Databases and PHP

Lecture 6

Outline

- Database Basics
- SQL
- Multi-table Queries
- Databases and PHP

Relational Databases

- **relational database**: A method of structuring data as tables associated to each other by shared attributes.
- a table row corresponds to a unit of data called a **record**; a column corresponds to an attribute of that record
- relational databases typically use **Structured Query Language** (SQL) to define, manage, and search data

Why use a database?

- **powerful**: can search it, filter data, combine data from multiple sources
- **fast**: can search/filter a database very quickly compared to a file
- **big**: scale well up to very large data sizes
- **safe**: built-in mechanisms for failure recovery (e.g. **transactions**)
- **multi-user**: concurrency features let many users view/edit data at same time
- **abstract**: provides layer of abstraction between stored data and app(s)
  - many database programs understand the same SQL commands

Database Software

- Oracle
- Microsoft SQL Server (powerful) and Microsoft Access (simple)
- PostgreSQL (powerful/complex free open-source database system)
- SQLite (transportable, lightweight free open-source database system)
- MySQL (simple free open-source database system)
  - many servers run "XAMP" (Linux/MacOS/Windows, Apache, MySQL, and PHP)
  - Wikipedia is run on PHP and MySQL
  - we will use MySQL in this course

Examples of databases

simpsons database

id	name	email
123	Bart	bart@fox.com
456	Milhouse	milhouse@fox.com
888	Lisa	lisa@fox.com
404	Ralph	ralph@fox.com

students

id	name
1234	Krabappel
5678	Hoover
9012	Stepp

teachers

id	name	teacher_id
10001	Computer Science 142	1234
10002	Computer Science 143	5678
10003	Computer Science 190M	9012
10004	Informatics 100	1234

courses

student_id	course_id	grade
123	10001	B-
123	10002	C
456	10001	B+
888	10002	A+
888	10003	A+
404	10004	D+

grades

world database

code	name	continent	independence_year	population	gnp	head_of_state	...
AFG	Afghanistan	Asia	1919	22720000	5976.0	Mohammad Omar	...
NLD	Netherlands	Europe	1581	15864000	371362.0	Beatrix	...
...	...	...	...	...	...	...	...

countries

Other columns: region, surface_area, life_expectancy, gnp_old, local_name, government_form, capital, code2

id	name	country_code	district	population
3793	New York	USA	New York	8008278
1	Los Angeles	USA	California	3694820
...	...	...	...	...

cities

country_code	language	official	percentage
AFG	Pashto	T	52.4
NLD	Dutch	T	95.6
...	...	...	...

languages

Example of databases

IMDB Database

id	first_name	last_name	gender
433259	William	Shatner	M
797926	Britney	Spears	F
831289	Sigourney	Weaver	F
...			

actors

id	name	year	rank
112290	Fight Club	1999	8.5
209658	Meet the Parents	2000	7
210511	Memento	2000	8.7
...			

movies

actor_id	movie_id	role
433259	313398	Capt. James T. Kirk
433259	407323	Sgt. T.J. Hooker
797926	342189	Herself
...		

roles

movie_id	genre
209658	Comedy
313398	Action
313398	Sci-Fi
...	

movies_genres

id	first_name	last_name
24758	David	Fincher
66965	Jay	Roach
72723	William	Shatner
...		

directors

director_id	movie_id
24758	112290
66965	209658
72723	313398
...	

movies_directors

SQL Basics

```sql
SELECT name FROM cities WHERE id = 17;
```

```sql
INSERT INTO countries VALUES ('SLD', 'ENG', 'T', 100.0);
```

- **Structured Query Language (SQL)**: a language for searching and updating a database
- a standard syntax that is used by all database software (with minor incompatiblities)
  - generally case-insensitive
- a **declarative** language: describes what data you are seeking, not exactly how to find it

Issuing SQL commands directly in MySQL

```sql
SHOW DATABASES;
USE database;
SHOW TABLES;
```

- SSH to Webster, then type:

```
$ mysql -u yourusername -p
Password:
Welcome to the MySQL monitor.  Commands end with ; or \g.

mysql> USE world;
Database changed

mysql> SHOW TABLES;
+-----------+
| cities    |
| countries |
| languages |
+-----------+
3 rows in set (0.00 sec)
```

The SQL SELECT statement

```
SELECT column(s) FROM table;
```

```
SELECT name, code FROM countries;
```

name	code
China	CHN
United States	IND
Indonesia	USA
Brazil	BRA
Pakistan	PAK
...	...

