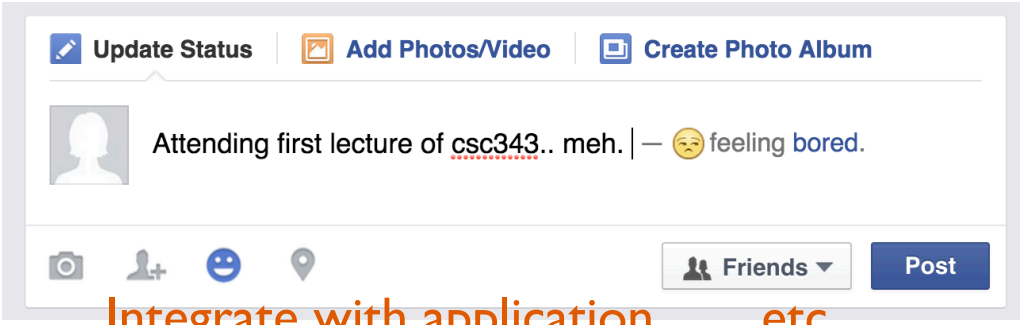
Embedded SQL

But why?

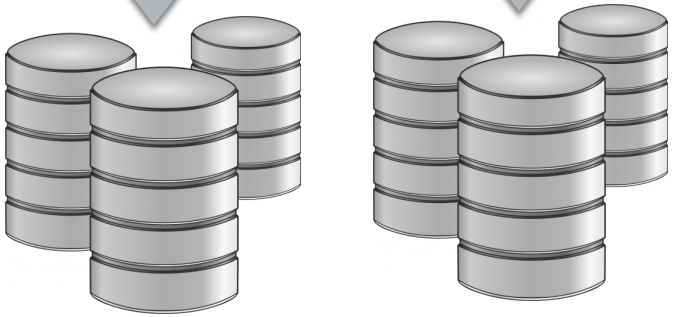
Users/Apps



Data processing Control Format Integrate with application etc

Database Management System (DBMS)

Data!



SQL + a conventional language

- If we can combine SQL with code in a conventional language, we can solve these problems.
- But we have another problem:
  - SQL is based on relations, and conventional languages have no such type.
- It is solved by
  - feeding tuples from SQL to the other language one at a time, and
  - feeding each attribute value into a particular *variable*.

Approaches

- Three approaches for combining SQL and a general-purpose language:
  - Stored Procedures
  - Statement-level Interface
  - Call-level interface

Three Approaches

1. Stored Procedures

FYI

- The SQL standard includes a language for defining "stored procedures", which can
  - have parameters and a return value,
  - use local variables, ifs, loops, etc.,
  - execute SQL queries.
- Stored procedures can be used in these ways:
  - called from the interpreter,
  - called from SQL queries,
  - called from another stored procedure,
  - be the action that a trigger performs.

Example (just to give you an idea)

FYI

Reference: textbook chapter 9

```
CREATE FUNCTION BandW(y INT, s CHAR(15)) RETURNS BOOLEAN
IF NOT EXISTS
   (SELECT *
    FROM Movies
    WHERE year = y AND studioName = s)
THEN RETURN TRUE;
ELSIF 1 <=
   (SELECT COUNT(*)
    FROM Movies
    WHERE year = y AND studioName = s AND
          genre = 'comedy')
THEN RETURN TRUE;
ELSE RETURN FALSE;
END IF;
```

Not very standard

FYI

- The language is called SQL/PSM (Persistent Stored Modules).
  - It came into the SQL standard in SQL3, 1999.
  - Reference: textbook, section 9.4
- By then, various commercial DBMSs had already defined their own proprietary languages for stored procedures
  - They have generally stuck to them.
- PostgreSQL has defined PL/pgSQL.
  - It supports some, but not all, of SQL/PSM.
  - Reference: Chapter 39 of the PostgreSQL documentation.

