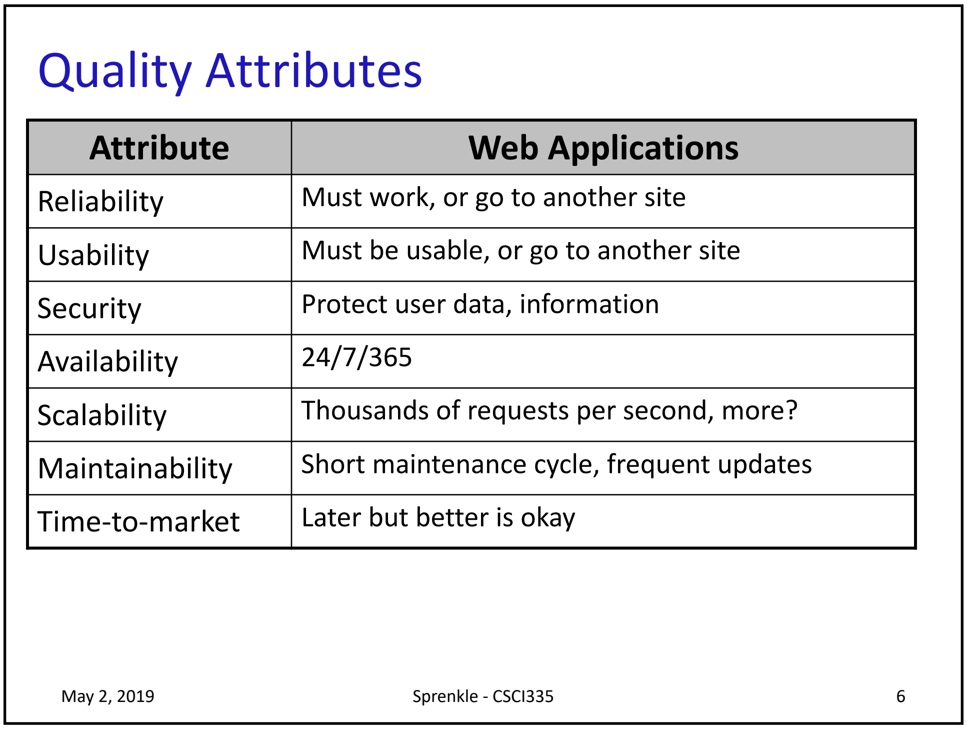
Quality Attributes

- How are web applications different from “traditional”/desktop applications?
  - Leads to differences in quality attributes
- React to “For most application types, commercial developers have traditionally had little motivation to produce high-quality software.”
- What are differences between 2002 (when article was originally published) and now?
- Let’s add another point in the comparison: mobile apps
  - Compare mobile apps with web and desktop



Comparison of Applications

Attribute	Traditional	Web Applications
Location	On clients	Client, Server (& more)
Languages	Java, C, C++, etc.	Traditional languages and Scripting languages, HTML, Other languages
Technologies		Network, DB
Development Team	Programmers	Programmers, graphics designers, usability engineers, Network, DB
Economics	Time to market	Returning customers; later but better
Releases	Infrequent (~monthly), expensive	Frequent (~days), inexpensive



Quality Attributes

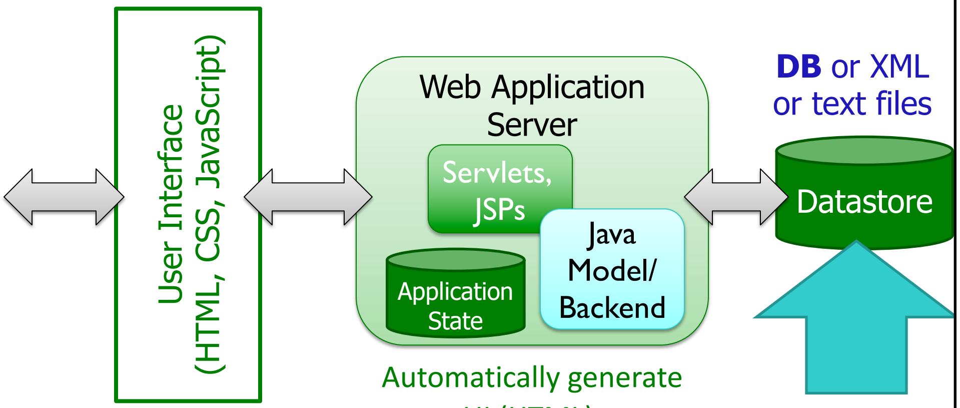
Attribute	Web Applications
Reliability	Must work, or go to another site
Usability	Must be usable, or go to another site
Security	Protect user data, information
Availability	24/7/365
Scalability	Thousands of requests per second, more?
Maintainability	Short maintenance cycle, frequent updates
Time-to-market	Later but better is okay

Discussion

- What are examples of sites that you used to use but you switched because something better came along?
  - How easy is it to switch now?

DATABASES AND SQL

Web Application Architecture Overview



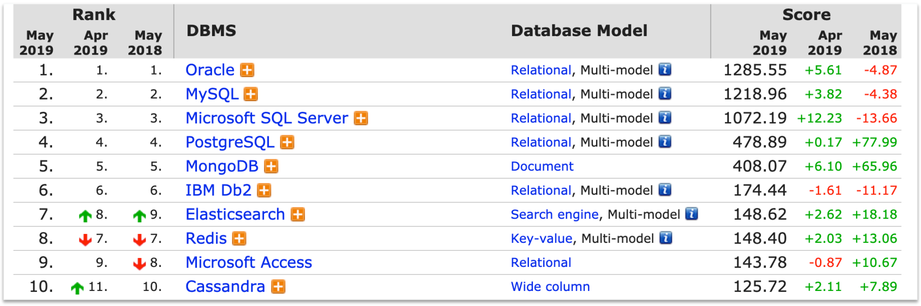
Automatically generate UI (HTML),
Handle user requests

Data structures,
helper classes

Database Overview

- Store data in such a way to allow *efficient* storage, search, and update
- **Relational Data Model** - currently most popular type of database
  - Many vendors: PostgreSQL, Oracle, MySQL, DB2, MSSQL
  - Data is stored in **tables**
  - ***Attributes***: column names (one word)
  - Often contain ***primary key***:
    a set of columns that uniquely identify a row

DB Popularity



Rank			DBMS	Database Model	Score		
May 2019	Apr 2019	May 2018			May 2019	Apr 2019	May 2018
1.	1.	1.	Oracle ⊞	Relational, Multi-model ℹ	1285.55	+5.61	-4.87
2.	2.	2.	MySQL ⊞	Relational, Multi-model ℹ	1218.96	+3.82	-4.38
3.	3.	3.	Microsoft SQL Server ⊞	Relational, Multi-model ℹ	1072.19	+12.23	-13.66
4.	4.	4.	PostgreSQL ⊞	Relational, Multi-model ℹ	478.89	+0.17	+77.99
5.	5.	5.	MongoDB ⊞	Document	408.07	+6.10	+65.96
6.	6.	6.	IBM Db2 ⊞	Relational, Multi-model ℹ	174.44	-1.61	-11.17
7.	↑ 8.	↑ 9.	Elasticsearch ⊞	Search engine, Multi-model ℹ	148.62	+2.62	+18.18
8.	↓ 7.	↓ 7.	Redis ⊞	Key-value, Multi-model ℹ	148.40	+2.03	+13.06
9.	9.	↓ 8.	Microsoft Access	Relational	143.78	-0.87	+10.67
10.	↑ 11.	10.	Cassandra ⊞	Wide column	125.72	+2.11	+7.89

Ranking based on web site mentions, searches, questions, job offers, professional profiles, social network mentions

https://db-engines.com/en/ranking

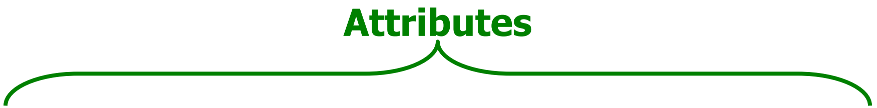
Example Students Table

- id is the *primary key*
- What are the attributes?

id	lastName	firstName	gradYear	major
10011	Aaronson	Aaron	2021	CSCI
43123	Brown	Allison	2020	ENGL

Example Students Table

- id is the primary key
- What are the attributes?



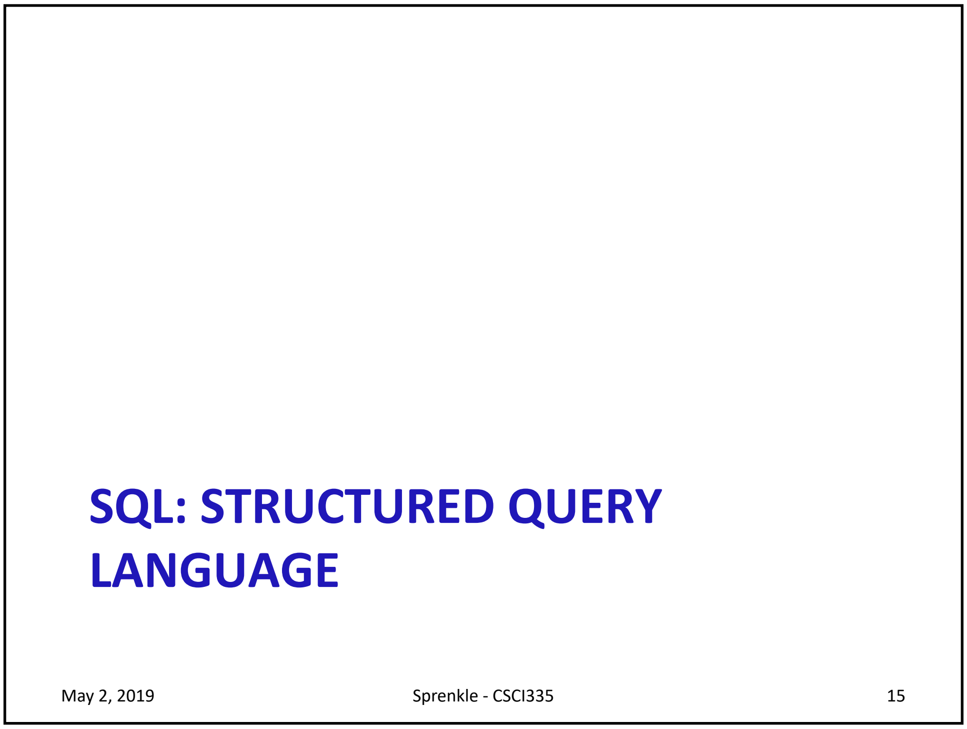
Attributes

id	lastName	firstName	gradYear	major
10011	Aaronson	Aaron	2021	CSCI
43123	Brown	Allison	2020	ENGL

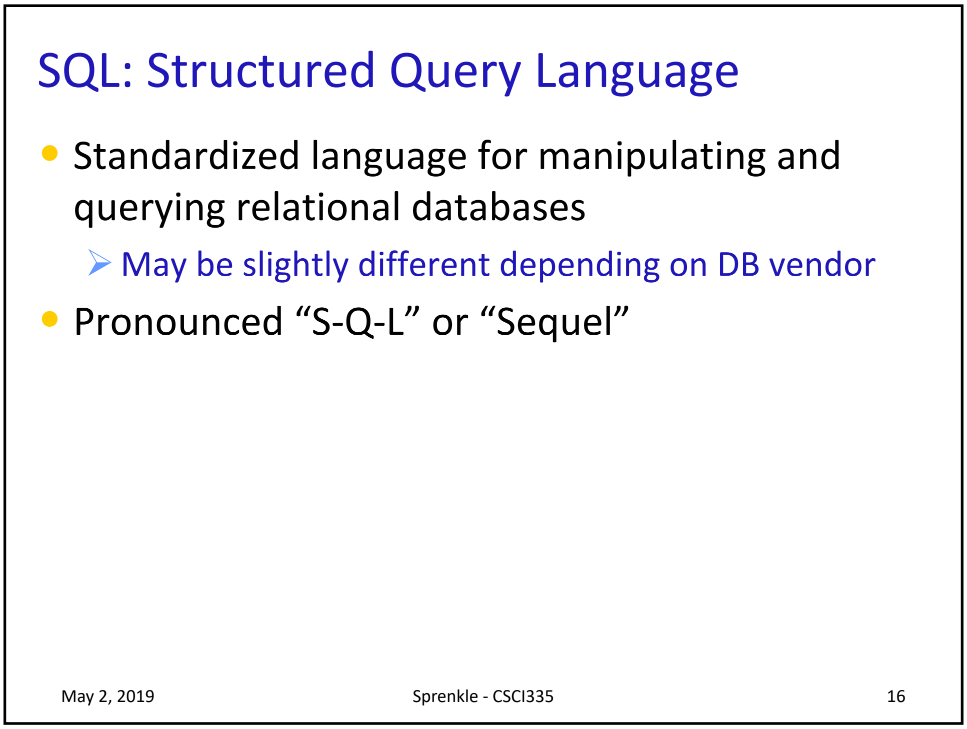
Courses Table

- Primary key is (Department, Number)
  - As a group, these uniquely identify a row

department	number	name	description
CSCI	101	Survey of Computer Science	A survey of …
CSCI	111	Fundamentals of Programming I	An introduction to …