- the SELECT statement searches a database and returns a set of results
  - the column name(s) written after SELECT filter which parts of the rows are returned
  - table and column names are case-sensitive
  - SELECT * FROM *table*; keeps all columns

The DISTINCT modifier

```sql
SELECT DISTINCT column(s) FROM table;
```

```sql
SELECT language
FROM languages;
```

language
Dutch
English
English
Papiamento
Spanish
Spanish
Spanish
...

```sql
SELECT DISTINCT language
FROM languages;
```

language
Dutch
English
Papiamento
Spanish
...

- eliminates duplicates from the result set

The WHERE clause

```
SELECT column(s) FROM table WHERE condition(s);
```

```
SELECT name, population FROM cities WHERE country_code = "FSM";
```

name	population
Weno	22000
Palikir	8600

- WHERE clause filters out rows based on their columns' data values
- in large databases, it's critical to use a WHERE clause to reduce the result set size
- suggestion: when trying to write a query, think of the FROM part first, then the WHERE part, and lastly the SELECT part

More about the WHERE clause

```
WHERE column operator value(s)
```

```
SELECT name, gnp FROM countries WHERE gnp > 2000000;
```

code	name	gnp
JPN	Japan	3787042.00
DEU	Germany	2133367.00
USA	United States	8510700.00
...	...	...

- the WHERE portion of a SELECT statement can use the following operators:
  - =, >, >=, <, <=
  - <> : not equal
  - BETWEEN *min* AND *max*
  - LIKE *pattern*
  - IN (*value*, *value*, ..., *value*)

Multiple WHERE clauses: AND, OR

```
SELECT * FROM cities WHERE code = 'USA' AND population >= 2000000;
```

id	name	country_code	district	population
3793	New York	USA	New York	8008278
3794	Los Angeles	USA	California	3694820
3795	Chicago	USA	Illinois	2896016
...	...	...	...	...

- multiple WHERE conditions can be combined using AND and OR

Approximate matches: LIKE

```
WHERE column LIKE pattern
```

```
SELECT code, name, population FROM countries WHERE name LIKE 'United%';
```

code	name	population
ARE	United Arab Emirates	2441000
GBR	United Kingdom	59623400
USA	United States	278357000
UMI	United States Minor Outlying Islands	0

- `LIKE 'text%'` searches for text that starts with a given prefix
- `LIKE '%text'` searches for text that ends with a given suffix
- `LIKE '%text%'` searches for text that contains a given substring

Sorting by a column: ORDER BY

```
ORDER BY column(s)
```

```
SELECT code, name, population FROM countries
WHERE name LIKE 'United%' ORDER BY population;
```

code	name	population
UMI	United States Minor Outlying Islands	0
ARE	United Arab Emirates	2441000
GBR	United Kingdom	59623400
USA	United States	278357000

- can write ASC or DESC to sort in ascending (default) or descending order:

```
SELECT * FROM countries ORDER BY population DESC;
```

- can specify multiple orderings in decreasing order of significance:

```
SELECT * FROM countries ORDER BY population DESC, gnp;
```

- see also: GROUP BY

Limiting rows: LIMIT

```
LIMIT number
```

```
SELECT name FROM cities WHERE name LIKE 'K%' LIMIT 5;
```

name
Kabul
Khulna
Kingston upon Hull
Koudougou
Kafr al-Dawwar

- can be used to get the top-N of a given category (`ORDER BY` and `LIMIT`)
- also useful as a sanity check to make sure your query doesn't return 10^7 rows

Learning about databases and tables

```sql
SHOW DATABASES;
SHOW TABLES;
DESCRIBE table;
```

```
SHOW TABLES;
+-----------+
| students  |
| courses   |
| grades    |
| teachers  |
+-----------+    4 rows in set
```

The SQL INSERT statement

```sql
INSERT INTO table
VALUES (value, value, ..., value);
```

```sql
INSERT INTO students
VALUES (789, "Nelson", "muntz@fox.com", "haha!");
```

- adds a new row to the given table
- columns' values should be listed in the same order as in the table
- How would we record that Nelson took CSE 190M and got a D+ in it?

