

CNT 4714: Enterprise Computing Fall 2012

Introduction To JDBC

Instructor : Dr. Mark Llewellyn
markl@cs.ucf.edu
HEC 236, 4078-823-2790
<http://www.cs.ucf.edu/courses/cnt4714/fall2012>

Department of Electrical Engineering and Computer Science
Computer Science Division
University of Central Florida



Introduction to JDBC

- JDBC was originally an acronym for Java Data Base Connectivity. Sun marketing now states this is no longer an acronym but the official name.
- JDBC is made up of about two dozen Java classes in the package `java.sql`. These classes provide access to relational data stored in a database or other table-oriented forms (like Excel, etc.).
- JDBC allows the programmer to use modern database features such as simultaneous connections to several databases, transaction management, precompiled statements with bind variables, calls to stored procedures, and access to metadata in the database dictionary.
- JDBC supports both static and dynamic SQL statements.
- The evolution of JDBC is shown on the next page.



Evolution of JDBC

| JDBC Version | Bundled with | Package Name | Contents |
|----------------------------------|-------------------|--------------|--|
| JDBC 1.0 (previously called 1.2) | JDK 1.1 | java.sql | Basic Java client to database connectivity. |
| JDBC 2.0 core API | JDK 1.2 and later | java.sql | Added features such as scrollable result sets, batch updates, new data types for SQL-3, and programmable updates using the result set. |
| JDBC 2.0 optional API | J2EE and later | javax.sql | Can be downloaded from www.java.sun.com/products/jdbc/ . Contains database server-side functionality. Prepares the ground for the use of database-aware Java beans. |
| JDBC 2.1 optional API | Not bundled | javax.sql | Incremental improvement and additions over the 2.0 API. |
| JDBC 3.0 core API | JDK 1.4 and later | java.sql | Adds support for connection pooling, statement pooling, and a migration path to the Connector Architecture. |



Connecting To A Database

- A database works in the classic client/server fashion. There is one database and many clients talk to it. (Larger applications may have multiple databases, but they can be considered independently for our purposes.)
- As we've seen in the earlier sections of notes dealing with networking, the clients are typically remote systems communicating over TCP/IP networks.
- In a 2-tier system, the clients talk directly to the database (DBMS actually) while in a 3-tier system, the clients talk to a business logic server which in turn talks to the database. The business logic server would also contain server-side JDBC functionality.



Connecting To A Database (cont.)

- A JDBC driver is typically available from the database vendor of the database to which you wish to connect.
- There are several different kinds of drivers depending on whether it was written in Java or native code, or whether it talks directly to the database or through another database access protocol (such as Microsoft's ODBC). From an application programmer's point of view, none of this matters very much as long as you have a working JDBC driver, you really don't care how it works (although your client may if its too slow!).
- JDBC supports four categories of drivers which are detailed in the table on the next page.



JDBC Driver Types

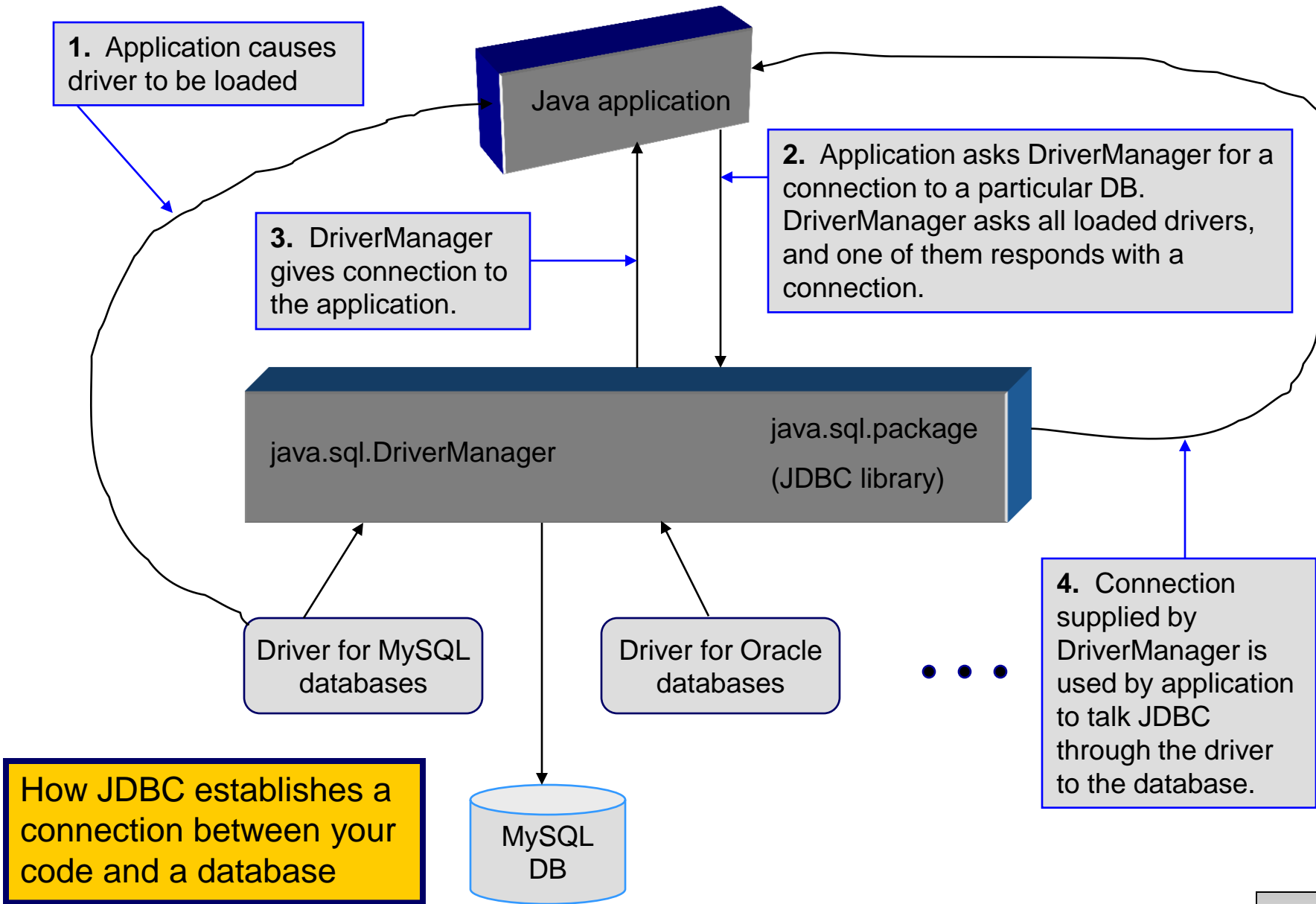
| Type | Description |
|------|---|
| 1 | JDBC-to-ODBC Bridge Driver – connects Java to a Microsoft ODBC (Open Database Connectivity) data source. This driver requires the ODBC driver to be installed on the client computer and configuration of the ODBC data source. This driver is used to allow Java programmers to build data-driver Java applications before the database vendor supplies a Type 3 or Type 4 driver. In general, this will not be used too much these days. |
| 2 | Native-API, Part Java Drivers – enable JDBC programs to use database-specific APIs (normally written in C or C++) that allow client programs to access databases via the Java Native Interface. This driver translates JDBC into database-specific code. Reasons for use are similar to Type 1. |
| 3 | JDBC-Net Pure Java Drivers – take JDBC requests and translate them into a network protocol that is not database specific. These requests are sent to a server, which translates the database requests into a database-specific protocol. |
| 4 | Native-protocol Pure Java Drivers – convert JDBC requests to database-specific network protocols, so that Java programs can connect directly to a database. |



Some Popular JDBC Drivers

| RDBMS | JDBC Driver Name |
|--------|---|
| MySQL | <p>Driver Name com.mysql.jdbc.Driver</p> <p>Database URL format: jdbc:mysql//hostname/databaseName</p> |
| Oracle | <p>Driver Name: oracle.jdbc.driver.OracleDriver</p> <p>Database URL format: jdbc:oracle:thin@hostname:portnumber:databaseName</p> |
| DB2 | <p>Driver Name: COM.ibm.db2.jdbc.net.DB2Driver</p> <p>Database URL format: jdbc:db2:hostname:portnumber/databaseName</p> |
| Access | <p>Driver Name: com.jdbc.odbc.JdbcOdbcDriver</p> <p>Database URL format: jdbc:odbc:databaseName</p> |





Loading A JDBC Driver

- The first step (as illustrated in the previous slide) is to load a JDBC driver.
- If your application connects to several different types of databases, all of their respective drivers must be loaded.
- The Java statement to load a JDBC driver is:

```
Class.forName(" JDBC Driver Class ");
```

- You don't need to create an instance of the driver class. Simply getting the class loaded is enough. Each JDBC driver has a static initializer that is run when the class is loaded, and in that code the driver registers itself with the JDBC. The JDBC driver does about 90% of the work that is done in JDBC.



