Oracle9*i*

JDBC Developer's Guide and Reference

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Oracle9*i* JDBC Developer's Guide and Reference, Release 2 (9.2)

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Preface

This preface introduces you to the *Oracle9i JDBC Developer's Guide and Reference*, discussing the intended audience, structure, and conventions of this document. A list of related Oracle documents is also provided.

This preface contains these topics:

- Intended Audience
- Documentation Accessibility
- Organization
- Related Documentation
- Conventions

Intended Audience

This manual is intended for anyone with an interest in JDBC programming but assumes at least some prior knowledge of the following:

- Java
- SQL
- Oracle PL/SQL
- Oracle databases

Documentation Accessibility

Our goal is to make Oracle products, services, and supporting documentation accessible, with good usability, to the disabled community. To that end, our documentation includes features that make information available to users of assistive technology. This documentation is available in HTML format, and contains markup to facilitate access by the disabled community. Standards will continue to evolve over time, and Oracle Corporation is actively engaged with other market-leading technology vendors to address technical obstacles so that our documentation can be accessible to all of our customers. For additional information, visit the Oracle Accessibility Program Web site at

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Accessibility of Code Examples in Documentation JAWS, a Windows screen reader, may not always correctly read the code examples in this document. The conventions for writing code require that closing braces should appear on an otherwise empty line; however, JAWS may not always read a line of text that consists solely of a bracket or brace.

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Organization

This document contains the following chapters and appendices:

- Chapter 1, "Overview"—Provides an overview of the Oracle implementation of JDBC and the Oracle JDBC driver architecture.
- Chapter 2, "Getting Started"—Introduces the Oracle JDBC drivers and some scenarios of how you can use them. This chapter also guides you through the basics of testing your installation and configuration.
- Chapter 3, "Basic Features"—Covers the basic steps in creating any JDBC application. It also discusses additional basic features of Java and JDBC supported by the Oracle JDBC drivers.
- Chapter 4, "Overview of JDBC 2.0 Support"—Presents an overview of JDBC 2.0 features and describes the differences in how these features are supported in the JDK 1.2.x and JDK 1.1.x environments.
- Chapter 6, "Overview of Oracle Extensions"—Provides an overview of the JDBC extension classes supplied by Oracle.
- Chapter 7, "Accessing and Manipulating Oracle Data"—Describes data access using the Oracle datatype formats rather than Java formats.
- Chapter 8, "Working with LOBs and BFILEs"—Covers the Oracle extensions to the JDBC standard that let you access and manipulate LOBs and LOB data.
- Chapter 9, "Working with Oracle Object Types"—Explains how to map Oracle object types to Java classes by using either standard JDBC or Oracle extensions.
- Chapter 10, "Working with Oracle Object References"—Describes the Oracle extensions to standard JDBC that let you access and manipulate object references.
- Chapter 11, "Working with Oracle Collections"—Discusses the Oracle extensions to standard JDBC that let you access and manipulate arrays and their data.
- Chapter 12, "Performance Extensions"—Describes Oracle extensions to the JDBC standard that enhance the performance of your applications.
- Chapter 13, "Result Set Enhancements"—This chapter discusses JDBC 2.0 result set enhancements such as scrollable result sets and updatable result sets, including support issues under JDK 1.1.x
- Chapter 18, "Statement Caching"—Describes Oracle extension statements for caching.

- Chapter 14, "Distributed Transactions"—Covers distributed transactions, otherwise known as global transactions, and standard XA functionality. (Distributed transactions are sets of transactions, often to multiple databases, that have to be committed in a coordinated manner.)
- Chapter 15, "Connection Pooling and Caching"—Discusses JDBC 2.0 data sources (and their usage of JNDI), connection pooling functionality (a framework for connection caching implementations), and a sample connection caching implementation provided by Oracle.
- Chapter 16, "JDBC OCI Extensions"—Describes extensions specific to the OCI driver.
- Chapter 17, "Advanced Topics"—Describes advanced JDBC topics such as globalization support, working with applets, the server-side driver, and embedded SQL92 syntax.
- Chapter 20, "Coding Tips and Troubleshooting"—Includes coding tips and general guidelines for troubleshooting your JDBC applications.
- Chapter 19, "Reference Information"—Contains detailed JDBC reference information.
- Appendix A, "Row Set"—Describes JDBC and cached row sets.
- Appendix B, "JDBC Error Messages"—Lists JDBC error messages and the corresponding ORA error numbers.

Related Documentation

Also available from the Oracle Java Platform group, for Oracle9*i* releases:

- *Oracle9i Java Developer's Guide*

  This book introduces the basic concepts of Java in Oracle9*i* and provides general information about server-side configuration and functionality. Information that pertains to the Oracle Java platform as a whole, rather than to a particular product (such as JDBC or SQLJ) is in this book.

- *Oracle9i Support for JavaServer Pages Reference*

  This book covers the use of JavaServer Pages technology to embed Java code and JavaBean invocations inside HTML pages. Both standard JSP features and Oracle-specific features are described. Discussion covers considerations for the Oracle9i release 2 Oracle HTTP Server JServ environment, but also covers

features for servlet 2.2 environments and emulation of some of those features by the Oracle JSP container for JServ.

- *Oracle9i SQLJ Developer's Guide and Reference*

  This book covers the use of SQLJ to embed static SQL operations directly into Java code, covering SQLJ language syntax and SQLJ translator options and features. Both standard SQLJ features and Oracle-specific SQLJ features are described.

- *Oracle9i JPublisher User's Guide*

  This book describes how to use the Oracle JPublisher utility to translate object types and other user-defined types to Java classes. If you are developing SQLJ or JDBC applications that use object types, VARRAY types, nested table types, or object reference types, then JPublisher can generate custom Java classes to map to them.

- *Oracle9i Java Stored Procedures Developer's Guide*

  This book discusses Java stored procedures—programs that run directly in the Oracle9*i* database. With stored procedures (functions, procedures, triggers, and SQL methods), Java developers can implement business logic at the server level, thereby improving application performance, scalability, and security.

The following OC4J documents, for Oracle9*i* Application Server releases, are also available from the Oracle Java Platform group:

- *Oracle9iAS Containers for J2EE User's Guide*

  This book provides some overview and general information for OC4J; primer chapters for servlets, JSP pages, and EJBs; and general configuration and deployment instructions.

- *Oracle9iAS Containers for J2EE Support for JavaServer Pages Reference*

  This book provides information for JSP developers who want to run their pages in OC4J. It includes a general overview of JSP standards and programming considerations, as well as discussion of Oracle value-added features and steps for getting started in the OC4J environment.

- *Oracle9iAS Containers for J2EE JSP Tag Libraries and Utilities Reference*

  This book provides conceptual information and detailed syntax and usage information for tag libraries, JavaBeans, and other Java utilities provided with OC4J.

- *Oracle9iAS Containers for J2EE Servlet Developer's Guide*

This book provides information for servlet developers regarding use of servlets and the servlet container in OC4J. It also documents relevant OC4J configuration files.

- *Oracle9iAS Containers for J2EE Services Guide*

  This book provides information about basic Java services supplied with OC4J, such as JTA, JNDI, and the Oracle9*i* Application Server Java Object Cache.

- *Oracle9iAS Containers for J2EE Enterprise JavaBeans Developer's Guide and Reference*

  This book provides information about the EJB implementation and EJB container in OC4J.

The following documents are from the Oracle Server Technologies group:

- *Oracle9i XML Developer's Kits Guide - XDK*
- *Oracle9i Application Developer's Guide - Fundamentals*
- *Oracle9i Supplied Java Packages Reference*
- *Oracle9i Supplied PL/SQL Packages and Types Reference*
- *PL/SQL User's Guide and Reference*
- *Oracle9i SQL Reference*
- *Oracle9i Net Services Administrator's Guide*
- *Oracle Advanced Security Administrator's Guide*
- *Oracle9i Database Reference*
- *Oracle9i Database Error Messages*

The following documents from the Oracle9*i* Application Server group may also be of some interest:

- *Oracle9i Application Server Administrator's Guide*
- *Oracle Enterprise Manager Administrator's Guide*
- *Oracle HTTP Server Administration Guide*
- *Oracle9i Application Server Performance Guide*
- *Oracle9i Application Server Globalization Support Guide*
- *Oracle9iAS Web Cache Administration and Deployment Guide*
- *Oracle9i Application Server: Migrating from Oracle9i Application Server 1.x*

The following are available from the JDeveloper group:

- Oracle JDeveloper online help
- Oracle JDeveloper documentation on the Oracle Technology Network:

  `http://otn.oracle.com/products/jdev/content.html`

In North America, printed documentation is available for sale in the Oracle Store at

`http://oraclestore.oracle.com/`

Customers in Europe, the Middle East, and Africa (EMEA) can purchase documentation from

`http://www.oraclebookshop.com/`

Other customers can contact their Oracle representative to purchase printed documentation.

To download free release notes, installation documentation, white papers, or other collateral, please visit the Oracle Technology Network (OTN). You must register online before using OTN; registration is free and can be done at

`http://otn.oracle.com/admin/account/membership.html`

If you already have a username and password for OTN, then you can go directly to the documentation section of the OTN Web site at

`http://otn.oracle.com/docs/index.htm`

To access the database documentation search engine directly, please visit

`http://tahiti.oracle.com`

The following Oracle Technology Network (OTN) resources are available for further information about JavaServer Pages:

- OTN Web site for Java servlets and JavaServer Pages:

  `http://otn.oracle.com/tech/java/servlets/`

- OTN JSP discussion forums, accessible through the following address:

  `http://www.oracle.com/forums/forum.jsp?id=399160`

The following resources are available from Sun Microsystems:

- Web site for JavaServer Pages, including the latest specifications:

`http://java.sun.com/products/jsp/index.html`

- Web site for Java Servlet technology, including the latest specifications:

  `http://java.sun.com/products/servlet/index.html`

- `jsp-interest` discussion group for JavaServer Pages

  To subscribe, send an e-mail to `listserv@java.sun.com` with the following line in the body of the message:

  `subscribe jsp-interest` *`yourlastname yourfirstname`*

  It is recommended, however, that you request only the daily digest of the posted e-mails. To do this add the following line to the message body as well:

  `set jsp-interest digest`

Conventions

This section describes the conventions used in the text and code examples of this documentation set. It describes:

- Conventions in Text
- Conventions in Code Examples

Conventions in Text

We use various conventions in text to help you more quickly identify special terms. The following table describes those conventions and provides examples of their use.

Convention	Meaning	Example
Italics	Italic typeface indicates book titles or emphasis, or terms that are defined in the text.	*Oracle9i Database Concepts* Ensure that the recovery catalog and target database do *not* reside on the same disk.
`UPPERCASE monospace (fixed-width) font`	Uppercase monospace typeface indicates elements supplied by the system. Such elements include parameters, privileges, datatypes, RMAN keywords, SQL keywords, SQL*Plus or utility commands, packages and methods, as well as system-supplied column names, database objects and structures, usernames, and roles.	You can specify this clause only for a `NUMBER` column. You can back up the database by using the `BACKUP` command. Query the `TABLE_NAME` column in the `USER_TABLES` data dictionary view. Use the `DBMS_STATS.GENERATE_STATS` procedure.
`lowercase monospace (fixed-width) font`	Lowercase monospace typeface indicates executables, filenames, directory names, and sample user-supplied elements. Such elements include computer and database names, net service names, and connect identifiers, as well as user-supplied database objects and structures, column names, packages and classes, usernames and roles, program units, and parameter values. **Note:** Some programmatic elements use a mixture of UPPERCASE and lowercase. Enter these elements as shown.	Enter `sqlplus` to open SQL*Plus. The password is specified in the `orapwd` file. Back up the data files and control files in the `/disk1/oracle/dbs` directory. The `department_id`, `department_name`, and `location_id` columns are in the `hr.departments` table. Set the `QUERY_REWRITE_ENABLED` initialization parameter to `true`. Connect as `oe` user. The `JRepUtil` class implements these methods.
`lowercase italic monospace (fixed-width) font`	Lowercase italic monospace font represents place holders or variables.	You can specify the *`parallel_clause`*. Run *`old_release`*`.SQL` where *`old_release`* refers to the release you installed prior to upgrading.