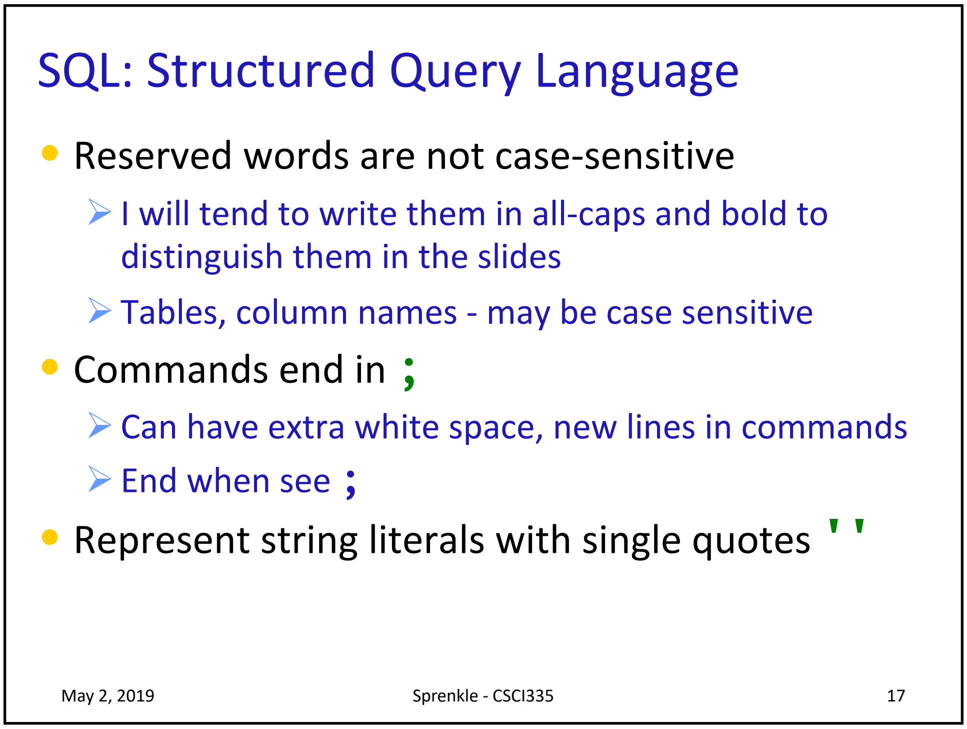


SQL: STRUCTURED QUERY LANGUAGE



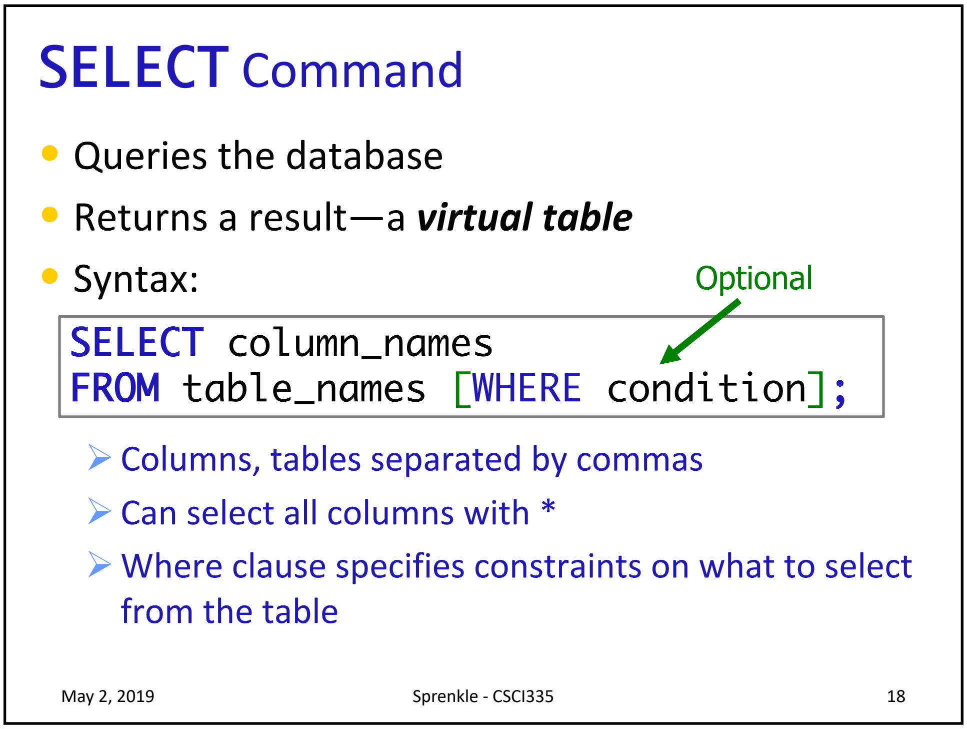
SQL: Structured Query Language

- Standardized language for manipulating and querying relational databases
  - May be slightly different depending on DB vendor
- Pronounced "S-Q-L" or "Sequel"



SQL: Structured Query Language

- Reserved words are not case-sensitive
  - I will tend to write them in all-caps and bold to distinguish them in the slides
  - Tables, column names - may be case sensitive
- Commands end in **;**
  - Can have extra white space, new lines in commands
  - End when see **;**
- Represent string literals with single quotes **' '**



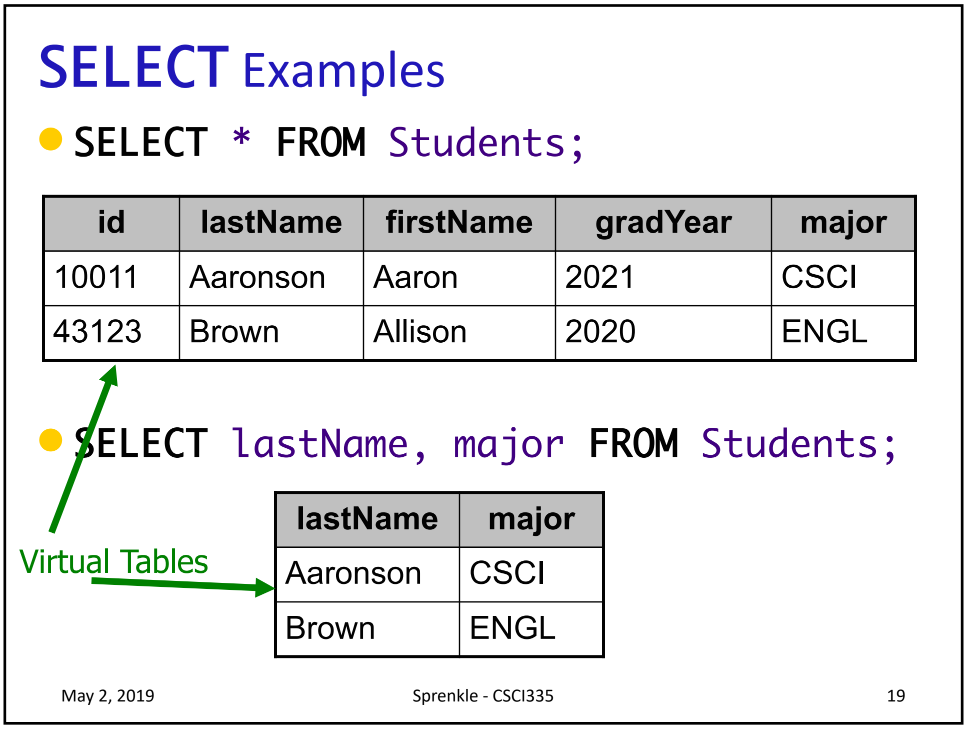
SELECT Command

- Queries the database
- Returns a result—a ***virtual table***
- Syntax:

Optional

```
SELECT column_names
FROM table_names [WHERE condition];
```

  - Columns, tables separated by commas
  - Can select all columns with *
  - Where clause specifies constraints on what to select from the table



SELECT Examples

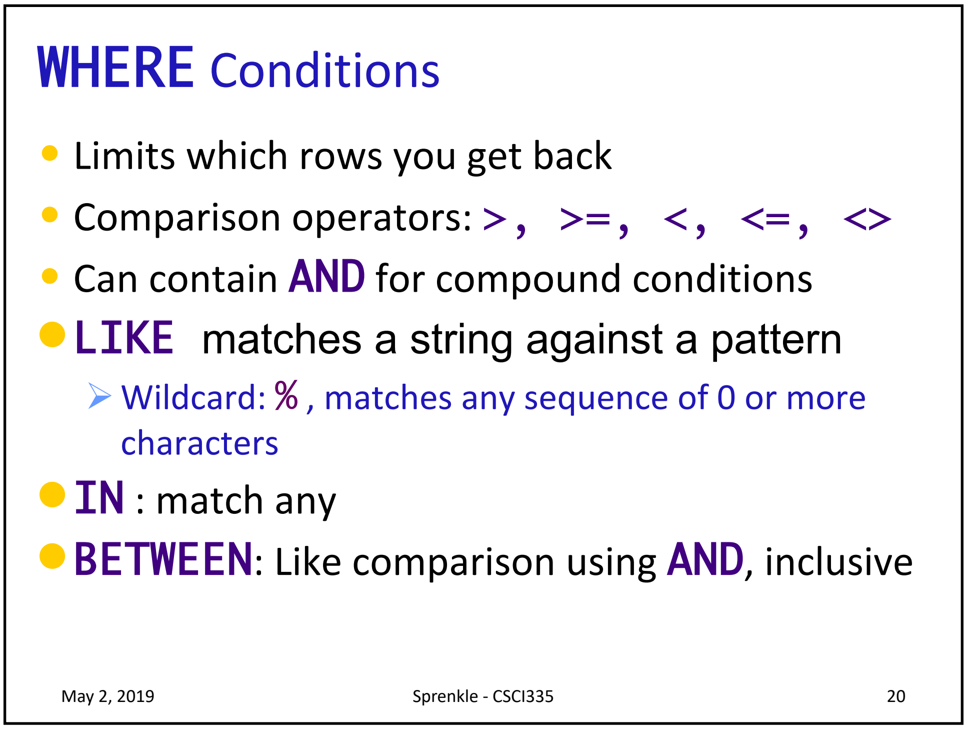
- SELECT * FROM Students;

id	lastName	firstName	gradYear	major
10011	Aaronson	Aaron	2021	CSCI
43123	Brown	Allison	2020	ENGL

- SELECT lastName, major FROM Students;