Establishing a Connection

- The second step involves the Java application requesting a connection to a database, using a string that looks like a URL as an argument.
- The JDBC library contains the class `java.sql.Connection` that knows how to use this string to guide it in its search for the correct database. As was shown in the table on page 7, the exact format of the pseudo-URL string will vary with each database, but it typically starts with “`jdbc:`” to indicate the protocol that will be used (just as “`http:`” indicates to a web server that you are using the hypertext transfer protocol).
- The Java statement to connect to a database invokes the static method `getConnection(databaseURL)` in the `DriverManager` class:

```
Connection connection =
```

```
    DriverManager.getConnection(url, username, password);
```



Optional parameters



Establishing a Connection (cont.)

- Behind the scenes, the `DriverManager` calls every JDBC driver that has been registered, and asks it if the URL is one that it can use to guide it to its database.
- If the URL is properly presented, it will be recognized by at least one of the drivers.
- The first driver to connect to its database with this URL, username, and password, will be used as the channel of communication.
- The application program gets back a `Connection` object (strictly speaking it gets an object that implements the `Connection` interface).
- The session has now been established and the connection is now used for communication between the application program and the database.
- You can think of the `Connection` object as cable linking your application program to the database.



Establishing a Connection (cont.)

- Connecting to a database is a time consuming operation. As a result, most databases have a way to share connections among several different processes. This arrangement is known as **connection pooling**.
- In summary:
 - Your application program knows which database it wants to talk to, and hence which database driver it needs to load.
 - The JDBC driver manager knows how to establish the JDBC end of a database connection.
 - The driver knows how to establish the database end of things.
 - The driver manager gives the application a connection into which you can pour standard SQL queries and get results.



Creating Statements

- If the `Connection` object can be viewed as a cable between your application program and the database, an object of `Statement` can be viewed as a cart that delivers SQL statements for execution by the database and brings the result back to the application program.
- Once a `Connection` object is created, you can create statements for executing SQL statements as follows:

```
Statement statement = connection.createStatement();
```

- At this point, you're now ready to begin issuing SQL commands to the database and getting back results. The table on the following page illustrates some of the methods contained in `java.sql.Connection`.



Selected Methods In `java.sql.Connection`

| Method | Purpose |
|--|--|
| Statement <code>createStatement()</code> | Returns a statement object that is used to send SQL to the database. |
| PreparedStatement <code>prepareStatement(String sql)</code> | Returns an object that can be used for sending parameterized SQL statements. |
| CallableStatement <code>prepareCall(String sql)</code> | Returns an object that can be used for calling stored procedures. |
| DatabaseMetaData <code>getMetaData()</code> | Gets an object that supplied database configuration information. |
| boolean <code>isClosed()</code> | Reports whether the database is currently open or not. |
| void <code>commit()</code> | Makes all changes permanent since previous <code>commit.rollback</code> . |
| void <code>rollback()</code> | Undoes and discards all changes done since the previous <code>commit/rollback</code> . |



Selected Methods In `java.sql.Connection` (cont.)

| Method | Purpose |
|--|---|
| <code>void setAutoCommit (boolean yn)</code> | Restores/removes auto-commit mode, which does an automatic commit after each statement. The default case is AutoCommit is on. |
| <code>void close()</code> | Closes the connection and releases the JDBC resources for the connection. |
| <code>boolean isReadOnly()</code> | Retrieves whether this Connection object is in read-only mode. |
| <code>void setReadOnly(boolean yn)</code> | Puts this connection in read-only mode as a hint to the driver to enable database optimizations. |



Creating Statements (cont.)

- The methods illustrated in the previous table are invoked on the Connection object returned by the JDBC driver manager.
- The connection is used to create a Statement object.
- The Statement object contains the methods that allow you to send the SQL statements to the database.
- Statement objects are very simple objects which allow you to send SQL statements as Strings.
- Here is how you would send a select query to the database:

```
Statement myStmt = connection.createStatement();  
ResultSet myResult;  
myResult = myStmt.executeQuery( "SELECT * FROM bikes;" );
```

More on
ResultSet later



Creating Statements (cont.)

- The different SQL statements have different return values. Some of them have no return value, some of them return the number of rows affected by the statement, and others return all the data extracted by the query.
- To handle these varied return results, you'll need to invoke a different method depending on what type of SQL statement you are executing.
- The most interesting of these is the SELECT statement that returns an entire result set of data.
- The following table highlights some of the methods in `java.sql.statement` to execute SQL statements.



Some Methods in java.sql.statement to Execute SQL Statements

| SQL statement | JDBC statement to use | Return Type | Comment |
|--|---------------------------|-------------|---|
| SELECT | executeQuery(String sql) | ResultSet | The return value will hold the data extracted from the database. |
| INSERT, UPDATE, DELETE, CREATE, DROP | executeUpdate(String sql) | int | The return value will give the count of the number of rows changed , or zero otherwise. |
| Stored procedure with multiple results | execute(String sql) | boolean | The return value is true if the first result is a ResultSet, false otherwise. |



Putting It All Together – A Simple Example

- Let's put all these pieces together and develop a Java application that will connect to our `bikedb` database (the sample database on the course website), execute a query, and return the results.
- This application will show, in the simplest terms, how to load the JDBC driver, establish a connection, create a statement, have the statement executed, and return the results to the application.
- The code is shown on the next page with results on the following page.



```
// Very basic JDBC example showing loading of JDBC driver, establishing
// a connection, creating a statement, executing a simple SQL query, and
// displaying the results.
```

```
import java.sql.*;
```

```
public class SimpleJdbc {
```

```
    public static void main(String[] args)
```

```
        throws SQLException, ClassNotFoundException {
```

```
        // Load the JDBC driver
```

```
            Class.forName("com.mysql.jdbc.Driver");
```

```
            System.out.println("Driver loaded");
```

```
        // Establish a connection
```

```
        Connection connection = DriverManager.getConnection
```

```
            ("jdbc:mysql://localhost:3309/bikedb", "root", "root");
```

```
        System.out.println("Database connected");
```

```
        // Create a statement
```

```
        Statement statement = connection.createStatement();
```

```
        // Execute a statement
```

```
        ResultSet resultSet = statement.executeQuery
```

```
            ("select bikename, cost, mileage from bikes");
```

```
        // Iterate through the result set and print the returned results
```

```
        while (resultSet.next())
```

```
            System.out.println(resultSet.getString(1) + " \t" +
```

```
                resultSet.getString(2) + " \t" + resultSet.getString(3));
```

```
        // Close the connection
```

```
        connection.close();
```

```
    }
```

```
}
```

Load JDBC driver

Establish connection
specifying database,
username, and password.

Create statement

Execute query

Iterate through resultSet

Close connection



SimpleJdbc.java – Execution Results

Java - JDBC/src/simpleJDBC.java - Eclipse

File Edit Source Refactor Navigate Search Project Run Window Help

Console X

<terminated> simpleJDBC [Java Application] C:\Program Files\Java\jre6\bin\javaw.exe (Sep 20, 2012 3:51:15 PM)

Driver loaded

Database connected

JDBC Driver name MySQL-AB JDBC Driver

JDBC Driver version mysql-connector-java-5.1.22 (Revision: \${bzd.revision-id})

Driver Major version 5

Driver Minor version 1

| | | |
|------------------------|------|-------|
| Battaglin Carrera | 4000 | 11200 |
| Bianchi Corse Evo 4 | 5700 | 300 |
| Bianchi Evolution 3 | 4800 | 2000 |
| Bianchi Infinito | 8900 | 0 |
| BMC SLC01 - Swiss | 8000 | 0 |
| Colnago Dream Rabobank | 5500 | 4300 |
| Colnago Superissimo | 3800 | 13000 |
| Eddy Merckx Domo | 5300 | 0 |
| Eddy Merckx Molteni | 5100 | 0 |
| Gianni Motta Personal | 4400 | 8700 |
| Gios Torino Super | 2000 | 9000 |
| Ridley Damocles | 7500 | 0 |
| Ridley X-Fire 2011 | 7500 | 0 |
| Schwinn Paramount P14 | 1800 | 200 |

Driver successfully loaded

Connection successfully established

JDBC driver version

Query results printed



Result Sets

- A `ResultSet` object is similar to a 2D array. Each call to `next()` moves to the next record in the result set. You must call `next()` before you can see the first result record, and it returns `false` when there are no more result records (this makes it quite convenient for controlling a while loop). (Also remember that the `Iterator` `next()` returns the next object and not a true/false value.)
- The class `ResultSet` has “getter” methods `getBlob()`, `getBigDecimal()`, `getDate()`, `getBytes()`, `getInt()`, `getLong()`, `getString()`, `getObject()`, and so on, for all the Java types that represent SQL types for a column name and column number argument. Look at the documentation for `java.sql.ResultSet` for a complete listing of the methods.