Conventions in Code Examples

Code examples illustrate SQL, PL/SQL, SQL*Plus, or other command-line statements. They are displayed in a monospace (fixed-width) font and separated from normal text as shown in this example:

```
SELECT username FROM dba_users WHERE username = 'MIGRATE';
```

The following table describes typographic conventions used in code examples and provides examples of their use.

Convention	Meaning	Example
[ ]	Brackets enclose one or more optional items. Do not enter the brackets.	`DECIMAL (`*`digits`*` [ , `*`precision`*` ])`
|	A vertical bar represents a choice of two or more options within brackets or braces. Enter one of the options. Do not enter the vertical bar.	`{ENABLE | DISABLE}` `[COMPRESS | NOCOMPRESS]`
...	Horizontal ellipsis points indicate either:	
	■ That we have omitted parts of the code that are not directly related to the example	`CREATE TABLE ... AS `*`subquery`*`;`
	■ That you can repeat a portion of the code	`SELECT `*`col1`*`, `*`col2`*`, ... , `*`coln`*` FROM employees;`
Other notation	You must enter symbols other than brackets, braces, vertical bars, and ellipsis points as shown.	`acctbal NUMBER(11,2);` `acct CONSTANT NUMBER(4) := 3;`
Italics	Italicized text indicates place holders or variables for which you must supply particular values.	`CONNECT SYSTEM/`*`system_password`* `DB_NAME = `*`database_name`*

UPPERCASE	Uppercase typeface indicates elements supplied by the system. We show these terms in uppercase in order to distinguish them from terms you define. Unless terms appear in brackets, enter them in the order and with the spelling shown. However, because these terms are not case sensitive, you can enter them in lowercase.	`SELECT last_name, employee_id FROM employees;`
		`SELECT * FROM USER_TABLES;`
		`DROP TABLE hr.employees;`

lowercase	Lowercase typeface indicates programmatic elements that you supply. For example, lowercase indicates names of tables, columns, or files.
	Note: Some programmatic elements use a mixture of UPPERCASE and lowercase. Enter these elements as shown.
		`SELECT last_name, employee_id FROM employees;`
		`sqlplus hr/hr`
		`CREATE USER mjones IDENTIFIED BY ty3MU9;`

1

Overview

This chapter provides an overview of the Oracle implementation of JDBC, covering the following topics:

- Introduction
- Overview of the Oracle JDBC Drivers
- Overview of Application and Applet Functionality
- Server-Side Basics
- Environments and Support
- Changes At This Release

Introduction

This section presents a brief introduction to Oracle JDBC, including a comparison to SQLJ.

What is JDBC?

JDBC (Java Database Connectivity) is a standard Java interface for connecting from Java to relational databases. The JDBC standard was defined by Sun Microsystems, allowing individual providers to implement and extend the standard with their own JDBC drivers.

JDBC is based on the X/Open SQL Call Level Interface and complies with the SQL92 Entry Level standard.

In addition to supporting the standard JDBC API, Oracle drivers have extensions to support Oracle-specific datatypes and to enhance performance.

JDBC versus SQLJ

Developers who are familiar with the Oracle Call Interface (OCI) layer of client-side C code will recognize that JDBC provides the power and flexibility for the Java programmer that OCI does for the C or C++ programmer. Just as with OCI, you can use JDBC to query and update tables where, for example, the number and types of the columns are not known until runtime. This capability is called *dynamic SQL*. Therefore, JDBC is a way to use dynamic SQL statements in Java programs. Using JDBC, a calling program can construct SQL statements at runtime. Your JDBC program is compiled and run like any other Java program. No analysis or checking of the SQL statements is performed. Any errors that are made in your SQL code raise runtime errors. JDBC is designed as an API for dynamic SQL.

However, many applications do not need to construct SQL statements dynamically because the SQL statements they use are fixed or *static*. In this case, you can use SQLJ to embed *static SQL* in Java programs. In static SQL, all the SQL statements are complete or "textually evident" in the Java program. That is, details of the database object, such as the column names, number of columns in the table, and table name, are known before runtime. SQLJ offers advantages for these applications because it permits error checking at precompile time.

The precompile step of a SQLJ program performs syntax-checking of the embedded SQL, type checking against the database to assure that the data exchanged between Java and SQL have compatible types and proper type conversions, and schema checking to assure congruence between SQL constructs and the database schema. The result of the precompilation is Java source code with SQL runtime code which,

in turn, can use JDBC calls. The generated Java code compiles and runs like any other Java program.

Although SQLJ provides direct support for static SQL operations known at the time the program is written, it can also interoperate with dynamic SQL through JDBC. SQLJ allows you to create JDBC objects when they are needed for dynamic SQL operations. In this way, SQLJ and JDBC can co-exist in the same program. Convenient conversions are supported between JDBC connections and SQLJ connection contexts, as well as between JDBC result sets and SQLJ iterators. For more information on this, see the *Oracle9i SQLJ Developer's Guide and Reference.*

The syntax and semantics of SQLJ and JDBC do not depend on the configuration under which they are running, thus enabling implementation on the client or database side or in the middle tier.

General Guidelines for Using JDBC and SQLJ

SQLJ is effective in the following circumstances:

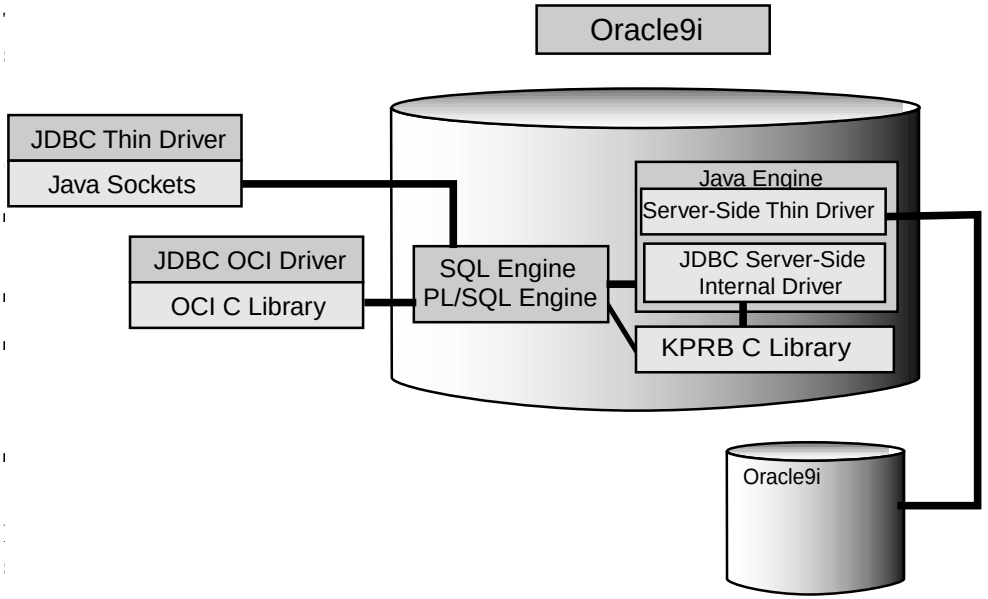
- You want to be able to check your program for errors at translation-time, rather than at run-time.
- You want to write an application that you can deploy to another database. Using SQLJ, you can customize the static SQL for that database at deployment-time.
- You are working with a database that contains compiled SQL. You will want to use SQLJ because you cannot compile SQL statements in a JDBC program.

JDBC is effective in the following circumstances:

- Your program uses dynamic SQL. For example, you have a program that builds queries in real-time or has an interactive query component.
- You do not want to have a SQLJ layer during deployment or development. For example, you might want to download only the JDBC Thin driver and not the SQLJ runtime libraries to minimize download time over a slow link.

Note: You can intermix SQLJ code and JDBC code in the same source. This is discussed in the *Oracle9i SQLJ Developer's Guide and Reference.*

Overview of the Oracle JDBC Drivers



Common Features of Oracle JDBC Drivers

The server-side and client-side Oracle JDBC drivers provide the same basic functionality. They all support the following standards and features:

- either JDK 1.2.x / JDBC 2.0 or JDK 1.1.x / JDBC 1.22 (with Oracle extensions for JDBC 2.0 functionality)

  These two implementations use different sets of class files.
- same syntax and APIs
- same Oracle extensions
- full support for multi-threaded applications

Oracle JDBC drivers implement standard Sun Microsystems `java.sql` interfaces. Through the `oracle.jdbc` package, you can access the Oracle features in addition to the Sun features. This package is equivalent to the `oracle.jdbc.driver` package which is deprecated for Oracle9*i*.

Table 1–1 shows how the client-side drivers compare.

Table 1–1 JDBC Client-Side Drivers Compared at a Glance

Driver	Type	Size	Protocol	100% Java	Use	External Libraries Needed	Platform-dependent	Performance	Completeness of Features
Thin	IV	Small	TTC	Yes	Applet and application	No	No	Better	Better
OCI	II	Large	TTC	No	Application	Yes	Yes	Best	Best

Note: Most JDBC 2.0 functionality, including that for objects, arrays, and LOBs, is available in a JDK 1.1.x environment through Oracle extensions.

JDBC Thin Driver

The Oracle JDBC Thin driver is a 100% pure Java, Type IV driver. It is targeted for Oracle JDBC applets but can be used for applications as well. Because it is written entirely in Java, this driver is platform-independent. It does not require any additional Oracle software on the client side. The Thin driver communicates with the server using TTC, a protocol developed by Oracle to access the Oracle Relational Database Management System (RDBMS).

For applets it can be downloaded into a browser along with the Java applet being run. The HTTP protocol is stateless, but the Thin driver is not. The initial HTTP request to download the applet and the Thin driver is stateless. Once the Thin driver establishes the database connection, the communication between the browser and the database is stateful and in a two-tier configuration.

The JDBC Thin driver allows a direct connection to the database by providing an implementation of TCP/IP that emulates Oracle Net and TTC (the wire protocol used by OCI) on top of Java sockets. Both of these protocols are lightweight implementation versions of their counterparts on the server. The Oracle Net protocol runs over TCP/IP only.

The driver supports only TCP/IP protocol and requires a TNS listener on the TCP/IP sockets from the database server.

> **Note:** When the JDBC Thin driver is used with an applet, the client browser must have the capability to support Java sockets.

Using the Thin driver inside an Oracle server or middle tier is considered separately, under "JDBC Server-Side Thin Driver" below.

JDBC OCI Driver

The JDBC OCI driver is a Type II driver for use with client-server Java applications. This driver requires an Oracle client installation, and therefore is Oracle platform-specific and not suitable for applets.

> **Note:** In Oracle9*i*, the OCI driver is a single OCI driver for use with all database versions. It replaces the distinct OCI8 and OCI7 drivers of previous releases. While the OCI8 and OCI7 drivers are deprecated for Oracle9*i*, they are still supported for backward compatibility.

The JDBC OCI driver provides OCI connection pooling functionality, which can either be part of the JDBC client or a JDBC stored procedure. OCI driver connection pooling requires fewer physical connections than standard connection pooling, it also provides a uniform interface, and allows you to dynamically configure the attributes of the connection pool. For a complete description of OCI driver connection pooling, see "OCI Driver Connection Pooling" on page 16-2.

The OCI driver supports Oracle7, Oracle8/8*i*, and Oracle9*i* with the highest compatibility. It also supports all installed Oracle Net adapters, including IPC, named pipes, TCP/IP, and IPX/SPX.

The OCI driver, written in a combination of Java and C, converts JDBC invocations to calls to the Oracle Call Interface (OCI), using native methods to call C-entry points. These calls are then sent over Oracle Net to the Oracle database server. The OCI driver communicate with the server using the Oracle-developed TTC protocol.

The OCI driver uses the OCI libraries, C-entry points, Oracle Net, CORE libraries, and other necessary files on the client machine on which it is installed.

The Oracle Call Interface (OCI) is an application programming interface (API) that allows you to create applications that use the native procedures or function calls of a third-generation language to access an Oracle database server and control all phases of SQL statement execution. The OCI driver is designed to build scalable, multi-threaded applications that can support large numbers of users securely.

The Oracle9*i* JDBC OCI driver has the following functionality:

- Uses OCI
- Connection Pooling
- OCI optimized fetch
- Prefetching
- Fastest LOB access
- Client-side object cache
- Transparent Application Failover (TAF)
- Middle-tier authentication
- Advanced security

JDBC Server-Side Thin Driver

The Oracle JDBC server-side Thin driver offers the same functionality as the client-side Thin driver, but runs inside an Oracle database and accesses a remote database.