More about INSERT

```sql
INSERT INTO table (columnName, columnName, ..., columnName)
VALUES (value, value, ..., value);
```

```sql
INSERT INTO students (name, email)
VALUES ("Lewis", "lewis@fox.com");
```

- some columns have default or auto-assigned values (such as IDs)
- omitting them from the INSERT statement uses the defaults

The SQL REPLACE statement

```sql
REPLACE INTO table (columnName, columnName, ..., columnName)
VALUES (value, value, ..., value);
```

```sql
REPLACE INTO students
VALUES (789, "Martin", "prince@fox.com");
```

- just like INSERT, but if an existing row exists for that key (ID), it will be replaced
- can pass optional list of column names, like with INSERT

The SQL UPDATE statement

```sql
UPDATE table
SET column = value,
    ...,
    column = value
WHERE column = value;
```

```sql
UPDATE students
SET email = "lisasimpson@gmail.com"
WHERE id = 888;
```

- modifies an existing row(s) in a table
- BE CAREFUL! If you omit the WHERE, it modifies ALL rows

The SQL DELETE statement

```sql
DELETE FROM table
WHERE condition;
```

```sql
DELETE FROM students
WHERE id = 888;
```

- removes existing row(s) in a table
- can be used with other syntax like LIMIT, LIKE, ORDER BY, etc.
- BE CAREFUL! If you omit the WHERE, it deletes ALL rows

Creating and deleting an entire database

```sql
CREATE DATABASE name;
DROP DATABASE name;
```

```sql
CREATE DATABASE warcraft;
```

- adds/deletes an entire database from the server

Creating and deleting a table

```sql
CREATE TABLE name (
  columnName type constraints,
  ...
  columnName type constraints
);
DROP TABLE name;
```

```sql
CREATE TABLE students (
  id INTEGER,
  name VARCHAR(20),
  email VARCHAR(32),
  password VARCHAR(16)
);
```

- adds/deletes a table from this database
- all columns' names and types must be listed *(see next slide)*

Modifying Tables

```sql
ALTER TABLE name RENAME TO newName;
```

```sql
ALTER TABLE students RENAME TO children;
```

- changes the name of an existing table

```sql
ALTER TABLE name
  ADD COLUMN columnName type constraints;

ALTER TABLE name DROP COLUMN columnName;

ALTER TABLE name
  CHANGE COLUMN oldColumnName newColumnName type constraints;
```

- adds/deletes/respecifies a column in an existing table
- if a column is added, all existing rows are given a default value for that column

MySQL data types

- BOOLEAN: either TRUE or FALSE
- INTEGER
- DOUBLE
- VARCHAR(*length*) : a string
- ENUM(*value*, ..., *value*): a fixed set of values
- DATE, TIME, DATETIME
- BLOB : binary data

Column constraints

```sql
CREATE TABLE students (
  id INTEGER UNSIGNED NOT NULL PRIMARY KEY,
  name VARCHAR(20) NOT NULL,
  email VARCHAR(32),
  password VARCHAR(16) NOT NULL DEFAULT "12345"
);
```

- `NOT NULL`: not allowed to insert a null/empty value in any row for that column
- `PRIMARY KEY` / `UNIQUE`: no two rows can have the same value
- `DEFAULT` *value*: if no value is provided, use the given default
- `AUTO_INCREMENT`: default value is the last row's value plus 1 (useful for IDs)
- `UNSIGNED`: don't allow negative numbers (`INTEGER` only)