Result Sets (cont.)

- A default `ResultSet` object is not updatable and has a cursor that only moves forward.
- Many database drivers support scrollable and updatable `ResultSet` objects.
 - Scrollable result sets simply provide a cursor to move backwards and forwards through the records of the result set.
 - Updatable result sets provide the user with the ability to modify the contents of the result set and update the database by returning the updated result set. NOTE: Not all updates can be reflected back into the database. It depends on the complexity of the query and how the data in the result set was derived. In general, base relation attribute values can be modified through an updatable result set. We'll see an example of this later.



ResultSet Constants for Specifying Properties

| ResultSet static type constant | Description |
|---------------------------------------|---|
| TYPE_FORWARD_ONLY | Specifies that the ResultSet cursor can move only in the forward direction, from the first row to the last row in the result set. |
| TYPE_SCROLL_INSENSITIVE | Specifies that the ResultSet cursor can scroll in either direction and that the changes made to the result set during ResultSet processing are not reflected in the ResultSet unless the database is queried again. |
| TYPE_SCROLL_SENSITIVE | Specifies that the ResultSet cursor can scroll in either direction and that changes made to the result set during ResultSet processing are reflected immediately in the ResultSet. |
| ResultSet static concurrency constant | Description |
| CONCUR_READ_ONLY | Specifies that the ResultSet cannot be updated (i.e. changes to it will not be reflected into the database). |
| CONCUR_UPDATABLE | Specifies that the ResultSet can be updated (i.e. changes to it will be reflected into the database using ResultSet update methods). |



ResultSet Examples

- The following two examples clarify the various constants which can be applied to result sets (assume that connection is a valid Connection).

```
//creates a ResultSet which is scrollable, insensitive  
//to changes by others and updatable.
```

```
Statement stmt = connection.createStatement(  
    (ResultSet.TYPE_SCROLL_INSENSITIVE,  
    ResultSet.CONCUR_UPDATABLE ) ;
```

```
//creates a ResultSet which is scrollable, sensitive  
//to changes by others and updatable.
```

```
Statement stmt = connection.createStatement(  
    (ResultSet.TYPE_SCROLL_SENSITIVE,  
    ResultSet.CONCUR_UPDATABLE) ;
```



Another Example

- In the previous example, notice that in the output, there was no information about what the columns represent. The output appears to be just data rather than information.
- A more sophisticated example, will access the database and use the metadata to provide more significance to the results.
- In the next example, we do just that by retrieving metadata from the database to help with the display of the result set.



DisplayBikes JDBC Application – page 1

// Displaying the contents of the bikes table.

```
import java.sql.Connection;
import java.sql.Statement;
import java.sql.DriverManager;
import java.sql.ResultSet;
import java.sql.ResultSetMetaData;
import java.sql.SQLException;
```

```
public class DisplayBikes{
    // JDBC driver name and database URL
    static final String JDBC_DRIVER = "com.mysql.jdbc.Driver";
    static final String DATABASE_URL = "jdbc:mysql://localhost:3309/bikedb";
```

// launch the application

```
public static void main( String args[] ) {
    Connection connection = null; // manages connection
    Statement statement = null; // query statement
```

// connect to database bikes and query database

```
try
{
    Class.forName( JDBC_DRIVER ); // load database driver class
```

Type 4 JDBC driver (pure Java driver) to connect to MySQL RDBMs

Specify name of database to connect to as well as JDBC driver protocol.

See Note on Page 31



DisplayBikes JDBC Application – page 2

```
// establish connection to database
connection =
    DriverManager.getConnection( DATABASE_URL, "root", "root" );
```

```
// create Statement for querying database
statement = connection.createStatement();
```

```
// query database
ResultSet resultSet = statement.executeQuery(
    "SELECT bikename, cost, mileage FROM bikes" );
```

```
// process query results
ResultSetMetaData metaData = resultSet.getMetaData();
int numberOfColumns = metaData.getColumnCount();
System.out.println( "Bikes Table of bikedb Database:" );
```

```
for ( int i = 1; i <= numberOfColumns; i++ )
    System.out.printf( "%-20s\t", metaData.getColumnName( i ) );
System.out.println();
```

```
while ( resultSet.next() )
{
    for ( int i = 1; i <= numberOfColumns; i++ )
        System.out.printf( "%-20s\t", resultSet.getObject( i ) );
```

The MySQL query to be executed remotely.

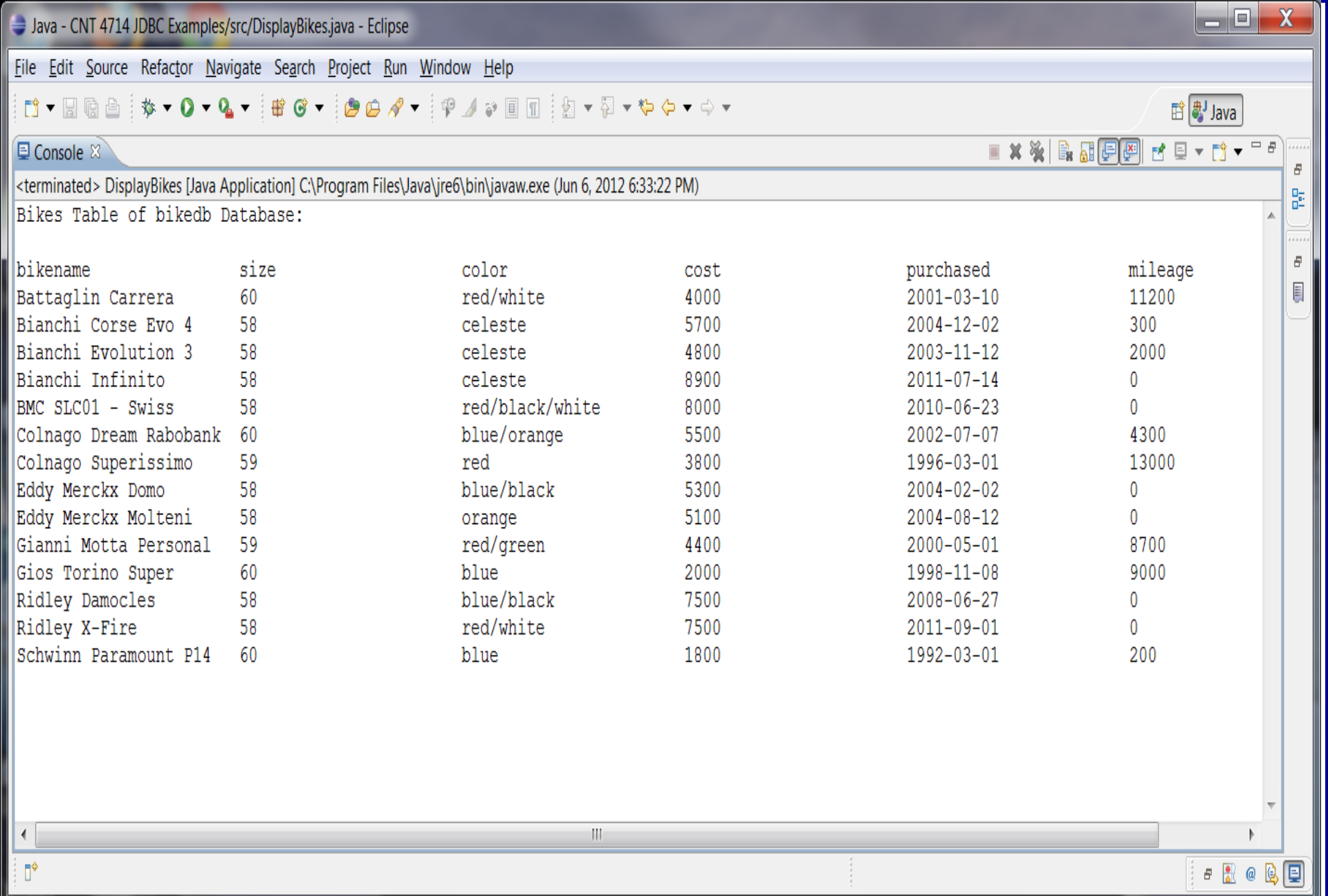
Get metadata from the resultSet to be used for the output formatting.



