core
WEB
programming

Introduction to JDBC

Agenda

- Overview of JDBC technology
- JDBC drivers
- Seven basic steps in using JDBC
- Retrieving data from a ResultSet
- Using prepared and callable statements
- Handling SQL exceptions
- Submitting multiple statements as a transaction

JDBC Introduction

- **JDBC provides a standard library for accessing relational databases**
  - API standardizes
    - Way to establish connection to database
    - Approach to initiating queries
    - Method to create stored (parameterized) queries
    - The data structure of query result (table)
      - Determining the number of columns
      - Looking up metadata, etc.
  - API does *not* standardize SQL syntax
    - JDBC is not embedded SQL
  - JDBC class located in `java.sql` package
- **Note: JDBC is not officially an acronym; unofficially, "Java Database Connectivity" is commonly used**

On-line Resources

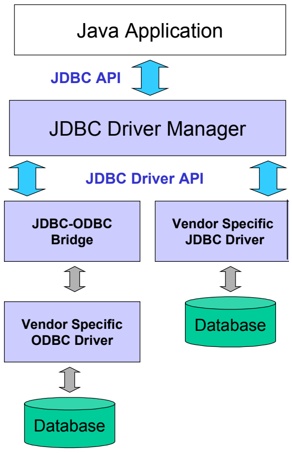
- **Sun's JDBC Site**
  - http://java.sun.com/products/jdbc/
- **JDBC Tutorial**
  - http://java.sun.com/docs/books/tutorial/jdbc/
- **List of Available JDBC Drivers**
  - http://industry.java.sun.com/products/jdbc/drivers/
- **API for java.sql**
  - http://java.sun.com/j2se/1.4/docs/api/java/sql/package-summary.html

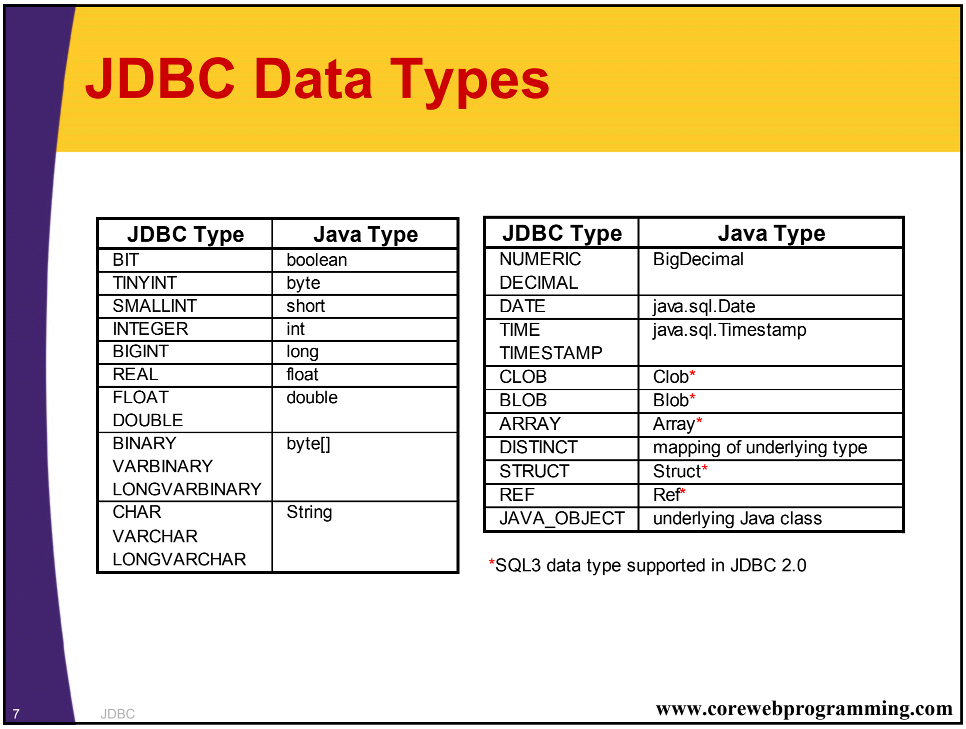
Oracle On-line Resources

- **Java Center**
  - http://technet.oracle.com/tech/java/content.html
- **SQLJ & JDBC Basic Samples**
  - http://technet.oracle.com/sample_code/tech/java/sqlj_jdbc/content.html
- **JDBC Drivers**
  - http://technet.oracle.com/software/tech/java/sqlj_jdbc/content.html
  - Requires free registration
- **Certification**
  - http://www.oracle.com/education/certification/

JDBC Drivers

- **JDBC consists of two parts:**
  - JDBC API, a purely Java-based API
  - JDBC Driver Manager,which communicates with vendor-specific drivers that perform the real communication with the database.
    - Point: translation to vendor format is performed on the client
      - No changes needed to server
      - Driver (translator) needed on client



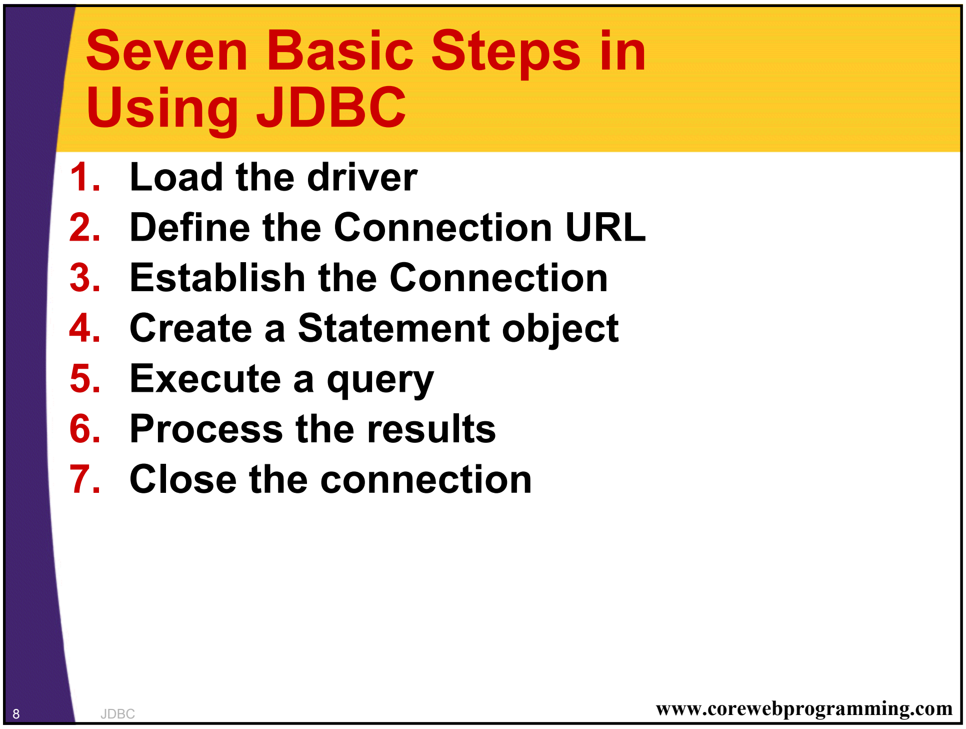


JDBC Data Types

JDBC Type	Java Type
BIT	boolean
TINYINT	byte
SMALLINT	short
INTEGER	int
BIGINT	long
REAL	float
FLOAT DOUBLE	double
BINARY VARBINARY LONGVARBINARY	byte[]
CHAR VARCHAR LONGVARCHAR	String

JDBC Type	Java Type
NUMERIC DECIMAL	BigDecimal
DATE	java.sql.Date
TIME TIMESTAMP	java.sql.Timestamp
CLOB	Clob*
BLOB	Blob*
ARRAY	Array*
DISTINCT	mapping of underlying type
STRUCT	Struct*
REF	Ref*
JAVA_OBJECT	underlying Java class

*SQL3 data type supported in JDBC 2.0



Seven Basic Steps in Using JDBC

1. Load the driver
2. Define the Connection URL
3. Establish the Connection
4. Create a Statement object
5. Execute a query
6. Process the results
7. Close the connection

JDBC: Details of Process

1. **Load the driver**

```
try {
  Class.forName("oracle.jdbc.driver.OracleDriver");
  Class.forName("org.gjt.mm.mysql.Driver");
} catch { ClassNotFoundException cnfe) {
  System.out.println("Error loading driver: " cnfe);
}
```

2. **Define the Connection URL**

```
String host = "dbhost.yourcompany.com";
String dbName = "someName";
int port = 1234;
String oracleURL = "jdbc:oracle:thin:@" + host +
                   ":" + port + ":" + dbName;
String mysqlURL = "jdbc:mysql://" + host  +
                  ":" + port + "/" + dbName;
```