Simpsons Database

id	name	email
123	Bart	bart@fox.com
456	Milhouse	milhouse@fox.com
888	Lisa	lisa@fox.com
404	Ralph	ralph@fox.com

students

id	name
1234	Krabappel
5678	Hoover
9012	Stepp

teachers

id	name	teacher_id
10001	Computer Science 142	1234
10002	Computer Science 143	5678
10003	Computer Science 190M	9012
10004	Informatics 100	1234

courses

student_id	course_id	grade
123	10001	B-
123	10002	C
456	10001	B+
888	10002	A+
888	10003	A+
404	10004	D+

grades

Querying multiple tables

When we have larger datasets spread across multiple tables, we need queries that can answer high-level questions such as:

- What courses has Bart taken and gotten a B- or better?
- What courses have been taken by both Bart and Lisa?
- Who are all the teachers Bart has had?
- How many total students has Ms. Krabappel taught, and what are their names?

To do this, we'll have to **join** data from several tables in our SQL queries.

Cross product with JOIN

```
SELECT column(s) FROM table1 JOIN table2;
```

SQL

```
SELECT * FROM students JOIN grades;
```

SQL

id	name	email	student_id	course_id	grade
123	Bart	bart@fox.com	123	10001	B-
404	Ralph	ralph@fox.com	123	10001	B-
456	Milhouse	milhouse@fox.com	123	10001	B-
888	Lisa	lisa@fox.com	123	10001	B-
123	Bart	bart@fox.com	123	10002	C
404	Ralph	ralph@fox.com	123	10002	C
... (24 rows returned)					

- **cross product** or **Cartesian product**: combines each row of first table with each row of second
  - produces *M* * *N* rows, where table 1 has *M* rows and table 2 has *N*
  - problem: produces too much irrelevant/meaningless data

Joining with ON clauses

```sql
SELECT column(s)
FROM table1
JOIN table2 ON condition(s)
...
JOIN tableN ON condition(s);
```

```sql
SELECT *
FROM students
JOIN grades ON id = student_id;
```

- **join**: combines records from two or more tables if they satisfy certain conditions
- the ON clause specifies which records from each table are matched
- the rows are often linked by their **key** columns (id)

Join example

```sql
SELECT *
FROM students
JOIN grades ON id = student_id;
```

id	name	email	student_id	course_id	grade
123	Bart	bart@fox.com	123	10001	B-
123	Bart	bart@fox.com	123	10002	C
404	Ralph	ralph@fox.com	404	10004	D+
456	Milhouse	milhouse@fox.com	456	10001	B+
888	Lisa	lisa@fox.com	888	10002	A+
888	Lisa	lisa@fox.com	888	10003	A+

- *table*.*column* can be used to disambiguate column names:

```sql
SELECT *
FROM students
JOIN grades ON students.id = grades.student_id;
```

Filtering columns in a join

```sql
SELECT name, course_id, grade
FROM students
JOIN grades ON id = student_id;
```

name	course_id	grade
Bart	10001	B-
Bart	10002	C
Ralph	10004	D+
Milhouse	10001	B+
Lisa	10002	A+
Lisa	10003	A+

```sql
SELECT name, course_id, grade
FROM students
JOIN grades ON id = student_id
WHERE name = 'Bart';
```

name	course_id	grade
Bart	10001	B-
Bart	10002	C

- FROM / JOIN glue the proper tables together, and WHERE filters the results
- what goes in the ON clause, and what goes in WHERE?
  - ON directly links columns of the joined tables
  - WHERE sets additional constraints such as particular values (123, 'Bart')

What's wrong with this?

```sql
SELECT name, id, course_id, grade
FROM students
JOIN grades ON id = 123
WHERE id = student_id;
```

name	id	course_id	grade
Bart	123	10001	B-
Bart	123	10002	C

- The above query produces the same rows as the previous one, but it is poor style. Why?
- The `JOIN ON` clause is poorly chosen. It doesn't really say what connects a `grades` record to a `students` record.
  - They are related when they are for a student with the same `id`.
  - Filtering out by a specific ID or name should be done in the `WHERE` clause, not `JOIN ON`.

