



# **Database Programming Overview**



Interaction with a database is often through programs. Programming with a database requires:

- A database server and its connection information
- A programming language for writing the code to query the database
- A library or driver for connecting to the particular database system

#### General process for programming with a database:

- 1) Load the database access library
- Create a connection to the database
- 3) Execute a SQL command
- 4) Retrieve database results produced by the command
- 5) Close the database connection

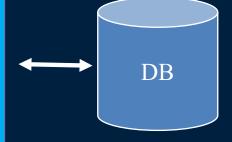
# **SQL Programming Architecture**





- 1. Load library into program
- 2. Create Connection
- 3. Execute SQL Command
- 4. Retrieve Results
- 5. Close connection

Database Server Software



- 1) Load Library Error:
- Library not found in path
- Wrong library

- 2) Create Connection Errors: 3) Execute SQL Errors:
- Invalid server URL
- Incorrect user/password -
- Network issues
- Wrong library

- Incorrect SQL Errors:
- Wrong database/table
- Improper library use

- 4) Retrieve Results Errors:
- Wrong column name
- Wrong column index
- Off-by-one
- Improper library use
- 5) Close Connection:
- FORGET TO DO IT!



## **SQL Programming Architecture Question**

Question: True or False: The user has sent a command to the database and an error is returned. This error is often related to the user providing an incorrect server URL.

A) true

B) false



# **Database Programming in Java**

**JDBC** is the most popular method for accessing databases using Java programs.

JDBC is an *application programming interface* (*API*) that contains methods to connect to a database, execute queries, and retrieve results.

For each DBMS, the vendor writes a JDBC driver that implements the API. Application programs can access different DBMSs simply by changing the driver used in their program.

# **DBC Interfaces**



#### The JDBC API consists of a set of interfaces.

- A Java *interface* is an abstract class consisting of a set of methods with no implementation.
- To create a JDBC driver, the DBMS vendor must implement the interfaces by defining their own classes and writing the code for the methods in the interface.

#### The main interfaces in the JDBC API are:

- Driver The main class of the entire driver.
- Connection For connecting to the DB using the driver.
- Statement For executing a query using a connection.
- ResultSet For storing and manipulating results returned by a Statement.
- DatabaseMetaData For retrieving metadata (schema) information from a database.





```
import java.sql.*; ← Import JDBC API
                                                    DB Connection Info
public class TestJDBCMySQL
    public static void main(String[] args)
         String url = "jdbc:mysql://localhost/WorksOn";
         String uid = "user";
                                                                      Make DB connection
         String pw = "testpw";
              (Connection con = DriverManager.getConnection(url, uid, pw);
         trv
                                                                                  Execute
             Statement stmt = con.createStatement();)
                                                                                  statement
  Create
              ResultSet rst = stmt.executeQuery("SELECT ename, salary FROM emp");
 statement
             System.out.println("Employee Name, Salary");
              while (rst.next())
              System.out.println(rst.getString("ename")+","+rst.getDouble("salary"));
         catch (SQLException ex)
         { System.out.println(ex); }
```

Using try-with-resources syntax so Statement and Connection objects closed at end of try





The Driver interface is the main interface that must be implemented by a DBMS vendor when writing a JDBC driver.

- The class itself does not do very much except allow a connection to be made to a database through the driver.
- Note that you do not call the Driver class directly to get a connection. Drivers self-register with the DriverManager so Class.forName() is no longer needed.
- When you call DriverManager.getConnection(), the DriverManager will attempt to locate a suitable driver using the URL.

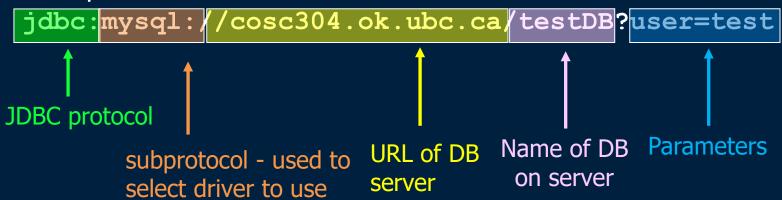




JDBC specifies connection information in a URL that has the form:

protocol:dbprotocol://server/database?params

#### Example:







The Connection interface contains methods for managing a connection or session.