2. Statement-level interface (SLI)

FYI

- Embed SQL statements into code in a conventional language like C or Java.
- Use a preprocessor to replace the SQL with calls written in the host language to functions defined in an SQL library.
- Special syntax indicates which bits of code the preprocessor needs to convert.

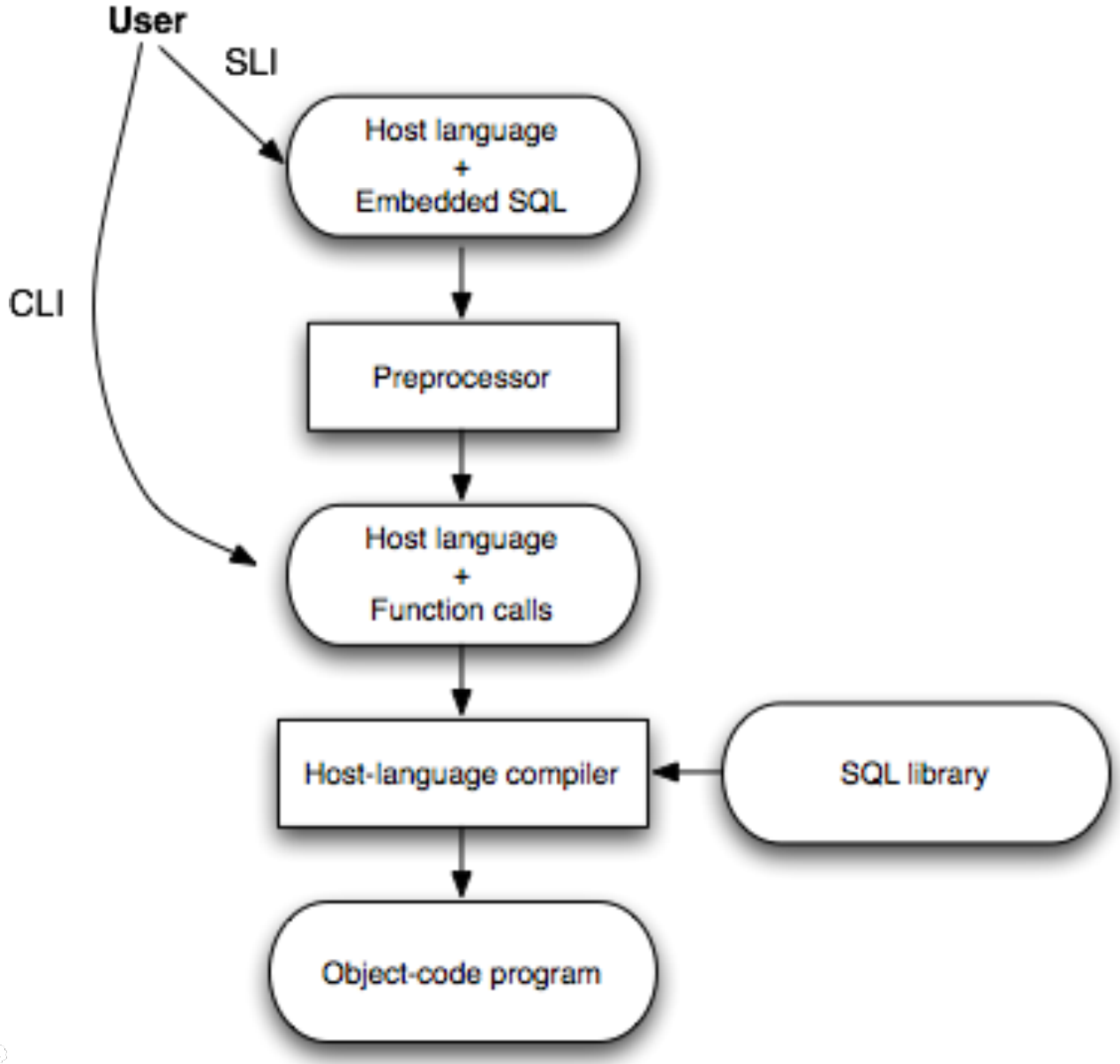
Example (just to give you an idea)