Giving aliases to tables

```sql
SELECT s.name, g.*
FROM students s
JOIN grades g ON s.id = g.student_id
WHERE g.grade <= 'C';
```

name	student_id	course_id	grade
Bart	123	10001	B-
Bart	123	10002	C
Milhouse	456	10001	B+
Lisa	888	10002	A+
Lisa	888	10003	A+

- can give names to tables, like a variable name in Java
- to specify all columns from a table, write *table*.*
- (grade column sorts alphabetically, so grades C or better are ones <= it)

Multi-way join

```sql
SELECT c.name
FROM courses c
JOIN grades g ON g.course_id = c.id
JOIN students bart ON g.student_id = bart.id
WHERE bart.name = 'Bart' AND g.grade <= 'B-';
```

name
Computer Science 142

- More than 2 tables can be joined, as shown above
- What does the above query represent?
- The names of all courses in which Bart has gotten a B- or better.

Sub-optimal Query

- Exercise: What courses have been taken by both Bart and Lisa?
- ```sql
  SELECT bart.course_id
  FROM grades bart
  JOIN grades lisa ON lisa.course_id = bart.course_id
  WHERE bart.student_id = 123
  AND lisa.student_id = 888;
  ```
- problem: requires us to know Bart/Lisa's Student IDs, and only spits back course IDs, not names.
- Write a version of this query that gets us the course *names*, and only requires us to know Bart/Lisa's names, not their IDs.
  ```

Better Query

- What courses have been taken by both Bart and Lisa?

```sql
SELECT DISTINCT c.name
FROM courses c
JOIN grades g1 ON g1.course_id = c.id
JOIN students bart ON g1.student_id = bart.id
JOIN grades g2 ON g2.course_id = c.id
JOIN students lisa ON g2.student_id = lisa.id
WHERE bart.name = 'Bart'
AND lisa.name = 'Lisa';
```

- What are the names of all teachers Bart has ever had?
- How many total students has Ms. Krapappel taught, and what are their names?

Answers

- What are the names of all teachers Bart has had?

```sql
SELECT DISTINCT t.name
FROM teachers t
JOIN courses c ON c.teacher_id = t.id
JOIN grades g ON g.course_id = c.id
JOIN students s ON s.id = g.student_id
WHERE s.name = 'Bart';
```

SQL

- How many total students has Ms. Krabappel taught, and what are their names?