This is especially useful in two situations:

- to access a remote Oracle server from an Oracle server acting as a middle tier
- more generally, to access one Oracle server from inside another, such as from any Java stored procedure or Enterprise JavaBean

There is no difference in your code between using the Thin driver from a client application or from inside a server.

Note: Statement `cancel()` and `setQueryTimeout()` methods are not supported by the server-side Thin driver.

About Permission for the Server-Side Thin Driver The thin driver opens a socket to use for its connection. Because the Oracle server is enforcing the Java security model, this means that a check is performed for a `SocketPermission` object.

To use the JDBC server-side Thin driver, the connecting user must be granted with the appropriate permission. This is an example of how the permission can be granted for user `SCOTT`:

```
create role jdbcthin;
call dbms_java.grant_permission('JDBCTHIN',
'java.net.SocketPermission',
'*', 'connect' );
grant jdbcthin to scott;
```

Note that `JDBCTHIN` in the `grant_permission` call must be in upper case. The '*' is a pattern. It is possible to limit the permission to allow connecting to specific machines or ports. See the Javadoc for complete details on the `java.net.SocketPermission` class. Also, refer to the *Oracle9i Java Developer's Guide* for further discussion of Java security inside the Oracle server.

JDBC Server-Side Internal Driver

The Oracle JDBC server-side internal driver supports any Java code that runs inside an Oracle database, such as in a Java stored procedures or Enterprise JavaBean, and must access the same database. This driver allows the Java virtual machine (JVM) to communicate directly with the SQL engine.

The server-side internal driver, the JVM, the database, KPRB (server-side) C library, and the SQL engine all run within the same address space, so the issue of network round trips is irrelevant. The programs access the SQL engine by using function calls.

The server-side internal driver is fully consistent with the client-side drivers and supports the same features and extensions. For more information on the server-side internal driver, see "JDBC in the Server: the Server-Side Internal Driver" on page 17-26.

Note: The server-side internal driver supports only JDK 1.2.x.

Choosing the Appropriate Driver

Consider the following when choosing a JDBC driver to use for your application or applet:

- If you are writing an applet, you must use the JDBC Thin driver. JDBC OCI-based driver classes will not work inside a Web browser, because they call native (C language) methods.
- If you want maximum portability and performance, use the JDBC Thin driver. You can connect to an Oracle server from either an application or an applet using the JDBC Thin driver.
- If you are writing a client application for an Oracle client environment and need maximum performance, then choose the JDBC OCI driver.
- For code that runs in an Oracle server acting as a middle tier, use the server-side Thin driver.
- If your code will run inside the target Oracle server, then use the JDBC server-side internal driver to access that server. (You can also access remote servers using the server-side Thin driver.)
- If performance is critical to your application, you want maximum scalability of the Oracle server, or you need the enhanced availability features like TAF or the enhanced proxy features like middle-tier authentication

Overview of Application and Applet Functionality

This section compares and contrasts the basic functionality of JDBC applications and applets, and introduces Oracle extensions that can be used by application and applet programmers.

Application Basics

You can use either the Oracle JDBC Thin or OCI driver for a client application. Because the JDBC OCI driver uses native methods, there can be significant performance advantages in using this driver for your applications.

An application that can run on a client can also run in the Oracle server, using the JDBC server-side internal driver.

If you are using a JDBC OCI driver in an application, then the application will require an Oracle installation on its clients. For example, the application will require the installation of Oracle Net and client libraries.

The JDBC Thin and OCI drivers offer support for data encryption and integrity checksum features of the Oracle Advanced Security option (formerly known as ANO or ASO). See "JDBC Client-Side Security Features" on page 17-8. Such security is not necessary for the server-side internal driver.

Applet Basics

This section describes the issues you should take into consideration if you are writing an applet that uses the JDBC Thin driver.

For more about applets and a discussion of relevant firewall, browser, and security issues, see "JDBC in Applets" on page 17-15.

Applets and Security

Without special preparations, an applet can open network connections only to the host machine from which it was downloaded. Therefore, an applet can connect to databases only on the originating machine. If you want to connect to a database running on a different machine, you have two options:

- Use the Oracle Connection Manager on the host machine. The applet can connect to Connection Manager, which in turn connects to a database on another machine.
- Use signed applets, which can request socket connection privileges to other machines.

Both of these topics are described in greater detail in "Connecting to the Database through the Applet" on page 17-15.

The Thin driver offers support for data encryption and integrity checksum features of the Oracle Advanced Security option. See "JDBC Client-Side Security Features" on page 17-8.

Applets and Firewalls

An applet that uses the JDBC Thin driver can connect to a database through a firewall. See "Using Applets with Firewalls" on page 17-20 for more information on configuring the firewall and on writing connect strings for the applet.

Packaging and Deploying Applets

To package and deploy an applet, you must place the JDBC Thin driver classes and the applet classes in the same zip file. This is described in detail in "Packaging Applets" on page 17-23.

Oracle Extensions

A number of Oracle extensions are available to Oracle JDBC application and applet programmers, in the following categories:

- type extensions (such as ROWIDs and REF CURSOR types)
- wrapper classes for SQL types (the `oracle.sql` package)
- support for custom Java classes to map to user-defined types
- extended LOB support
- extended connection, statement, and result set functionality
- performance enhancements

See Chapter 6, "Overview of Oracle Extensions" for an overview of type extensions and extended functionality, and succeeding chapters for further detail. See Chapter 12, "Performance Extensions" regarding Oracle performance enhancements.

Package oracle.jdbc

Beginning in Oracle9*i*, the Oracle extensions to JDBC are captured in the package `oracle.jdbc`. This package contains classes and interfaces that specify the Oracle extensions in a manner similar to the way the classes and interfaces in `java.sql` specify the public JDBC API.

Your code should use the package `oracle.jdbc` instead of the package `oracle.jdbc.driver` used in earlier versions of Oracle. Use of the package `oracle.jdbc.driver` is now deprecated, but will continue to be supported for backwards compatibility.

All that is required to convert your code is to replace "`oracle.jdbc.driver`" with "`oracle.jdbc`" in the source and recompile. This cannot be done piece-wise. You must convert all classes and interfaces that are referenced by an application. Conversion is not required, but is highly recommended. Future releases of Oracle may have features that are incompatible with use of the package `oracle.jdbc.driver`.

The purpose of this change is to enable the Oracle JDBC drivers to have multiple implementations. In all releases up to and including Oracle9*i*, all of the Oracle JDBC drivers have used the same top level implementation classes, the classes in the package `oracle.jdbc.driver`. By converting your code to use `oracle.jdbc`, you will be able to take advantage of future enhancements that use different implementation classes. There are no such enhancements in Oracle9*i*, but there are plans for such enhancements in the future.

Additionally, these interfaces permit the use of some code patterns that are difficult to use when your code uses the package `oracle.jdbc.driver`. For example, you can more easily develop wrapper classes for the Oracle JDBC classes. If you wished to wrap the `OracleStatement` class in order to log all SQL statements, you could easily do so by creating a class that wraps `OracleStatment`. That class would implement the interface `oracle.jdbc.OracleStatement` and hold an `oracle.jdbc.OracleStatement` as an instance variable. This wrapping pattern is much more difficult when your code uses the package `oracle.jdbc.driver` as you cannot extend the class `oracle.jdbc.driver.OracleStatement`.

Once again, your code should use the new package `oracle.jdbc` instead of the package `oracle.jdbc.driver`. Conversion is not required as `oracle.jdbc.driver` will continue to be supported for backwards compatibility. Conversion is highly recommended as there may in later releases be features that are not supported if your code uses `oracle.jdbc.driver`.

Server-Side Basics

By using the Oracle JDBC server-side internal driver, code that runs in an Oracle database, such as in Java stored procedures or Enterprise JavaBeans, can access the database in which it runs.

For a complete discussion of the server-side driver, see "JDBC in the Server: the Server-Side Internal Driver" on page 17-26.

Session and Transaction Context

The server-side internal driver operates within a default session and default transaction context. For more information on default session and transaction context for the server-side driver, see "Session and Transaction Context for the Server-Side Internal Driver" on page 17-30.

Connecting to the Database

The server-side internal driver uses a default connection to the database. You can connect to the database with either the `DriverManager.getConnection()` method or the Oracle-specific `OracleDriver` class `defaultConnection()` method. For more information on connecting to the database with the server-side driver, see "Connecting to the Database with the Server-Side Internal Driver" on page 17-26.

Environments and Support

This section provides a brief discussion of platform, environment, and support features of the Oracle JDBC drivers. The following topics are discussed:

- Supported JDK and JDBC Versions
- JNI and Java Environments
- JDBC and IDEs

Supported JDK and JDBC Versions

Starting at Oracle8*i* release 8.1.6, Oracle has two versions of the Thin and OCI drivers—one that is compatible with versions JDK 1.2.x and higher, and one that is compatible with JDK 1.1.x. The JDK 1.2.x versions support standard JDBC 2.0. The JDK 1.1.x versions support most JDBC 2.0 features, but must do so through Oracle extensions because JDBC 2.0 features are not available in JDK 1.1.x versions.

Very little is required to migrate from a JDK 1.1.x environment to a JDK 1.2.x environment. For information, see "Migration from JDK 1.1.x to JDK 1.2.x" on page 4-5.

Notes:

- The server-side internal driver supports only JDK 1.2.x.
- Each driver implementation uses its own JDBC classes ZIP file—`classes12.zip` for JDK 1.4, 1.3.x, and1.2.x versions, and `classes111.zip` for JDK 1.1.x versions.

For information about supported combinations of driver versions, JDK versions, and database versions, see "Requirements and Compatibilities for Oracle JDBC Drivers" on page 2-2.

JNI and Java Environments

Beginning with Oracle8*i* release 8.1.6, the Oracle JDBC OCI driver uses the standard JNI (Java Native Interface) to call Oracle OCI C libraries. Prior to 8.1.6, when the OCI drivers supported JDK 1.0.2, they used NMI (Native Method Interface) for C calls. NMI was an earlier specification by Sun Microsystems and was the only native call interface supported by JDK 1.0.2.

Because JNI is now supported by Oracle JDBC, you can use the OCI driver with Java virtual machines other than that of Sun Microsystems—in particular, with Microsoft and IBM JVMs. These JVMs support only JNI for native C calls.

JDBC and IDEs

The Oracle JDeveloper Suite provides developers with a single, integrated set of products to build, debug, and deploy component-based database applications for the Oracle Internet platform. The Oracle JDeveloper environment contains integrated support for JDBC and SQLJ, including the 100% pure JDBC Thin driver and the native OCI drivers. The database component of Oracle JDeveloper uses the JDBC drivers to manage the connection between the application running on the client and the server. See your Oracle JDeveloper documentation for more information.

Changes At This Release

Release 2 (9.2) of Oracle JDBC provides the following enhancements:

- Support for some JDBC 3.0 and JDK 1.4 features. See Chapter 5, "Overview of Supported JDBC 3.0 Features".
- A new statement cache API; the old API is now deprecated. See Chapter 18, "Statement Caching".
- Support for the Oracle datatypes TS, TSTZ, and TSLTZ .

Desupport Of J2EE In The Oracle Database

With the introduction of Oracle9i Application Server Containers for J2EE (OC4J)—a new, lighter-weight, easier-to-use, faster, and certified J2EE container—Oracle will desupport the Java 2 Enterprise Edition (J2EE) and CORBA stacks from the database, starting with Oracle9i Database release 2. However, the database-embedded Java VM (Oracle JVM) will still be present and will continue to be enhanced to offer Java 2 Standard Edition (J2SE) features, Java stored procedures, JDBC, and SQLJ in the database.

As of Oracle9*i*DB Release 2 (version 9.2.0), Oracle will no longer support the following technologies in the database:

- Enterprise Java Beans (EJB) container
- JavaServer Pages (JSP) container
- Oracle Servlet Engine (OSE)
- the embedded Common Object Request Broker Architecture (CORBA) framework based on Visibroker for Java

Customers will no longer be able to deploy servlets, JSP pages, EJBs and CORBA objects in Oracle databases . Oracle9*i* Release 1 (version 9.0.1) will be the last database release to support the J2EE and CORBA stack. Oracle is encouraging customers to migrate existing J2EE applications running in the database to OC4J now.