DisplayBikes JDBC Application – page 3

```
        System.out.println();
    } // end while
} // end try
catch ( SQLException sqlException ) {
    sqlException.printStackTrace();
    System.exit( 1 );
} // end catch
catch ( ClassNotFoundException classNotFound ) {
    classNotFound.printStackTrace();
    System.exit( 1 );
} // end catch
finally { // ensure statement and connection are closed properly
    try {
        statement.close();
        connection.close();
    } // end try
    catch ( Exception exception ) {
        exception.printStackTrace();
        System.exit( 1 );
    } // end catch
} // end finally
} // end main
} // end class DisplayBikes
```





<terminated> DisplayBikes [Java Application] C:\Program Files\Java\jre6\bin\javaw.exe (Jun 6, 2012 6:33:22 PM)

Bikes Table of bikedb Database:

| bikename | size | color | cost | purchased | mileage |
|------------------------|------|-----------------|------|------------|---------|
| Battaglin Carrera | 60 | red/white | 4000 | 2001-03-10 | 11200 |
| Bianchi Corse Evo 4 | 58 | celeste | 5700 | 2004-12-02 | 300 |
| Bianchi Evolution 3 | 58 | celeste | 4800 | 2003-11-12 | 2000 |
| Bianchi Infinito | 58 | celeste | 8900 | 2011-07-14 | 0 |
| BMC SLC01 - Swiss | 58 | red/black/white | 8000 | 2010-06-23 | 0 |
| Colnago Dream Rabobank | 60 | blue/orange | 5500 | 2002-07-07 | 4300 |
| Colnago Superissimo | 59 | red | 3800 | 1996-03-01 | 13000 |
| Eddy Merckx Domo | 58 | blue/black | 5300 | 2004-02-02 | 0 |
| Eddy Merckx Molteni | 58 | orange | 5100 | 2004-08-12 | 0 |
| Gianni Motta Personal | 59 | red/green | 4400 | 2000-05-01 | 8700 |
| Gios Torino Super | 60 | blue | 2000 | 1998-11-08 | 9000 |
| Ridley Damocles | 58 | blue/black | 7500 | 2008-06-27 | 0 |
| Ridley X-Fire | 58 | red/white | 7500 | 2011-09-01 | 0 |
| Schwinn Paramount P14 | 60 | blue | 1800 | 1992-03-01 | 200 |



Note Regarding Static Method `forName`

- The database driver must be loaded before connecting to the database. The static method `forName` of class `Class` is used to load the class for the database driver.
- This method throws a checked exception of type `java.lang.ClassNotFoundException` if the class loader cannot locate the driver class.
- To avoid this exception, you need to include the `mysql-connector-java-5.1.22-bin.jar` in your program's classpath when you execute the program.
- Copy the `mysql-connector-java-5.1.22-bin.jar` file to the JRE's `lib/ext` directory. (www.mysql.com)



Querying the `bikedb` MySQL Database

- In this example, we'll allow the user to enter any valid MySQL query into the Java application to query the bikes table of the bikedb database.
- The results of the query are returned in a JTable, using a TableModel object to provide the ResultSet data to the JTable.
- Class ResultSetTableModel performs the connection to the database and maintains the ResultSet.
- Class DisplayQueryResults creates the GUI and specifies an instance of class ResultSetTableModel to provide the data for the JTable.



Class: ResultSetTableModel – page 1

```
// A TableModel that supplies ResultSet data to a JTable.
import java.sql.Connection;
import java.sql.Statement;
import java.sql.DriverManager;
import java.sql.ResultSet;
import java.sql.ResultSetMetaData;
import java.sql.SQLException;
import javax.swing.table.AbstractTableModel;

// ResultSet rows and columns are counted from 1 and JTable
// rows and columns are counted from 0. When processing
// ResultSet rows or columns for use in a JTable, it is
// necessary to add 1 to the row or column number to manipulate
// the appropriate ResultSet column (i.e., JTable column 0 is
// ResultSet column 1 and JTable row 0 is ResultSet row 1).
public class ResultSetTableModel extends AbstractTableModel {
    private Connection connection;
    private Statement statement;
    private ResultSet resultSet;
    private ResultSetMetaData metaData;
    private int numberOfRows;

    // keep track of database connection status
    private boolean connectedToDatabase = false;
```

This class maintains the connection to the database and handles the results being returned from the database to the application.



Class: ResultSetTableModel – page 2

```
// constructor initializes resultSet and obtains its meta data object;
// determines number of rows
public ResultSetTableModel( String driver, String url,
    String username, String password, String query )
    throws SQLException, ClassNotFoundException
{
    // load database driver class
    Class.forName( driver );

    // connect to database
    connection = DriverManager.getConnection( url, username, password );

    // create Statement to query database
    statement = connection.createStatement(
        ResultSet.TYPE_SCROLL_INSENSITIVE,
        ResultSet.CONCUR_READ_ONLY );

    // update database connection status
    connectedToDatabase = true;

    // set query and execute it
    setQuery( query );
} // end constructor ResultSetTableModel
```



Class: ResultSetTableModel – page 3

```
// get class that represents column type
public Class getColumnClass( int column ) throws IllegalStateException {
    // ensure database connection is available
    if ( !connectedToDatabase )
        throw new IllegalStateException( "Not Connected to Database" );

    // determine Java class of column
    try {
        String className = metaData.getColumnClassName( column + 1 );
        // return Class object that represents className
        return Class.forName( className );
    } // end try
    catch ( Exception exception ) {
        exception.printStackTrace();
    } // end catch

    return Object.class; // if problems occur above, assume type Object
} // end method getColumnClass

// get number of columns in ResultSet
public int getColumnCount() throws IllegalStateException {
    // ensure database connection is available
    if ( !connectedToDatabase )
        throw new IllegalStateException( "Not Connected to Database" );
```



Class: ResultSetTableModel – page 4

```
// determine number of columns
try {
    return metaData.getColumnCount();
} // end try
catch ( SQLException sqlException ) {
    sqlException.printStackTrace();
} // end catch

return 0; // if problems occur above, return 0 for number of columns
} // end method getColumnCount

// get name of a particular column in ResultSet
public String getColumnName( int column ) throws IllegalStateException {
    // ensure database connection is available
    if ( !connectedToDatabase )
        throw new IllegalStateException( "Not Connected to Database" );

    // determine column name
    try {
        return metaData.getColumnName( column + 1 );
    } // end try
    catch ( SQLException sqlException ) {
        sqlException.printStackTrace();
    } // end catch
}
```



Class: ResultSetTableModel – page 5

```
    return ""; // if problems, return empty string for column name
} // end method getColumnName

// return number of rows in ResultSet
public int getRowCount() throws IllegalStateException {
    // ensure database connection is available
    if ( !connectedToDatabase )
        throw new IllegalStateException( "Not Connected to Database" );

    return numberOfRows;
} // end method getRowCount

// obtain value in particular row and column
public Object getValueAt( int row, int column )
    throws IllegalStateException
{
    // ensure database connection is available
    if ( !connectedToDatabase )
        throw new IllegalStateException( "Not Connected to Database" );

    // obtain a value at specified ResultSet row and column
    try {
        resultSet.absolute( row + 1 );
        return resultSet.getObject( column + 1 );
    } // end try
```



Class: ResultSetTableModel – page 6

```
catch ( SQLException sqlException ) {
    sqlException.printStackTrace();
} // end catch

return ""; // if problems, return empty string object
} // end method getValueAt

// set new database query string
public void setQuery( String query )
    throws SQLException, IllegalStateException
{
    // ensure database connection is available
    if ( !connectedToDatabase )
        throw new IllegalStateException( "Not Connected to Database" );

    // specify query and execute it
    resultSet = statement.executeQuery( query );

    // obtain meta data for ResultSet
    metaData = resultSet.getMetaData();

    // determine number of rows in ResultSet
    resultSet.last();           // move to last row
    numberOfRows = resultSet.getRow(); // get row number
```



