Database systems in 21 minutes

- **Relational Database Management Systems**
  - MySQL, Postgres, SQLite, Oracle, Sybase, DB2, …
- **a database is a collection of tables**
- **each table has a fixed number of columns**
  - each column is an "attribute" common to all rows
- **and a variable number of rows**
  - each row is a "record" that contains data

isbn	*title*	*author*	*price*
1234	*MySQL*	*DuBois*	*49.95*
4321	*TPOP*	*K & P*	*24.95*
2468	*Ruby*	*Flanagan*	*79.99*
2467	*Java*	*Flanagan*	*89.99*
2466	*Javascript*	*Flanagan*	*99.99*
1357	*Networks*	*Peterson*	*105.00*
1111	*Practical Ethics*	*Singer*	*25.00*
4320	*C Prog Lang*	*K & R*	*40.00*

Relational model

- **simplest database has one table holding all data**
  - e.g., Excel spreadsheet
- **relational model: data in separate tables "related" by common attributes**
  - e.g., **id** in **custs** matches **custid** in **sales**
- **schema: content and structure of the tables**

```
books
     isbn   title   author   price
custs
     id   name   adr
sales
     isbn   custid   date   price   qty
stock
     isbn   count
```

- **extract desired info by queries**
- **query processing figures out what info comes from what tables, extracts it efficiently**

Sample database

- **books**

```
1234  MySQL           DuBois    49.95
4321  TPOP            K & P     24.95
2468  Ruby            Flanagan  79.99
2467  Java            Flanagan  89.99
```

- **custs**

```
11   Brian   Princeton
22   Bob     Princeton
33   Bill    Redmond
44   Bob     Palo Alto
```

- **sales**

```
4321   11  2010-02-28  45.00   1
2467   22  2010-01-01  60.00  10
2467   11  2010-03-05  57.00   3
4321   33  2010-03-05  45.00   1
```

- **stock**

```
1234   100
4321    20
2468     5
2467     0
```

Retrieving data from a single table

- **SQL ("Structured Query Language") is the standard language for expressing queries**
  - all major database systems support it

- **general format**

select *column-names* **from** *tables* **where** *condition* **;**

```
select * from books;
select name, adr from custs;
select title, price from books where price > 50;
select * from books where author = "Flanagan";
select author, title from books where author like "F%";
select author, title from books order by author;
select author, count(*) from books group by author;
```

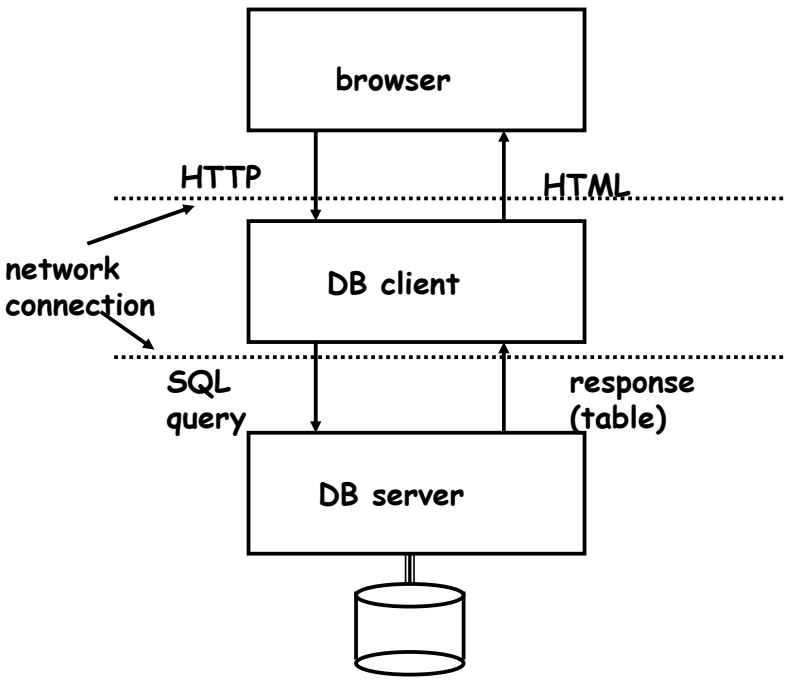
- **result is a table**

Multiple tables and joins

- **if desired info comes from multiple tables, this implies a "join" operator to relate data in different tables**
  - in effect join makes a big table for later selection

```
select title, count from books, stock
   where books.isbn = stock.isbn;

select * from books, sales
   where books.isbn = sales.isbn
     and books.author like "F%";

select custs.name, books.title
  from books, custs, sales
    where custs.id = sales.custid
      and sales.isbn = books.isbn;

select price, count(*) as count from books
   where author like 'F%'
     group by author order by count desc;
```