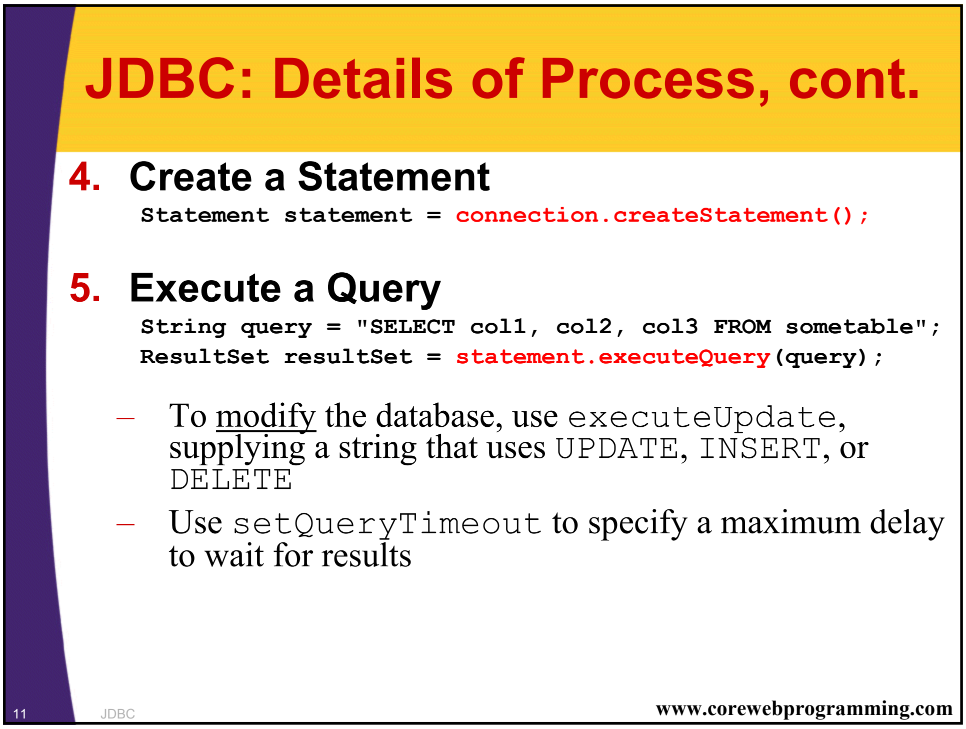
JDBC: Details of Process, cont.

3. **Establish the Connection**

```
String username = "jay_debesee";
String password = "secret";
Connection connection =
  DriverManager.getConnection(oracleURL,
                              username,
                              password);
```

- **Optionally, look up information about the database**

```
DatabaseMetaData dbMetaData = connection.getMetaData();
String productName =
  dbMetaData.getDatabaseProductName();
System.out.println("Database: " + productName);
String productVersion =
  dbMetaData.getDatabaseProductVersion();
System.out.println("Version: " + productVersion);
```



JDBC: Details of Process, cont.

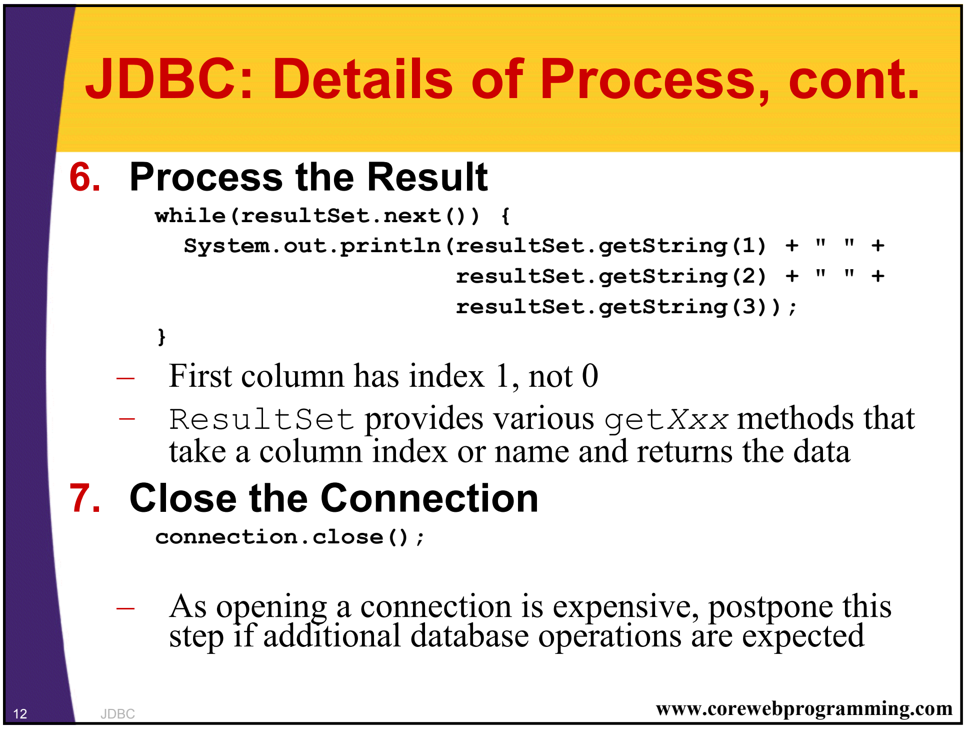
4. Create a Statement

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

5. Execute a Query

```
String query = "SELECT col1, col2, col3 FROM sometable";
ResultSet resultSet = statement.executeQuery(query);
```

- To modify the database, use `executeUpdate`, supplying a string that uses `UPDATE`, `INSERT`, or `DELETE`
- Use `setQueryTimeout` to specify a maximum delay to wait for results



JDBC: Details of Process, cont.

6. Process the Result

```
while(resultSet.next()) {
  System.out.println(resultSet.getString(1) + " " +
                     resultSet.getString(2) + " " +
                     resultSet.getString(3));
}
```

- First column has index 1, not 0
- `ResultSet` provides various `get`*`Xxx`* methods that take a column index or name and returns the data

7. Close the Connection

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

- As opening a connection is expensive, postpone this step if additional database operations are expected

Basic JDBC Example

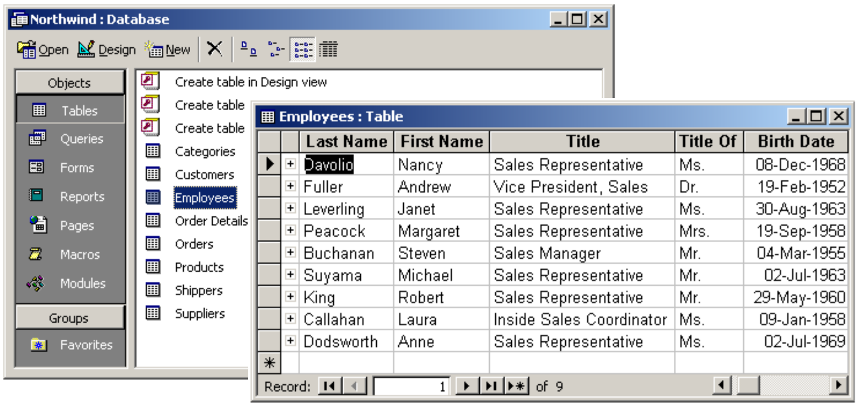
```
import java.sql.*;

public class TestDB {
  public static void main(String[] args) {

    // Use driver from Connect SW.
    String driver = "connect.microsoft.MicrosoftDriver";
    try {
      Class.forName(driver);
      String url = "jdbc:ff-microsoft://" +      // FastForward
                   "dbtest.apl.jhu.edu:1433/" + // Host:port
                   "pubs";                      // Database name
      String user = "sa", password="";

      Connection connection =
        DriverManager.getConnection(url, user, password);
      Statement statement = connection.createStatement();
      String query =
        "SELECT col1, col2, col3 FROM testDB";

      // Execute query and save results.
      ResultSet results = statement.executeQuery(query);
```

Basic JDBC Example, cont.

```
      // Print column names.
      String divider =   "-----+------+-----";
      System.out.println("Col1 | Col2 | Col3\n" + divider);

      // Print results
      while(results.next()) {
        System.out.println
          (pad(results.getString(1), 4) + " | " +
           pad(results.getString(2), 4) + " | " +
           results.getString(3) + "\n" + divider);
      }
      connection.close();
    } catch(ClassNotFoundException cnfe) {
      System.out.println("No such class: " + driver);
    } catch(SQLException se) {
      System.out.println("SQLException: " + se);
    }
  }
  ...
```

Microsoft Access Example

- **Northwind sample database**

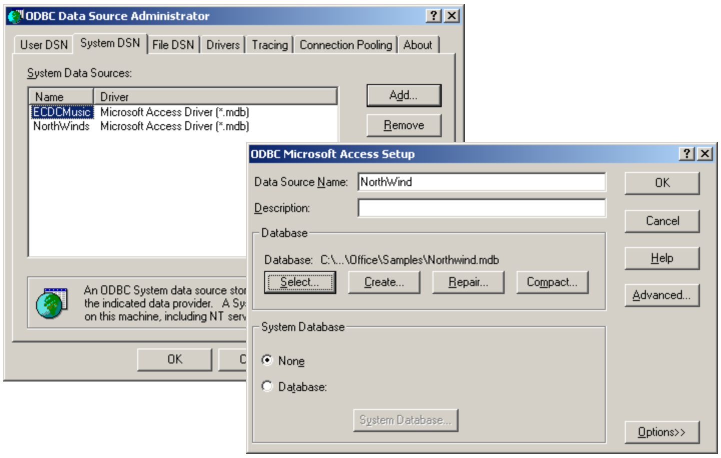


Last Name	First Name	Title	Title Of	Birth Date
Davolio	Nancy	Sales Representative	Ms.	08-Dec-1968
Fuller	Andrew	Vice President, Sales	Dr.	19-Feb-1952
Leverling	Janet	Sales Representative	Ms.	30-Aug-1963
Peacock	Margaret	Sales Representative	Mrs.	19-Sep-1958
Buchanan	Steven	Sales Manager	Mr.	04-Mar-1955
Suyama	Michael	Sales Representative	Mr.	02-Jul-1963
King	Robert	Sales Representative	Mr.	29-May-1960
Callahan	Laura	Inside Sales Coordinator	Ms.	09-Jan-1958
Dodsworth	Anne	Sales Representative	Ms.	02-Jul-1969