2

Getting Started

This chapter begins by discussing compatibilities between Oracle JDBC driver versions, database versions, and JDK versions. It then guides you through the basics of testing your installation and configuration, and running a simple application. The following topics are discussed:

- Requirements and Compatibilities for Oracle JDBC Drivers
- Verifying a JDBC Client Installation

Requirements and Compatibilities for Oracle JDBC Drivers

Table 2–1 lists the compatibilities between Oracle JDBC driver versions and Oracle database versions. The JDK versions supported by each JDBC driver version are also listed.

Note: Notice that starting with Oracle8*i* release 8.1.6, the Oracle JDBC drivers no longer support JDK 1.0.x versions.

Table 2–1 JDBC Driver-Database Compatibility

Driver Versions	Database Versions Supported	JDK Versions Supported	Drivers Available	Remarks
9.2.0	9.2.0, 9.0.1, 8.1.7, 8.1.6, 8.1.5, 8.0.6, 8.0.5, 8.0.4	1.4, 1.3.x,1.2.x, 1.1.x	JDBC Thin driver	
			JDBC OCI driver	
			JDBC server-side Thin driver	
			JDBC server-side internal driver (*supports 9.2.0 database and JDK 1.2.x only*)	
9.0.1	9.0.1, 8.1.7, 8.1.6, 8.1.5, 8.0.6, 8.0.5, 8.0.4, 7.3.4	1.2.x, 1.1.x	JDBC Thin driver	
			JDBC OCI driver	
			JDBC server-side Thin driver	
			JDBC server-side internal driver (*supports 9.0.1 database and JDK 1.2.x only*)	
8.1.7	8.1.7, 8.1.6, 8.1.5, 8.0.6, 8.0.5, 8.0.4, 7.3.4	1.2.x, 1.1.x	JDBC Thin driver	
			JDBC OCI driver	
			JDBC server-side Thin driver	
			JDBC server-side internal driver (*supports 8.1.7 database and JDK 1.2.x only*)	

Table 2–1 JDBC Driver-Database Compatibility(Cont.)

Driver Versions	Database Versions Supported	JDK Versions Supported	Drivers Available	Remarks
8.1.6	8.1.6, 8.1.5, 8.0.6, 8.0.5, 8.0.4, 7.3.4	1.2.x, 1.1.x	JDBC Thin driver JDBC OCI driver JDBC server-side Thin driver JDBC server-side internal driver (*supports 8.1.6 database and JDK 1.2.x only*)	The Thin driver is also available in the server with the standard server installation. This has the same usage and functionality as the client-side Thin driver, for accessing a remote database from inside a database.
8.1.5	8.1.5, 8.0.6, 8.0.5, 8.0.4, 7.3.4	1.1.x, 1.0.x	JDBC Thin driver JDBC OCI driver JDBC server-side internal driver (*supports 8.1.5 database and JDK 1.1.x only*)	Both client- and server-side drivers offer full support for structured objects when run against an 8.1.5 database.
8.0.6	8.0.6, 8.0.5, 8.0.4, 7.3.4	1.1.x, 1.0.x	JDBC Thin driver JDBC OCI driver ***Note:*** *the JDBC server-side internal driver is not available for 8.0.x and prior versions.*	.
8.0.5	8.0.5, 8.0.4, 7.3.4	1.1.x, 1.0.x	JDBC Thin driver JDBC OCI driver ***Note:*** *the JDBC server-side internal driver is not available for 8.0.x and prior versions.*	
8.0.4	8.0.4, 7.3.4	1.1.x, 1.0.x	JDBC Thin driver JDBC OCI driver ***Note:*** *the JDBC server-side internal driver is not available for 8.0.x and prior versions.*	

Notes:

- Different JDKs require different class files—classes in `classes12.zip`, `classes111.zip`, respectively.
- The JDBC drivers do not support structured objects when run against an 8.0.*x* database. This is because JDBC depends on PL/SQL functions that did not exist in those releases.
- Any client-side driver might work with 7.x databases, but this has not been tested and is not supported.

Verifying a JDBC Client Installation

This section covers the following topics:

- Check Installed Directories and Files
- Check the Environment Variables
- Make Sure You Can Compile and Run Java
- Determine the Version of the JDBC Driver
- Testing JDBC and the Database Connection: JdbcCheckup

Installation of an Oracle JDBC driver is platform-specific. Follow the installation instructions for the driver you want to install in your platform-specific documentation.

This section describes the steps of verifying an Oracle client installation of the JDBC drivers. It assumes that you have already installed the driver of your choice.

If you have installed the JDBC Thin driver, no further installation on the client machine is necessary (the JDBC Thin driver requires a TCP/IP listener to be running on the database machine).

If you have installed the JDBC OCI driver, you must also install the Oracle client software. This includes Oracle Net and the OCI libraries.

Check Installed Directories and Files

This section assumes that you have already installed the Sun Microsystems *Java Developer's Kit (JDK)* on your system (although other forms of Java are also supported). Oracle offers JDBC drivers compatible with the JDK1.4, 1.3.x, 1.2.x, and 1.1.x versions.

Installing the Oracle9 Java products creates, among other things, an `[ORACLE_HOME]/jdbc` directory containing these subdirectories and files:

- `demo/samples`: The `samples` subdirectory contains sample programs, including examples of how to use SQL92 and Oracle SQL syntax, PL/SQL blocks, streams, user-defined types, additional Oracle type extensions, and Oracle performance extensions.
- `doc`: The `doc` directory contains documentation about the JDBC drivers.
- `lib`: The `lib` directory contains `.zip` files with these required Java classes:

  - `classes12.zip` contains the classes for use with 1.2.x, 1.3.x, and 1.4—all the JDBC driver classes except the classes necessary for globalization support.
  - `nls_charset12.zip` contains the classes necessary for globalization support with JDK 1.2.x, 1.3.x, and 1.4.
  - `jta.zip` and `jndi.zip` contain classes for the Java Transaction API and the Java Naming and Directory Interface for JDK 1.2.x, 1.3.x, and 1.4. These are only required if you will be using JTA features for distributed transaction management or JNDI features for naming services. (These files can also be obtained from the Sun Microsystems Web site, but it is advisable to use the versions from Oracle, because those have been tested with the Oracle drivers.)
  - `classes111.zip` contains the classes for use with JDK 1.1.x—all the JDBC driver classes except the classes necessary for globalization support.

    `classes111.zip` also contains Oracle extensions that allow you to use JDBC 2.0 functionality for objects, arrays, and LOBs under JDK 1.1.x.
  - `nls_charset11.zip` contains the classes necessary for globalization support with the JDK 1.1.x.

  The `nls_charset12.zip` and `nls_charset11.zip` files provide support for specific character sets. They have been separated out from the `classes*.zip` files to give you the option of excluding character sets in situations where complete globalization support is not needed. For more information on `nls_charset12.zip` and `nls_charset11.zip`, see "Globalization Support and Object Types" on page 17-4.

  - `ojdbc14.jar` contains classes for use with JDK 1.4. It contains the JDBC driver classes except classes necessary for globalization support in Object and Collection types.

- `readme.txt`: The `readme.txt` file contains late-breaking and release-specific information about the drivers that might not be in this manual.

Check that all these directories have been created and populated.

Check the Environment Variables

This section describes the environment variables that must be set for the JDBC OCI driver and the JDBC Thin driver, focusing on the Sun Microsystems Solaris and Microsoft Windows NT platforms.

You must set the CLASSPATH for your installed JDBC OCI or Thin driver. Depending on which JDK version you use, you must set one of these values for the CLASSPATH:

JDK Version	CLASSPATH
1.4, 1.3.x, 1.2.x	`[OracleHome]/jdbc/lib/classes12.zip` `[OracleHome]/jdbc/lib/nls_charset12.zip` for full globalization support
1.1.x	`[OracleHome]/jdbc/lib/classes111.zip` `[OracleHome]/jdbc/lib/nls_charset11.zip` for full globalization support

Ensure that there is only one `classes*.zip` file version and one `nls_charset*.zip` file version in your CLASSPATH.

> **Note:** If you will be using JTA features or JNDI features, both of which are discussed in Chapter 15, "Connection Pooling and Caching", then you will also need to have `jta.zip` and `jndi.zip` in your CLASSPATH.

JDBC OCI Driver: If you are installing the JDBC OCI driver, you must also set the following value for the library path environment variable

- On Solaris, set LD_LIBRARY_PATH as follows:

  ```
  [Oracle Home]/lib
  ```

  This directory contains the `libocijdbc9.so` shared object library.

- On Windows NT, set PATH as follows:

  ```
  [Oracle Home]\lib
  ```

  This directory contains the `ocijdbc8.dll` dynamic link library.

JDBC Thin Drivers: If you are installing the JDBC Thin driver, you do not have to set any other environment variables.

Make Sure You Can Compile and Run Java

To further ensure that Java is set up properly on your client system, go to the `samples` directory (for example, `C:\oracle\ora81\jdbc\demo\samples` if you are using the JDBC driver on a Windows NT machine), then see if `javac` (the Java compiler) and `java` (the Java interpreter) will run without error. Enter:

```
javac
```

then enter:

```
java
```

Each should give you a list of options and parameters and then exit. Ideally, verify that you can compile and run a simple test program.

Determine the Version of the JDBC Driver

If at any time you must determine the version of the JDBC driver that you installed, you can invoke the `getDriverVersion()` method of the `OracleDatabaseMetaData` class.

Here is sample code showing how to do it:

```
import java.sql.*;
import oracle.jdbc.driver.*;

class JDBCVersion
{
   public static void main (String args[])
          throws SQLException
   {
      // Load the Oracle JDBC driver
      DriverManager.registerDriver
              (new oracle.jdbc.driver.OracleDriver());
      Connection conn = DriverManager.getConnection
              ("jdbc:oracle:thin:scott/tiger@host:port/service");

      // Create Oracle DatabaseMetaData object
      DatabaseMetaData meta = conn.getMetaData();

      // gets driver info:
      System.out.println("JDBC driver version is " + meta.getDriverVersion());
   }
}
```

Testing JDBC and the Database Connection: JdbcCheckup

The `samples` directory contains sample programs for a particular Oracle JDBC driver. One of the programs, `JdbcCheckup.java`, is designed to test JDBC and the database connection. The program queries you for your user name, password, and the name of a database to which you want to connect. The program connects to the database, queries for the string "`Hello World`", and prints it to the screen.

Go to the `samples` directory and compile and run `JdbcCheckup.java`. If the results of the query print without error, then your Java and JDBC installations are correct.

Although `JdbcCheckup.java` is a simple program, it demonstrates several important functions by executing the following:

- imports the necessary Java classes, including JDBC classes
- registers the JDBC driver
- connects to the database
- executes a simple query
- outputs the query results to your screen

"First Steps in JDBC" on page 3-2, describes these functions in greater detail. A listing of `JdbcCheckup.java` for the JDBC OCI driver appears below.

```
/*
 * This sample can be used to check the JDBC installation.
 * Just run it and provide the connect information.  It will select
 * "Hello World" from the database.
 */

// You need to import the java.sql package to use JDBC
import java.sql.*;

// We import java.io to be able to read from the command line
import java.io.*;

class JdbcCheckup
{
   public static void main(String args[])
          throws SQLException, IOException
   {
      // Load the Oracle JDBC driver
      DriverManager.registerDriver(new oracle.jdbc.driver.OracleDriver());
```

```
   // Prompt the user for connect information
   System.out.println("Please enter information to test connection to
                       the database");
   String user;
   String password;
   String database;

   user = readEntry("user: ");
   int slash_index = user.indexOf('/');
   if (slash_index != -1)
   {
      password = user.substring(slash_index + 1);
      user = user.substring(0, slash_index);
   }
   else
      password = readEntry("password: ");
   database = readEntry("database(a TNSNAME entry): ");

   System.out.print("Connecting to the database...");
   System.out.flush();

   System.out.println("Connecting...");
   Connection conn = DriverManager.getConnection
                     ("jdbc:oracle:oci:@" + database, user, password);
   System.out.println("connected.");

   // Create a statement
   Statement stmt = conn.createStatement();

   // Do the SQL "Hello World" thing
   ResultSet rset = stmt.executeQuery("select 'Hello World'
                                       from dual");

   while (rset.next())
      System.out.println(rset.getString(1));
   // close the result set, the statement and connect
   rset.close();
   stmt.close();
   conn.close();
   System.out.println("Your JDBC installation is correct.");
}

// Utility function to read a line from standard input
static String readEntry(String prompt)
{
```

```
      try
      {
         StringBuffer buffer = new StringBuffer();
         System.out.print(prompt);
         System.out.flush();
         int c = System.in.read();
         while (c != '\n' && c != -1)
         {
            buffer.append((char)c);
            c = System.in.read();
         }
         return buffer.toString().trim();
      }
      catch(IOException e)
      {
         return "";
      }
   }
}
```

3

Basic Features

This chapter covers the most basic steps taken in any JDBC application. It also describes additional basic features of Java and JDBC supported by the Oracle JDBC drivers.