FYI

Reference: textbook example 9.7

```
void printNetWorth() {
  EXEC SQL BEGIN DECLARE SECTION;
    char studioName[50];
    int presNetWorth;
    char SQLSTATE[6]; // Status of most recent SQL stmt
  EXEC SQL END DECLARE SECTION;
  /* OMITTED: Get value for studioName from the user. */
  EXEC SQL SELECT netWorth
           INTO :presNetWorth
           FROM Studio, MovieExec
           WHERE Studio.name = :studioName;
  /* OMITTED: Report back to the user */
```

Big picture (figure 9.5)

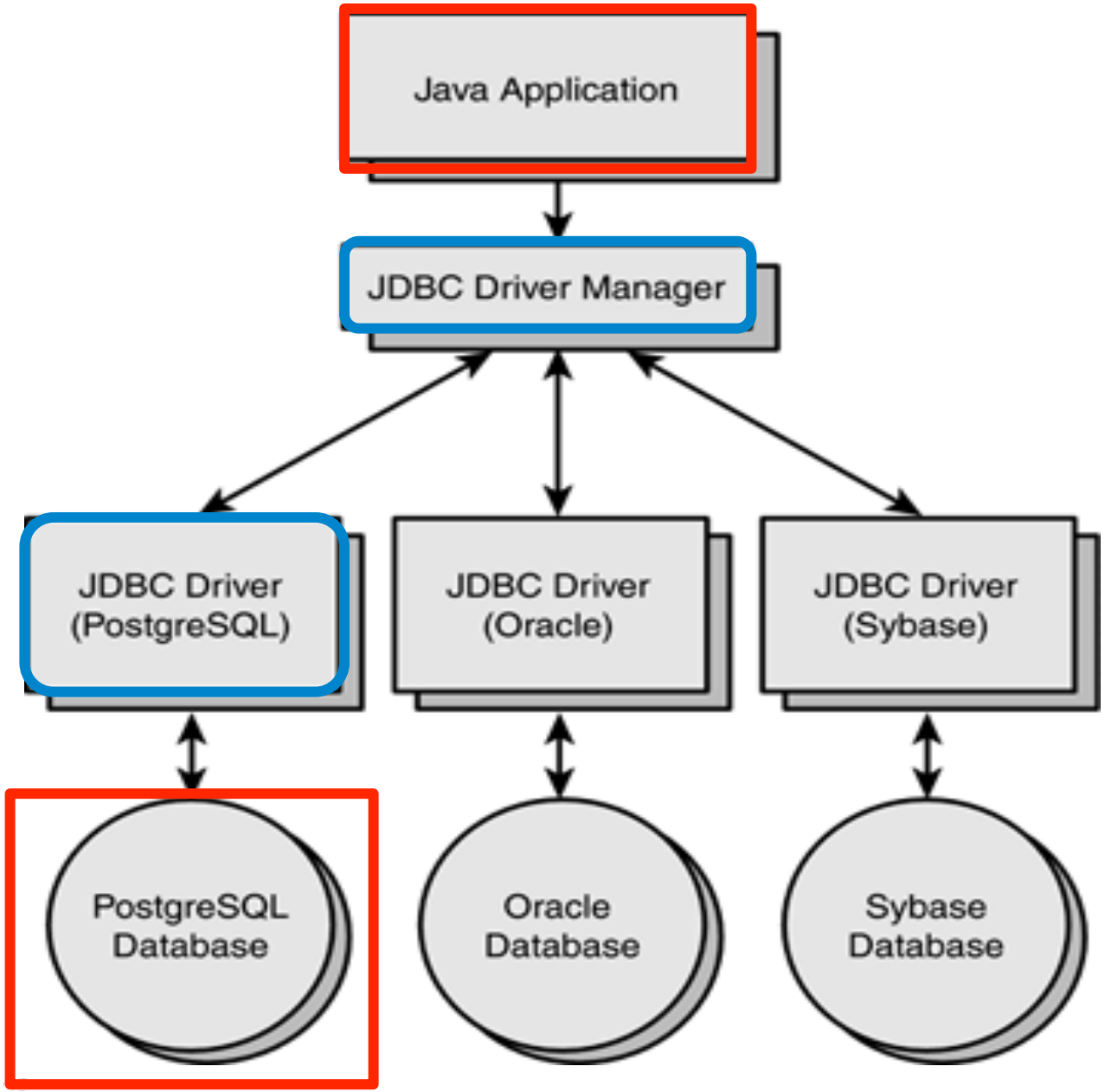


3. Call-level interface (CLI)

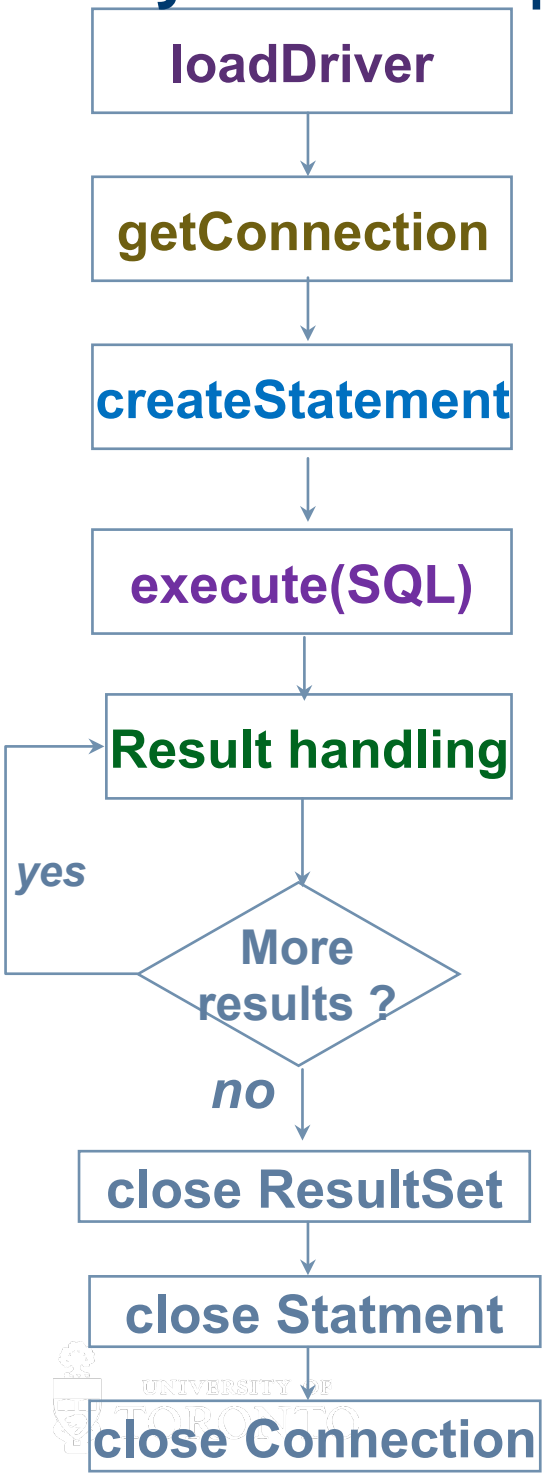
- Instead of using a pre-processor to replace embedded SQL with calls to library functions, write those calls yourself.
- Eliminates need to preprocess.
- Each language has its own set of library functions for this.
  - for C, it's called SQL/CLI
  - for Java, it's called JDBC
  - for PHP, it's called PEAR DB
- We'll look at just one: JDBC.