  - Northwind.mdb located in C:\Program Files\Microsoft Office\Office\Samples
  - http://office.microsoft.com/downloads/2000/Nwind2k.aspx

MS Access Example: Setup

- **Create System DSN through ODBC data source**



System Data Sources:

Name	Driver
ECDCMusic	Microsoft Access Driver (*.mdb)
NorthWinds	Microsoft Access Driver (*.mdb)

An ODBC System data source stor
the indicated data provider. A Sy
on this machine, including NT serv

Data Source Name: NorthWind

Description:

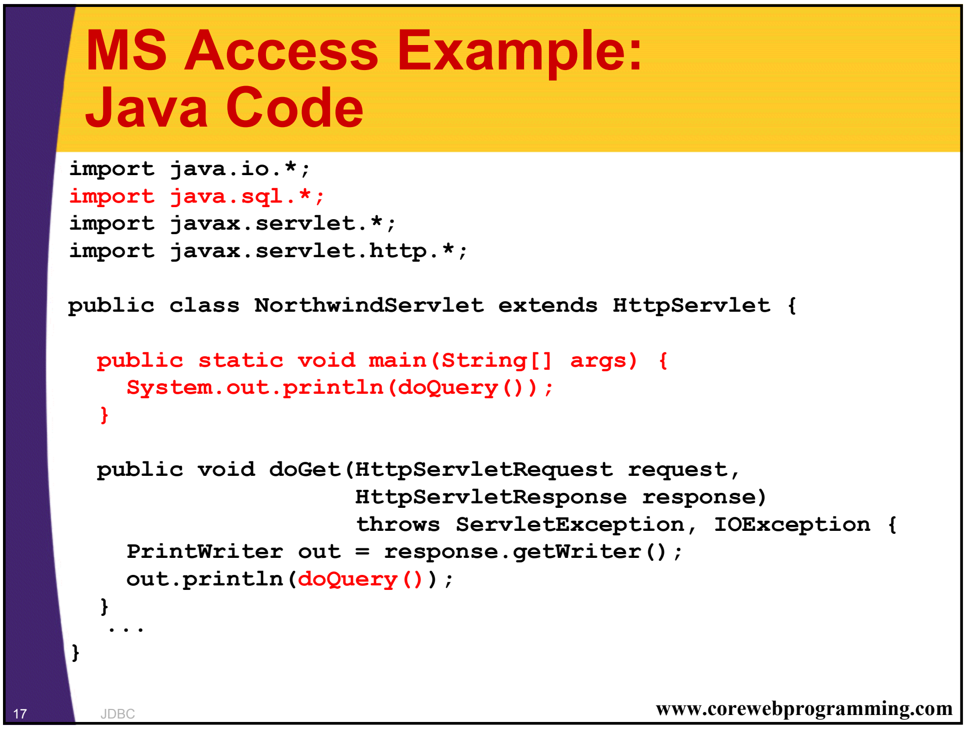
Database

Database: C:\...\Office\Samples\Northwind.mdb

System Database

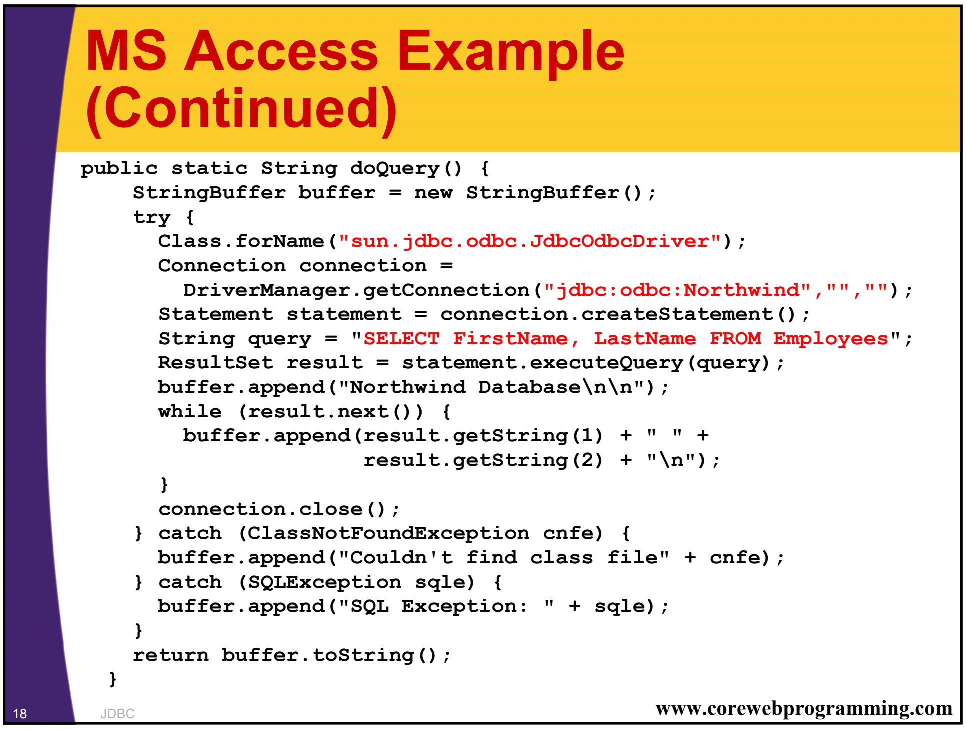
● None

○ Database:



MS Access Example: Java Code

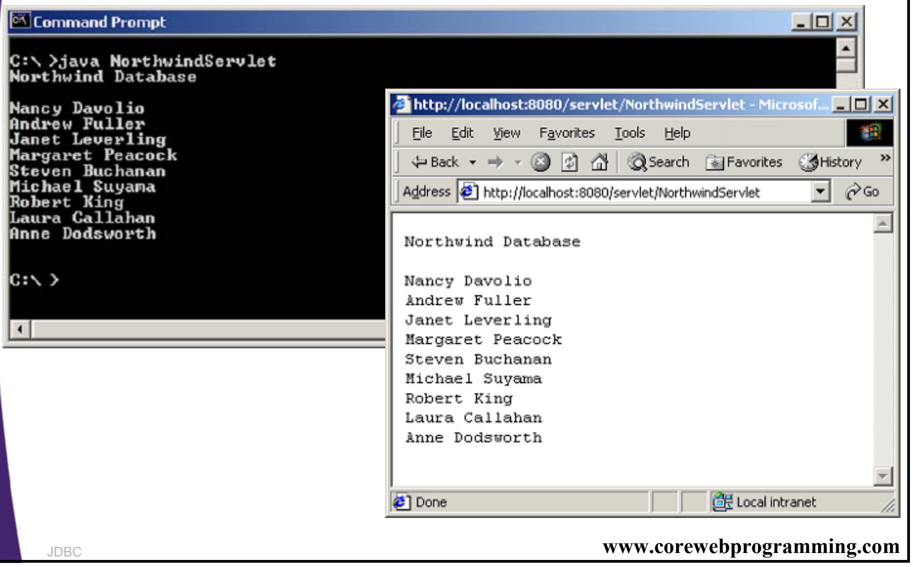
```
import java.io.*;
import java.sql.*;
import javax.servlet.*;
import javax.servlet.http.*;

public class NorthwindServlet extends HttpServlet {

  public static void main(String[] args) {
    System.out.println(doQuery());
  }

  public void doGet(HttpServletRequest request,
                    HttpServletResponse response)
                    throws ServletException, IOException {
    PrintWriter out = response.getWriter();
    out.println(doQuery());
  }
   ...
}
```



MS Access Example (Continued)

```
public static String doQuery() {
    StringBuffer buffer = new StringBuffer();
    try {
      Class.forName("sun.jdbc.odbc.JdbcOdbcDriver");
      Connection connection =
        DriverManager.getConnection("jdbc:odbc:Northwind","","");
      Statement statement = connection.createStatement();
      String query = "SELECT FirstName, LastName FROM Employees";
      ResultSet result = statement.executeQuery(query);
      buffer.append("Northwind Database\n\n");
      while (result.next()) {
        buffer.append(result.getString(1) + " " +
                      result.getString(2) + "\n");
      }
      connection.close();
    } catch (ClassNotFoundException cnfe) {
      buffer.append("Couldn't find class file" + cnfe);
    } catch (SQLException sqle) {
      buffer.append("SQL Exception: " + sqle);
    }
    return buffer.toString();
  }
```