```sql
SELECT DISTINCT s.name
FROM students s
JOIN grades g ON s.id = g.student_id
JOIN courses c ON g.course_id = c.id
JOIN teachers t ON t.id = c.teacher_id
WHERE t.name = 'Krabappel';
```

SQL

Designing a query

- Figure out the proper SQL queries in the following way:
  - Which table(s) contain the critical data? (`FROM`)
  - Which columns do I need in the result set? (`SELECT`)
  - How are tables connected (`JOIN`) and values filtered (`WHERE`)?
- Test on a small data set (`imdb_small`).
- Confirm on the real data set (`imdb`).
- Try out the queries first in the MySQL console.
- Write the PHP code to run those same queries.
  - Make sure to check for SQL errors at every step!!

IMDB Database

id	first_name	last_name	gender
433259	William	Shatner	M
797926	Britney	Spears	F
831289	Sigourney	Weaver	F
...			

actors

id	name	year	rank
112290	Fight Club	1999	8.5
209658	Meet the Parents	2000	7
210511	Memento	2000	8.7
...			

movies

actor_id	movie_id	role
433259	313398	Capt. James T. Kirk
433259	407323	Sgt. T.J. Hooker
797926	342189	Herself
...		

roles

movie_id	genre
209658	Comedy
313398	Action
313398	Sci-Fi
...	

movies_genres

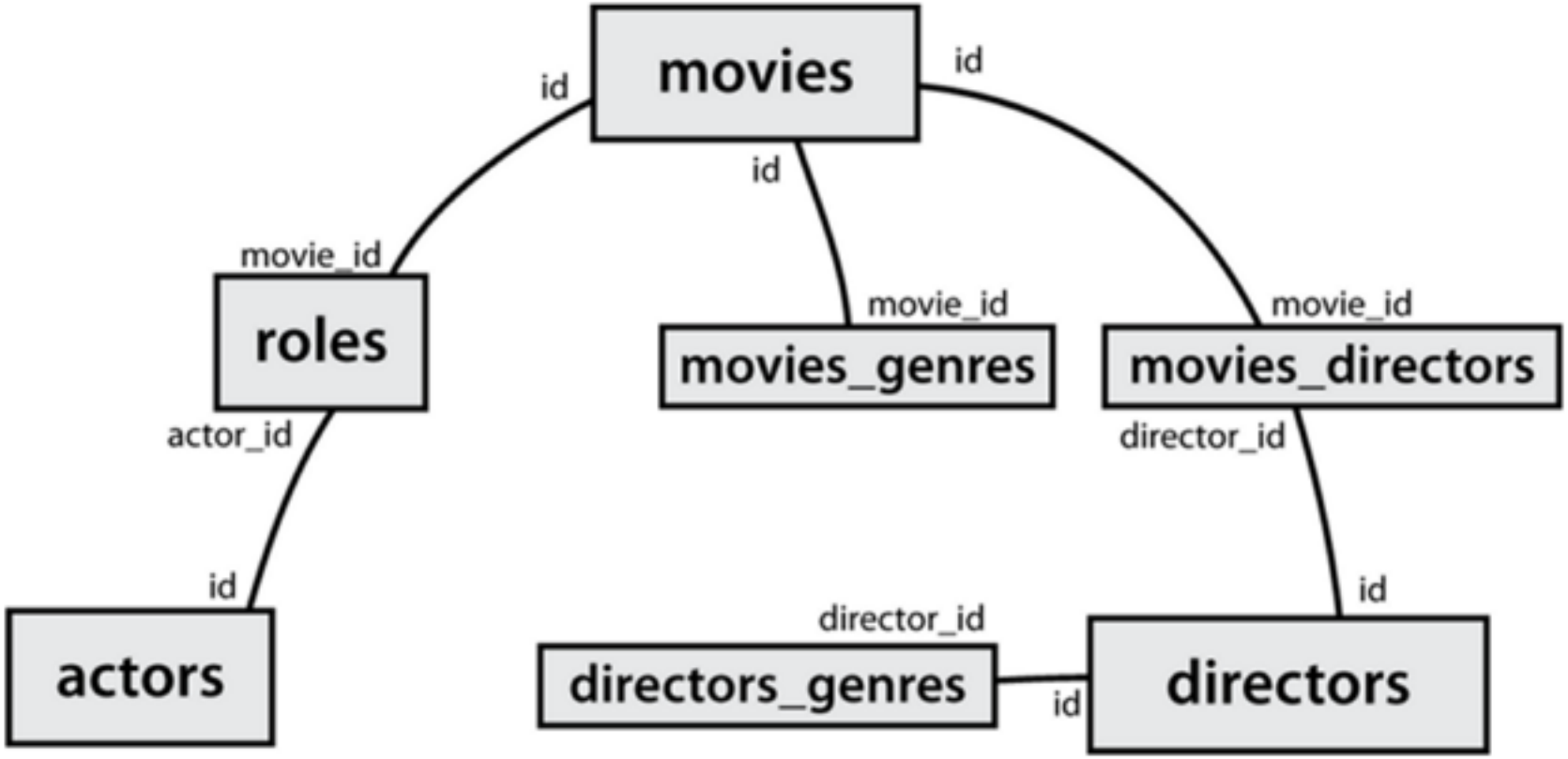
id	first_name	last_name
24758	David	Fincher
66965	Jay	Roach
72723	William	Shatner
...		

directors

director_id	movie_id
24758	112290
66965	209658
72723	313398
...	

movies_directors

IMDB Database Schema



IMDB query example

```
[stepp@webster ~]$ mysql -u myusername -p
Enter password:
Welcome to the MySQL monitor.  Commands end with ; or \g.