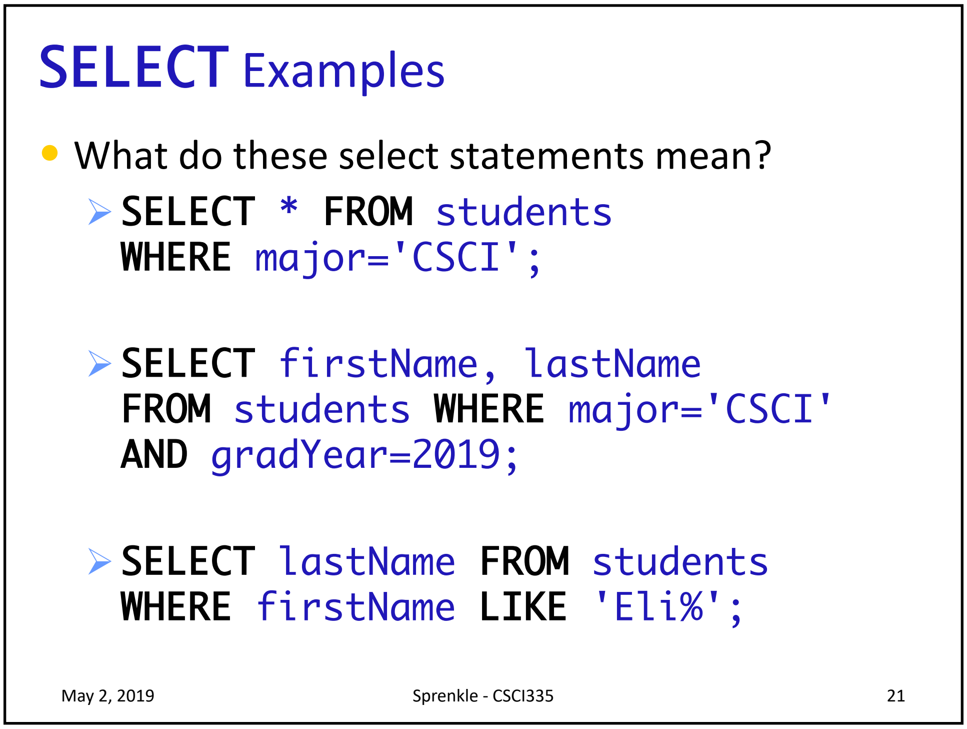
lastName	major
Aaronson	CSCI
Brown	ENGL

Virtual Tables



WHERE Conditions

- Limits which rows you get back
- Comparison operators: >, >=, <, <=, <>
- Can contain **AND** for compound conditions
- **LIKE** matches a string against a pattern
  - Wildcard: % , matches any sequence of 0 or more characters
- **IN** : match any
- **BETWEEN**: Like comparison using **AND**, inclusive



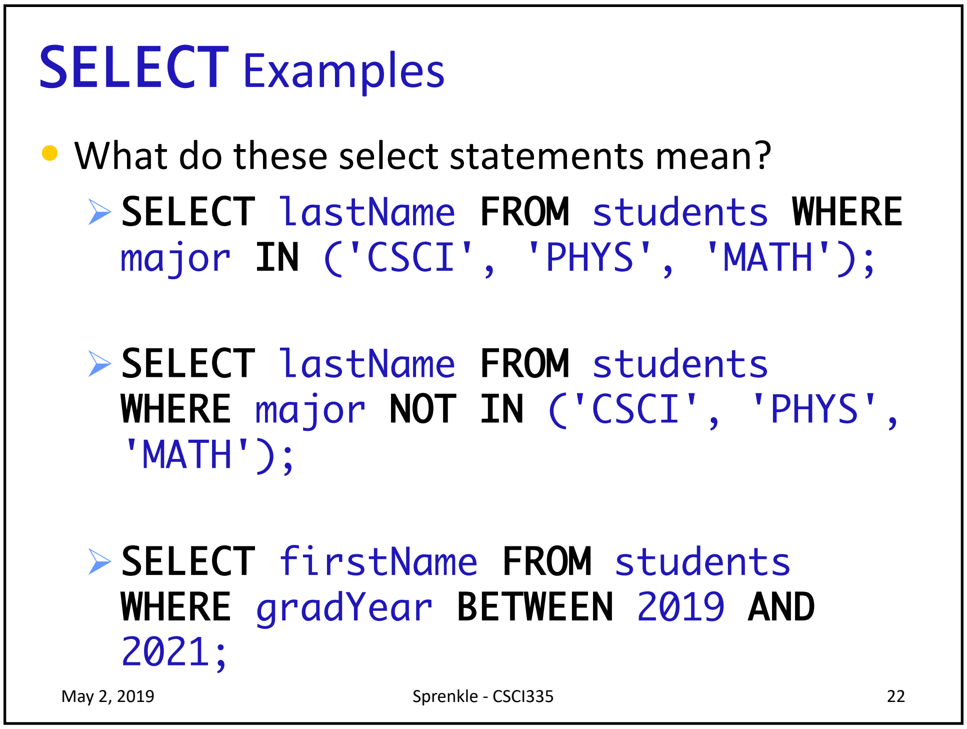
SELECT Examples

- What do these select statements mean?

  -
    ```
    SELECT * FROM students
    WHERE major='CSCI';
    ```

  -
    ```
    SELECT firstName, lastName
    FROM students WHERE major='CSCI'
    AND gradYear=2019;
    ```

  -
    ```
    SELECT lastName FROM students
    WHERE firstName LIKE 'Eli%';
    ```



SELECT Examples

- What do these select statements mean?

  -
    ```
    SELECT lastName FROM students WHERE
    major IN ('CSCI', 'PHYS', 'MATH');
    ```

  -
    ```
    SELECT lastName FROM students
    WHERE major NOT IN ('CSCI', 'PHYS',
    'MATH');
    ```

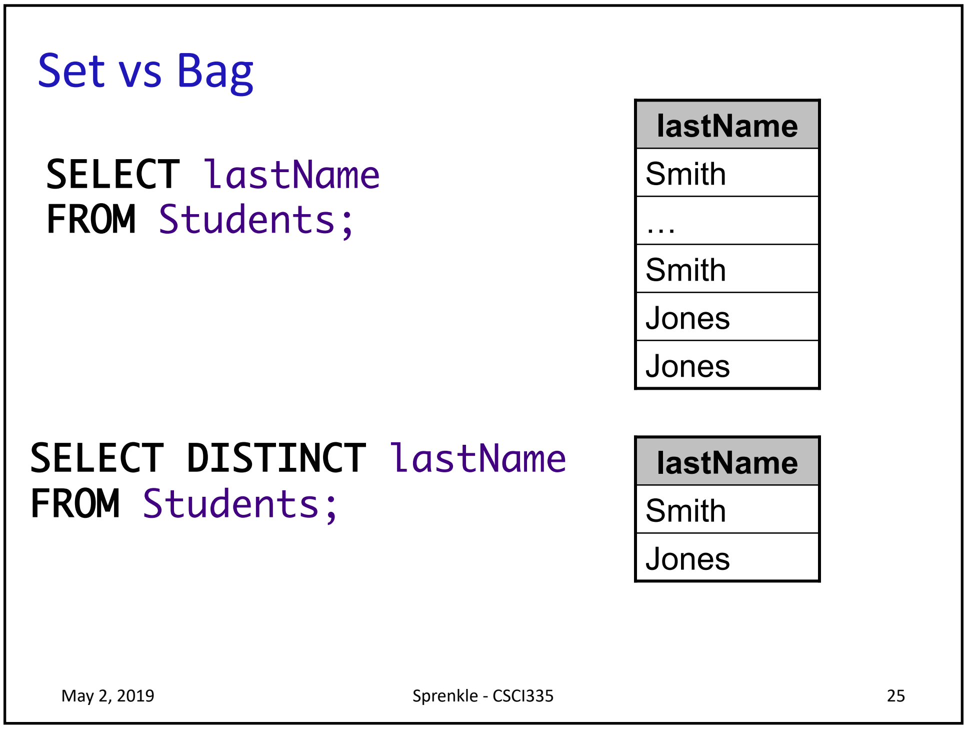
  -
    ```
    SELECT firstName FROM students
    WHERE gradYear BETWEEN 2019 AND
    2021;
    ```

Set vs Bag Semantics

- Data structures review

Set vs Bag Semantics

- Bag
  - Duplicates allowed
  - Number of duplicates is significant
  - Used by SQL by default
- Set
  - No duplicates
  - Use keyword **`DISTINCT`**



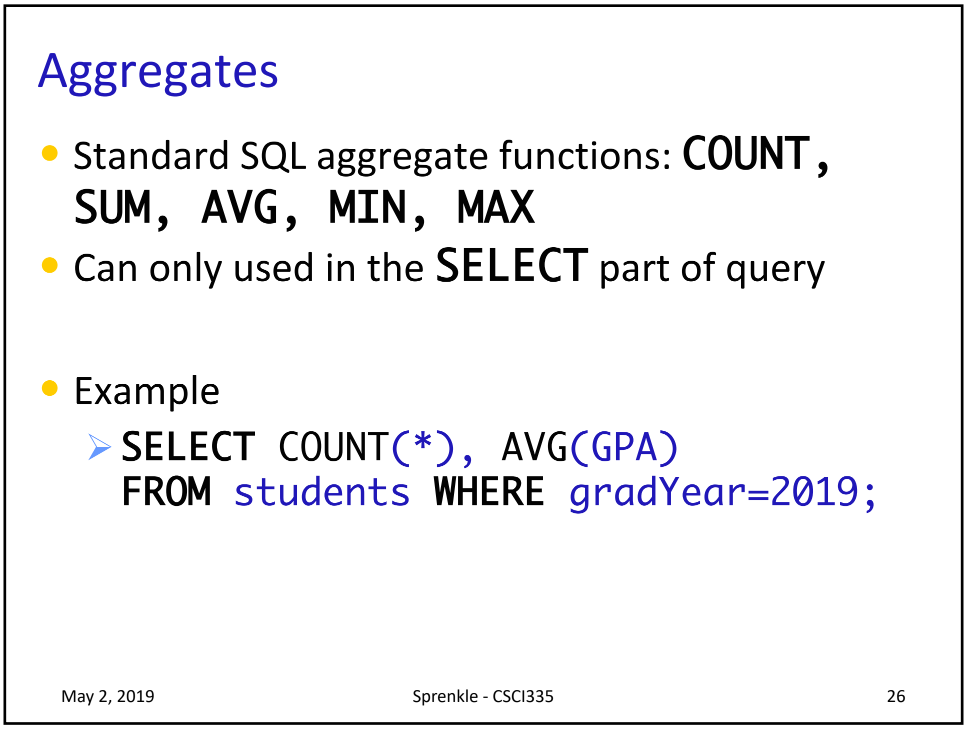
Set vs Bag

```
SELECT lastName
FROM Students;
```

lastName
Smith
…
Smith
Jones
Jones

```
SELECT DISTINCT lastName
FROM Students;
```

lastName
Smith
Jones



Aggregates

- Standard SQL aggregate functions: **COUNT, SUM, AVG, MIN, MAX**
- Can only used in the **SELECT** part of query
- Example

  -
    ```
    SELECT COUNT(*), AVG(GPA)
    FROM students WHERE gradYear=2019;
    ```

ORDER BY

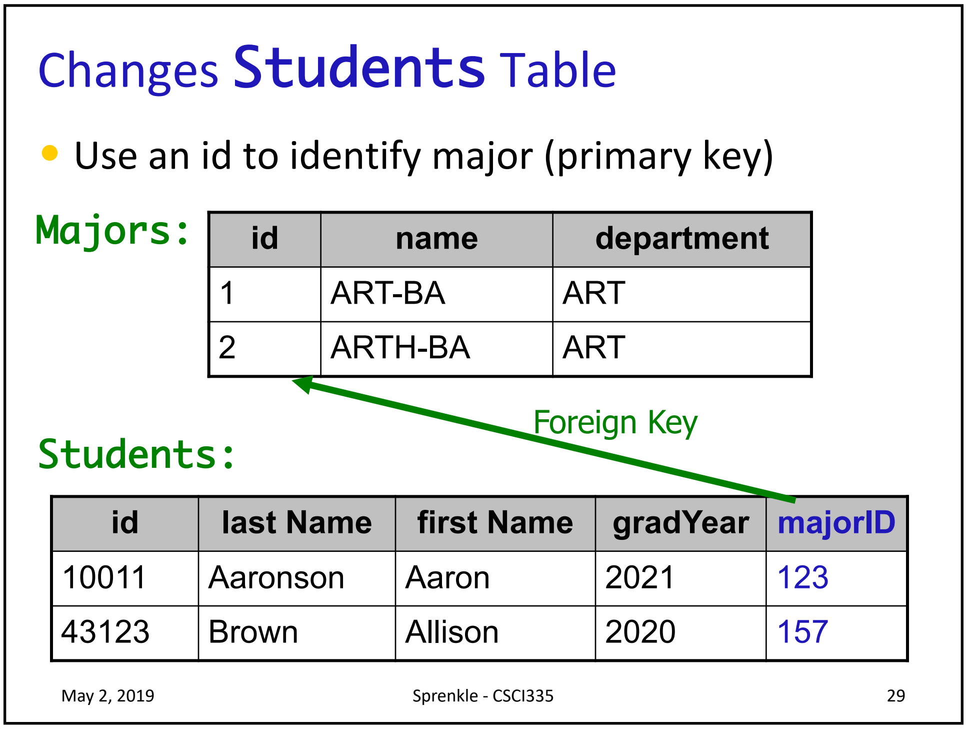
- Last operation performed, last in query
- Orders:
  - ASC = ascending
  - DESC = descending
- Example

  -
    ```
    SELECT firstName, lastName
    FROM Students WHERE gradYear=2019
    ORDER BY GPA DESC;
    ```