- A connection is opened after the call to getConnection() and should be closed when you are done.
- The Connection interface is used to create statements for execution on the database.

```
Connection con = DriverManager.getConnection(url, uid, pw);
Statement stmt = con.createStatement();
...
con.close();
```



### Connection Interface and MetaData

A Connection to a database can also be used to retrieve the database metadata (or schema).

• This is useful when you are writing generic tools where you do not know the schema of the database that you are querying in advance.

The method getMetaData() can be used to retrieve a DatabaseMetaData object.





```
String []tblTypes = {"TABLE"}; // What table types to retrieve
try {
    DatabaseMetaData dmd = con.getMetaData(); // Get metadata
    ResultSet rs1, rs2, rs5;
    System.out.println("List all tables in database: ");
    rs1 = dmd.getTables(null, null, "%", tblTypes);
    while (rs1.next()) {
        String tblName = rs1.getString(3);
        Statement stmt = con.createStatement();
        rs2 = stmt.executeQuery("SELECT COUNT(*) FROM "+tblName);
        rs2.next();
        System.out.println("Table: "+tblName+" # records: "+rs2.getInt(1));
        rs5 = dmd.getColumns(null, null, tblName, "%");
        System.out.println(" Attributes: ");
        while (rs5.next()) {
             System.out.println(rs5.getString(4));
      // end outer while
    end try
```



#### JDBC Statement Interface

The Statement interface contains abstract methods for executing a single static SQL statement and returning the results it produces.

```
Statement stmt = con.createStatement();
ResultSet rst = stmt.executeQuery("SELECT ename, salary FROM emp");
```

- The Statement object is created by Connection.createStatement().
- The statement is then executed by calling executeQuery() and passing the SQL string to execute.



# JDBC Statement Interface (2)

There are two important variations of executing statements that are important and are used often.

• 1) The Statement executed is an INSERT, UPDATE, or DELETE and no results are expected to be returned:

```
rowcount = stmt.executeUpdate("UPDATE emp Set salary=0");
```

• 2) The Statement executed is an INSERT which is creating a new record in a table whose primary key field is an autonumber field:



# PreparedStatement and CallableStatement

#### There are two special types of Statement objects:

- PreparedStatement extends Statement and is used to execute precompiled SQL statements.
  - Useful when executing the same statement multiple times with different parameters as the DBMS can optimize its parsing and execution.
  - Also useful to prevent SQL injection attacks.

```
String SQL = "UPDATE emp SET salary = ? WHERE ID = ?";
PreparedStatement pstmt = con.prepareStatement(SQL);
pstmt.setBigDecimal(1, 55657.34); // Set parameters
pstmt.setString(2, "E1");
int rowcount = pstmt.executeUpdate();
```

- CallableStatement extends PreparedStatement and is used to execute stored procedures.
  - Stored procedures are precompiled SQL code stored at the database that take in parameters for their execution.





The ResultSet interface provides methods for manipulating the result returned by the SQL statement.

- Remember that the result is a relation (table) which contains rows and columns.
- The methods provide ways of navigating through the rows and then selecting columns of the current row.
- A ResultSet object maintains a cursor pointing to its current row of data. Initially the cursor is positioned before the first row.
- The next() method moves the cursor to the next row. It returns false when there are no more rows in the ResultSet object, so it can be used in a while loop to iterate through the result set.

## JDBC ResultSet (2)



By default a ResultSet is not *updatable* and the cursor can move *forward-only* (can only use next() method).

```
while (rst.next()) {
    System.out.println(rst.getString("ename")+","+rst.getDouble(2));
}
```

- Remember, the first call to next() places the row cursor on the first row as the cursor starts off before the first row.
- Use the getType () methods to retrieve a particular type.
  - getArray(), getBlob(), getBoolean(), getClob(), getDate(), getDouble(), getFloat(), getInt(), getLong(), getObject(), getString(), getTime()
  - All methods take as a parameter the column index in the ResultSet (indexed from 1) or the column name and return the requested type.
  - Java will attempt to perform casting if the type you request is not the type returned by the database.