Database system organization



ACID

- **the central properties of a database system:**

- **Atomicity**
  - all or nothing: all steps of a transaction are completed
  - no partially completed transactions

- **Consistency**
  - each transaction maintains consistency of whole database

- **Isolation**
  - effects of a transaction not visible to other transactions until committed

- **Durability**
  - changes are permanent, survive system failure
  - consistency guaranteed

MySQL

- **open source (?) relational database system**
  `www.mysql.com`
- **"LAMP"**
  - **L**inux
  - **A**pache
  - **M**ySQL
  - **P***: Perl, Python, PHP
- **command-line interface:**
  - connect to server using command interface

```
mysql -h studentdb -u bwk –p
```

  - type commands, read responses

```
show databases;
use bwk;
show tables;
select now(), version(), user();
source cmdfile;
```

Creating and loading a table

- **create table**

```
create table books (
  isbn varchar(15) primary key,
  title varchar(35), author varchar(20),
  price decimal(10,2)
);
```

- **load table from file (tab-separated text)**

```
load data local infile "books" into table books
     fields terminated by "\t"
     ignore 1 lines;
```

- **fields have to be left justified.**
- **terminated clause must be single character**
  - not whitespace: multiple blanks are NOT treated as single separator

- **can also insert one record at a time**

```
insert into books values('2464','AWK','Flanagan','89.99');
```

Item types

- **INT**
  - of several sizes
- **FLOAT, DOUBLE, DECIMAL**
- **CHAR, VARCHAR**
- **BLOB (binary large object)**
  - of several sizes
- **TEXT**
  - of several sizes
- **ENUM**
  - e.g., 'M', 'F'
- **SET**
- **DATE, TIME, …**

Other statements

- **generic SQL**
  - ought to be the same for all db systems
  - (though they are not always)

```
insert into sales
   values('1234','44','2008-03-06','27.95');
update books set price = 99.99
    where author = "Flanagan";
delete from books where author = "Singer";
```

- **MySQL-specific**
  - other db's have analogous but different statements

```
use bwk;
show tables;
describe books;
drop tables if exists books, custs;
```

SQLite: an alternative (www.sqlite.org)

- **small, fast, simple, embeddable**
  - no configuration
  - no server
  - single cross-platform database file
- **most suitable for**
  - embedded devices (cellphones)
  - web sites with modest traffic & rapid processing
    <100K hits/day, 10 msec transaction times
  - ad hoc file system or format replacement
  - internal or temporary databases
- **probably not right for**
  - large scale client server
  - high volume web sites
  - gigabyte databases
  - high concurrency
- **"SQLite is not designed to replace Oracle.**
  It is designed to replace fopen()."

Program interfaces to MySQL

- **original and basic interface is in *C***
  - about 50 functions
  - other interfaces build on this
  - most efficient access though query complexity is where the time goes
  - significant complexity in managing storage for query results
- **API's exist for most other languages**
  - Perl, Python, PHP, Ruby, ...
  - C++, Java, …
  - can use MySQL from Excel, etc., with ODBC module
- **basic structure for all API's is**

```
db_handle = connect to database
repeat {
    stmt_handle = prepare an SQL statement
    execute (stmt_handle)
    fetch result
} until tired
disconnect (db_handle)
```

Simple standalone Perl example

```
#!/usr/local/bin/perl -w
use strict;
use DBI;

my $dsn = "DBI:mysql:bwk:studentdb.cs.princeton.edu";
my $dbh = DBI->connect( $dsn, "bwk", "xxx", {RaiseError=>1});
print "Enter query: ";
while (<>) {
   chomp;
   next if $_ eq "";
   $sth = $dbh->prepare("$_");
   $sth->execute();
   while (my @ary = $sth->fetchrow_array()) {
      print join ("\t", @ary), "\n";
   }
   $sth->finish();
   print "Enter query: ";
}

$dbh->disconnect();
```