The following topics are discussed:

- First Steps in JDBC
- Sample: Connecting, Querying, and Processing the Results
- Datatype Mappings
- Java Streams in JDBC
- Stored Procedure Calls in JDBC Programs
- Processing SQL Exceptions

First Steps in JDBC

This section describes how to get up and running with the Oracle JDBC drivers. When using the Oracle JDBC drivers, you must include certain driver-specific information in your programs. This section describes, in the form of a tutorial, where and how to add the information. The tutorial guides you through creating code to connect to and query a database from the client.

To connect to and query a database from the client, you must provide code for these tasks:

1. Importing Packages
2. Registering the JDBC Drivers
3. Opening a Connection to a Database
4. Creating a Statement Object
5. Executing a Query and Return a Result Set Object
6. Processing the Result Set
7. Closing the Result Set and Statement Objects
8. Making Changes to the Database
9. Committing Changes
10. Closing the Connection

You must supply Oracle driver-specific information for the first three tasks, which allow your program to use the JDBC API to access a database. For the other tasks, you can use standard JDBC Java code as you would for any Java application.

Importing Packages

Regardless of which Oracle JDBC driver you use, include the following `import` statements at the beginning of your program (`java.math` only if needed):

`import java.sql.*;`	for standard JDBC packages
`import java.math.*;`	for `BigDecimal` and `BigInteger` classes

Import the following Oracle packages when you want to access the extended functionality provided by the Oracle drivers. However, they are not required for the example presented in this section:

```
import oracle.jdbc.*;          for Oracle extensions to JDBC
import oracle.sql.*;
```

For an overview of the Oracle extensions to the JDBC standard, see Chapter 6, "Overview of Oracle Extensions".

Registering the JDBC Drivers

You must provide the code to register your installed driver with your program. You do this with the static `registerDriver()` method of the JDBC `DriverManager` class. This class provides a basic service for managing a set of JDBC drivers.

Note: Alternatively, you can use the `forName()` method of the `java.lang.Class` class to load the JDBC drivers directly. For example:

```
Class.forName ("oracle.jdbc.OracleDriver");
```

However, this method is valid only for JDK-compliant Java virtual machines. It is not valid for Microsoft Java virtual machines.

Because you are using one of Oracle's JDBC drivers, you declare a specific driver name string to `registerDriver()`. You register the driver only once in your Java application.

```
DriverManager.registerDriver (new oracle.jdbc.OracleDriver());
```

Opening a Connection to a Database

Open a connection to the database with the static `getConnection()` method of the JDBC `DriverManager` class. To create a connection, you must specify a connection string containing a database URL.

Notes: Many applications use datasources and JNDI (Java Naming and Directory Interface) to make connections. See "A Brief Overview of Oracle Data Source Support for JNDI" on page 15-2 and "Creating a Data Source Instance, Registering with JNDI, and Connecting" on page 15-8.

Oracle JDBC does not support login timeouts. Calling the static `DriverManager.setLoginTimeout()` method has no effect.

Database URLs and Database Specifiers

Database URLs are strings. The complete URL syntax is:

`jdbc:oracle:<driver_type>:[<username>/<password>]@<database_specifier>`

Notes: The brackets indicate that the `<username>/<password>` pair is optional.

kprb, the internal server-side driver, uses an implicit connection; database URLs for the server-side driver end after the `<driver_type>`. See "Connecting to the Database with the Server-Side Internal Driver" on page 17-26.

The Thin driver does not support OS authentication in making the connection, and therefore does not support special logins.

The remainder of the URL contains an optional username and password separated by a slash, an @, and the *database specifier*, which uniquely identifies the database being connected. Some database specifiers are valid only for the Thin driver, some only for the OCI driver, and some for both. The following list gives the valid database specifiers, and gives an example of each specifier within a valid database URL:

- an Oracle Net connection descriptor (Thin and OCI drivers)

```
"jdbc:oracle:thin:@(description=(address=(host=myhost)
(protocol=tcp)(port=1521))(connect_data=(SERVICE_NAME=orcl)))"
```

- a TNS connection string (Thin and OCI drivers)

```
"jdbc:oracle:thin:@(description=(address_list=
   (address=(protocol=tcp)(port=1521)(host=prodHost)))
```

```
   (connect_data=(sid=ORCL)))"
"jdbc:oracle:oci:@(DESCRIPTION=(ADDRESS=(PROTOCOL=tcp)(PORT=1521)
  (HOST=myhost))(CONNECT_DATA=(SID=mrwork)(FAILOVER_MODE=(TYPE=SELECT)
  (METHOD=BASIC)(BACKUP=inst2_failback))))"
```

> **Note:** For information on how to specify an Oracle Net connection descriptor or a TNS connection string, see your *Oracle Net Services Administrator's Guide*.

- **(Thin driver only)** @ / / <*host_name*>:<*port_number*> / <*service_name*>

```
"jdbc:oracle:thin:scott/tiger@//myhost:1521/myservicename"
```

> **Notes:** *host_name* can be the name of a single host or a *cluster_alias* .
>
> The JDBC Thin driver supports only the TCP / IP protocol..

- **(Thin driver only)** @ / / <*host_name*>:<*port_number*>:<*service_id*>

```
"jdbc:oracle:thin:scott/tiger@//myhost:1521:serviceid"
```

> **Note:** Oracle is replacing the SID mechanism for identifying databases with service names. We strongly encourage you to transition from SIDs to service names as quickly as possible, because SIDs will stop being supported in a future database release.

- **(Thin driver only)** directory naming using LDAP syntax (see your *Oracle Net Services Administrator's Guide* for details.)

```
"jdbc:oracle:thin:@ldap://ldap.acme.com:7777/sales,cn=OracleContext,dc=com"
```

- **(OCI driver only)** Empty database specifier (means that the connection uses the OCI bequeathed connection to connect to the default Oracle database)

```
"jdbc:oracle:oci:scott/tiger"
```

- **(OCI driver only)** a TNSNAMES alias (deprecated)

You can find the available TNSNAMES entries listed in the file tnsnames.ora on the client computer from which you are connecting. On Windows NT, this file is located in the [ORACLE_HOME]\NETWORK\ADMIN directory. On UNIX systems, you can find it in the /var/opt/oracle directory.

For example, if you want to connect to the database on host myhost as user scott with password tiger that has a TNSNAMES entry of MyHostString, enter:

```
Connection conn = DriverManager.getConnection
  ("jdbc:oracle:oci:@MyHostString", "scott", "tiger");
```

Note: Because the JDBC Thin driver can be used in applets that do not depend on an Oracle client installation, you cannot use a TNSNAMES entry to set up a Thin driver connection.

Understanding the Forms of getConnection()

Ther are several different DriverManager.getConnection() methods:

- One that accepts a database URL, user name, and password as separate arguments (see "Specifying a Database URL, User Name, and Password" on page 3-6).
- One that accepts a database URL containing user name and password (see "Specifying a Database URL That Includes User Name and Password" on page 3-7).
- One that accepts a database URL and a properties object (see "Specifying a Database URL and Properties Object" on page 3-7.)

Specifying a Database URL, User Name, and Password

The following signature takes the URL, user name, and password as separate parameters:

```
getConnection(String URL, String user, String password);
```

(For URL format, see Database URLs and Database Specifiers on page 3-4.)

The following example connects user scott with password tiger to a database with service orcl through port 1521 of host myhost, using the Thin driver.

```
Connection conn = DriverManager.getConnection
                  ("jdbc:oracle:thin:@//myhost:1521/orcl","scott", "tiger");
```

Note: A username and password specified in the arguments override any username and specified in the URL.

Specifying a Database URL That Includes User Name and Password

The following signature takes a URL parameter that contains an embedded username and password:

```
getConnection(String URL);
```

(For URL format, see Database URLs and Database Specifiers on page 3-4.)

The following example connects user `scott` with password `tiger` to a database on host `myhost` using the OCI driver. In this case, however, the URL includes the userid and password, and is the only input parameter.

```
Connection conn = DriverManager.getConnection
                        ("jdbc:oracle:oci:scott/tiger@myhost);
```

If you want to connect using the Thin driver you must specify the port number. For example, if you want to connect to the database on host `myhost` that has a TCP/IP listener up on port 1521 and the service identifier is `orcl`:

```
Connection conn = DriverManager.getConnection
                        ("jdbc:oracle:thin:scott/tiger@myhost:1521/orcl);
```

Specifying a Database URL and Properties Object

The following signature takes a URL and a properties object that specifies user name and password (perhaps among other things):

```
getConnection(String URL, Properties info);
```

(For URL format, see Database URLs and Database Specifiers on page 3-4.) In addition to the URL, use an object of the standard Java `Properties` class as input. For example:

```
java.util.Properties info = new java.util.Properties();
info.put ("user", "scott");
info.put ("password","tiger");
info.put ("defaultRowPrefetch","15");
getConnection ("jdbc:oracle:oci:@",info);
```

Note: A username and password specified in the properties override any username specified in the URL and/or in arguments.

Table 3–1 lists the connection properties that Oracle JDBC drivers support.

Table 3–1 Connection Properties Recognized by Oracle JDBC Drivers

Name	Short Name	Type	Description
user	n/a	String	the user name for logging into the database
password	n/a	String	the password for logging into the database
database	server	String	the connect string for the database
internal_logon	n/a	String	a role, such as `sysdba` or `sysoper`, that allows you to log on as `sys`
defaultRowPrefetch	prefetch	String (containing integer value)	the default number of rows to prefetch from the server (default value is "10")
remarksReporting	remarks	String (containing boolean value)	"true" if `getTables()` and `getColumns()` should report `TABLE_REMARKS`; equivalent to using `setRemarksReporting()` (default value is "false")
defaultBatchValue	batchvalue	String (containing integer value)	the default batch value that triggers an execution request (default value is "10")
includeSynonyms	synonyms	String (containing boolean value)	"true" to include column information from predefined "synonym" SQL entities when you execute a `DataBaseMetaData getColumns()` call; equivalent to connection `setIncludeSynonyms()` call (default value is "false")

Table 3–1 Connection Properties Recognized by Oracle JDBC Drivers (Cont.)

Name	Short Name	Type	Description
processEscapes		String (containing boolean value)	"true" if escape processing is enabled for all statements, "false" if escape processing is disabled (default value is "false")

See Table 17–4, "OCI Driver Client Parameters for Encryption and Integrity" and Table 17–5, "Thin Driver Client Parameters for Encryption and Integrity" for descriptions of encryption and integrity drivers.

Using Roles for Sys Logon

To specify the role (mode) for `sys` logon, use the `internal_logon` connection property. (See Table 3–1, "Connection Properties Recognized by Oracle JDBC Drivers", for a complete description of this connection property.) To logon as `sys`, set the `internal_logon` connection property to `sysdba` or `sysoper`.

> **Note:** The ability to specify a role is supported only for `sys` user name.

Example The following example illustrates how to use the `internal_logon` and `sysdba` arguments to specify `sys` logon.

```
//import packages and register the driver
import java.sql.*;
import java.math.*;
DriverManager.registerDriver (new oracle.jdbc.OracleDriver());

//specify the properties object
java.util.Properties info = new java.util.Properties();
info.put ("user", "sys");
info.put ("password", "change_on_install");
info.put ("internal_logon","sysdba");

//specify the connection object
Connection conn = DriverManager.getConnection
                        ("jdbc:oracle:thin:@database",info);
...
```

Properties for Oracle Performance Extensions Some of these properties are for use with Oracle performance extensions. Setting these properties is equivalent to using corresponding methods on the `OracleConnection` object, as follows:

- Setting the `defaultRowPrefetch` property is equivalent to calling `setDefaultRowPrefetch()`.