MS Access Example, Result


Command Prompt
http://localhost:8080/servlet/NorthwindServlet - Microsof...
File Edit View Favorites Tools Help
Back Search Favorites History
Address http://localhost:8080/servlet/NorthwindServlet Go
Done
Local intranet

```
C:\ >java NorthwindServlet
Northwind Database

Nancy Davolio
Andrew Fuller
Janet Leverling
Margaret Peacock
Steven Buchanan
Michael Suyama
Robert King
Laura Callahan
Anne Dodsworth

C:\ >
```

```
Northwind Database

Nancy Davolio
Andrew Fuller
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Steven Buchanan
Michael Suyama
Robert King
Laura Callahan
Anne Dodsworth
```
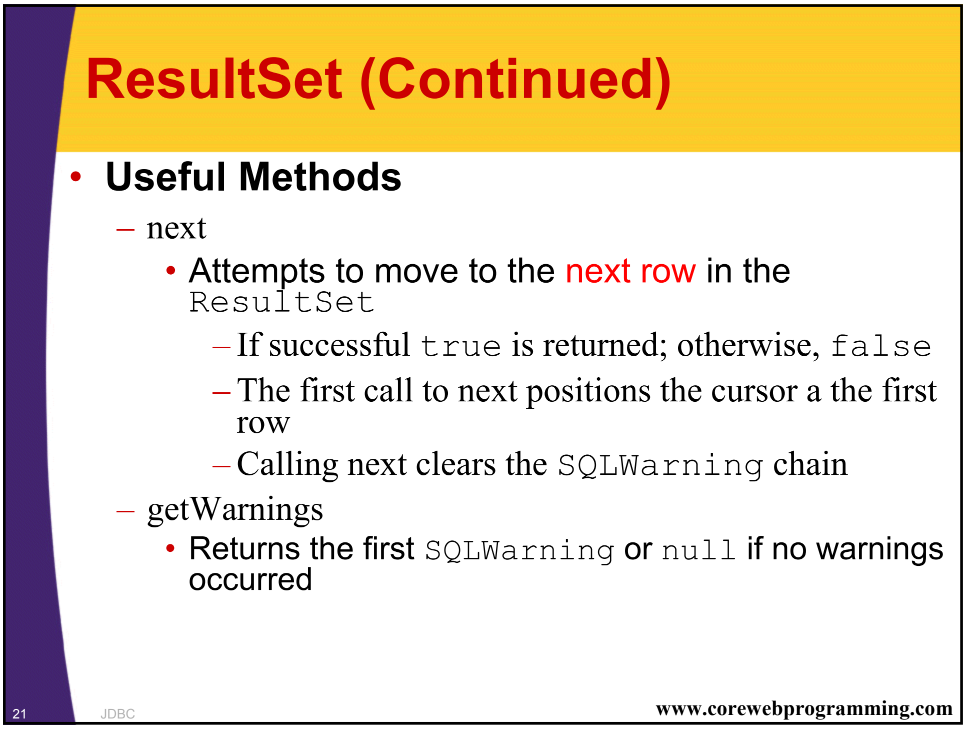
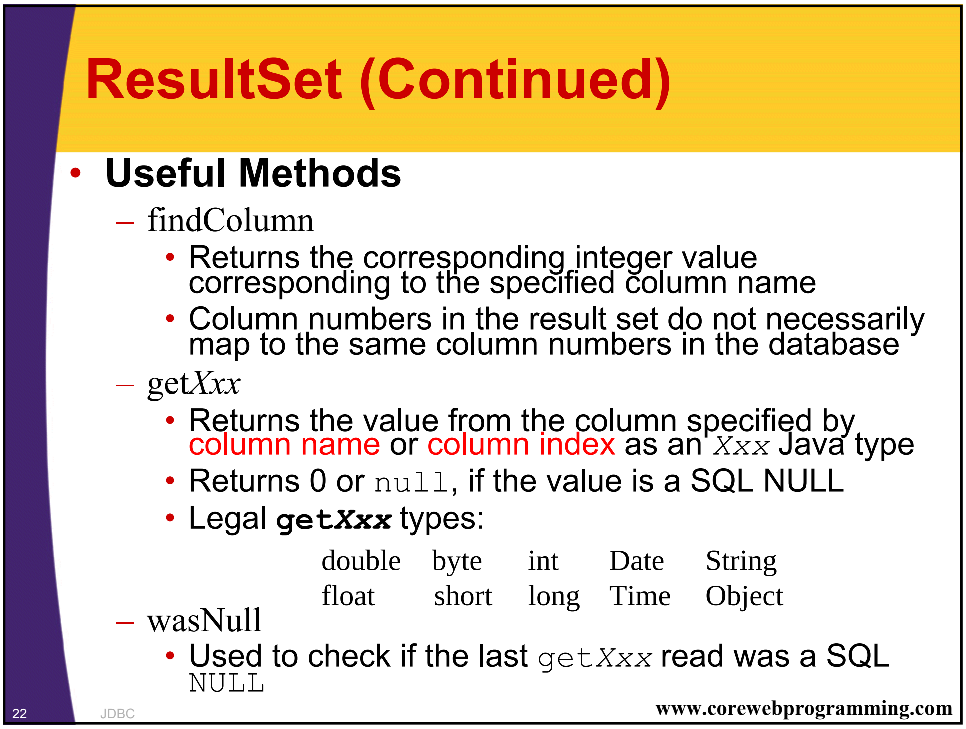

ResultSet

- **Overview**
  - A `ResultSet` contains the results of the SQL query
    - Represented by a table with rows and columns
    - In JDBC 1.0 you can only proceed forward through the rows using `next`
- **Useful Methods**
    - All methods can throw a `SQLException`
  - close
    - Releases the JDBC and database resources
    - The result set is automatically closed when the associated `Statement` object executes a new query
  - getMetaDataObject
    - Returns a `ResultSetMetaData` object containing information about the columns in the `ResultSet`



ResultSet (Continued)

- **Useful Methods**
  - next
    - Attempts to move to the next row in the `ResultSet`
      - If successful `true` is returned; otherwise, `false`
      - The first call to next positions the cursor a the first row
      - Calling next clears the `SQLWarning` chain
  - getWarnings
    - Returns the first `SQLWarning` or `null` if no warnings occurred



ResultSet (Continued)

- **Useful Methods**
  - findColumn
    - Returns the corresponding integer value corresponding to the specified column name
    - Column numbers in the result set do not necessarily map to the same column numbers in the database
  - get*Xxx*
    - Returns the value from the column specified by column name or column index as an `Xxx` Java type
    - Returns 0 or `null`, if the value is a SQL NULL
    - Legal **`getXxx`** types:

double	byte	int	Date	String
float	short	long	Time	Object

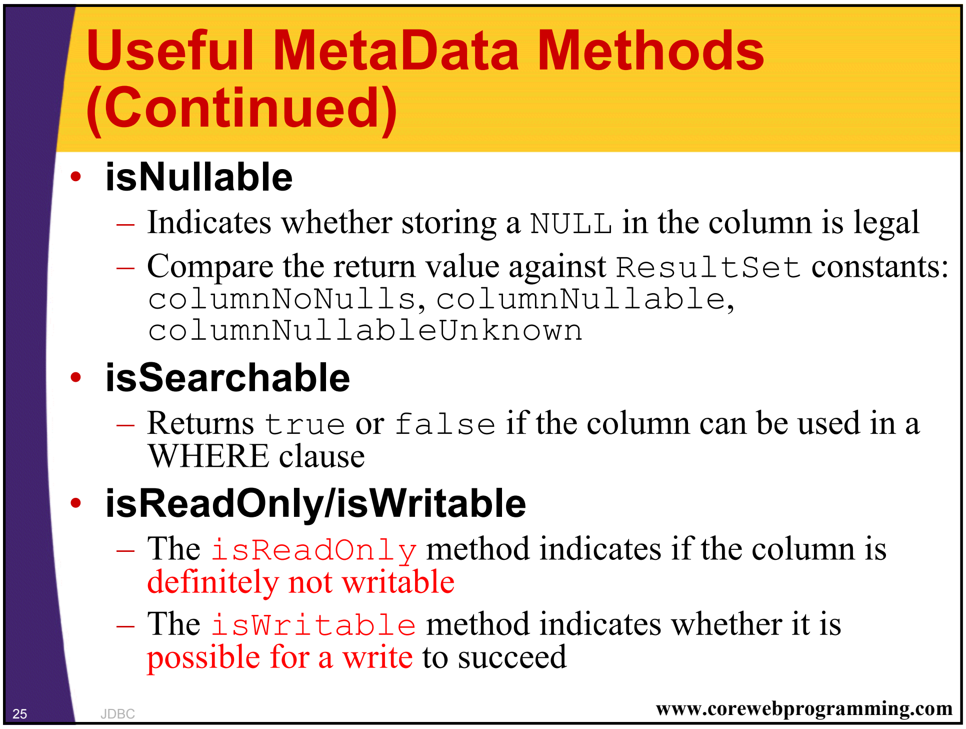
  - wasNull
    - Used to check if the last `getXxx` read was a SQL `NULL`

Using MetaData

- **Idea**
  - From a `ResultSet` (the return type of `executeQuery`), derive a `ResultSetMetaData` object
  - Use that object to look up the number, names, and types of columns
- **ResultSetMetaData answers the following questions:**
  - How many columns are in the result set?
  - What is the name of a given column?
  - Are the column names case sensitive?
  - What is the data type of a specific column?
  - What is the maximum character size of a column?
  - Can you search on a given column?