Majors Table

- Another table to keep track of majors
- Primary Key: id

id	name	department
1	ART-BA	ART
2	ARTH-BA	ART



Changes **Students** Table

- Use an id to identify major (primary key)

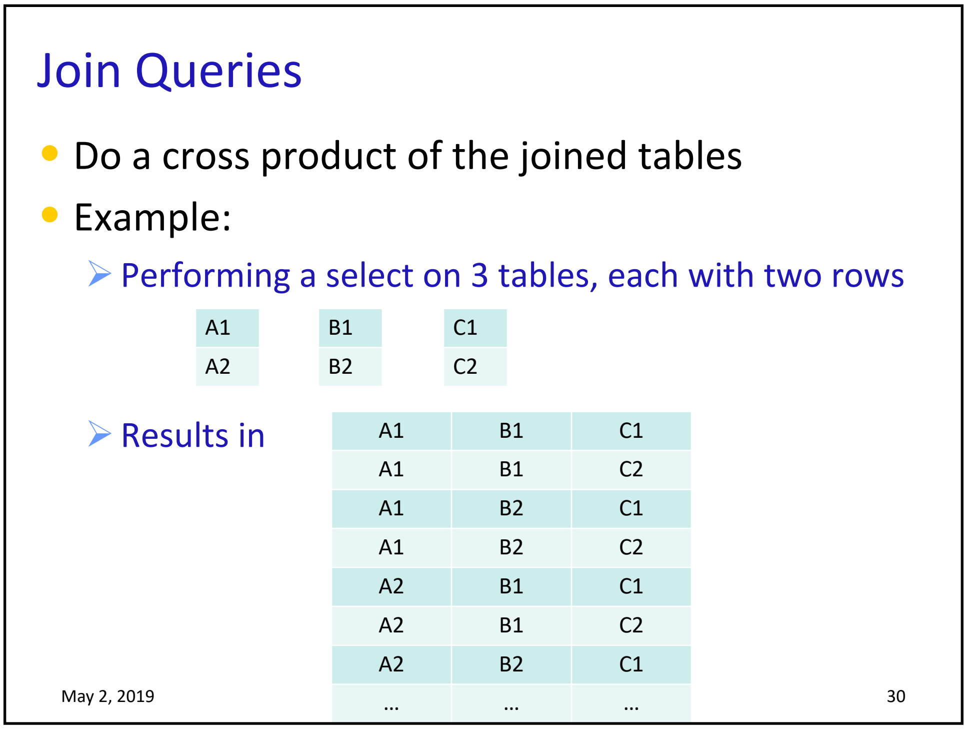
Majors:

id	name	department
1	ART-BA	ART
2	ARTH-BA	ART

Foreign Key

Students:

id	last Name	first Name	gradYear	majorID
10011	Aaronson	Aaron	2021	123
43123	Brown	Allison	2020	157



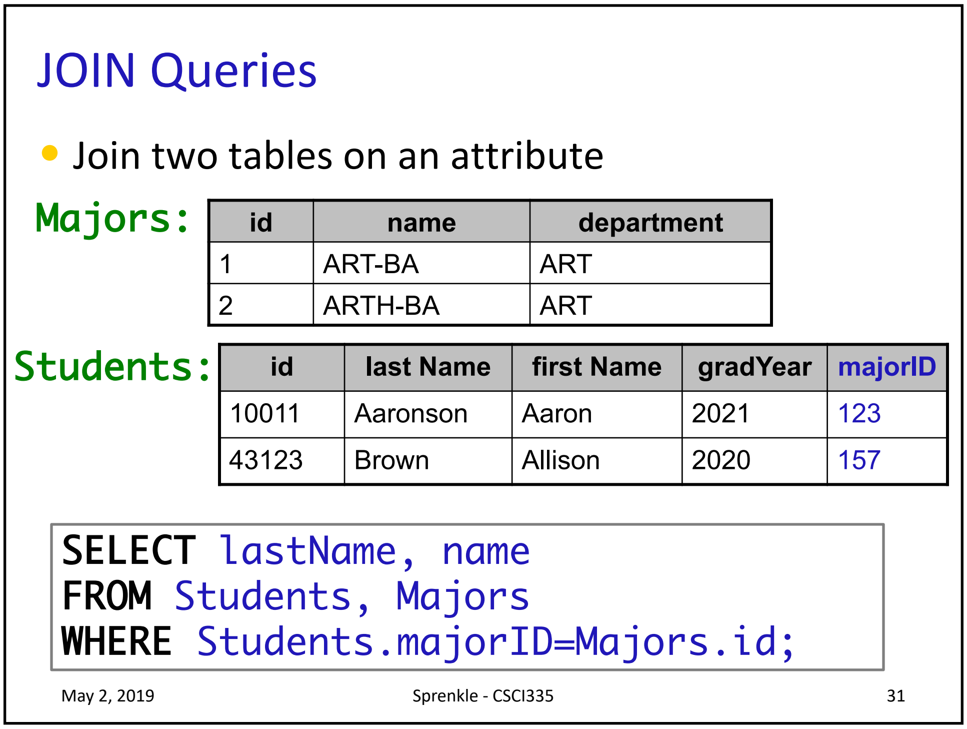
Join Queries

- Do a cross product of the joined tables
- Example:
  - Performing a select on 3 tables, each with two rows

A1	B1	C1
A2	B2	C2

  - Results in

A1	B1	C1
A1	B1	C2
A1	B2	C1
A1	B2	C2
A2	B1	C1
A2	B1	C2
A2	B2	C1
…	…	…



JOIN Queries

- Join two tables on an attribute

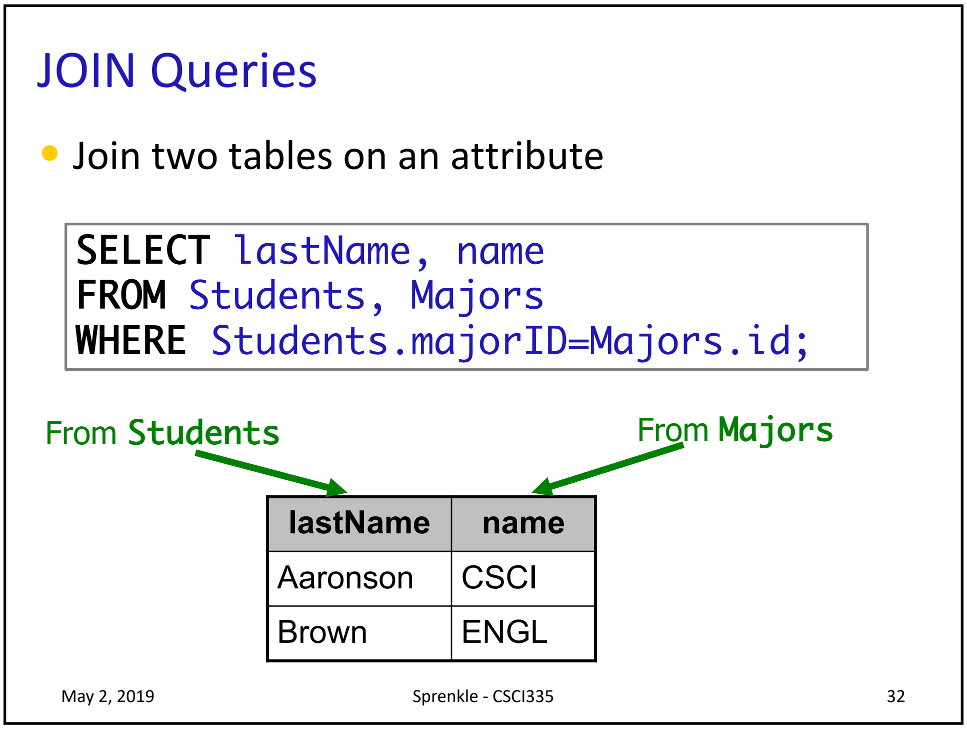
Majors:

id	name	department
1	ART-BA	ART
2	ARTH-BA	ART

Students:

id	last Name	first Name	gradYear	majorID
10011	Aaronson	Aaron	2021	123
43123	Brown	Allison	2020	157

```
SELECT lastName, name
FROM Students, Majors
WHERE Students.majorID=Majors.id;
```



JOIN Queries

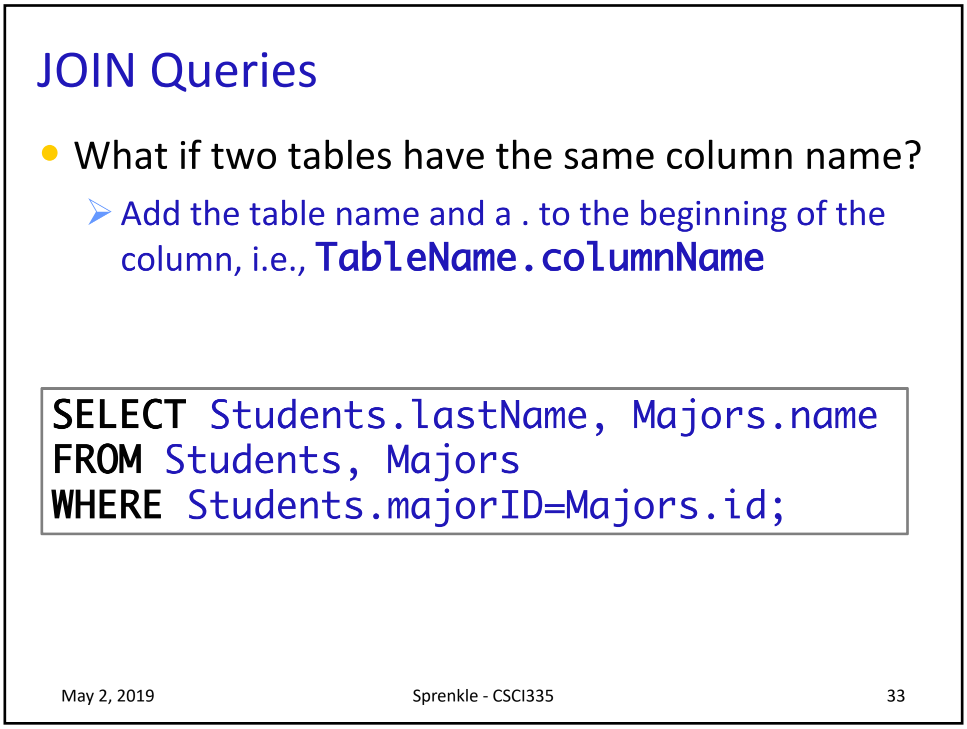
- Join two tables on an attribute

```
SELECT lastName, name
FROM Students, Majors
WHERE Students.majorID=Majors.id;
```

From Students

From Majors

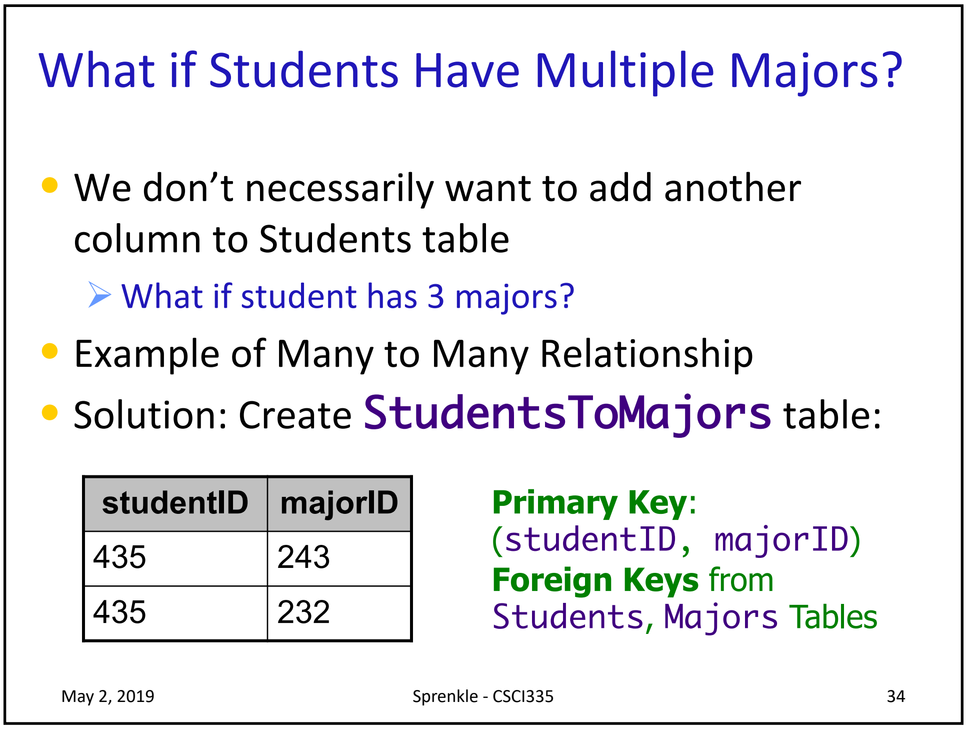
lastName	name
Aaronson	CSCI
Brown	ENGL



JOIN Queries

- What if two tables have the same column name?
  - Add the table name and a . to the beginning of the column, i.e., `TableName.columnName`

```
SELECT Students.lastName, Majors.name
FROM Students, Majors
WHERE Students.majorID=Majors.id;
```