  See "Oracle Row Prefetching" on page 12-20.

- Setting the `remarksReporting` property is equivalent to calling `setRemarksReporting()`.

  See "DatabaseMetaData TABLE_REMARKS Reporting" on page 12-26.

- Setting the `defaultBatchValue` property is equivalent to calling `setDefaultExecuteBatch()`.

  See "Oracle Update Batching" on page 12-4.

Example The following example shows how to use the `put()` method of the `java.util.Properties` class, in this case to set Oracle performance extension parameters.

```
//import packages and register the driver
import java.sql.*;
import java.math.*;
DriverManager.registerDriver (new oracle.jdbc.OracleDriver());

//specify the properties object
java.util.Properties info = new java.util.Properties();
info.put ("user", "scott");
info.put ("password", "tiger");
info.put ("defaultRowPrefetch","20");
info.put ("defaultBatchValue", "5");

//specify the connection object
Connection conn = DriverManager.getConnection
                        ("jdbc:oracle:thin:@database",info);
...
```

Creating a Statement Object

Once you connect to the database and, in the process, create your `Connection` object, the next step is to create a `Statement` object. The `createStatement()` method of your JDBC `Connection` object returns an object of the JDBC

`Statement` class. To continue the example from the previous section where the `Connection` object `conn` was created, here is an example of how to create the `Statement` object:

```
Statement stmt = conn.createStatement();
```

Note that there is nothing Oracle-specific about this statement; it follows standard JDBC syntax.

Executing a Query and Return a Result Set Object

To query the database, use the `executeQuery()` method of your `Statement` object. This method takes a SQL statement as input and returns a JDBC `ResultSet` object.

To continue the example, once you create the `Statement` object `stmt`, the next step is to execute a query that populates a `ResultSet` object with the contents of the `ENAME` (employee name) column of a table of employees named `EMP`:

```
ResultSet rset = stmt.executeQuery ("SELECT ename FROM emp");
```

Again, there is nothing Oracle-specific about this statement; it follows standard JDBC syntax.

Processing the Result Set

Once you execute your query, use the `next()` method of your `ResultSet` object to iterate through the results. This method steps through the result set row by row, detecting the end of the result set when it is reached.

To pull data out of the result set as you iterate through it, use the appropriate `getXXX()` methods of the `ResultSet` object, where `XXX` corresponds to a Java datatype.

For example, the following code will iterate through the `ResultSet` object `rset` from the previous section and will retrieve and print each employee name:

```
while (rset.next())
   System.out.println (rset.getString(1));
```

Once again, this is standard JDBC syntax. The `next()` method returns false when it reaches the end of the result set. The employee names are materialized as Java strings.

Closing the Result Set and Statement Objects

You must explicitly close the `ResultSet` and `Statement` objects after you finish using them. This applies to all `ResultSet` and `Statement` objects you create when using the Oracle JDBC drivers. The drivers do not have finalizer methods; cleanup routines are performed by the `close()` method of the `ResultSet` and `Statement` classes. If you do not explicitly close your `ResultSet` and `Statement` objects, serious memory leaks could occur. You could also run out of cursors in the database. Closing a result set or statement releases the corresponding cursor in the database.

For example, if your `ResultSet` object is `rset` and your `Statement` object is `stmt`, close the result set and statement with these lines:

```
rset.close();
stmt.close();
```

When you close a `Statement` object that a given `Connection` object creates, the connection itself remains open.

Note: Typically, you should put `close()` statements in a `finally` clause.

Making Changes to the Database

To write changes to the database, such as for `INSERT` or `UPDATE` operations, you will typically create a `PreparedStatement` object. This allows you to execute a statement with varying sets of input parameters. The `prepareStatement()` method of your JDBC `Connection` object allows you to define a statement that takes variable bind parameters, and returns a JDBC `PreparedStatement` object with your statement definition.

Use `setXXX()` methods on the `PreparedStatement` object to bind data into the prepared statement to be sent to the database. The various `setXXX()` methods are described in "Standard setObject() and Oracle setOracleObject() Methods" on page 7-11 and "Other setXXX() Methods" on page 7-12.

Note that there is nothing Oracle-specific about the functionality described here; it follows standard JDBC syntax.

The following example shows how to use a prepared statement to execute `INSERT` operations that add two rows to the `EMP` table.

```
    // Prepare to insert new names in the EMP table
```

```
PreparedStatement pstmt =
  conn.prepareStatement ("insert into EMP (EMPNO, ENAME) values (?, ?)");

// Add LESLIE as employee number 1500
pstmt.setInt (1, 1500);          // The first ? is for EMPNO
pstmt.setString (2, "LESLIE");   // The second ? is for ENAME
// Do the insertion
pstmt.execute ();

// Add MARSHA as employee number 507
pstmt.setInt (1, 507);           // The first ? is for EMPNO
pstmt.setString (2, "MARSHA");   // The second ? is for ENAME
// Do the insertion
pstmt.execute ();

// Close the statement
pstmt.close();
```

Committing Changes

By default, DML operations (`INSERT`, `UPDATE`, `DELETE`) are committed automatically as soon as they are executed. This is known as *auto-commit* mode. You can, however, disable auto-commit mode with the following method call on the `Connection` object:

```
conn.setAutoCommit(false);
```

(For further discussion of auto-commit mode and an example of disabling it, see "Disabling Auto-Commit Mode" on page 20-6.)

If you disable auto-commit mode, then you must manually commit or roll back changes with the appropriate method call on the `Connection` object:

```
conn.commit();
```

or:

```
conn.rollback();
```

A `COMMIT` or `ROLLBACK` operation affects all DML statements executed since the last `COMMIT` or `ROLLBACK`.

Important:

- If auto-commit mode is disabled and you close the connection without explicitly committing or rolling back your last changes, then an implicit `COMMIT` operation is executed.
- Any DDL operation, such as `CREATE` or `ALTER`, always includes an implicit `COMMIT`. If auto-commit mode is disabled, this implicit `COMMIT` will not only commit the DDL statement, but also any pending DML operations that had not yet been explicitly committed or rolled back.

Closing the Connection

You must close your connection to the database once you finish your work. Use the `close()` method of the `Connection` object to do this:

```
conn.close();
```

Note: Typically, you should put `close()` statements in a `finally` clause.

Sample: Connecting, Querying, and Processing the Results

The steps in the preceding sections are illustrated in the following example, which registers an Oracle JDBC Thin driver, connects to the database, creates a `Statement` object, executes a query, and processes the result set.

Note that the code for creating the `Statement` object, executing the query, returning and processing the `ResultSet` object, and closing the statement and connection all follow standard JDBC syntax.

```
import java.sql.*;
import java.math.*;
import java.io.*;
import java.awt.*;

class JdbcTest {
   public static void main (String args []) throws SQLException {
      // Load Oracle driver
      DriverManager.registerDriver (new oracle.jdbc.OracleDriver());
      // Connect to the local database
      Connection conn = DriverManager.getConnection
                ("jdbc:oracle:thin:@myhost:1521:ORCL","scott", "tiger");

      // Query the employee names
      Statement stmt = conn.createStatement ();
      ResultSet rset = stmt.executeQuery ("SELECT ename FROM emp");
      // Print the name out
      while (rset.next ())
         System.out.println (rset.getString (1));

      //close the result set, statement, and the connection
      rset.close();
      stmt.close();
      conn.close();
   }
}
```

If you want to adapt the code for the OCI driver, replace the `Connection` statement with the following:

```
Connection conn = DriverManager.getConnection
                  ("jdbc:oracle:oci:@MyHostString", "scott", "tiger");
```

Where `MyHostString` is an entry in the `TNSNAMES.ORA` file.

Datatype Mappings

The Oracle JDBC drivers support standard JDBC 1.0 and 2.0 types as well as Oracle-specific `BFILE` and `ROWID` datatypes and types of the `REF CURSOR` category.

This section documents standard and Oracle-specific SQL-Java default type mappings.

Table of Mappings

For reference, Table 3–2 shows the default mappings between SQL datatypes, JDBC typecodes, standard Java types, and Oracle extended types.

The **SQL Datatypes** column lists the SQL types that exist in the database.

The **JDBC Typecodes** column lists data typecodes supported by the JDBC standard and defined in the `java.sql.Types` class, or by Oracle in the `oracle.jdbc.OracleTypes` class. For standard typecodes, the codes are identical in these two classes.

The **Standard Java Types** column lists standard types defined in the Java language.

The **Oracle Extension Java Types** column lists the `oracle.sql.*` Java types that correspond to each SQL datatype in the database. These are Oracle extensions that let you retrieve all SQL data in the form of a `oracle.sql.*` Java type. Mapping SQL datatypes into the `oracle.sql` datatypes lets you store and retrieve data without losing information. Refer to "Package oracle.sql" on page 6-7 for more information on the `oracle.sql.*` package.

Table 3–2 Default Mappings Between SQL Types and Java Types

SQL Datatypes	JDBC Typecodes	Standard Java Types	Oracle Extension Java Types
	STANDARD JDBC 1.0 TYPES:		
CHAR	java.sql.Types.CHAR	java.lang.String	oracle.sql.CHAR
VARCHAR2	java.sql.Types.VARCHAR	java.lang.String	oracle.sql.CHAR
LONG	java.sql.Types.LONGVARCHAR	java.lang.String	oracle.sql.CHAR
NUMBER	java.sql.Types.NUMERIC	java.math.BigDecimal	oracle.sql.NUMBER
NUMBER	java.sql.Types.DECIMAL	java.math.BigDecimal	oracle.sql.NUMBER
NUMBER	java.sql.Types.BIT	boolean	oracle.sql.NUMBER

Table 3–2 Default Mappings Between SQL Types and Java Types (Cont.)

SQL Datatypes	JDBC Typecodes	Standard Java Types	Oracle Extension Java Types
NUMBER	java.sql.Types.TINYINT	byte	oracle.sql.NUMBER
NUMBER	java.sql.Types.SMALLINT	short	oracle.sql.NUMBER
NUMBER	java.sql.Types.INTEGER	int	oracle.sql.NUMBER
NUMBER	java.sql.Types.BIGINT	long	oracle.sql.NUMBER
NUMBER	java.sql.Types.REAL	float	oracle.sql.NUMBER
NUMBER	java.sql.Types.FLOAT	double	oracle.sql.NUMBER
NUMBER	java.sql.Types.DOUBLE	double	oracle.sql.NUMBER
RAW	java.sql.Types.BINARY	byte[]	oracle.sql.RAW
RAW	java.sql.Types.VARBINARY	byte[]	oracle.sql.RAW
LONGRAW	java.sql.Types.LONGVARBINARY	byte[]	oracle.sql.RAW
DATE	java.sql.Types.DATE	java.sql.Date	oracle.sql.DATE
DATE	java.sql.Types.TIME	java.sql.Time	oracle.sql.DATE
DATE	java.sql.Types.TIMESTAMP	javal.sql.Timestamp	oracle.sql.DATE
	STANDARD JDBC 2.0 TYPES:		
BLOB	java.sql.Types.BLOB	java.sql.Blob	oracle.sql.BLOB
CLOB	java.sql.Types.CLOB	java.sql.Clob	oracle.sql.CLOB
user-defined object	java.sql.Types.STRUCT	java.sql.Struct	oracle.sql.STRUCT
user-defined reference	java.sql.Types.REF	java.sql.Ref	oracle.sql.REF
user-defined collection	java.sql.Types.ARRAY	java.sql.Array	oracle.sql.ARRAY
	ORACLE EXTENSIONS:		
BFILE	oracle.jdbc.OracleTypes.BFILE	n/a	oracle.sql.BFILE
ROWID	oracle.jdbc.OracleTypes.ROWID	n/a	oracle.sql.ROWID
REF CURSOR type	oracle.jdbc.OracleTypes.CURSOR	java.sql.ResultSet	oracle.jdbc.OracleResultSet

Table 3–2 Default Mappings Between SQL Types and Java Types (Cont.)