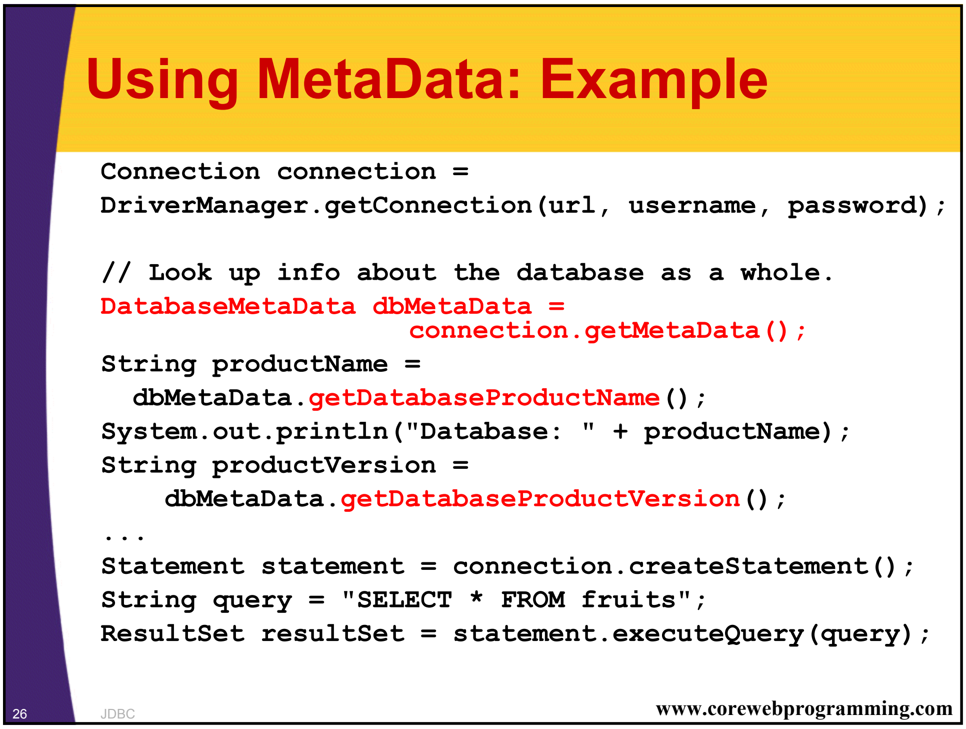
Useful MetaData Methods

- **getColumnCount**
  - Returns the number of columns in the result set
- **getColumnDisplaySize**
  - Returns the maximum width of the specified column in characters
- **getColumnName/getColumnLabel**
  - The `getColumnName` method returns the database name of the column
  - The `getColumnLabel` method returns the suggested column label for printouts
- **getColumnType**
  - Returns the SQL type for the column to compare against types in `java.sql.Types`



Useful MetaData Methods (Continued)

- **isNullable**
  - Indicates whether storing a `NULL` in the column is legal
  - Compare the return value against `ResultSet` constants: `columnNoNulls`, `columnNullable`, `columnNullableUnknown`
- **isSearchable**
  - Returns `true` or `false` if the column can be used in a WHERE clause
- **isReadOnly/isWritable**
  - The `isReadOnly` method indicates if the column is definitely not writable
  - The `isWritable` method indicates whether it is possible for a write to succeed



Using MetaData: Example

```
Connection connection =
DriverManager.getConnection(url, username, password);

// Look up info about the database as a whole.
DatabaseMetaData dbMetaData =
                   connection.getMetaData();
String productName =
  dbMetaData.getDatabaseProductName();
System.out.println("Database: " + productName);
String productVersion =
    dbMetaData.getDatabaseProductVersion();
...
Statement statement = connection.createStatement();
String query = "SELECT * FROM fruits";
ResultSet resultSet = statement.executeQuery(query);
```

Using MetaData: Example

```
// Look up information about a particular table.
ResultSetMetaData resultsMetaData =
   resultSet.getMetaData();
int columnCount = resultsMetaData.getColumnCount();
// Column index starts at 1 (a la SQL) not 0 (a la Java).
for(int i=1; i<columnCount+1; i++) {
  System.out.print(resultsMetaData.getColumnName(i) +
                   "  ");
}
System.out.println();

// Print results.
while(resultSet.next()) {
  // Quarter
  System.out.print("    " + resultSet.getInt(1));
  // Number of Apples
  ...
}
```

Using MetaData, Result

```
Prompt> java cwp.FruitTest dbhost1.apl.jhu.edu PTE
        hall xxxx oracle

Database: Oracle
Version: Oracle7 Server Release 7.2.3.0.0 - Production Release
PL/SQL Release 2.2.3.0.0 - Production

Comparing Apples and Oranges
============================
QUARTER  APPLES  APPLESALES  ORANGES  ORANGESALES  TOPSELLER
    1     32248   $3547.28    18459    $3138.03       Maria
    2     35009   $3850.99    18722    $3182.74       Bob
    3     39393   $4333.23    18999    $3229.83       Joe
    4     42001   $4620.11    19333    $3286.61       Maria
```

Using Statement

- **Overview**
  - Through the Statement object, SQL statements are sent to the database.
  - Three types of statement objects are available:
    - Statement
      - for executing a simple SQL statements
    - PreparedStatement
      - for executing a precompiled SQL statement passing in parameters
    - CallableStatement
      - for executing a database stored procedure

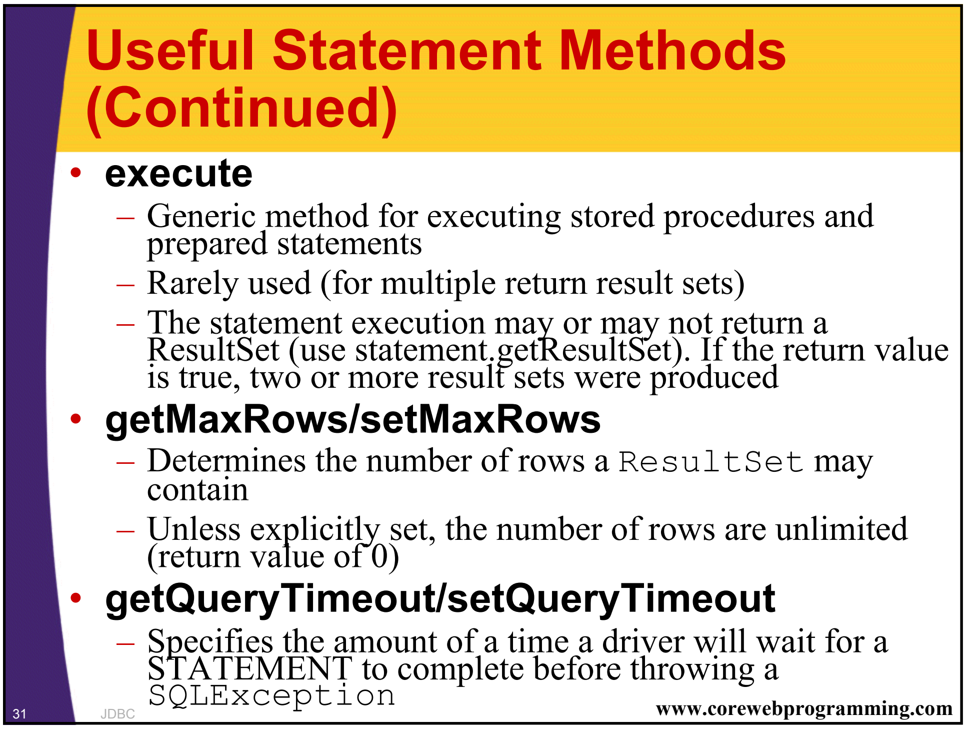
Useful Statement Methods

- **executeQuery**
  - Executes the SQL query and returns the data in a table (ResultSet)
  - The resulting table may be empty but never null

```
ResultSet results =
  statement.executeQuery("SELECT a, b FROM table");
```