Class: ResultSetTableModel – page 7

```
// notify JTable that model has changed
fireTableStructureChanged();
} // end method setQuery

// close Statement and Connection
public void disconnectFromDatabase() {
    if ( !connectedToDatabase )
        return;

    // close Statement and Connection
    try {
        statement.close();
        connection.close();
    } // end try
    catch ( SQLException sqlException ) {
        sqlException.printStackTrace();
    } // end catch
    finally // update database connection status
    {
        connectedToDatabase = false;
    } // end finally
} // end method disconnectFromDatabase
} // end class ResultSetTableModel
```



Class: DisplayQueryResults – page 1

```
// Display the contents of the bikes table in the bikedb database.
import java.awt.BorderLayout;
import java.awt.event.ActionListener;
import java.awt.event.ActionEvent;
import java.awt.event.WindowAdapter;
import java.awt.event.WindowEvent;
import java.sql.SQLException;
import javax.swing.JFrame;
import javax.swing.JTextArea;
import javax.swing.JScrollPane;
import javax.swing.ScrollPaneConstants;
import javax.swing.JTable;
import javax.swing.JOptionPane;
import javax.swing.JButton;
import javax.swing.Box;

public class DisplayQueryResults extends JFrame
{
    // JDBC driver, database URL, username and password
    static final String JDBC_DRIVER = "com.mysql.jdbc.Driver";
    static final String DATABASE_URL = "jdbc:mysql://localhost:3309/bikedb";
    static final String USERNAME= "root";
    static final String PASSWORD= "root";
```

This class extends the JFrame class and creates the user interface (GUI) and creates an instance of the ResultSetTableModel to handle the data displayed in the JTable.



Class: DisplayQueryResults – page 2

```
// default query retrieves all data from bikes table
static final String DEFAULT_QUERY = "SELECT * FROM bikes";

private ResultSetTableModel tableModel;
private JTextArea queryArea;

// create ResultSetTableModel and GUI
public DisplayQueryResults() {
    super( "Displaying Query Results" );
    // create ResultSetTableModel and display database table
    try {
        // create TableModel for results of query SELECT * FROM bikes
        tableModel = new ResultSetTableModel( JDBC_DRIVER, DATABASE_URL,
            USERNAME, PASSWORD, DEFAULT_QUERY );

        // set up JTextArea in which user types queries
        queryArea = new JTextArea( DEFAULT_QUERY, 3, 100 );
        queryArea.setWrapStyleWord( true );
        queryArea.setLineWrap( true );

        JScrollPane scrollPane = new JScrollPane( queryArea,
            ScrollPaneConstants.VERTICAL_SCROLLBAR_AS_NEEDED,
            ScrollPaneConstants.HORIZONTAL_SCROLLBAR_NEVER );
```



Class: DisplayQueryResults – page 3

```
// set up JButton for submitting queries
JButton submitButton = new JButton( "Submit Query" );

// create Box to manage placement of queryArea and
// submitButton in GUI
Box box = Box.createHorizontalBox();
box.add( scrollPane );
box.add( submitButton );

// create JTable delegate for tableModel
JTable resultTable = new JTable( tableModel );

// place GUI components on content pane
add( box, BorderLayout.NORTH );
add( new JScrollPane( resultTable ), BorderLayout.CENTER );

// create event listener for submitButton
submitButton.addActionListener(

    new ActionListener() {
        // pass query to table model
        public void actionPerformed( ActionEvent event ) {
            // perform a new query
```



Class: DisplayQueryResults – page 4

```
try {
    tableModel.setQuery( queryArea.getText() );
} // end try
catch ( SQLException sqlException ) {
    JOptionPane.showMessageDialog( null,
        sqlException.getMessage(), "Database error",
        JOptionPane.ERROR_MESSAGE );
    // try to recover from invalid user query by executing default query
    try {
        tableModel.setQuery( DEFAULT_QUERY );
        queryArea.setText( DEFAULT_QUERY );
    } // end try
    catch ( SQLException sqlException2 ) {
        JOptionPane.showMessageDialog( null,
            sqlException2.getMessage(), "Database error",
            JOptionPane.ERROR_MESSAGE );
        // ensure database connection is closed
        tableModel.disconnectFromDatabase();
        System.exit( 1 ); // terminate application
    } // end inner catch
} // end outer catch
} // end actionPerformed
} // end ActionListener inner class
); // end call to addActionListener
```



Class: DisplayQueryResults – page 5

```
setSize( 500, 250 ); // set window size
setVisible( true ); // display window
} // end try
catch ( ClassNotFoundException classNotFound ) {
    JOptionPane.showMessageDialog( null,
        "MySQL driver not found", "Driver not found",
        JOptionPane.ERROR_MESSAGE );

    System.exit( 1 ); // terminate application
} // end catch
catch ( SQLException sqlException ) {
    JOptionPane.showMessageDialog( null, sqlException.getMessage(),
        "Database error", JOptionPane.ERROR_MESSAGE );
    // ensure database connection is closed
    tableModel.disconnectFromDatabase();
    System.exit( 1 ); // terminate application
} // end catch
// dispose of window when user quits application (this overrides
// the default of HIDE_ON_CLOSE)
setDefaultCloseOperation( DISPOSE_ON_CLOSE );
// ensure database connection is closed when user quits application
addWindowListener(
```



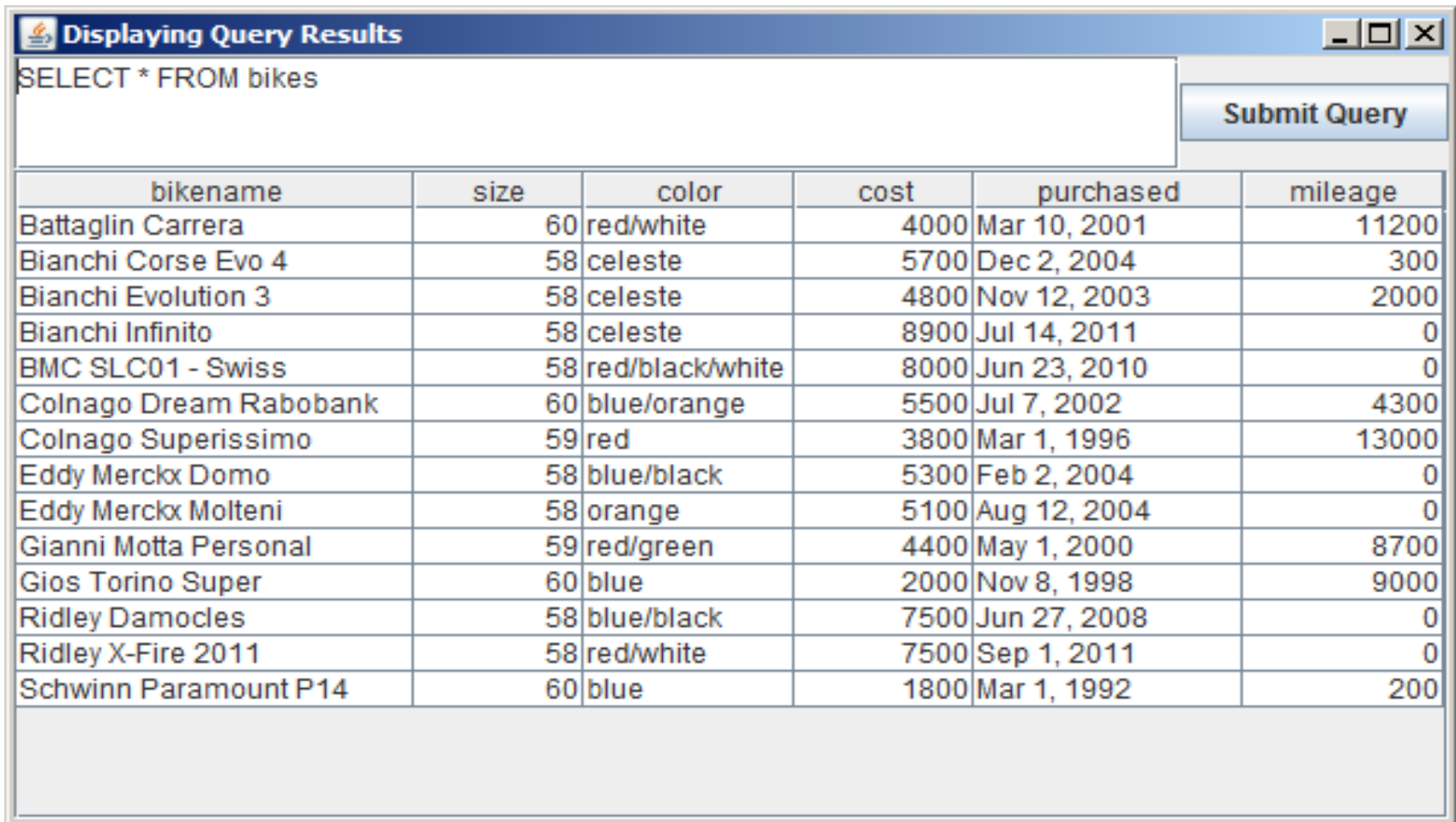
Class: DisplayQueryResults – page 6

```
new WindowAdapter()
{
    // disconnect from database and exit when window has closed
    public void windowClosed( WindowEvent event )
    {
        tableModel.disconnectFromDatabase();
        System.exit( 0 );
    } // end method windowClosed
} // end WindowAdapter inner class
); // end call to addWindowListener
} // end DisplayQueryResults constructor

// execute application
public static void main( String args[] )
{
    new DisplayQueryResults();
} // end main
} // end class DisplayQueryResults
```