SQL Datatypes	JDBC Typecodes	Standard Java Types	Oracle Extension Java Types
TS	oracle.jdbc.OracleTypes.TIMESTAMP	n/a	oracle.sql.TIMESTAMP
TSTZ	oracle.jdbc.OracleTypes.TIMESTAMPTZ	n/a	oracle.sql.TIMESTAMPTZ
TSLTZ	oracle.jdbc.OracleTypes.TIMESTAMPLTZ	n/a	oracle.sql.TIMESTAMPLTZ

Note: Under JDK 1.1.x, the Oracle package `oracle.jdbc2` is required to support JDBC 2.0 types. (Under JDK 1.2.x they are supported by the standard `java.sql` package.)

For a list of all the Java datatypes to which you can validly map a SQL datatype, see "Valid SQL-JDBC Datatype Mappings" on page 19-2.

See Chapter 6, "Overview of Oracle Extensions", for more information on type mappings. In Chapter 6 you can also find more information on the following:

- packages `oracle.sql`, `oracle.jdbc`, and `oracle.jdbc2`
- type extensions for the Oracle `BFILE` and `ROWID` datatypes and user-defined types of the `REF CURSOR` category

Notes Regarding Mappings

This section goes into further detail regarding mappings for `NUMBER` and user-defined types.

Regarding User-Defined Types

User-defined types such as objects, object references, and collections map by default to weak Java types (such as `java.sql.Struct`), but alternatively can map to strongly typed *custom Java classes*. Custom Java classes can implement one of two interfaces:

- The standard `java.sql.SQLData` (for user-defined objects only)

- The Oracle-specific `oracle.sql.ORAData` (primarily for user-defined objects, object references, and collections, but able to map from *any* SQL type where you want customized processing of any kind)

For information about custom Java classes and the `SQLData` and `ORAData` interfaces, see "Mapping Oracle Objects" on page 9-2 and "Creating and Using Custom Object Classes for Oracle Objects" on page 9-10. (Although these sections focus on custom Java classes for user-defined objects, there is some general information about other kinds of custom Java classes as well.)

Regarding NUMBER Types

For the different typecodes that an Oracle `NUMBER` value can correspond to, call the getter routine that is appropriate for the size of the data for mapping to work properly. For example, call `getByte()` to get a Java `tinyint` value, for an item `x` where -128 < x < 128.

Java Streams in JDBC

This section covers the following topics:

- Streaming LONG or LONG RAW Columns
- Streaming CHAR, VARCHAR, or RAW Columns
- Data Streaming and Multiple Columns
- Streaming and Row Prefetching
- Closing a Stream
- Streaming LOBs and External Files

This section describes how the Oracle JDBC drivers handle Java streams for several datatypes. Data streams allow you to read `LONG` column data of up to 2 gigabytes. Methods associated with streams let you read the data incrementally.

Oracle JDBC drivers support the manipulation of data streams in either direction between server and client. The drivers support all stream conversions: binary, ASCII, and Unicode. Following is a brief description of each type of stream:

- binary stream—Used for `RAW` bytes of data. This corresponds to the `getBinaryStream()` method.
- ASCII stream—Used for ASCII bytes in ISO-Latin-1 encoding. This corresponds to the `getAsciiStream()` method.
- Unicode stream—Used for Unicode bytes with the `UTF-16` encoding. This corresponds to the `getUnicodeStream()` method.

The methods `getBinaryStream()`, `getAsciiStream()`, and `getUnicodeStream()` return the bytes of data in an `InputStream` object. These methods are described in greater detail in Chapter 8, "Working with LOBs and BFILEs".

Streaming LONG or LONG RAW Columns

When a query selects one or more `LONG` or `LONG RAW` columns, the JDBC driver transfers these columns to the client in streaming mode. After a call to `executeQuery()` or `next()`, the data of the `LONG` column is waiting to be read.

To access the data in a `LONG` column, you can get the column as a Java `InputStream` and use the `read()` method of the `InputStream` object. As an alternative, you can get the data as a string or byte array, in which case the driver will do the streaming for you.

You can get LONG and LONG RAW data with any of the three stream types. The driver performs conversions for you, depending on the character set of your database and the driver. For more information about globalization support, see "JDBC and Globalization Support" on page 17-2.

LONG RAW Data Conversions

A call to `getBinaryStream()` returns RAW data "as-is". A call to `getAsciiStream()` converts the RAW data to hexadecimal and returns the ASCII representation. A call to `getUnicodeStream()` converts the RAW data to hexadecimal and returns the Unicode bytes.

For example, if your LONG RAW column contains the bytes 20 21 22, you receive the following bytes:

LONG RAW	BinaryStream	ASCIIStream	UnicodeStream
20 21 22	20 21 22	49 52 49 53 49 54 which is also '1' '4' '1' '5' '1' '6'	0049 0052 0049 0053 0049 0054 which is also: '1' '4' '1' '5' '1' '6'

For example, the LONG RAW value 20 is represented in hexadecimal as 14 or "1" "4". In ASCII, 1 is represented by "49" and "4" is represented by "52". In Unicode, a padding of zeros is used to separate individual values. So, the hexadecimal value 14 is represented as 0 "1" 0 "4". The Unicode representation is 0 "49" 0 "52".

LONG Data Conversions

When you get LONG data with `getAsciiStream()`, the drivers assume that the underlying data in the database uses an `US7ASCII` or `WE8ISO8859P1` character set. If the assumption is true, the drivers return bytes corresponding to ASCII characters. If the database is not using an `US7ASCII` or `WE8ISO8859P1` character set, a call to `getAsciiStream()` returns meaningless information.

When you get LONG data with `getUnicodeStream()`, you get a stream of Unicode characters in the `UTF-16` encoding. This applies to all underlying database character sets that Oracle supports.

When you get LONG data with `getBinaryStream()`, there are two possible cases:

- If the driver is JDBC OCI and the client character set is not `US7ASCII` or `WE8ISO8859P1`, then a call to `getBinaryStream()` returns `UTF-8`. If the

client character set is US7ASCII or WE8ISO8859P1, then the call returns a US7ASCII stream of bytes.

- If the driver is JDBC Thin and the database character set is not US7ASCII or WE8ISO8859P1, then a call to getBinaryStream() returns UTF-8. If the server-side character set is US7ASCII or WE8ISO8859P1, then the call returns a US7ASCII stream of bytes.

For more information on how the drivers return data based on character set, see "JDBC and Globalization Support" on page 17-2.

> **Note:** Receiving LONG or LONG RAW columns as a stream (the default case) requires you to pay special attention to the order in which you receive data from the database. For more information, see "Data Streaming and Multiple Columns" on page 3-26.

Table 3–3 summarizes LONG and LONG RAW data conversions for each stream type.

Table 3–3 LONG and LONG RAW Data Conversions

Datatype	BinaryStream	AsciiStream	UnicodeStream
LONG	bytes representing characters in Unicode UTF-8. The bytes can represent characters in US7ASCII or WE8ISO8859P1 if: ■ the value of NLS_LANG on the client is US7ASCII or WE8ISO8859P1. or: ■ the database character set is US7ASCII or WE8ISO8859P1.	bytes representing characters in ISO-Latin-1 (WE8ISO8859P1) encoding	bytes representing characters in Unicode UTF-16 encoding
LONG RAW	as-is	ASCII representation of hexadecimal bytes	Unicode representation of hexadecimal bytes

Streaming Example for LONG RAW Data

One of the features of a getXXXStream() method is that it allows you to fetch data incrementally. In contrast, getBytes() fetches all the data in one call. This section contains two examples of getting a stream of binary data. The first version uses the getBinaryStream() method to obtain LONG RAW data; the second version uses the getBytes() method.

Getting a LONG RAW Data Column with getBinaryStream() This Java example writes the contents of a LONG RAW column to a file on the local file system. In this case, the driver fetches the data incrementally.

The following code creates the table that stores a column of LONG RAW data associated with the name LESLIE:

```
-- SQL code:
create table streamexample (NAME varchar2 (256), GIFDATA long raw);
insert into streamexample values ('LESLIE', '00010203040506070809');
```

The following Java code snippet writes the data from the LESLIE LONG RAW column into a file called `leslie.gif`:

```
ResultSet rset = stmt.executeQuery
                 ("select GIFDATA from streamexample where NAME='LESLIE'");

// get first row
if (rset.next())
{
    // Get the GIF data as a stream from Oracle to the client
    InputStream gif_data = rset.getBinaryStream (1);
   try
   {
      FileOutputStream file = null;
      file = new FileOutputStream ("leslie.gif");
      int chunk;
      while ((chunk = gif_data.read()) != -1)
         file.write(chunk);
   }
   catch (Exception e)
   {
      String err = e.toString();
      System.out.println(err);
   }
   finally
   {
      if file != null()
         file.close();
   }
}
```

In this example the contents of the GIFDATA column are transferred incrementally in chunk-sized pieces between the database and the client. The `InputStream`

object returned by the call to `getBinaryStream()` reads the data directly from the database connection.

Getting a LONG RAW Data Column with getBytes() This version of the example gets the content of the `GIFDATA` column with `getBytes()` instead of `getBinaryStream()`. In this case, the driver fetches all the data in one call and stores it in a byte array. The previous code snippet can be rewritten as:

```
ResultSet rset2 = stmt.executeQuery
                  ("select GIFDATA from streamexample where NAME='LESLIE'");

// get first row
if (rset2.next())
{
   // Get the GIF data as a stream from Oracle to the client
   byte[] bytes = rset2.getBytes(1);
   try
   {
      FileOutputStream file = null;
      file = new FileOutputStream ("leslie2.gif");
      file.write(bytes);
   }
   catch (Exception e)
   {
      String err = e.toString();
      System.out.println(err);
   }
   finally
   {
      if file != null()
         file.close();
   }
}
```

Because a `LONG RAW` column can contain up to 2 gigabytes of data, the `getBytes()` example will probably use much more memory than the `getBinaryStream()` example. Use streams if you do not know the maximum size of the data in your `LONG` or `LONG RAW` columns.

Avoiding Streaming for LONG or LONG RAW

The JDBC driver automatically streams any `LONG` and `LONG RAW` columns. However, there may be situations where you want to avoid data streaming. For

example, if you have a very small LONG column, you might want to avoid returning the data incrementally and instead, return the data in one call.

To avoid streaming, use the defineColumnType() method to redefine the type of the LONG column. For example, if you redefine the LONG or LONG RAW column as type VARCHAR or VARBINARY, then the driver will not automatically stream the data.

If you redefine column types with defineColumnType(), you must declare the types of *all* columns in the query. If you do not, executeQuery() will fail. In addition, you must cast the Statement object to an oracle.jdbc.OracleStatement object.

As an added benefit, using defineColumnType() saves the driver two round trips to the database when executing the query. Without defineColumnType(), the JDBC driver has to request the datatypes of the column types.

Using the example from the previous section, the Statement object stmt is cast to the OracleStatement and the column containing LONG RAW data is redefined to be of the type VARBINARAY. The data is not streamed—instead, it is returned in a byte array.

```
//cast the statement stmt to an OracleStatement
oracle.jdbc.OracleStatement ostmt =
   (oracle.jdbc.OracleStatement)stmt;

//redefine the LONG column at index position 1 to VARBINARY
ostmt.defineColumnType(1, Types.VARBINARY);

// Do a query to get the images named 'LESLIE'
ResultSet rset = ostmt.executeQuery
         ("select GIFDATA from streamexample where NAME='LESLIE'");

// The data is not streamed here
rset.next();
byte [] bytes = rset.getBytes(1);
```

Streaming CHAR, VARCHAR, or RAW Columns

If you use the defineColumnType() Oracle extension to redefine a CHAR, VARCHAR, or RAW column as a LONGVARCHAR or LONGVARBINARY, then you can get the column as a stream. The program will behave as if the column were actually of type LONG or LONG RAW. Note that there is not much point to this, because these columns are usually short.

If you try to get a CHAR, VARCHAR, or RAW column as a data stream without redefining the column type, the JDBC driver will return a Java `InputStream`, but no real streaming occurs. In the case of these datatypes, the JDBC driver fully fetches the data into an in-memory buffer during a call to the `executeQuery()` method or `next()` method. The `getXXXStream()` entry points return a stream that reads data from this buffer.