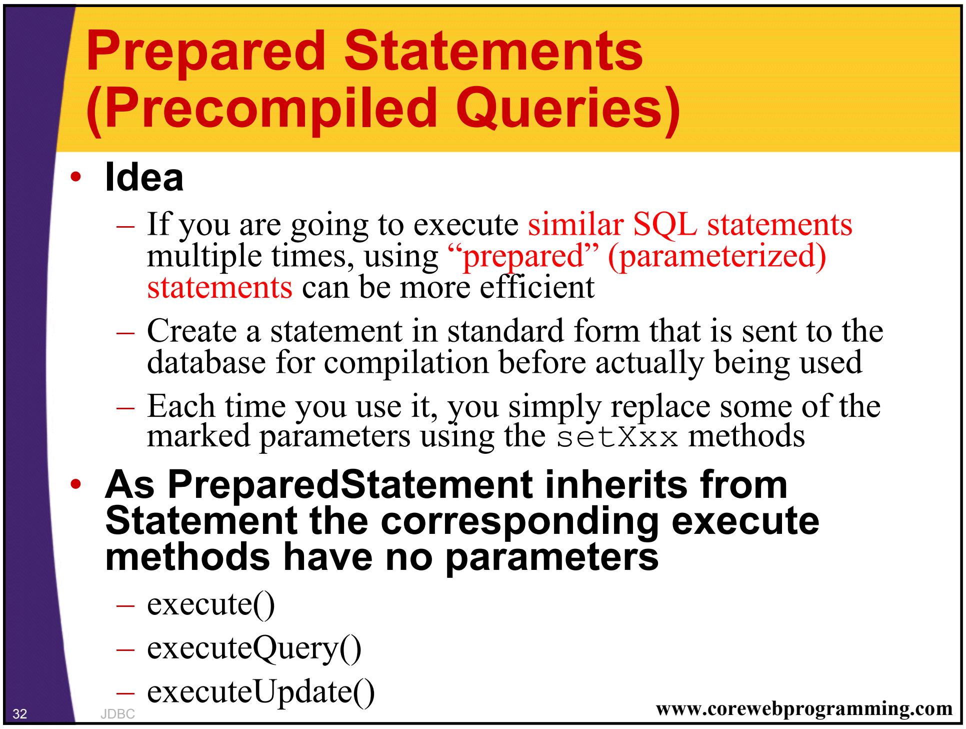
- **executeUpdate**
  - Used to execute for INSERT, UPDATE, or DELETE SQL statements
  - The return is the number of rows that were affected in the database
  - Supports Data Definition Language (DDL) statements CREATE TABLE, DROP TABLE and ALTER TABLE

```
int rows =
  statement.executeUpdate("DELETE FROM EMPLOYEES" +
                          "WHERE STATUS=0");
```



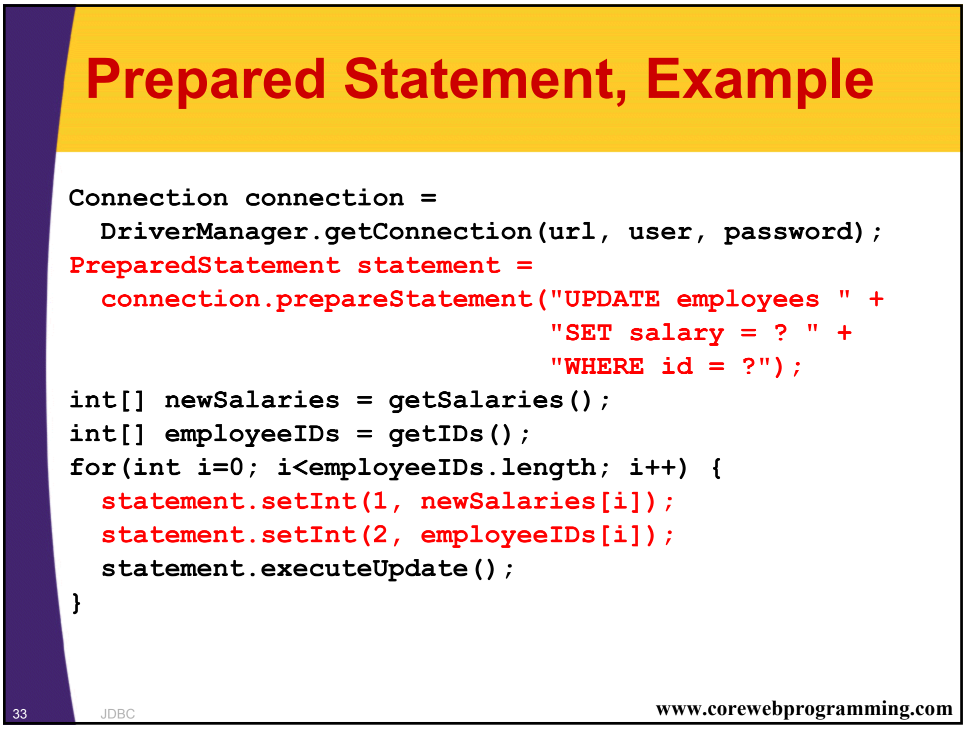
Useful Statement Methods (Continued)

- **execute**
  - Generic method for executing stored procedures and prepared statements
  - Rarely used (for multiple return result sets)
  - The statement execution may or may not return a ResultSet (use statement.getResultSet). If the return value is true, two or more result sets were produced
- **getMaxRows/setMaxRows**
  - Determines the number of rows a `ResultSet` may contain
  - Unless explicitly set, the number of rows are unlimited (return value of 0)
- **getQueryTimeout/setQueryTimeout**
  - Specifies the amount of a time a driver will wait for a STATEMENT to complete before throwing a `SQLException`



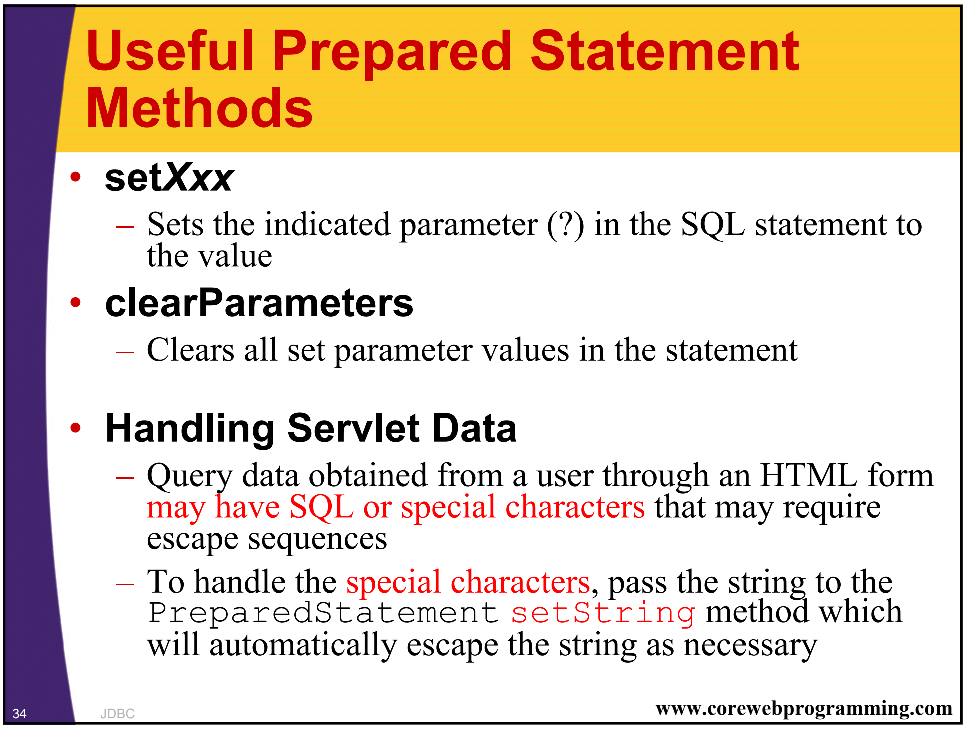
Prepared Statements (Precompiled Queries)

- **Idea**
  - If you are going to execute similar SQL statements multiple times, using "prepared" (parameterized) statements can be more efficient
  - Create a statement in standard form that is sent to the database for compilation before actually being used
  - Each time you use it, you simply replace some of the marked parameters using the `setXxx` methods
- **As PreparedStatement inherits from Statement the corresponding execute methods have no parameters**
  - execute()
  - executeQuery()
  - executeUpdate()



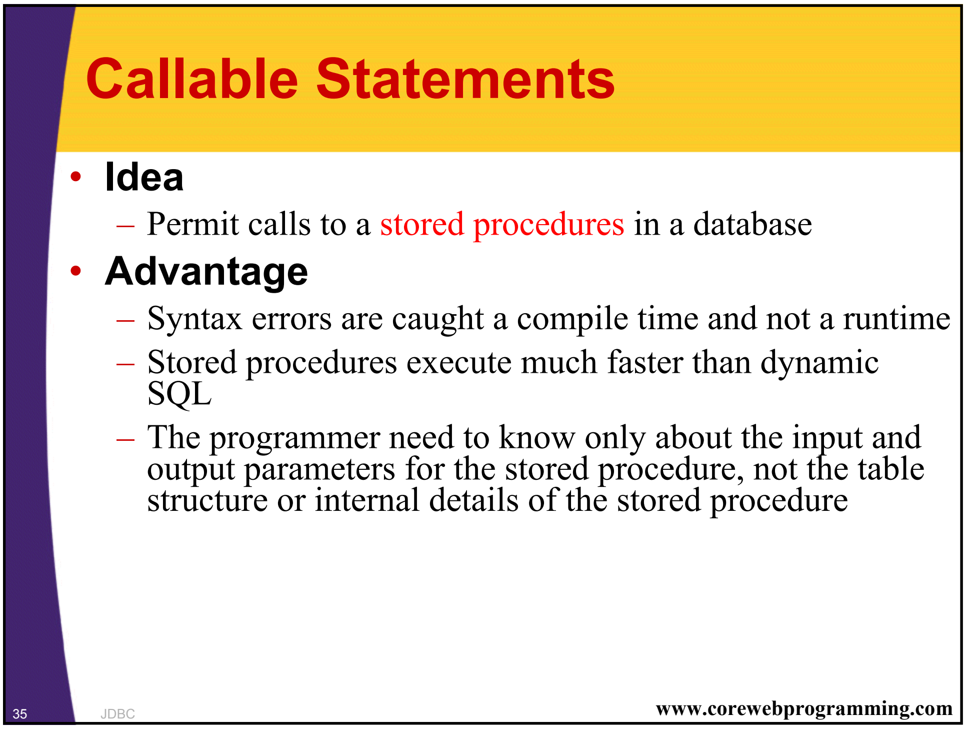
Prepared Statement, Example

```
Connection connection =
  DriverManager.getConnection(url, user, password);
PreparedStatement statement =
  connection.prepareStatement("UPDATE employees " +
                              "SET salary = ? " +
                              "WHERE id = ?");
int[] newSalaries = getSalaries();
int[] employeeIDs = getIDs();
for(int i=0; i<employeeIDs.length; i++) {
  statement.setInt(1, newSalaries[i]);
  statement.setInt(2, employeeIDs[i]);
  statement.executeUpdate();
}
```