mysql> use imdb_small;
Database changed

mysql> select * from actors where first_name like '%mick%';
+--------+------------+-----------+--------+
| id     | first_name | last_name | gender |
+--------+------------+-----------+--------+
|  71699 | Mickey     | Cantwell  | M      |
| 115652 | Mickey     | Dee       | M      |
| 470693 | Mick       | Theo      | M      |
| 716748 | Mickie     | McGowan   | F      |
+--------+------------+-----------+--------+
4 rows in set (0.01 sec)
```

PHP Data Objects

```
$name = new PDO("dbprogram:dbname=database;host=server", username, password);
$name->query("SQL query");
```
PHP

```
# connect to world database on local server
$db = new PDO("mysql:dbname=world;host=localhost", "traveler", "packmybags");
$db->query("SELECT * FROM countries WHERE population > 100000000;");
```
PHP

- PDO database library allows you to connect to many different database programs
  - replaces older, less versatile functions like `mysql_connect`
- PDO object's `query` function returns rows that match a query

```
$db = new PDO("mysql:dbname=world;host=localhost", "traveler", "packmybags");
$rows = $db->query("SELECT * FROM countries WHERE population > 100000000;");
foreach ($rows as $row) {
  do something with $row;
}
```
PHP

- query returns all result rows
  - each row is an associative array of [column name -> value]
  - example: `$row["population"]` gives the value of the `population` column

Another example

```php
$db = new PDO("mysql:dbname=imdb_small", "jessica", "guinness");
$rows = $db->query("SELECT * FROM actors WHERE last_name LIKE 'Del%'");
foreach ($rows as $row) {
  ?>
  <li> First name: <?= $row["first_name"] ?>,
       Last name:  <?= $row["last_name"]  ?> </li>
  <?php
}
```

PHP

- First name: Benicio, Last name: Del Toro
- First name: Michael, Last name: Delano
- ...

output

PDO methods

name	description
query	performs a SQL SELECT query on the database
exec	performs a SQL query that modifies the database (INSERT, DELETE, UPDATE, etc.)
getAttribute, setAttribute	get/set various DB connection properties
quote	encodes a value for use within a query

PDOStatement methods

The $rows returned by PDO's query method is technically not an array but an object of type *PDOStatement*. Here are its methods:

columnCount()	number of columns in the results
fetch()	return the next row from the results
fetchColumn(*number*)	return the next column from the results
rowCount()	number of rows returned by the query

```
if ($db->rowCount() > 0) {
  $first_row = $db->fetch();
  ...
}
```

Including variable in a query

```
# get query parameter for name of movie
$title = $_GET["movietitle"];
$rows = $db->query("SELECT year FROM movies WHERE name = '$title'");
```

- you should not directly include variables or query parameters in a query
- they might contain illegal characters or SQL syntax to mess up the query

Instead, variables need to be quoted.

```
# get query parameter for name of movie
$title = $_GET["movietitle"];
$title = $db->quote($title);
$rows = $db->query("SELECT year FROM movies WHERE name = $title");
```

PHP

- call PDO's `quote` method on any variable to be inserted
- `quote` escapes any illegal chars and surrounds the value with ' quotes
- prevents bugs and security problems in queries containing user input

Selecting using PDOStatement

- PDO object has *prepare()* method which return *PDOStatement* object.
- *PDOStatement->execute(params_array)*; #executes prepared statement

```php
<?php
/* Execute a prepared statement by passing an array of values */
$sth = $dbh->prepare('SELECT name, colour, calories
    FROM fruit
    WHERE calories < ? AND colour = ?');
$sth->execute(array(150, 'red'));
$red = $sth->fetchAll();
$sth->execute(array(175, 'yellow'));
$yellow = $sth->fetchAll();
?>
```

Inserting/Updating/Deleting Records using PDOStatement

```php
<?php
$stmt = $dbh->prepare("INSERT INTO REGISTRY (name, value) VALUES (?, ?)");
$stmt->bindParam(1, $name);
$stmt->bindParam(2, $value);

// insert one row
$name = 'one';
$value = 1;
$stmt->execute();