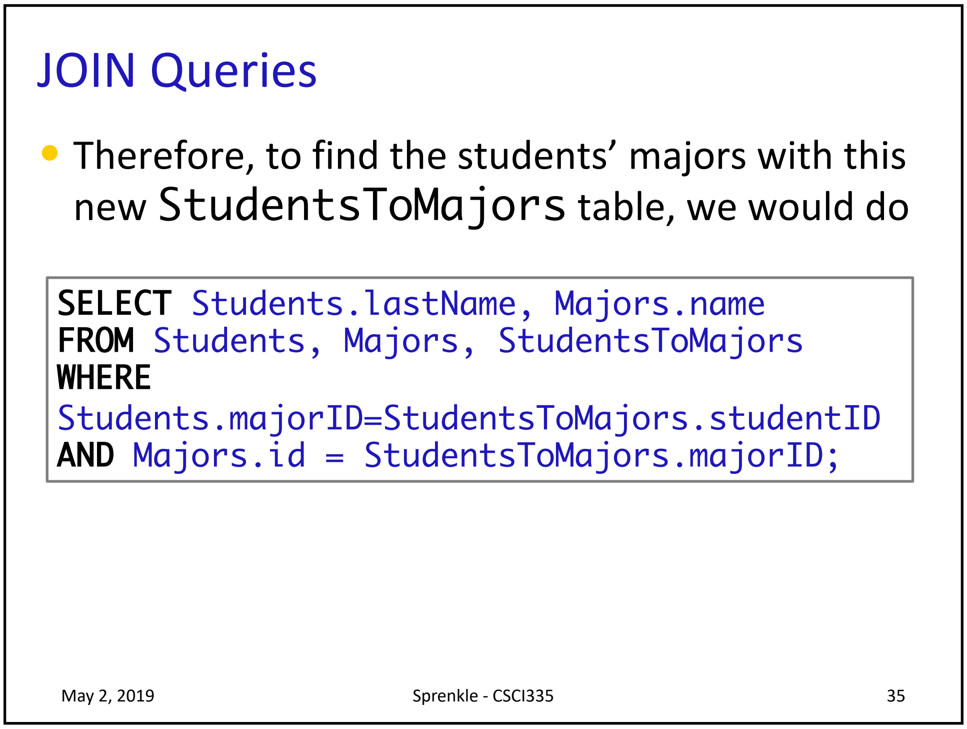


What if Students Have Multiple Majors?

- We don’t necessarily want to add another column to Students table
  - What if student has 3 majors?
- Example of Many to Many Relationship
- Solution: Create `StudentsToMajors` table:

studentID	majorID
435	243
435	232

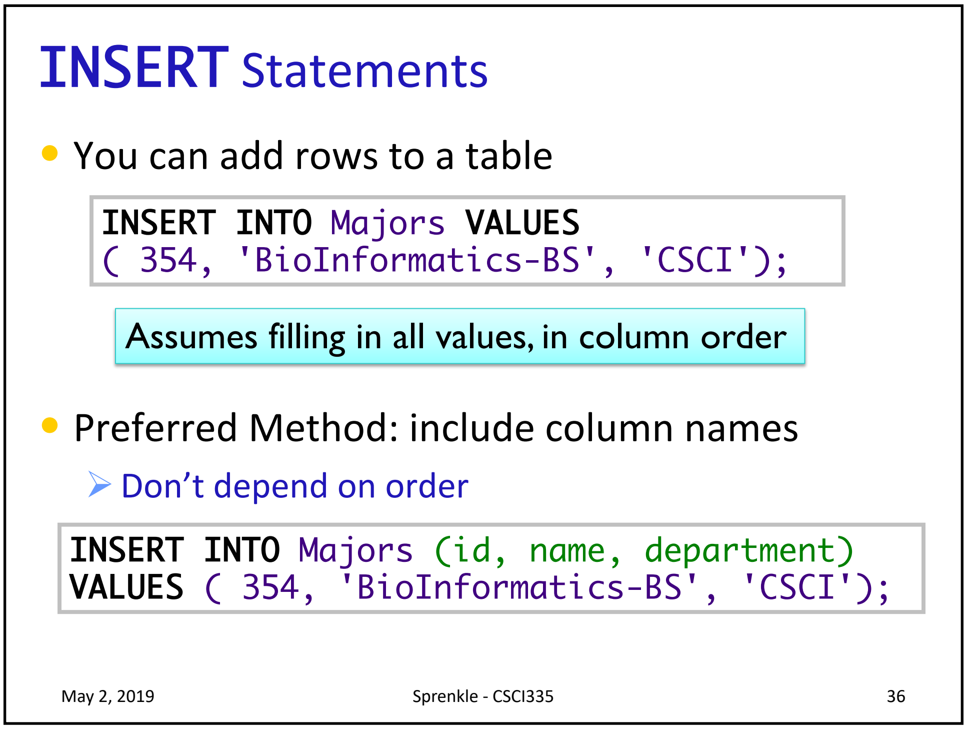
Primary Key: (`studentID, majorID`)
Foreign Keys from `Students`, `Majors` Tables



JOIN Queries

- Therefore, to find the students’ majors with this new StudentsToMajors table, we would do

```
SELECT Students.lastName, Majors.name
FROM Students, Majors, StudentsToMajors
WHERE
Students.majorID=StudentsToMajors.studentID
AND Majors.id = StudentsToMajors.majorID;
```



INSERT Statements

- You can add rows to a table

```
INSERT INTO Majors VALUES
( 354, 'BioInformatics-BS', 'CSCI');
```

Assumes filling in all values, in column order

- Preferred Method: include column names
  - Don’t depend on order

```
INSERT INTO Majors (id, name, department)
VALUES ( 354, 'BioInformatics-BS', 'CSCI');
```

INSERT Statements

- Automatically create ids

```
INSERT INTO Majors (id, name, department)
VALUES ( nextval('majors_sequence'),
'Bio-Informatics-BS', 'CSCI' );
```

- If table is set up appropriately, let the DB handle creating unique ids:

```
INSERT INTO Majors (name, department)
VALUES ( 'Bio-Informatics-BS', 'CSCI' );
```

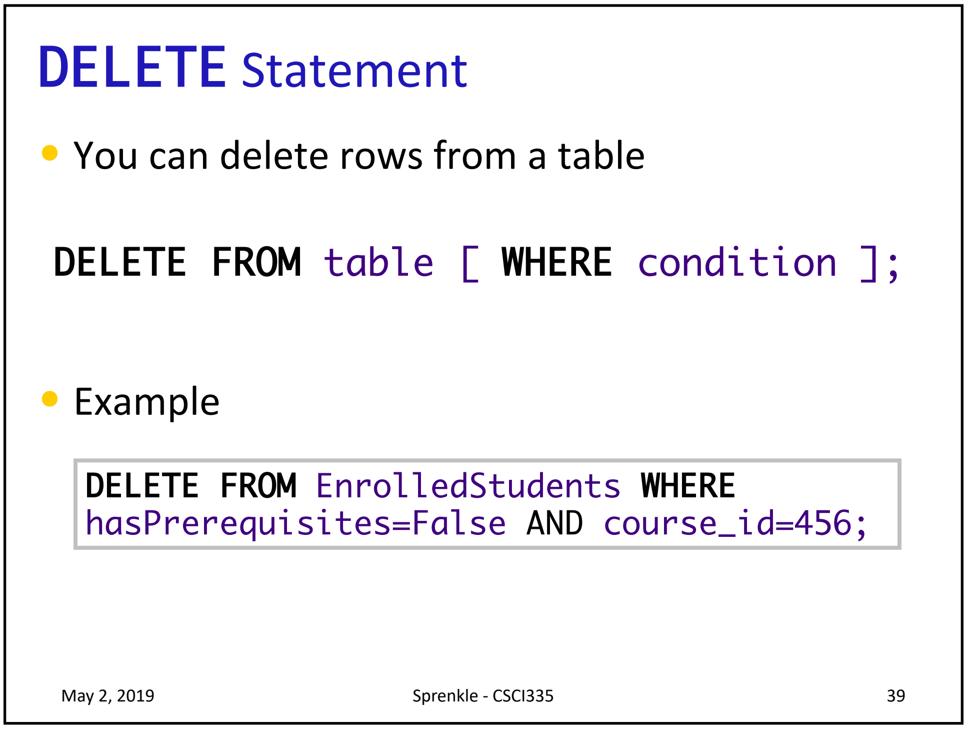
UPDATE Statement

- You can modify rows of a table
- Use **WHERE** condition to specify which rows to update
- Example: Update a student’s married name

```
UPDATE Students SET
LastName='Smith-Jones' WHERE id=12;
```

- Example: Update all first years to undeclared

```
UPDATE Students SET majorID=345
WHERE gradYear=2022;
```



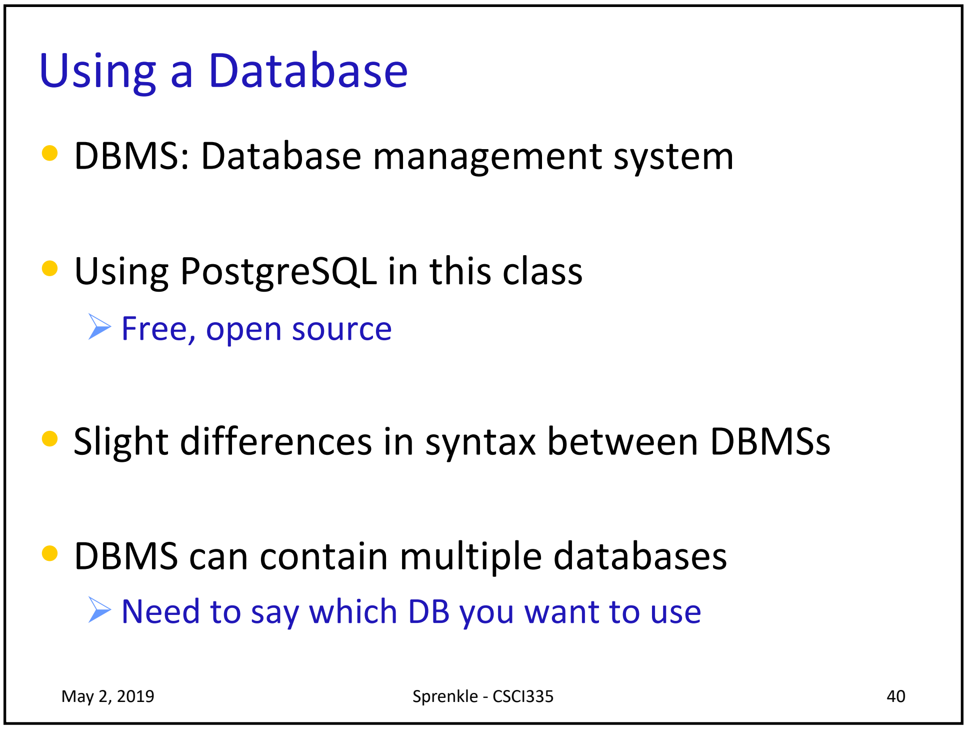
DELETE Statement

- You can delete rows from a table

```
DELETE FROM table [ WHERE condition ];
```

- Example

```
DELETE FROM EnrolledStudents WHERE
hasPrerequisites=False AND course_id=456;
```