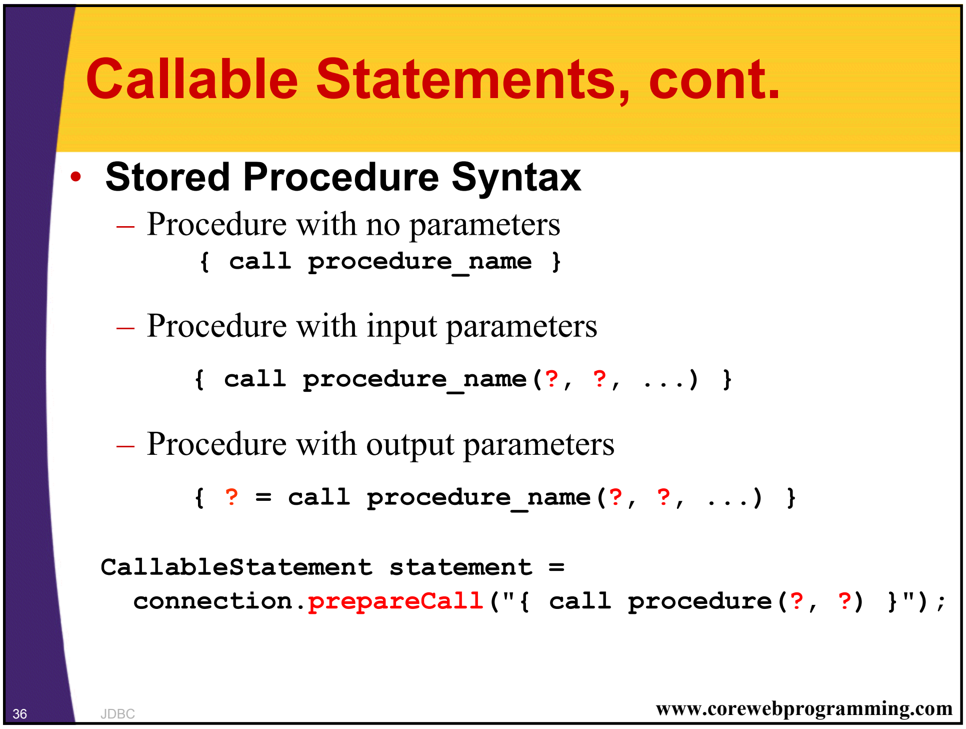
Useful Prepared Statement Methods

- **set*Xxx***
  - Sets the indicated parameter (?) in the SQL statement to the value
- **clearParameters**
  - Clears all set parameter values in the statement
- **Handling Servlet Data**
  - Query data obtained from a user through an HTML form may have SQL or special characters that may require escape sequences
  - To handle the special characters, pass the string to the `PreparedStatement` `setString` method which will automatically escape the string as necessary



Callable Statements

- **Idea**
  - Permit calls to a stored procedures in a database
- **Advantage**
  - Syntax errors are caught a compile time and not a runtime
  - Stored procedures execute much faster than dynamic SQL
  - The programmer need to know only about the input and output parameters for the stored procedure, not the table structure or internal details of the stored procedure



Callable Statements, cont.

- **Stored Procedure Syntax**
  - Procedure with no parameters

```
{ call procedure_name }
```

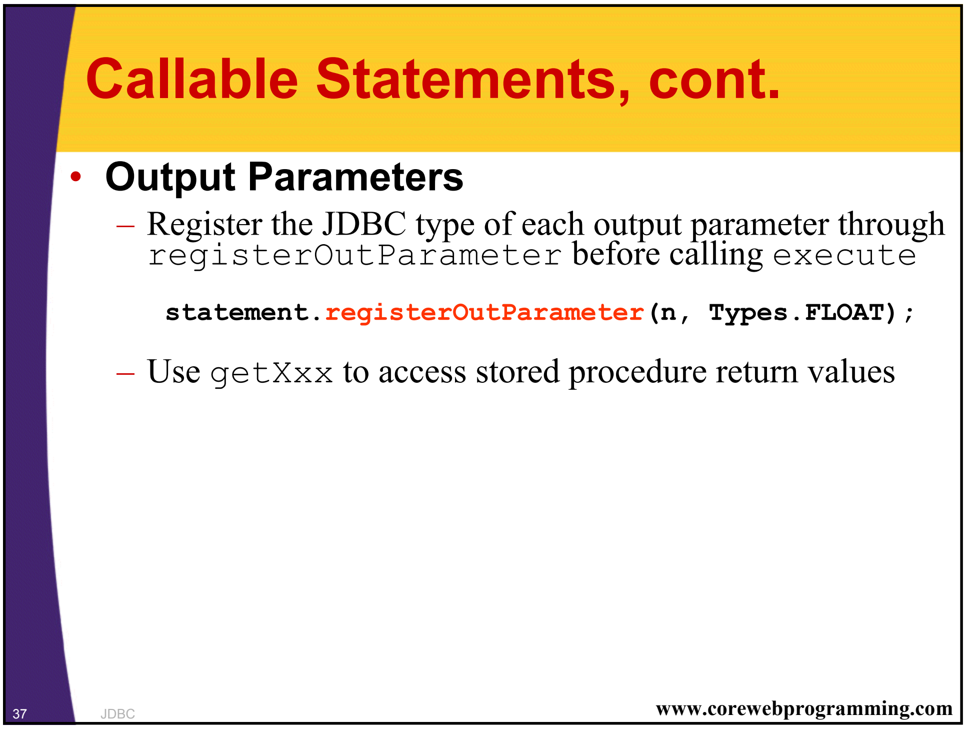
  - Procedure with input parameters

```
{ call procedure_name(?, ?, ...) }
```

  - Procedure with output parameters

```
{ ? = call procedure_name(?, ?, ...) }
```

```
CallableStatement statement =
  connection.prepareCall("{ call procedure(?, ?) }");
```

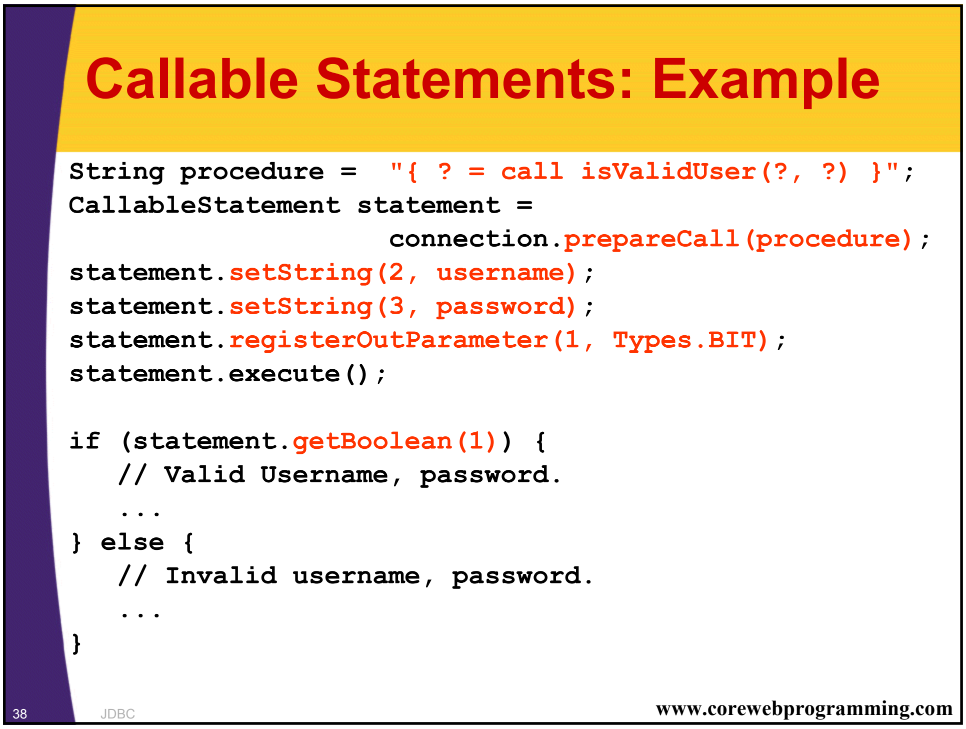


Callable Statements, cont.