Perl CGI version (part 1: get query, access db)

```
#!/usr/local/bin/perl -w
use strict;
use DBI;
use CGI;
my $query = new CGI;
my $ret = "";
my $passwd = $query->param("password");
if (defined($query->param("sql"))) {
  my $dsn = "DBI:mysql:bwk:studentdb.cs.princeton.edu";
  my $dbh = DBI->connect($dsn, "bwk", $passwd, {RaiseError=>1});
  my $q = $query->param("sql");
  my $sth = $dbh->prepare($q);
  my $nchg = $sth->execute();
  my @ary;
  if ($nchg > 0) {
     while (@ary = $sth->fetchrow_array()) {
        $ret .= join ("\t", @ary), "\n";
     }
  }
  $sth->finish();
  $dbh->disconnect();
}
```

Perl CGI version (part 2: generate HTML)

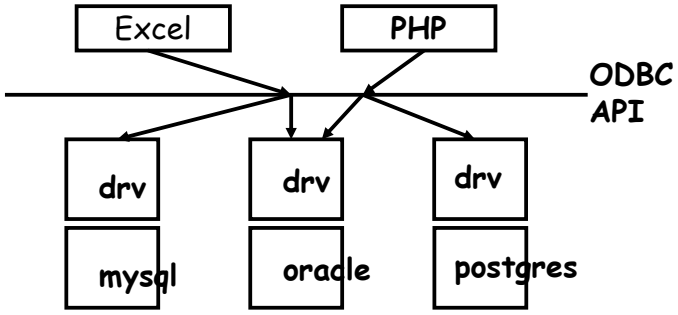
```
print $query->header;
print $query->start_html(-title=>'MySQL test', -
  bgcolor=>'white');

print qq( <P><form METHOD=POST enctype="multipart/form-data"
  ACTION="http://www.cs.princeton.edu/
                    ~bwk/mysql.cgi">\n );
my $s = $query->param("sql");
print qq(Password: <input type="password"
   name=password text="" size="30">\n );
print qq( <br><textarea name=sql rows=5
   cols=65 wrap>$s</textarea>\n);
print qq( <br><input type="submit"
   value="Submit"> <input type=reset>\n);
print qq( <br><textarea name=results
    rows=15 cols=60 wrap>\n
    $ret\n</textarea>\n );
print "</form>\n";

print $query->end_html();
```

PHP version (just enough to demonstrate connectivity)

```
<html>
<title>test</title>
<body bgcolor=white>
<?php
$con = mysql_connect("studentdb.cs.princeton.edu", "bwk", "xx");
if (!$con) {
  echo "Error: couldn't connect<br>\n";
  $er = mysql_error($con);
  echo "<li> $er\n";
  exit;
}
mysql_select_db("bwk", $con);
$result = mysql_query("select * from books");
while ($row = mysql_fetch_array($result)) {
  for ($i = 0; $i < mysql_num_fields($result); $i++) {
       printf("%s ", $row[$i]);
  }
  printf("<br>\n");
}
?>
</body></html>
```

ODBC, JDBC, and all that

- **ODBC ("open database connectivity")**
  - Microsoft standard interface between applications and databases
  - API provides basic SQL interface
  - driver does whatever work is needed to convert
  - underlying database has to provide basic services
  - used for applications like Excel, Visual Basic, C/C++, ...
  - drivers exist for all major databases
  - makes applications relatively independent of specific database being used
- **JDBC is the same thing for Java**
  - passes calls through to ODBC drivers or other database software



MySQL access from Java (Connector/J JDBC package)

```
import java.sql.*;

public class mysql {
  public static void main(String args[]) {
   String url = "jdbc:mysql://studentdb.cs.princeton.edu/bwk";
   try {
      Class.forName("com.mysql.jdbc.Driver");
   } catch(java.lang.ClassNotFoundException e) {
      System.err.print("ClassNotFoundException: " + e.getMessage());
   }
   try {
      Connection con = DriverManager.getConnection(url, "bwk", "xxx");
      Statement stmt = con.createStatement();
      ResultSet rs = stmt.executeQuery("select * from books");
      while (rs.next())
         System.out.println(rs.getString("title") + " "
                                  + rs.getString("author"));
      stmt.close();
      con.close();
   } catch(SQLException ex) {
      System.err.println("SQLException: " + ex.getMessage());
   }
  }
```

Interface design

- **two different possible table structures:**

```
books
   isbn   title   author   price
booktitle, bookauthor, bookprice
   isbn  title
   isbn  author
   isbn  price
```

- **they need different SQL queries:**

```
select title, author, price from books;
select title, author, price
  from booktitle, bookauthor,bookprice
    where booktitle.isbn = bookauthor.isbn
     and bookauthor.isbn = bookprice.isbn;
```

- **most of the program should be independent of the specific table organization**
  - shouldn't know or care which one is being used

```
getList(title, author, price)
```