Execution of DisplayQueryResults

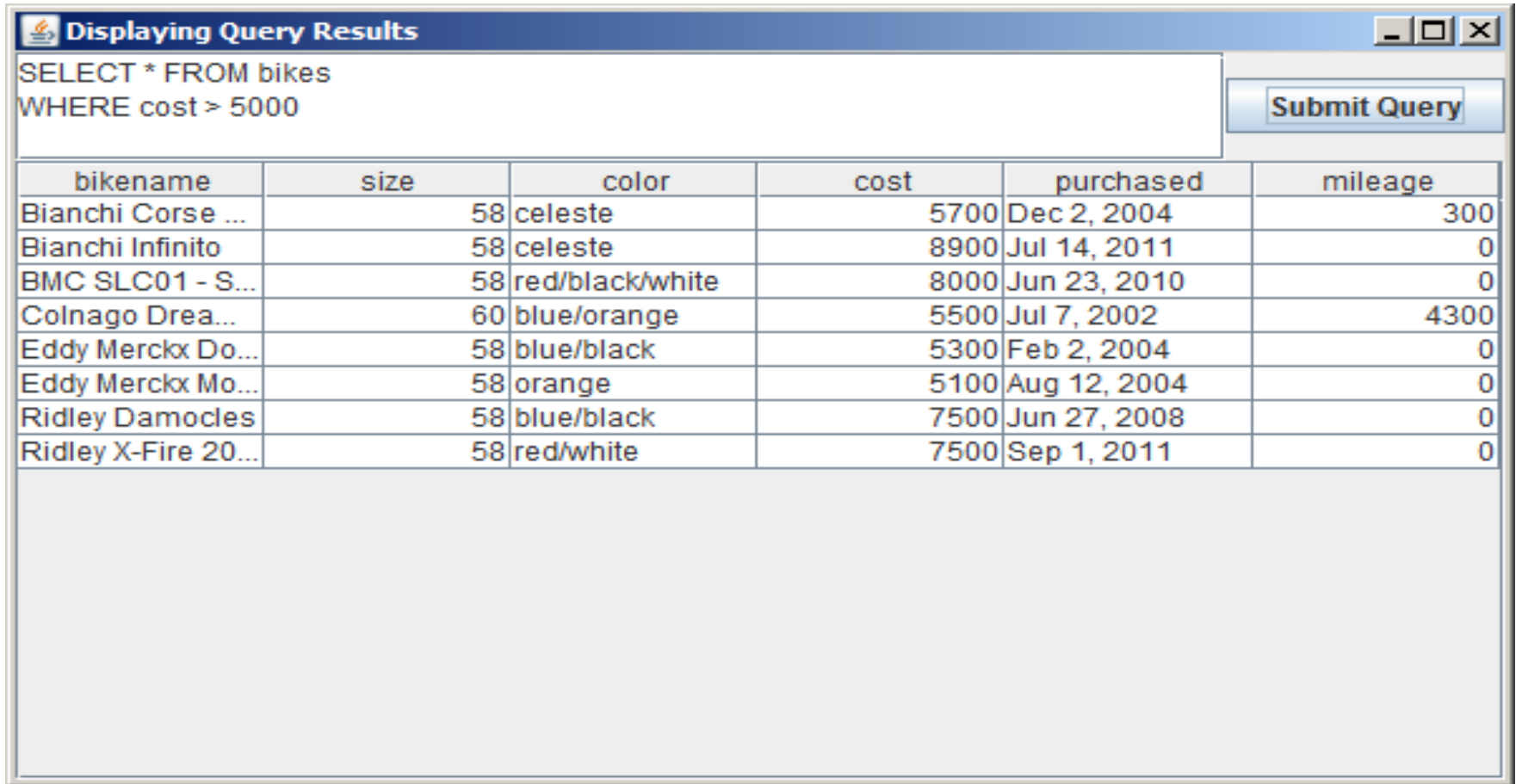


| bikename | size | color | cost | purchased | mileage |
|------------------------|------|-----------------|------|--------------|---------|
| Battaglin Carrera | 60 | red/white | 4000 | Mar 10, 2001 | 11200 |
| Bianchi Corse Evo 4 | 58 | celeste | 5700 | Dec 2, 2004 | 300 |
| Bianchi Evolution 3 | 58 | celeste | 4800 | Nov 12, 2003 | 2000 |
| Bianchi Infinito | 58 | celeste | 8900 | Jul 14, 2011 | 0 |
| BMC SLC01 - Swiss | 58 | red/black/white | 8000 | Jun 23, 2010 | 0 |
| Colnago Dream Rabobank | 60 | blue/orange | 5500 | Jul 7, 2002 | 4300 |
| Colnago Superissimo | 59 | red | 3800 | Mar 1, 1996 | 13000 |
| Eddy Merckx Domo | 58 | blue/black | 5300 | Feb 2, 2004 | 0 |
| Eddy Merckx Molteni | 58 | orange | 5100 | Aug 12, 2004 | 0 |
| Gianni Motta Personal | 59 | red/green | 4400 | May 1, 2000 | 8700 |
| Gios Torino Super | 60 | blue | 2000 | Nov 8, 1998 | 9000 |
| Ridley Damocles | 58 | blue/black | 7500 | Jun 27, 2008 | 0 |
| Ridley X-Fire 2011 | 58 | red/white | 7500 | Sep 1, 2011 | 0 |
| Schwinn Paramount P14 | 60 | blue | 1800 | Mar 1, 1992 | 200 |

Display of default query results from DisplayQueryResults application



Execution of DisplayQueryResults



The screenshot shows a window titled "Displaying Query Results" with a text area containing the SQL query: `SELECT * FROM bikes WHERE cost > 5000`. A "Submit Query" button is located to the right of the text area. Below the text area is a table with the following data:

| bikename | size | color | cost | purchased | mileage |
|---------------------|------|-----------------|------|--------------|---------|
| Bianchi Corse ... | 58 | celeste | 5700 | Dec 2, 2004 | 300 |
| Bianchi Infinito | 58 | celeste | 8900 | Jul 14, 2011 | 0 |
| BMC SLC01 - S... | 58 | red/black/white | 8000 | Jun 23, 2010 | 0 |
| Colnago Drea... | 60 | blue/orange | 5500 | Jul 7, 2002 | 4300 |
| Eddy Merckx Do... | 58 | blue/black | 5300 | Feb 2, 2004 | 0 |
| Eddy Merckx Mo... | 58 | orange | 5100 | Aug 12, 2004 | 0 |
| Ridley Damocles | 58 | blue/black | 7500 | Jun 27, 2008 | 0 |
| Ridley X-Fire 20... | 58 | red/white | 7500 | Sep 1, 2011 | 0 |

Display of user-formed query results from DisplayQueryResults application



The PreparedStatement Interface

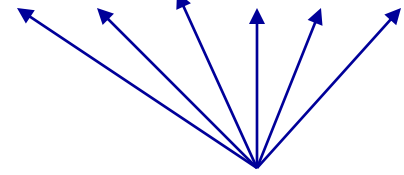
- In the previous examples, once we established a connection to a particular database, it was used to send an SQL statement from the application to the database.
- The Statement interface is used to execute static SQL statements that contain no parameters.
- The PreparedStatement interface, which extends the Statement interface, is used to execute a precompiled SQL statement with or without IN parameters.
- Since the SQL statements are precompiled, they are extremely efficient for repeated execution.



The PreparedStatement Interface (cont.)

- A PreparedStatement object is created using the preparedStatement method in the Connection interface.

```
Statement pstmt = connection.prepareStatement  
("insert into bikes (bikename, size, color,  
cost, purchased, mileage) +  
values ( ?, ?, ?, ?, ?, ?) " );
```



Placeholders for the values that will be dynamically provided by the user.