Using a Database

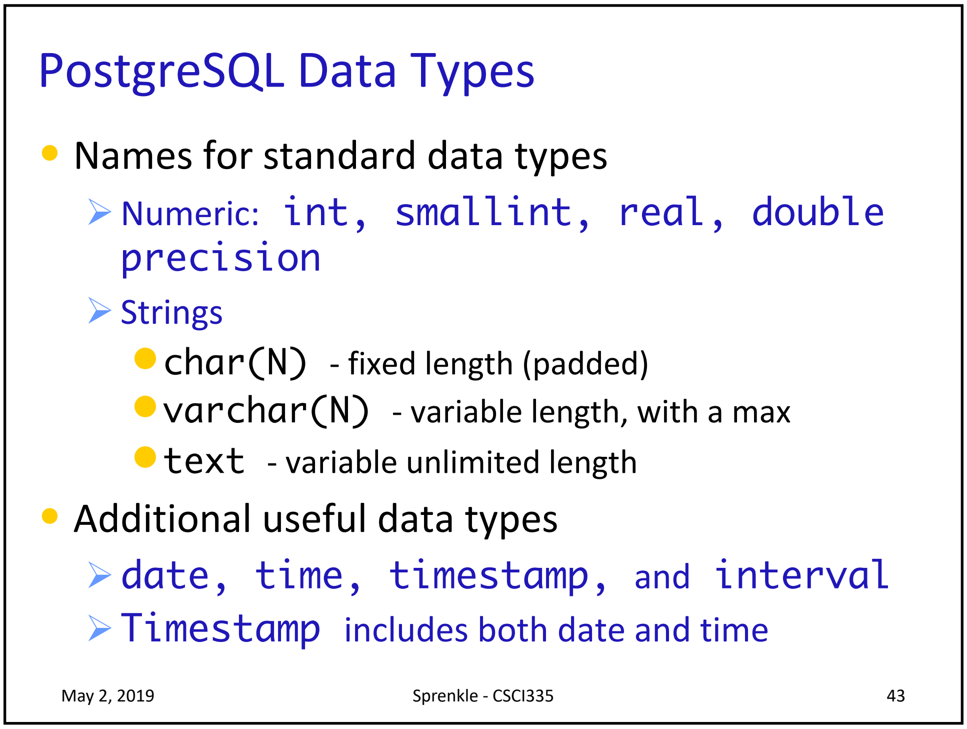
- DBMS: Database management system
- Using PostgreSQL in this class
  - Free, open source
- Slight differences in syntax between DBMSs
- DBMS can contain multiple databases
  - Need to say which DB you want to use

Designing a DB

- Design tables to hold your data
  - Data’s name and types
- Similar to OO design
  - No duplication of data
  - Have pointers to info in other tables
- Main difference: no lists
  - If you think “list”, think of a OneToMany or a ManyToMany table that contains the relationships between the data

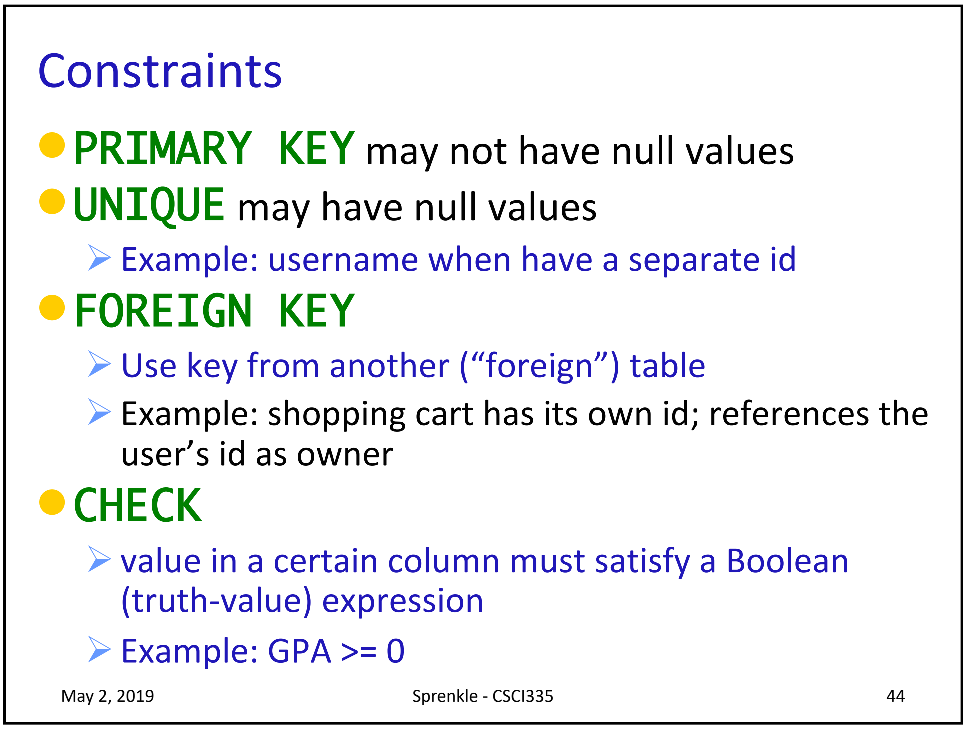
Standard Data Types

- Standard to SQL
  - CHAR - fixed-length character
  - VARCHAR - variable-length character
    - Requires more processing than CHAR
  - INTEGER - whole numbers
  - NUMERIC
  - Names for types in specific DB may vary
- More data types available in each DB



PostgreSQL Data Types

- Names for standard data types
  - Numeric: `int, smallint, real, double precision`
  - Strings
    - `char(N)` - fixed length (padded)
    - `varchar(N)` - variable length, with a max
    - `text` - variable unlimited length
- Additional useful data types
  - `date, time, timestamp,` and `interval`
  - `Timestamp` includes both date and time



Constraints

- **PRIMARY KEY** may not have null values
- **UNIQUE** may have null values
  - Example: username when have a separate id
- **FOREIGN KEY**
  - Use key from another (“foreign”) table
  - Example: shopping cart has its own id; references the user’s id as owner
- **CHECK**
  - value in a certain column must satisfy a Boolean (truth-value) expression
  - Example: GPA >= 0

Creating a Table

- Example:

```
CREATE TABLE weather (
    city            varchar(80),
    temp_lo         int,          -- low temperature
    temp_hi         int,          -- high temperature
    prcp            real,         -- precipitation
    date            date
);
```

Join Queries

- Joining two tables: creates a cross-product
- Where clauses restrict the number of results produced

“The Hack”

> Second Washington University hacked data base! Washington and Lee University full unedited database! gist.github.com/anonymous/4971… <https://t.co/3fqGJwXC>#SweetInfoOp <http://twitter.com/search?q=%23SweetInfoOp>

- Notified by W&L News Director
- President’s Day
- Actual link: https://gist.github.com/anonymous/4971936
  - Target : http://www.cs.wlu.edu/
  - Only some of the data, not all in database
- Figured out they just found my posted SQL file

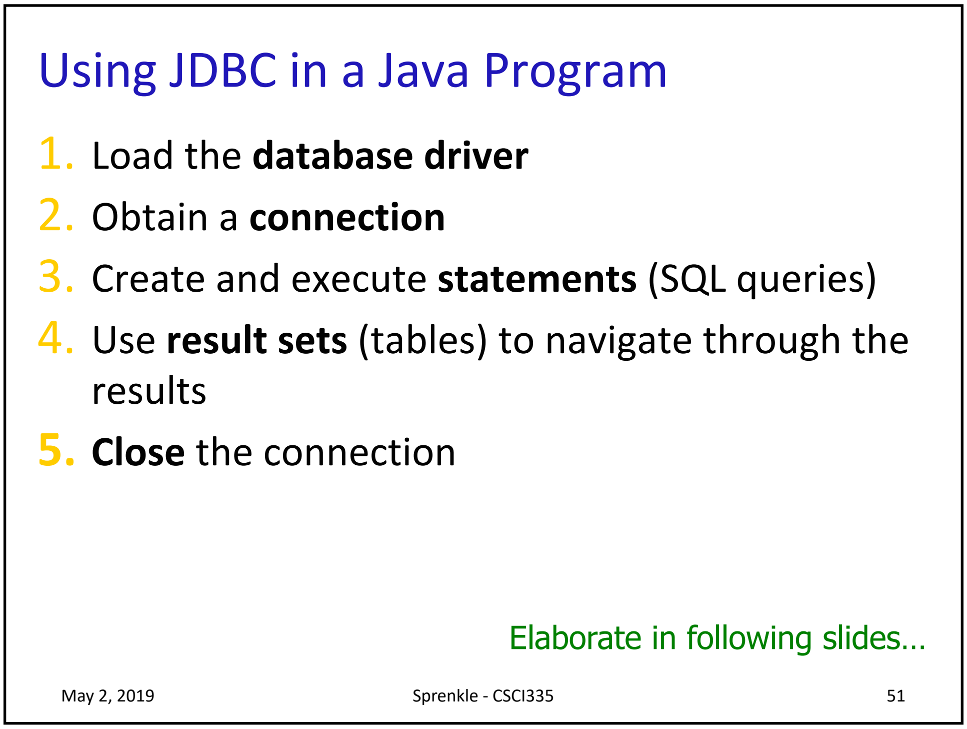
ChemTutor Database

- What tables will you need?
- What data?
- What constraints?

JDBC

JDBC: **J**ava **D**ata**b**ase **C**onnectivity

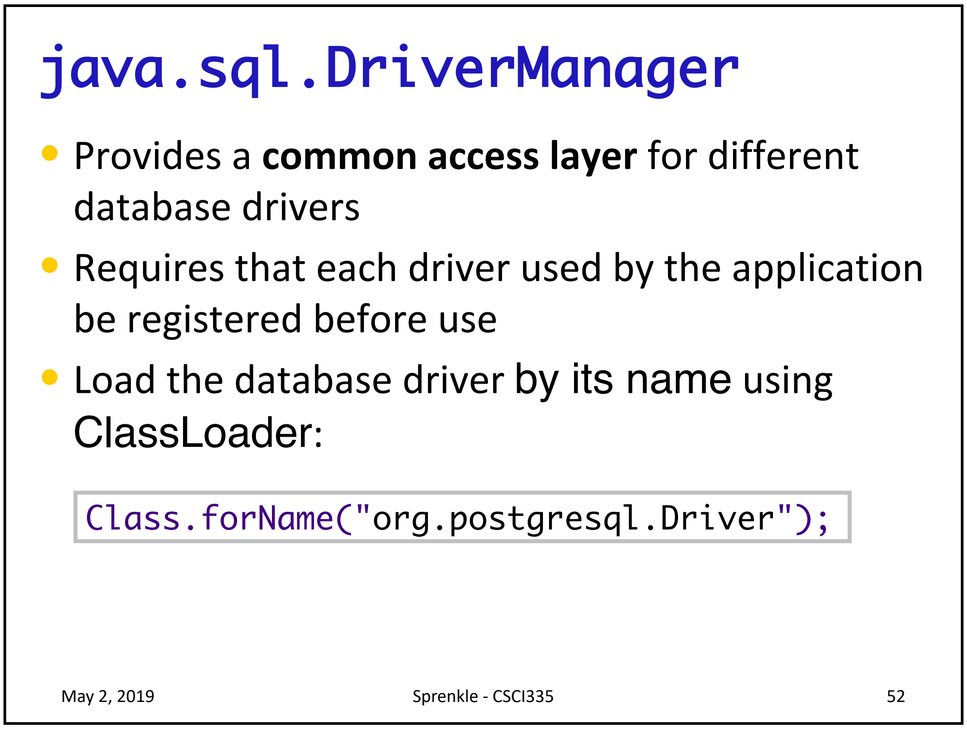
- Database-independent connectivity
    - JDBC converts generalized JDBC calls into vendor-specific SQL calls
- Classes in `java.sql.*` and `javax.sql.*` packages



Using JDBC in a Java Program

1. Load the **database driver**
2. Obtain a **connection**
3. Create and execute **statements** (SQL queries)
4. Use **result sets** (tables) to navigate through the results
5. **Close** the connection