It is also possible to request ResultSets that allow you to navigate backwards as well as forwards.

• Request ResultSet type during createStatement.

Scrollable ResultSets allow you to navigate in any direction through it, and these methods can now be used:

- absolute (int row) set cursor to point to the given row (starting at 1)
- afterLast(), beforeFirst(), first(), last(), next(), previous()
- Scrollable ResultSets may be less efficient than forward-only ResultSets.



# Updatable ResultSets

Updatable ResultSets allow you to update fields in the query result and update entire rows.

#### Updating an existing row:



# Updatable ResultSets (2)

#### Adding a new row to a ResultSet:

```
// rs will be scrollable and updatable record set
Statement stmt = con.createStatement(
                       ResultSet.TYPE SCROLL INSENSITIVE,
                       ResultSet.CONCUR UPDATABLE);
ResultSet rs = stmt.executeQuery("SELECT eno, ename FROM emp");
rs.moveToInsertRow();
                                      // Move cursor to insert row
rs.updateString(1, "E9");
rs.updateString("ename", "Joe Smith");
                                      // Insert new row in DB
rs.insertRow();
rs.moveToCurrentRow();
                                      // Move cursor to row you were on
                                      // before insert
```





**Question:** Which one is not a JDBC API interface?

- A) Driver
- B) Connection
- C) Statement
- D) ResultSet
- E) HashMap





**Question:** Select a true statement.

- A) When a ResultSet is first opened, the current row is 0.
- B) When a ResultSet is first opened, the current row is 1.
- C) When asking for columns, the first column is index 0.
- D) The method call first() is allowed for a forward-only ResultSet.

## **Custom APIs**



Many databases have custom APIs for various languages.

 For example, MySQL has APIs for C/C++ and PHP in addition to ODBC and JDBC drivers.

When to use a custom API?

- Custom APIs may be useful when the ODBC/JDBC standard does not provide sufficient functionality.
- Also useful if *know* that application will only access one database. (Be careful with this .. think of the future).

Custom APIs may have improved performance and increased functionality. The disadvantage is that your code is written for a specific DBMS which makes changes difficult.

 If you use a custom API, always isolate the database access code to a few general classes and methods!

# **Object-Relational Mapping Java Persistence Architecture (JPA)**



A huge challenge with database programming is converting the database results to and from Java objects. This is called object-relational mapping, and it is tedious and error-prone.

• *Impedance mismatch* - Database returns values in tables and rows and Java code manipulates objects, classes, and methods.

Various vendors (e.g. Hibernate) have produced object-relational mapping technologies that help the programmer convert database results into Java objects.

The Java Persistence Architecture (JPA) has been developed as a standard interface. Vendors can then implement the interface in their products.

## **JDBC Question**



#### Create a JDBC program that:

- Connects to WorksOn database on localhost.
- Prints on the console each department and its list of projects.

#### Variant:

- Output in reverse order by department number. Two versions:
  - Change SQL
  - Use scrollable ResultSets (hint: previous() method).

#### Challenge:

 Improve your code so that it prints the department number, name, and how many projects in that department THEN the list of projects.

## Conclusion



Querying databases can be done from any language with many different APIs. Querying has these steps:

- 1) Load the database access library
- 2) Create a connection to the database
- 3) Execute a SQL command
- 4) Retrieve database results produced by the command
- 5) Close the database connection

Queried MySQL and Microsoft SQL Server with Java.

**JDBC** is an API for accessing databases using Java. Steps:

Load a Driver for the database, Make a Connection, Create a Statement,
 Execute a query to produce a ResultSet, Navigate the ResultSet to display results or update the DB

# **Objectives**



- Explain the common steps in querying a database using a programming language.
- Draw and explain the database-program architecture and the key components.
- List the main JDBC classes (Driver, Connection, Statement, ResultSet) and explain the role of each.
- Discuss the different types of ResultSets including scrollable and updatable ResultSets.
- Write a simple JDBC program (given methods of the JDBC API).
- Discuss and explain the advantages and disadvantages of using a standard API versus a vendor-based APIs.