The PreparedStatement Interface (cont.)

- As a subinterface of Statement, the PreparedStatement interface inherits all the methods defined in Statement. It also provides the methods for setting parameters in the object of PreparedStatement.
- These methods are used to set the values for the parameters before executing statements or procedures.
- In general, the set methods have the following signature:

```
setX (int parameterIndex, X value);
```

where X is the type of parameter and parameterIndex is the index of the parameter in the statement.



The PreparedStatement Interface (cont.)

- As an example, the method

```
setString( int parameterIndex, String value)
```

sets a String value to the specified parameter.

- Once the parameters are set, the prepared statement is executed like any other SQL statement where `executeQuery()` is used for SELECT statements and `executeUpdate()` is used for DDL or update commands.
- These two methods are similar to those found in the Statement interface except that they have no parameters since the SQL statements are already specified in the `prepareStatement` method when the object of a `PreparedStatement` is created.



FindBikeUsingPreparedStatement

```
import javax.swing.*;
import java.sql.*;
import java.awt.*;
import java.awt.event.*;

public class FindBikeUsingPreparedStatement extends JApplet {
    boolean isStandalone = false;
    private JTextField jtfbike = new JTextField(25);
    private JTextField jtfcost = new JTextField(6);
    private JButton jbtShowCost = new JButton("Show Bike Cost Info");

    // PreparedStatement for executing queries
    private PreparedStatement pstmt;

    /** Initialize the applet */
    public void init() {
        // Initialize database connection and create a PreparedStatement object
        initializeDB();

        jbtShowCost.addActionListener(
            new java.awt.event.ActionListener() {
                public void actionPerformed(ActionEvent e) {
                    jbtShowCost_actionPerformed(e);
                }
            }
        );
    }
}
```

PreparedStatement object



```
JPanel jPanel1 = new JPanel();
jPanel1.add(new JLabel("Bike Name"));
jPanel1.add(jtfbike);
jPanel1.add(jbtShowCost);
this.getContentPane().add(jPanel1, BorderLayout.NORTH);
}
```

```
private void initializeDB() {
    try {
        // Load the JDBC driver
        Class.forName("com.mysql.jdbc.Driver");
        System.out.println("Driver loaded");
        // Establish a connection
        Connection connection = DriverManager.getConnection
            ("jdbc:mysql://localhost:3309/bikedb", "root", "root");
        System.out.println("Database connected");

        String queryString = "select cost from bikes where bikename = ?";
        // Create a statement
        pstmt = connection.prepareStatement(queryString);
    }
    catch (Exception ex) {
        ex.printStackTrace();
    }
}
```

queryString contains the SQL statement with the ? Placeholder for the value to be determined at run-time.

Invoke the preparedStatement() method on the connection.



```

private void jbtShowCost_actionPerformed(ActionEvent e) {
String bikename = jtfbike.getText();
String cost = jtfcost.getText();
try {
    pstmt.setString(1, bikename);
    ResultSet rset = pstmt.executeQuery();
    if (rset.next()) {
        String price = rset.getString(1);
        // Display result in a dialog box
        JOptionPane.showMessageDialog(null, bikename + " cost $" + price);
    }
    else { // Display result in a dialog box
        JOptionPane.showMessageDialog(null, "Bike Not Found");
    }
}
}
catch (SQLException ex) {
    ex.printStackTrace();
}
}

```

Set first parameter value for PreparedStatement object

Execute query using PreparedStatement object

Get data from results set returned by JDBC.

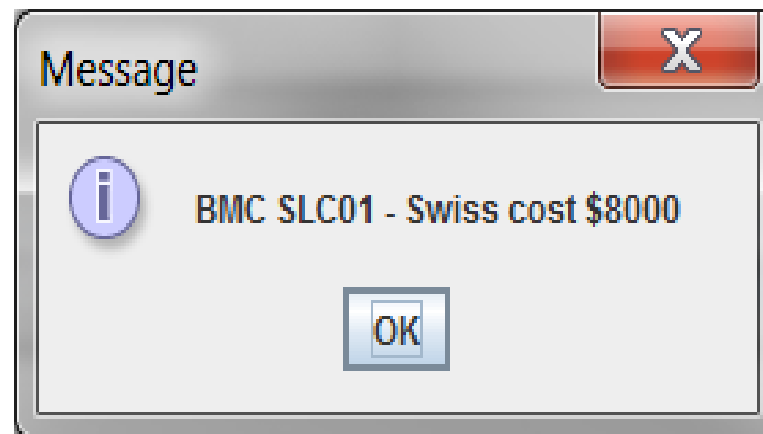
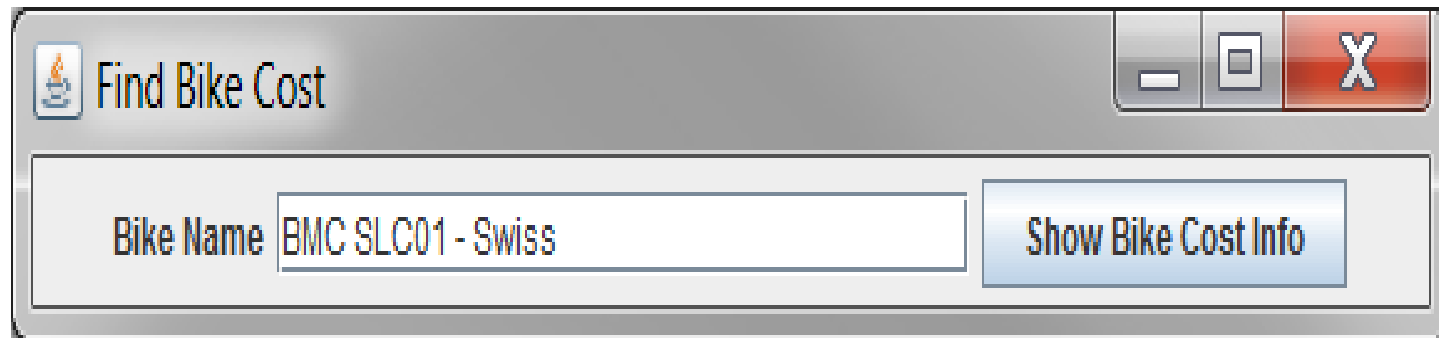
```

/** Main method */
public static void main(String[] args) {
    FindBikeUsingPreparedStatement applet = new
    FindBikeUsingPreparedStatement();
    JFrame frame = new JFrame();
    frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
    frame.setTitle("Find Bike Cost");
    frame.getContentPane().add(applet, BorderLayout.CENTER);
    applet.init(); applet.start(); frame.setSize(580, 80);
    Dimension d = Toolkit.getDefaultToolkit().getScreenSize();
    frame.setLocation((d.width - frame.getSize().width) / 2,
        (d.height - frame.getSize().height) / 2);
    frame.setVisible(true);
} }

```



Output from FindBikeUsingPreparedStatement



The RowSet Interface (cont.)

- Interface RowSet provides several set methods that allow the programmer to specify the properties needed to establish a connection (such as the database URL, user name, password, etc.) and a create a Statement (such as a query).
- Interface RowSet also provides several get methods that return these properties.
- More information on these methods can be found at:
<http://java.sun.com/j2se/1.6.0/docs/api/javax/sql/RowSet.html>



The RowSet Interface (cont.)

- RowSet is part of the `javax.sql` package.
- Although part of the Java 2 Standard Edition, the classes and interfaces of package `javax.sql` are most often used in the context of the Java 2 Platform Enterprise Edition (J2EE).
- We will get to some J2EE development later in the semester. You can learn more about J2EE at www.java.sun.com/j2ee.



Using the RowSet Interface

- There are two types of RowSet objects – **connected** and **disconnected**.
- A **connected RowSet** object connects to the database once and remains connected until the application terminates.
- A **disconnected RowSet** object connects to the database, executes a query to retrieve the data from the database and then closed the connection. A program may change the data in a disconnected RowSet while it is disconnected. Modified data can be updated to the database after a disconnected RowSet reestablishes the connection with the database.



Using the RowSet Interface (cont.)

- J2SE 5.0 package `javax.sql.rowset` contains two subinterfaces of `RowSet` – `JdbcRowSet` and `CachedRowSet`.
- `JdbcRowSet`, a connected `RowSet`, acts as a wrapper around a `ResultSet` object, and allows programmers to scroll through and update the rows in the `ResultSet` object. Recall that by default, a `ResultSet` object is non-scrollable and read only – you must explicitly set the result-set type constant to `TYPE_SCROLL_INSENSITIVE` and set the result set concurrency constant to `CONCUR_UPDATABLE` to make a `ResultSet` object scrollable and updatable.