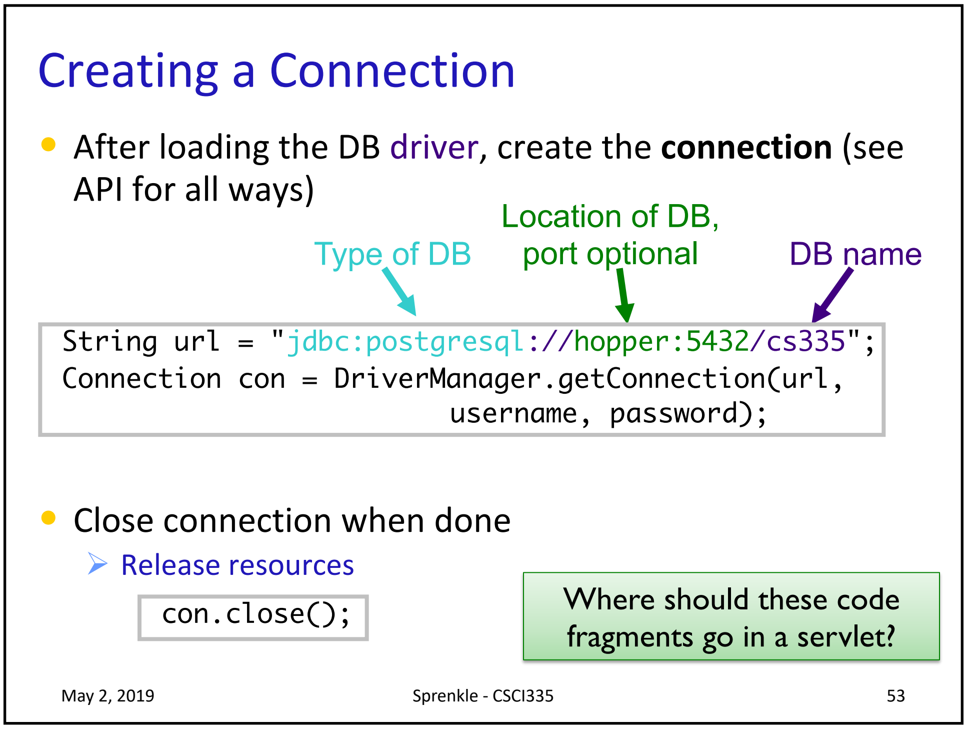
Elaborate in following slides…



java.sql.DriverManager

- Provides a **common access layer** for different database drivers
- Requires that each driver used by the application be registered before use
- Load the database driver by its name using ClassLoader:

```
Class.forName("org.postgresql.Driver");
```



Creating a Connection

- After loading the DB driver, create the **connection** (see API for all ways)

Type of DB

Location of DB, port optional

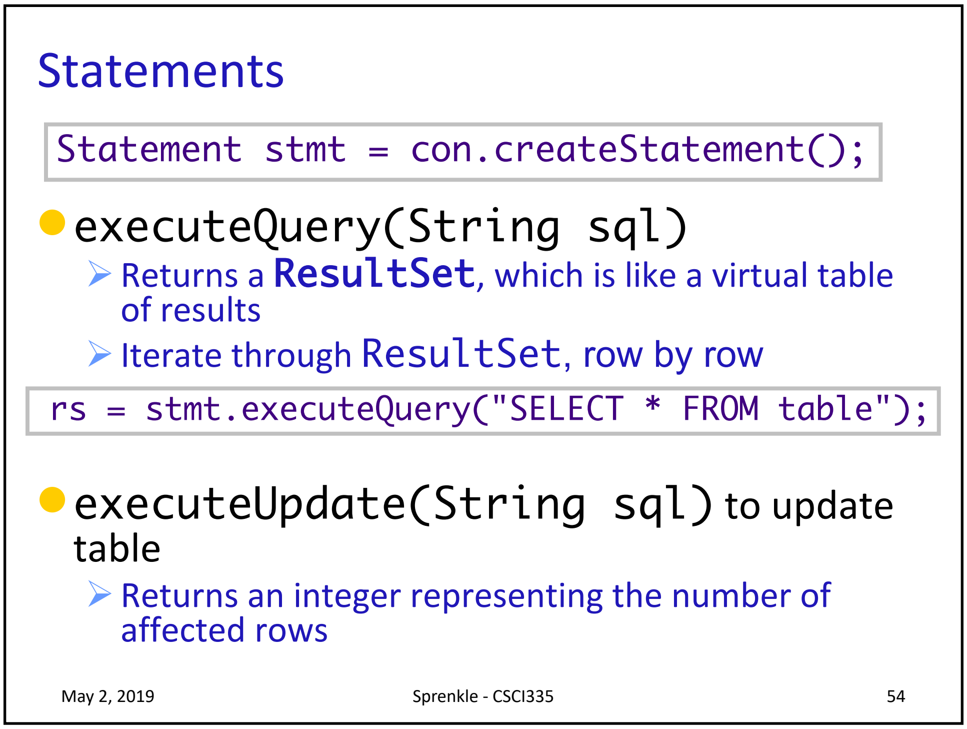
DB name

```
String url = "jdbc:postgresql://hopper:5432/cs335";
Connection con = DriverManager.getConnection(url,
                        username, password);
```

- Close connection when done
  - Release resources

```
con.close();
```

Where should these code fragments go in a servlet?



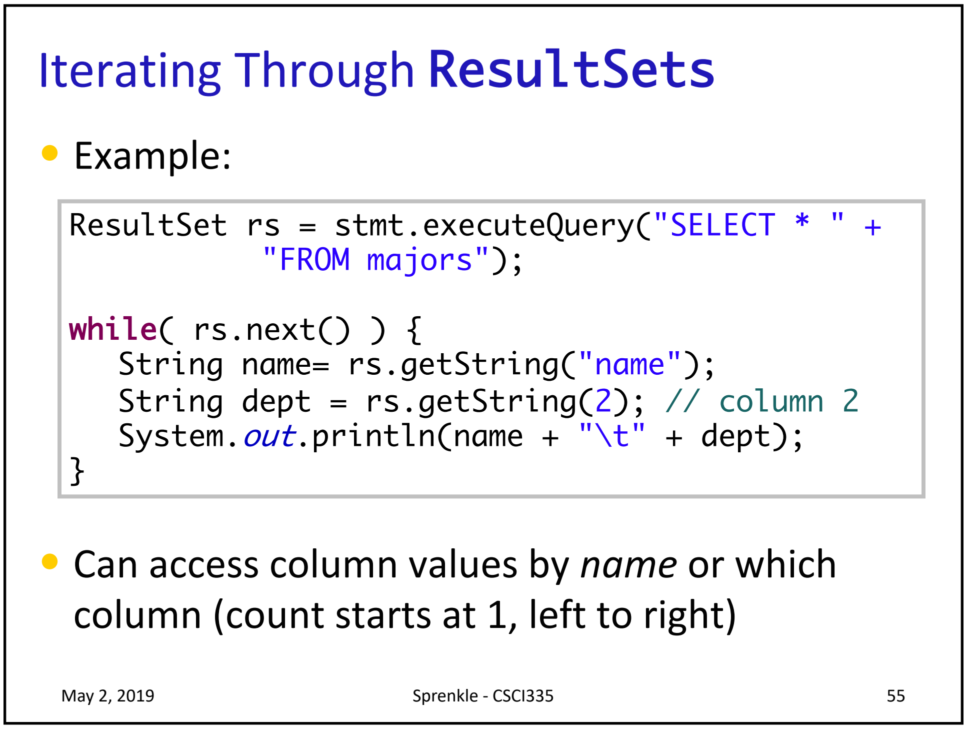
Statements

```
Statement stmt = con.createStatement();
```

- executeQuery(String sql)
  - Returns a **ResultSet**, which is like a virtual table of results
  - Iterate through ResultSet, row by row

```
rs = stmt.executeQuery("SELECT * FROM table");
```

- executeUpdate(String sql) to update table
  - Returns an integer representing the number of affected rows



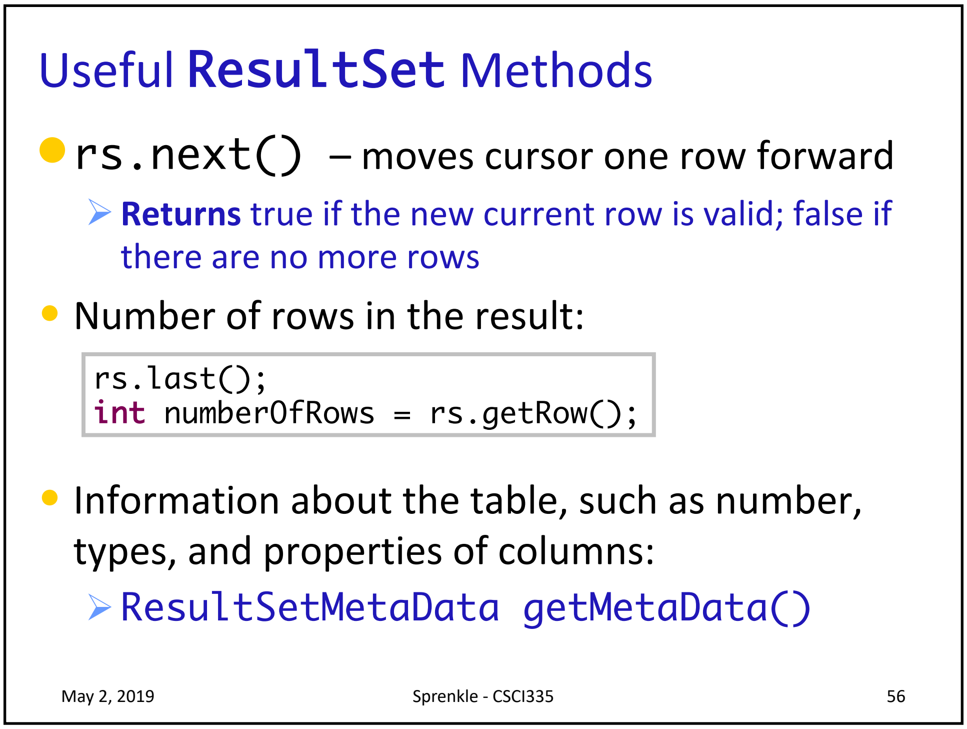
Iterating Through ResultSets

- Example:

```
ResultSet rs = stmt.executeQuery("SELECT * " +
           "FROM majors");

while( rs.next() ) {
   String name= rs.getString("name");
   String dept = rs.getString(2); // column 2
   System.out.println(name + "\t" + dept);
}
```

- Can access column values by *name* or which column (count starts at 1, left to right)

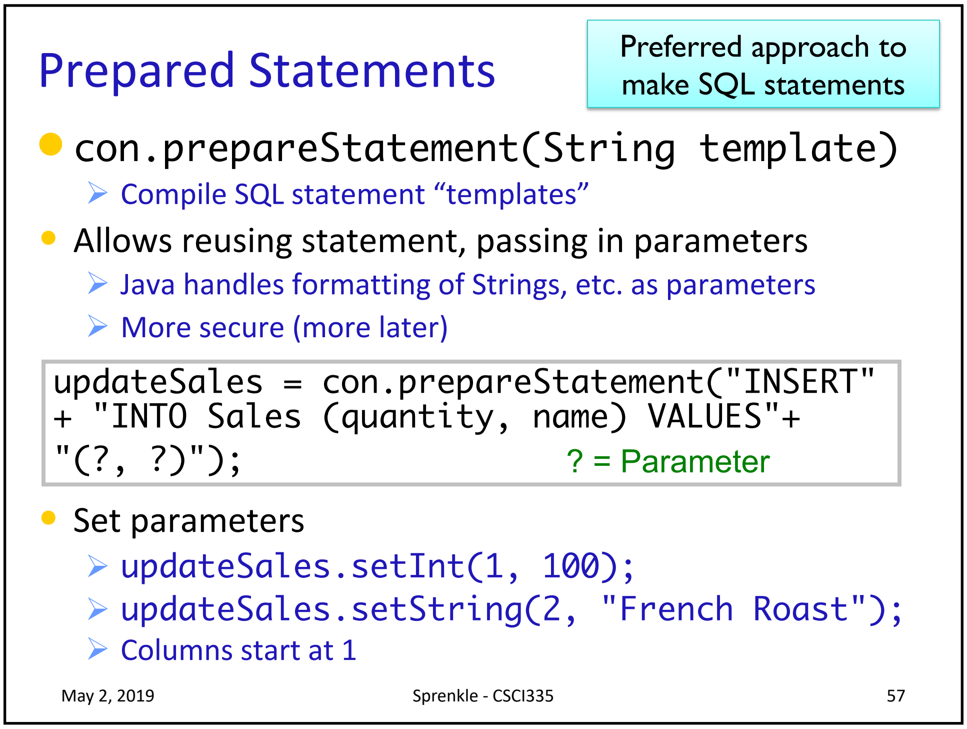


Useful ResultSet Methods

- `rs.next()` – moves cursor one row forward
  - **Returns** true if the new current row is valid; false if there are no more rows
- Number of rows in the result:

```
rs.last();
int numberOfRows = rs.getRow();
```

- Information about the table, such as number, types, and properties of columns:
  - `ResultSetMetaData getMetaData()`