// insert another row with different values
$name = 'two';
$value = 2;
$stmt->execute();
?>
```

Common mistakes

```
$db = new PDO("mysql:dbname=imdb_small", "jessica", "guinness");
$rows = $db->query("SEEELECT * FROM movies WHERE year = 2000");   # FALSE
```

- database commands can often fail (invalid query; server not responding; etc.)
- normally, PDO commands fail silently by returning FALSE or NULL
- but this makes it hard to notice and handle problems

```
$db = new PDO("mysql:dbname=imdb_small", "jessica", "guinness");
$db->setAttribute(PDO::ATTR_ERRMODE, PDO::ERRMODE_EXCEPTION);
$rows = $db->query("SEEELECT * FROM movies WHERE year = 2000");   # kaboom!
```

- using `setAttribute`, you can tell PDO to throw (generate) a `PDOException` when an error occurs
- the exceptions will appear as error messages on the page output
- you can **catch** the exception to gracefully handle the error

Catching an exception

```
try {
   statement(s);
} catch (ExceptionType $name) {
   code to handle the error;
}
```
PHP

- a `try/catch` statement attempts to run some code, but if it throws a given kind of exception, the program jumps to the `catch` block and runs that code to handle the error

```
try {
  $db = new PDO("mysql:dbname=imdb_small", "jessica", "guinness");
  $db->setAttribute(PDO::ATTR_ERRMODE, PDO::ERRMODE_EXCEPTION);
  $rows = $db->query("SEEELECT * FROM movies WHERE year = 2000");
  foreach ($rows as row) { ... }
} catch (PDOException $ex) {
  ?>
  <p>Sorry, a database error occurred. Please try again later.</p>
  <p>(Error details: <?= $ex->getMessage() ?>)</p>
  <?php
}
```
PHP

Database design principles

- **database design** : the act of deciding the schema for a database
- **database schema**: a description of what tables a database should have, what columns each table should contain, which columns' values must be unique, etc.
- some database design principles:
  - keep it simple, stupid (KISS)
  - provide an identifier by which any row can be uniquely fetched
  - eliminate redundancy, especially of lengthy data (strings)
    - integers are smaller than strings and better to repeat
  - favor integer data for comparisons and repeated values
    - integers are smaller than strings and better to repeat
    - integers can be compared/searched more quickly than strings, real numbers

What's good/bad about this design?

name	email	course	teacher	grade
Bart	bart@fox.com	Computer Science 142	Krabappel	B-
Bart	bart@fox.com	Computer Science 143	Hoover	C
Milhouse	milhouse@fox.com	Computer Science 142	Krabappel	B+
Lisa	lisa@fox.com	Computer Science 143	Hoover	A+
Lisa	lisa@fox.com	Computer Science 190M	Stepp	A+
Ralph	ralph@fox.com	Informatics 100	Krabappel	D+

student_grades

- what's good and bad about this design?
  - good: simple (one table), can see all data in one place
  - bad: redundancy (name, email, course repeated frequently)
  - bad: most searches (e.g. find a student's courses) will have to rely on string comparisons
  - bad: there is no single column whose value will be unique in each row

Improved database design

id	name	email
123	Bart	bart@fox.com
456	Milhouse	milhouse@fox.com
888	Lisa	lisa@fox.com
404	Ralph	ralph@fox.com

students

id	name	teacher_id
10001	Computer Science 142	1234
10002	Computer Science 143	5678
10003	Computer Science 190M	9012
10004	Informatics 100	1234

courses

student_id	course_id	grade
123	10001	B-
123	10002	C
456	10001	B+
888	10002	A+
888	10003	A+
404	10004	D+

grades

id	name
1234	Krabappel
5678	Hoover
9012	Stepp

teachers

- normalizing: splitting tables to improve structure / redundancy (linked by unique IDs)
- **primary key**: a column guaranteed to be unique for each record (e.g. Lisa Simpson's ID 888)
- **foreign key**: a column in table A storing a primary key value from table B
  - (e.g. records in `grades` with `student_id` of 888 are Lisa's grades)