JDBC

JDBC Architecture



JDBC - Steps



Steps:

1- Load the driver and register it with the driver manager
(provided you've already downloaded the driver "jar" file)

2- Connect to a database

3- Create an SQL statement

4- Execute a query and retrieve the results, or, make changes to the database

5- Disconnect from the database

Using JDBC on cdf

- You need to run your JDBC code on dbsrv1.
- The PostgreSQL driver for JDBC is on cdf here:

  `/local/packages/jdbc-postgresql`

  You'll also find an example program and a how-to in that directory.
- To run JDBC code, you need this driver in your classpath.
- Example: Suppose you have a class called Jelly.java.

```
javac Jelly.java
java -cp ~/bin/postgresql-8.3-607.jdbc4.jar: Jelly
```

JDBC Example (see section 9.6)

conn

Do this once in your program:

```
/* Get ready to execute queries. */
import java.sql.*;

/* A static method of the Class class. It loads the
   specified driver */
Class.forName("org.postgresql.jdbc.Driver");
Connection conn = DriverManager.getConnection(
   jdbc:postgresql://localhost:5432/csc343h-userID,
   userID,"");
/* Continued ... */
```

The arguments to getConnection

```
Connection conn = DriverManager.getConnection(
   jdbc:postgresql://localhost:5432/csc343h-userID,
   userID,"");
```

- `jdbc:postgresql`
  We'll use this, but it could be, e.g., `jdbc:mysql`
- `localhost:5432`
  You must use exactly this for cdf.
- `csc343h-userID` and `userID`
  Substitute your cdf userid.
- `""`
  Password (unrelated to your cdf password).
  Literally use the empty string.

Do this once per query in your program:

conn

```
/* Execute a query and iterate through the resulting
   tuples. */
PreparedStatement execStat = conn.prepareStatement(
   "SELECT netWorth FROM MovieExec");

ResultSet worths = execStat.executeQuery();
while (worths.next()) {
   int worth = worths.getInt(1);
   /* If the tuple also had a float and another int
      attribute, you'd get them by calling
      worths.getFloat(2) and worths.getInt(3).
      Or you can look up values by attribute name.
      Example: worths.getInt(netWorth)
   */
   /* OMITTED: Process this net worth */
```

Exceptions can occur

- Any of these calls can generate an exception.
- Therefore, they should be inside try/catch blocks.

```
try {
    /* OMITTED: JDBC code */
} catch (SQLException ex) {
    /* OMITTED: Handle the exception */
}
```

- The class **`SQLException`** has methods to return the **`SQLSTATE`**, etc.

What is “preparation”?

- Preparing a statement includes parsing the SQL, compiling and optimizing it.
- The resulting `PreparedStatement` can be executed any number of times without having to repeat these steps.

If the query isn't known until run time

- You may need input and computation to determine the query.
- You can hard-code in the parts you know, and use "`?`" as a placeholder for the values you don't know.
- This is enough to allow a `PreparedStatement` to be constructed.
- Once you know values for the placeholders, methods `setString`, `setInt`, etc. let you fill in those values.

Example (figure 9.22)

```
PreparedStatement studioStat =
    conn.prepareStatement(
        “INSERT INTO Studio(name, address)
         VALUES(?, ?)”
);

/* OMITTED: Get values for studioName and studioAddr */
studioStat.setString(1, studioName);
studioStat.setString(2, studioAddr);
studioStat.executeUpdate();
```

Why not just build the query in a string?

- We constructed an incomplete `preparedStatement` and filled in the missing values using method calls.
- Instead, we could just build up the query in an ordinary string at run time, and ask to execute that.
- There are classes and methods that will do this in JDBC.
- But never use that approach because it is vulnerable to injections: insertion of strings into a query with malicious intent.
- Always use a `preparedStatement` instead.