Prepared Statements

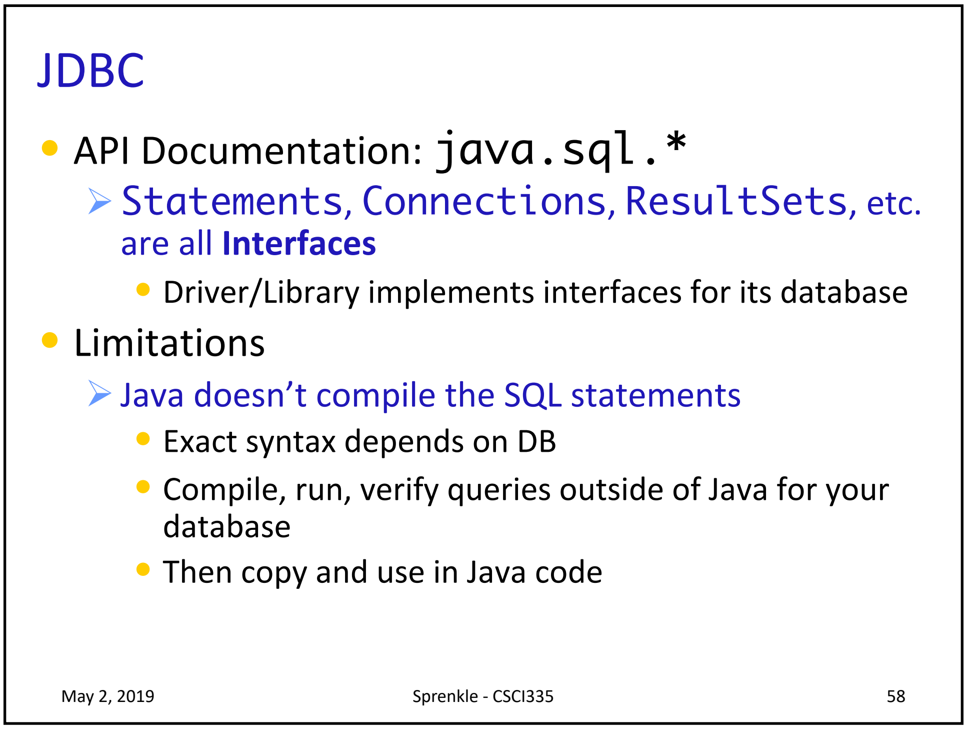
Preferred approach to make SQL statements

- `con.prepareStatement(String template)`
  - Compile SQL statement “templates”
- Allows reusing statement, passing in parameters
  - Java handles formatting of Strings, etc. as parameters
  - More secure (more later)

```
updateSales = con.prepareStatement("INSERT"
+ "INTO Sales (quantity, name) VALUES"+
"(?, ?)");
```

? = Parameter

- Set parameters
  - `updateSales.setInt(1, 100);`
  - `updateSales.setString(2, "French Roast");`
  - Columns start at 1



JDBC

- API Documentation: `java.sql.*`
  - `Statements`, `Connections`, `ResultSets`, etc. are all **Interfaces**
    - Driver/Library implements interfaces for its database
- Limitations
  - Java doesn’t compile the SQL statements
    - Exact syntax depends on DB
    - Compile, run, verify queries outside of Java for your database
    - Then copy and use in Java code

Using PostgreSQL on Command-Line

- In a terminal, **ssh** into **hopper**
  - ssh -XY hopper
- Run the PostgreSQL client: **psql** , connecting to the appropriate database
  - psql cs335
- At the prompt, type in SQL statements, ending in ;

Examples Using JDBC

Transactions in JDBC

- By default, a connection is in **auto-commit** mode
  - Each statement is a transaction
  - Automatically committed as soon as executed

Transactions in JDBC

- You can turn off auto-commit and execute multiple statements as a transaction
  - Database can keep handling others' reads
  - Others won't see updates until you commit

```
con.setAutoCommit(false);
// execute SQL statements …
con.commit(); // commit those statements
con.setAutoCommit(true);
```

- Can call `rollback` to abort updates

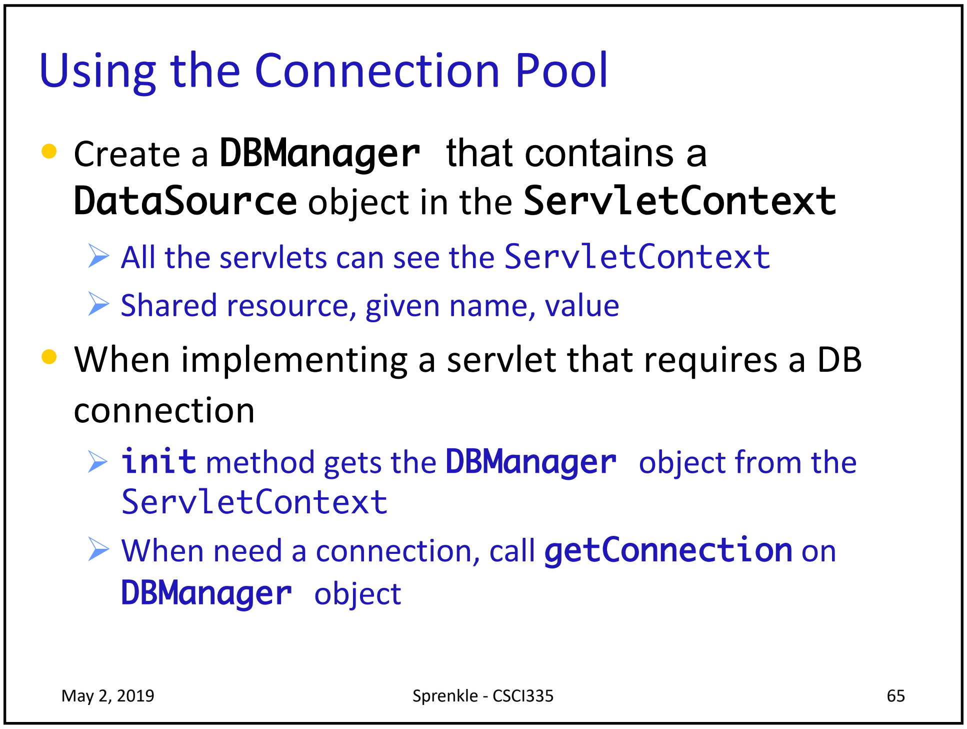
Storing Passwords

- Use **md5** function on passwords
  - `md5('password')`
- Compare user’s input password md5’d with password in database
  - `SELECT COUNT(id) FROM Users WHERE username=? AND password=md5(?);`
  - What are the possible outputs from this query?
- Example: username and password = ‘test’

There are stronger ways to encrypt passwords, but for this practice exercise, this is fine.

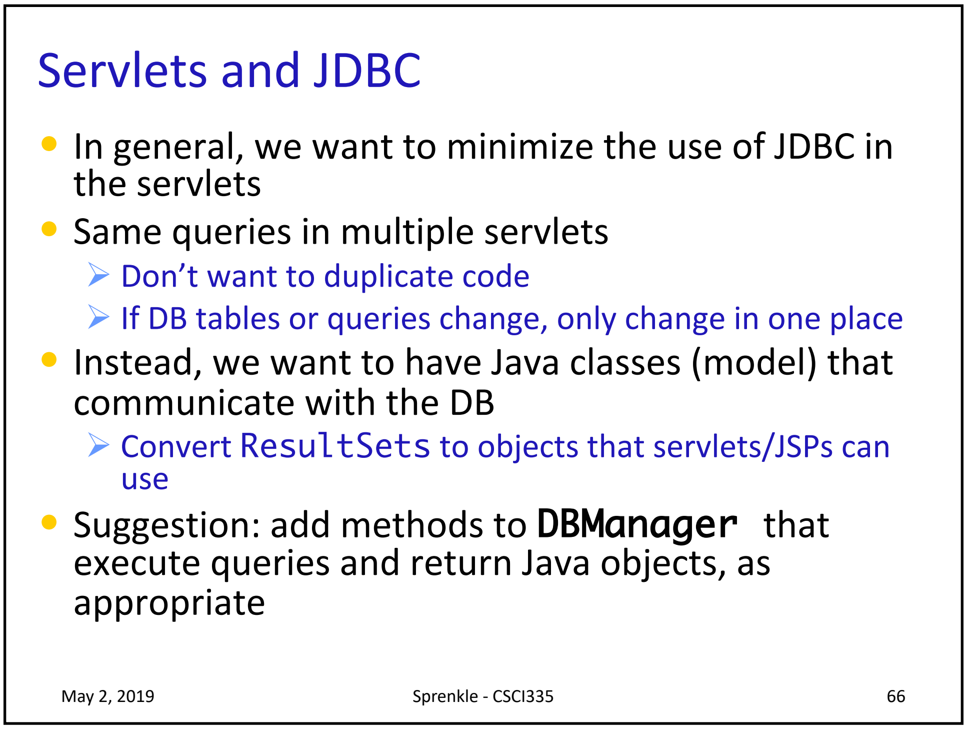
Connection Pool

- Want to reuse DB connections
  - Reduce overhead of creating and closing connections to database
- Could write our own connection pool class
  - Many examples online
- Apache wrote the one that we’ll use
  - `http://commons.apache.org/dbcp/`



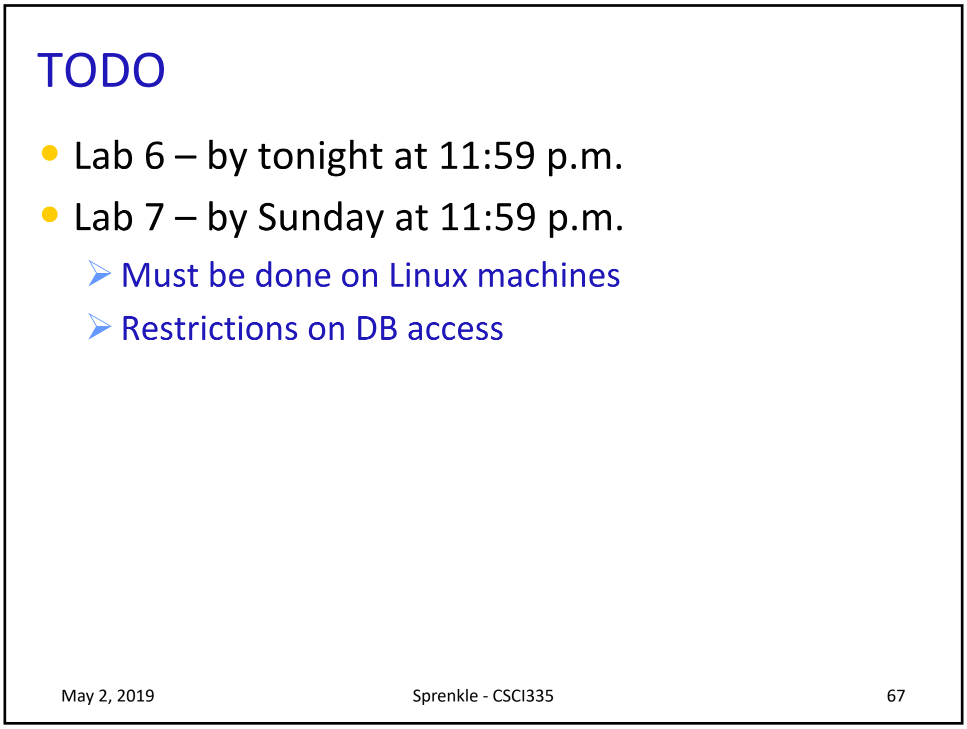
Using the Connection Pool

- Create a **`DBManager`** that contains a **`DataSource`** object in the **`ServletContext`**
  - All the servlets can see the `ServletContext`
  - Shared resource, given name, value
- When implementing a servlet that requires a DB connection
  - **`init`** method gets the **`DBManager`** object from the `ServletContext`
  - When need a connection, call **`getConnection`** on **`DBManager`** object



Servlets and JDBC

- In general, we want to minimize the use of JDBC in the servlets
- Same queries in multiple servlets
  - Don’t want to duplicate code
  - If DB tables or queries change, only change in one place
- Instead, we want to have Java classes (model) that communicate with the DB
  - Convert `ResultSets` to objects that servlets/JSPs can use
- Suggestion: add methods to **`DBManager`** that execute queries and return Java objects, as appropriate



TODO

- Lab 6 – by tonight at 11:59 p.m.
- Lab 7 – by Sunday at 11:59 p.m.
  - Must be done on Linux machines
  - Restrictions on DB access