Using the RowSet Interface (cont.)

- A `JdbcRowSet` object is scrollable and updatable by default.
- `CachedRowSet`, a disconnected `RowSet`, caches the data of a `ResultSet` in memory and disconnects from the database. Like `JdbcRowSet`, a `CachedRowSet` object is scrollable and updatable by default.
- A `CachedRowSet` is also serializable, so it can be passed between Java applications through a network.
- However, a `CachedRowSet` has a limitation – the amount of data that can be stored in memory is limited.
- There are three other subinterfaces in this package (`FilteredRowSet`, `WebRowSet`, and `JoinRowSet`).



Using the RowSet Interface (cont.)

- The code example on the next couple of pages illustrates the use of the RowSet interface.
- Notice that unlike the TableSet version in the previous set of notes, the connection is made and the query executed automatically.



Class: JdbcRowSetTest – page 1

```
// Displaying the contents of the bikes table using JdbcRowSet.
import java.sql.ResultSetMetaData;
import java.sql.SQLException;
import javax.sql.rowset.JdbcRowSet;
import com.sun.rowset.JdbcRowSetImpl; // Sun's JdbcRowSet implementation

public class JdbcRowSetTest
{
    // JDBC driver name and database URL
    static final String JDBC_DRIVER = "com.mysql.jdbc.Driver";
    static final String DATABASE_URL = "jdbc:mysql://localhost:3309/bikedb";
    static final String USERNAME = "root";
    static final String PASSWORD = "root";

    // constructor connects to database, queries database, processes
    // results and displays results in window
    public JdbcRowSetTest()
    {
        // connect to database books and query database
        try
        {
            Class.forName( JDBC_DRIVER ); // load database driver class
```



Class: JdbcRowSetTest – page 2

```
// specify properties of JdbcRowSet
JdbcRowSet rowSet = new JdbcRowSetImpl();
rowSet.setUrl( DATABASE_URL ); // set database URL
rowSet.setUsername( USERNAME ); // set username
rowSet.setPassword( PASSWORD ); // set password
//set query

rowSet.setCommand( "SELECT bikename,size,purchased,cost FROM bikes" );
rowSet.execute(); // execute query

// process query results
ResultSetMetaData metaData = rowSet.getMetaData();
int numberOfColumns = metaData.getColumnCount();
System.out.println( "Bikes Table of bikedb Database (using the rowSet implementation):" );

// display rowset header
for ( int i = 1; i <= numberOfColumns; i++ )
    System.out.printf( "%-12s\t", metaData.getColumnName( i ) );
System.out.println();
```

SQL command to be executed.



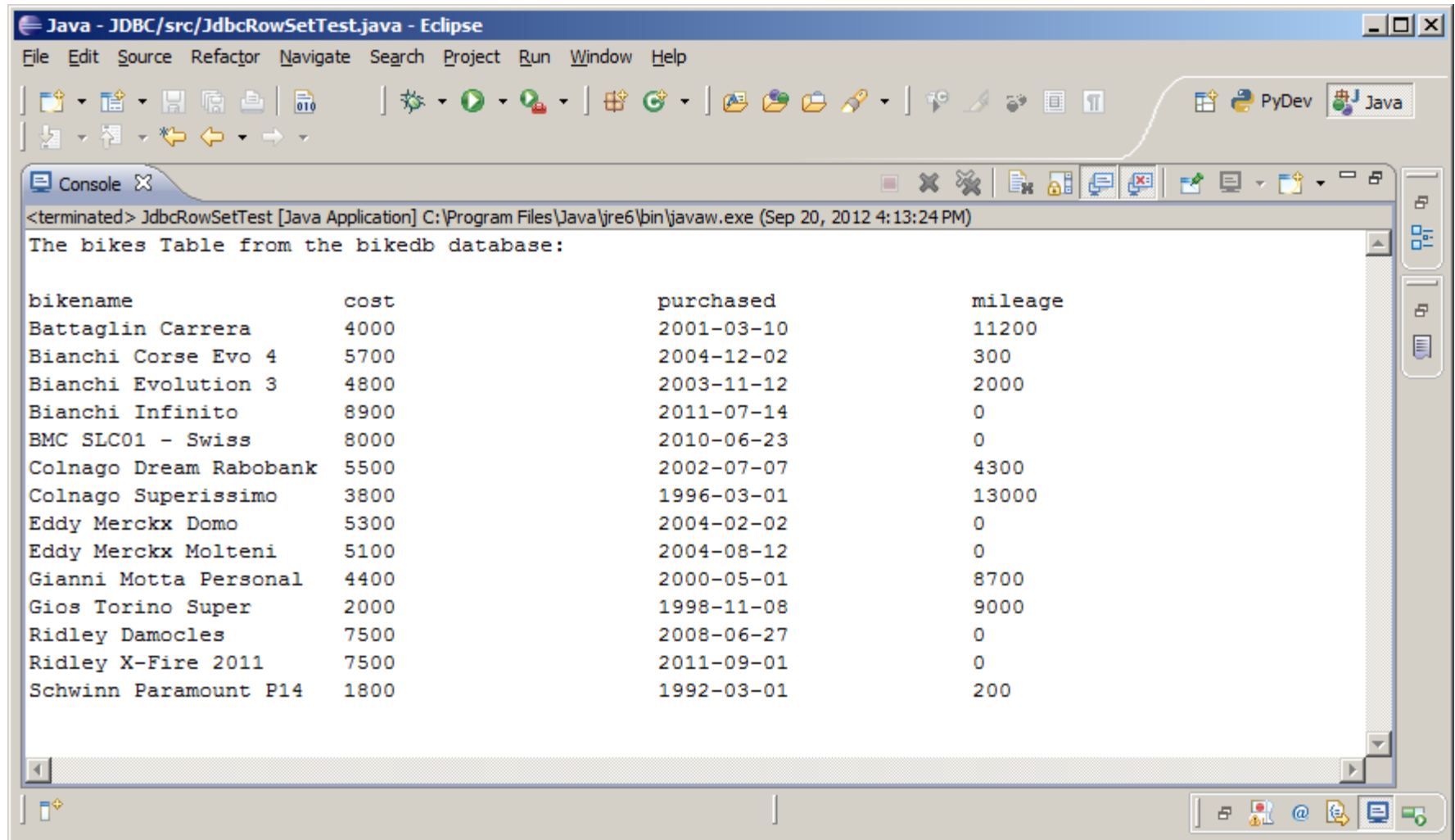
Class: JdbcRowSetTest – page 3

```
// display each row
while ( rowSet.next() ) {
    for ( int i = 1; i <= numberOfColumns; i++ )
        System.out.printf( "%-12s\t", rowSet.getObject( i ) );
    System.out.println();
} // end while
} // end try
catch ( SQLException sqlException ) {
    sqlException.printStackTrace();
    System.exit( 1 );
} // end catch
catch ( ClassNotFoundException classNotFound ) {
    classNotFound.printStackTrace();
    System.exit( 1 );
} // end catch
} // end DisplayBikes constructor

// launch the application
public static void main( String args[] ) {
    {   JdbcRowSetTest window = new JdbcRowSetTest();
    } // end main
} // end class JdbcRowSetTest
```



Execution of JdbcRowSetTest



```
<terminated> JdbcRowSetTest [Java Application] C:\Program Files\Java\jre6\bin\javaw.exe (Sep 20, 2012 4:13:24 PM)
The bikes Table from the bikedb database:

bikename          cost      purchased      mileage
Battaglin Carrera 4000      2001-03-10    11200
Bianchi Corse Evo 4 5700      2004-12-02    300
Bianchi Evolution 3 4800      2003-11-12    2000
Bianchi Infinito   8900      2011-07-14    0
BMC SLC01 - Swiss 8000      2010-06-23    0
Colnago Dream Rabobank 5500     2002-07-07    4300
Colnago Superissimo 3800     1996-03-01    13000
Eddy Merckx Domo   5300      2004-02-02    0
Eddy Merckx Molteni 5100      2004-08-12    0
Gianni Motta Personal 4400     2000-05-01    8700
Gios Torino Super 2000      1998-11-08    9000
Ridley Damocles   7500      2008-06-27    0
Ridley X-Fire 2011 7500      2011-09-01    0
Schwinn Paramount P14 1800     1992-03-01    200
```

Display of default query results from JdbcRowSetTest application