Example with `createStatement`

```
Statement stat = conn.createStatement();
String query =
   "SELECT networth
    FROM MovieExec
    WHERE execName like '%Spielberg%';
   "
ResultSet worths = stat.executeQuery(query);
```

Example: Some vulnerable code

Suppose we want the user to provide the string to compare to

You can do this rather than hard-coding `Spielberg` into the query:

```
Statement stat = conn.createStatement();
String who = /* get a string from the user */
String query =
   "SELECT networth
    FROM MovieExec
    WHERE execName like '%" + who + "%';
   "
ResultSet worths = stat.executeQuery(query);
```

A gentle user does no harm

If a user enters `Cameron`, the SQL code we execute is this:

```
SELECT networth
FROM MovieExec
WHERE execName like '%Cameron%';
```

Nothing bad happens.

An injection can exploit the vulnerability

What could a malicious user enter?

```
SELECT networth
FROM MovieExec
WHERE execName like '%??????????????%';
```

An injection can exploit the vulnerability

But if a malicious user enters

```
Milch%'; drop table Contracts; --
```

the code we execute is this:

```
SELECT networth
FROM MovieExec
WHERE execName like '%Milch%'; DROP TABLE Contracts; --%';
```

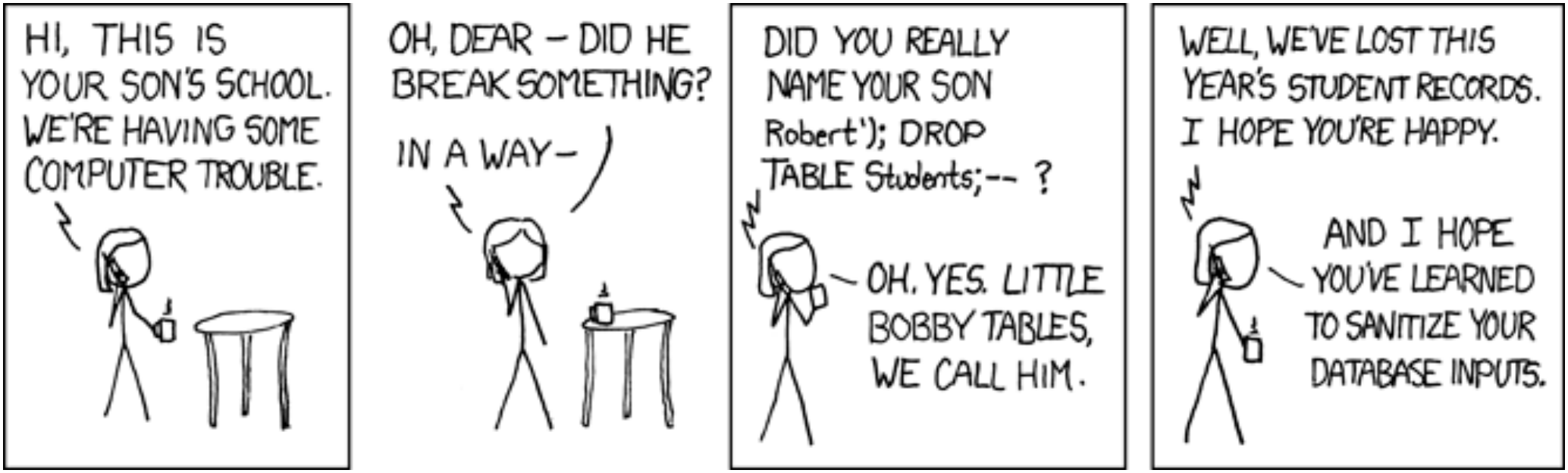
In other words:

```
SELECT networth
FROM MovieExec
WHERE execName like '%Milch%';

DROP TABLE Contracts; --%';
```

xkcd <3

"Did you really name your son Robert'); DROP TABLE Students; -- ?"



Queries vs updates in JDBC

- The previous examples used `executeQuery`.
- This method is only for pure queries.
- For SQL statements that change the database (insert, delete or modify tuples, or change the schema), use the analogous method `executeUpdate`.