- **Output Parameters**
  - Register the JDBC type of each output parameter through `registerOutParameter` before calling `execute`

```
statement.registerOutParameter(n, Types.FLOAT);
```

  - Use `getXxx` to access stored procedure return values



Callable Statements: Example

```
String procedure =  "{ ? = call isValidUser(?, ?) }";
CallableStatement statement =
                    connection.prepareCall(procedure);
statement.setString(2, username);
statement.setString(3, password);
statement.registerOutParameter(1, Types.BIT);
statement.execute();

if (statement.getBoolean(1)) {
   // Valid Username, password.
   ...
} else {
   // Invalid username, password.
   ...
}
```

Useful CallableStatement Methods

- **CallableStatement inherits from PreparedStatement**
- **getXxx(int parameterIndex)**
  - Retrieves the JDBC output parameter at the specified index as the xxx Java type
- **registerOutputParameter**
  - Binds indexed output parameter to a JDBC type
  - Can also provide a scale parameter to specify the number of digits to the right of the decimal point for NUMERIC or DECIMAL JDBC types

```
statement.registerOutParameter(2, Types.DECIMAL, 3);
```

Exception Handling

- **SQL Exceptions**
  - Nearly every JDBC method can throw a `SQLException` in response to a data access error
  - If more than one error occurs, they are chained together
  - SQL exceptions contain:
    - Description of the error, `getMessage`
    - The SQLState (Open Group SQL specification) identifying the exception, `getSQLState`
    - A vendor-specific integer, error code, `getErrorCode`
    - A chain to the next `SQLException`, `getNextException`

SQL Exception Example

```
try {
     ... // JDBC statement.
} catch (SQLException sqle) {
  while (sqle != null) {
    System.out.println("Message:  " + sqle.getMessage());
    System.out.println("SQLState: " + sqle.getSQLState());
    System.out.println("Vendor Error: " +
                       sqle.getErrorCode());
    sqle.printStrackTrace(System.out);
    sqle = sqle.getNextException();
  }
}
```

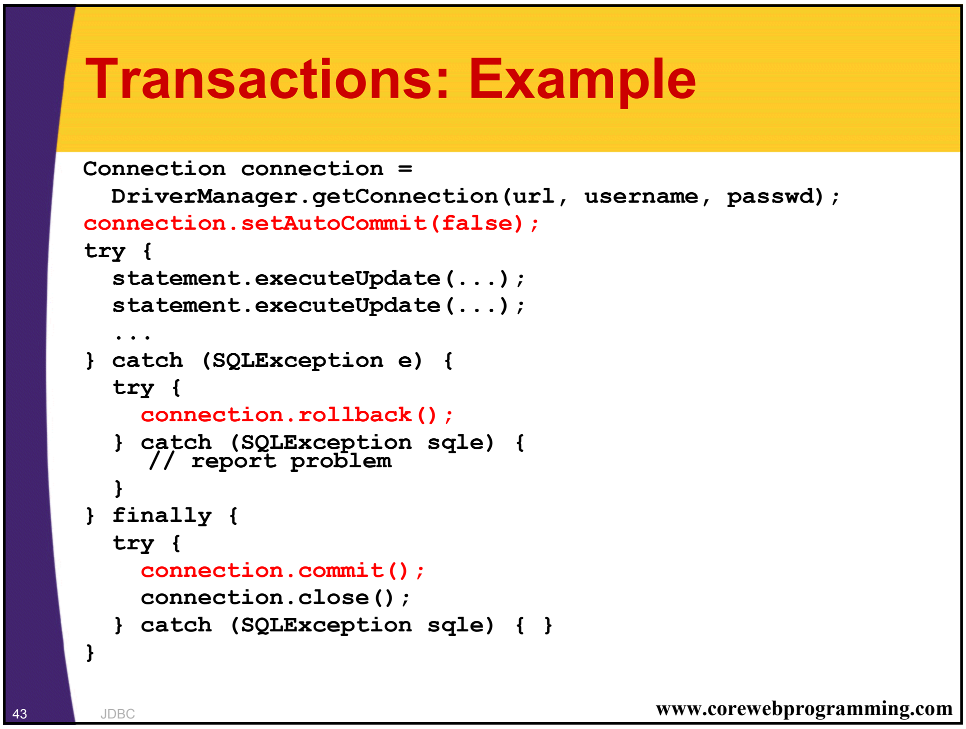
- Don’t make assumptions about the state of a transaction after an exception occurs
- The safest best is to attempt a rollback to return to the initial state

Transactions

- **Idea**
  - By default, after each SQL statement is executed the changes are automatically committed to the database
  - Turn auto-commit off to group two or more statements together into a transaction

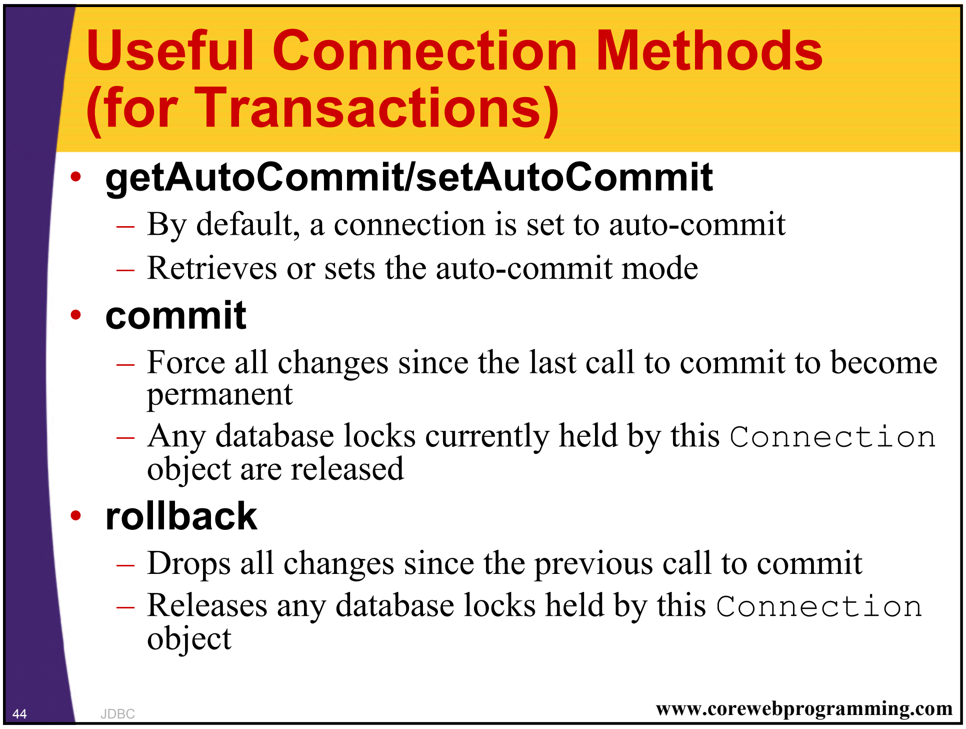
```
connection.setAutoCommit(false)
```

  - Call commit to permanently record the changes to the database after executing a group of statements
  - Call rollback if an error occurs



Transactions: Example

```
Connection connection =
  DriverManager.getConnection(url, username, passwd);
connection.setAutoCommit(false);
try {
  statement.executeUpdate(...);
  statement.executeUpdate(...);
  ...
} catch (SQLException e) {
  try {
    connection.rollback();
  } catch (SQLException sqle) {
    // report problem
  }
} finally {
  try {
    connection.commit();
    connection.close();
  } catch (SQLException sqle) { }
}
```



Useful Connection Methods (for Transactions)

- **getAutoCommit/setAutoCommit**
  - By default, a connection is set to auto-commit
  - Retrieves or sets the auto-commit mode
- **commit**
  - Force all changes since the last call to commit to become permanent
  - Any database locks currently held by this `Connection` object are released
- **rollback**
  - Drops all changes since the previous call to commit
  - Releases any database locks held by this `Connection` object

Some JDBC Utilities

- **Idea**
  - Performing JDBC queries and formatting output are common tasks, so create helper classes to perform this function: `DatabaseUtilities` and `DBResults`
- **Class methods**
  - getQueryResults
    - Connects to a database, executes a query, retrieves all the rows as arrays of strings, and puts them inside a `DBResults` object
  - createTable
    - Given a table name, a string denoting the column formats, and an array of strings denoting row values, this method issues a CREATE TABLE command and then sends a series of INSERT INTO commands for each row
  - printTable
    - Given a table name, this method connects to the database, retrieves all the rows, and prints them on the standard output
  - printTableData
    - Given a DBResults object from a previous query, prints the results to standard output. Useful for debugging

Using JDBC Utilities

- **Usage Example**

```
DBResults results =
  DatabaseUtilities.getQueryResults(driver, url,
                                    username, password,
                                    query, true);
out.println(results.toHTMLTable("CYAN"));
```

Summary

- In JDBC 1.0, can only step forward (`next`) through the `ResultSet`
- `MetaDataResultSet` provides details about returned `ResultSet`
- Improve performance through prepared statements
- Be sure to handle the situation where `getXxx` returns a NULL
- Be default, a connection is auto-commit
- SQL Exceptions are chained together

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Questions?