Data Streaming and Multiple Columns

If your query selects multiple columns and one of the columns contains a data stream, then the contents of the columns following the stream column are not available until the stream has been read, and the stream column is no longer available once any following column is read. Any attempt to read a column beyond a streaming column closes the streaming column. See "Streaming Data Precautions" on page 3-29 for more information.

Streaming Example with Multiple Columns

Consider the following query:

```
ResultSet rset = stmt.executeQuery
        ("select DATECOL, LONGCOL, NUMBERCOL from TABLE");
while rset.next()
{
   //get the date data
   java.sql.Date date = rset.getDate(1);

   // get the streaming data
   InputStream is = rset.getAsciiStream(2);

   // Open a file to store the gif data
   FileOutputStream file = new FileOutputStream ("ascii.dat");

   // Loop, reading from the ascii stream and
   // write to the file
   int chunk;
   while ((chunk = is.read ()) != -1)
      file.write(chunk);
   // Close the file
   file.close();

   //get the number column data
   int n = rset.getInt(3);
}
```

The incoming data for each row has the following shape:

```
<a date><the characters of the long column><a number>
```

As you process each row of the iterator, you must complete any processing of the stream column before reading the number column.

An exception to this behavior is LOB data, which is also transferred between server and client as a Java stream. For more information on how the driver treats LOB data, see "Streaming LOBs and External Files" on page 3-27.

Bypassing Streaming Data Columns

There might be situations where you want to avoid reading a column that contains streaming data. If you do not want to read the data for the streaming column, then call the `close()` method of the stream object. This method discards the stream data and allows the driver to continue reading data for all the non-streaming columns that follow the stream. Even though you are intentionally discarding the stream, it is good programming practice to call the columns in SELECT-list order.

In the following example, the stream data in the LONG column is discarded and the data from only the DATE and NUMBER column is recovered:

```
ResultSet rset = stmt.executeQuery
        ("select DATECOL, LONGCOL, NUMBERCOL from TABLE");

while rset.next()
{
   //get the date
   java.sql.Date date = rset.getDate(1);

   // access the stream data and discard it with close()
   InputStream is = rset.getAsciiStream(2);
   is.close();

   // get the number column data
   int n = rset.getInt(3);
}
```

Streaming LOBs and External Files

The term *large object* (LOB) refers to a data item that is too large to be stored directly in a database table. Instead, a locator is stored in the database table and points to

the location of the actual data. External files (binary files, or BFILEs) are managed similarly. The JDBC drivers can support these types through the use of streams:

- BLOBs (unstructured binary data)
- CLOBs (character data)
- BFILEs (external files)

LOBs and BFILEs behave differently from the other types of streaming data described in this chapter. The driver transfers data between server and client as a Java stream. However, unlike most Java streams, a locator representing the data is stored in the table. Thus, you can access the data at any time during the life of the connection.

Streaming BLOBs and CLOBs

When a query selects one or more `CLOB` or `BLOB` columns, the JDBC driver transfers to the client the data pointed to by the locator. The driver performs the transfer as a Java stream. To manipulate CLOB or BLOB data from JDBC, use methods in the Oracle extension classes `oracle.sql.BLOB` and `oracle.sql.CLOB`. These classes provide functionality such as reading from the CLOB or BLOB into an input stream, writing from an output stream into a CLOB or BLOB, determining the length of a CLOB or BLOB, and closing a CLOB or BLOB.

For a complete discussion of how to use streaming CLOB and BLOB data, see "Reading and Writing BLOB and CLOB Data" on page 8-6.

Important: The JDBC 2.0 specification states that `PreparedStatement` methods `setBinaryStream()` and `setObject()` can be used to input a stream value as a BLOB, and that the `PreparedStatement` methods `setAsciiStream()`, `setUnicodeStream()`, `setCharacterStream()`, and `setObject()` can be used to input a stream value as a CLOB. This bypasses the LOB locator, going directly to the LOB data itself.

In the implementation of the Oracle JDBC drivers, this functionality is supported *only* for a configuration using an 8.1.6 database and 8.1.6 JDBC OCI driver. **Do not use this functionality for any other configuration, as data corruption can result.**

Streaming BFILEs

An external file, or BFILE, is used to store a locator to a file outside the database, stored somewhere on the filesystem of the data server. The locator points to the actual location of the file.

When a query selects one or more `BFILE` columns, the JDBC driver transfers to the client the file pointed to by the locator. The transfer is performed in a Java stream. To manipulate BFILE data from JDBC, use methods in the Oracle extension class `oracle.sql.BFILE`. This class provides functionality such as reading from the BFILE into an input stream, writing from an output stream into a BFILE, determining the length of a BFILE, and closing a BFILE.

For a complete discussion of how to use streaming BFILE data, see "Reading BFILE Data" on page 8-22.

Closing a Stream

You can discard the data from a stream at any time by calling the stream's `close()` method. You can also close and discard the stream by closing its result set or connection object. You can find more information about the `close()` method for data streams in "Bypassing Streaming Data Columns" on page 3-27. For information on how to avoid closing a stream and discarding its data by accident, see "Streaming Data Precautions" on page 3-29.

Notes and Precautions on Streams

This section discusses several noteworthy and cautionary issues regarding the use of streams:

- Streaming Data Precautions
- Using Streams to Avoid Limits on setBytes() and setString()
- Streaming and Row Prefetching

Streaming Data Precautions

This section describes some of the precautions you must take to ensure that you do not accidentally discard or lose your stream data. The drivers automatically discard stream data if you perform any JDBC operation that communicates with the database, other than reading the current stream. Two common precautions are described:

- Use the stream data after you access it.

To recover the data from a column containing a data stream, it is not enough to `get` the column; you must immediately process its contents. Otherwise, the contents will be discarded when you get the next column.

- Call the stream column in SELECT-list order.

  If your query selects multiple columns, the database sends each row as a set of bytes representing the columns in the `SELECT` order. If one of the columns contains stream data, the database sends the entire data stream before proceeding to the next column.

  If you do not use the SELECT-list order to access data, then you can lose the stream data. That is, if you bypass the stream data column and access data in a column that follows it, the stream data will be lost. For example, if you try to access the data for the `NUMBER` column *before* reading the data from the stream data column, the JDBC driver first reads then discards the streaming data automatically. This can be very inefficient if the `LONG` column contains a large amount of data.

  If you try to access the `LONG` column later in the program, the data will not be available and the driver will return a "`Stream Closed`" error.

The second point is illustrated in the following example:

```
ResultSet rset = stmt.executeQuery
        ("select DATECOL, LONGCOL, NUMBERCOL from TABLE");
while rset.next()
{
   int n = rset.getInt(3);  // This discards the streaming data
   InputStream is = rset.getAsciiStream(2);
                            // Raises an error: stream closed.
}
```

If you get the stream but do not use it *before* you get the `NUMBER` column, the stream still closes automatically:

```
ResultSet rset = stmt.executeQuery
                ("select DATECOL, LONGCOL, NUMBERCOL from TABLE");
while rset.next()
{
   InputStream is = rset.getAsciiStream(2); // Get the stream
   int n = rset.getInt(3);
   // Discards streaming data and closes the stream
}
int c = is.read(); // c is -1: no more characters to read-stream closed
```

Using Streams to Avoid Limits on setBytes() and setString()

There is a limit on the maximum size of the array which can be bound using the `PreparedStatement` class `setBytes()` method, and on the size of the string which can be bound using the `setString()` method.

Above the limits, which depend on the version of the server you use, you should use `setBinaryStream()` or `setCharacterStream()` instead.

Table 3–4 Bind-Size Limitations By Database

Database Version	maximum setBytes() (equals maximum RAW size)	maximum setString() (equals maximum VARCHAR2 size)
Oracle8 and later	2000	4000
Oracle7	255	2000

Note: This discussion applies to binds in SQL, not PL/SQL. If you use `setBinaryStream()` in PL/SQL, the maximum array size is 32 Kbytes.

The 8.1.6 Oracle JDBC drivers may not raise an error if you exceed the limit when using `setBytes()` or `setString()`, but you may receive the following error:

```
ORA-17070: Data size bigger than max size for this type
```

Future versions of the Oracle drivers will raise an error if the length exceeds these limits.

Streaming and Row Prefetching

If the JDBC driver encounters a column containing a data stream, row prefetching is set back to 1.

Row prefetching is an Oracle performance enhancement that allows multiple rows of data to be retrieved with each trip to the database. See "Oracle Row Prefetching" on page 12-20.

Stored Procedure Calls in JDBC Programs

This section describes how the Oracle JDBC drivers support the following kinds of stored procedures:

- PL/SQL Stored Procedures
- Java Stored Procedures

PL/SQL Stored Procedures

Oracle JDBC drivers support execution of PL/SQL stored procedures and anonymous blocks. They support both SQL92 escape syntax and Oracle PL/SQL block syntax. The following PL/SQL calls would work with any Oracle JDBC driver:

```
// SQL92 syntax
CallableStatement cs1 = conn.prepareCall
                        ( "{call proc (?,?)}" ) ; // stored proc
CallableStatement cs2 = conn.prepareCall
                        ( "{? = call func (?,?)}" ) ; // stored func
// Oracle PL/SQL block syntax
CallableStatement cs3 = conn.prepareCall
                        ( "begin proc (?,?); end;" ) ; // stored proc
CallableStatement cs4 = conn.prepareCall
                        ( "begin ? := func(?,?); end;" ) ; // stored func
```

As an example of using Oracle syntax, here is a PL/SQL code snippet that creates a stored function. The PL/SQL function gets a character sequence and concatenates a suffix to it:

```
create or replace function foo (val1 char)
return char as
begin
   return val1 || 'suffix';
end;
```

Your invocation call in your JDBC program should look like:

```
Connection conn = DriverManager.getConnection
                  ("jdbc:oracle:oci:@<hoststring>", "scott", "tiger");

CallableStatement cs = conn.prepareCall ("begin ? := foo(?); end;");
cs.registerOutParameter(1,Types.CHAR);
cs.setString(2, "aa");
cs.executeUpdate();
```

```
String result = cs.getString(1);
```

Java Stored Procedures

You can use JDBC to invoke Java stored procedures through the SQL and PL/SQL engines. The syntax for calling Java stored procedures is the same as the syntax for calling PL/SQL stored procedures, presuming they have been properly "published" (that is, have had call specifications written to publish them to the Oracle data dictionary). See the *Oracle9i Java Stored Procedures Developer's Guide* for more information on writing, publishing, and using Java stored procedures.

Processing SQL Exceptions

To handle error conditions, the Oracle JDBC drivers throws SQL exceptions, producing instances of class `java.sql.SQLException` or a subclass. Errors can originate either in the JDBC driver or in the database (RDBMS) itself. Resulting messages describe the error and identify the method that threw the error. Additional run-time information can also be appended.

Basic exception-handling can include retrieving the error message, retrieving the error code, retrieving the SQL state, and printing the stack trace. The `SQLException` class includes functionality to retrieve all of this information, where available.

Errors originating in the JDBC driver are listed with their `ORA` numbers in Appendix B, "JDBC Error Messages".

Errors originating in the RDBMS are documented in the *Oracle9i Error Messages* reference.

Retrieving Error Information

You can retrieve basic error information with these `SQLException` methods:

- `getMessage()`

  For errors originating in the JDBC driver, this method returns the error message with no prefix. For errors originating in the RDBMS, it returns the error message prefixed with the corresponding `ORA` number.

- `getErrorCode()`

  For errors originating in either the JDBC driver or the RDBMS, this method returns the five-digit `ORA` number.

- `getSQLState()`

  For errors originating in the JDBC driver, this returns no useful information. For errors originating in the RDBMS, this method returns a five-digit code indicating the SQL state. Your code should be prepared to handle null data.

The following example prints output from a `getMessage()` call.

```
catch(SQLException e)
{
   System.out.println("exception: " + e.getMessage());
}
```

This would print output such as the following for an error originating in the JDBC driver:

```
exception: Invalid column type
```

(There is no ORA number message prefix for errors originating in the JDBC driver, although you can get the ORA number with a `getErrorCode()` call.)

> **Note:** Error message text is available in alternative languages and character sets supported by Oracle.

Printing the Stack Trace

The `SQLException` class provides the following method for printing a stack trace.

- `printStackTrace()`

  This method prints the stack trace of the throwable object to the standard error stream. You can also specify a `java.io.PrintStream` object or `java.io.PrintWriter` object for output.

The following code fragment illustrates how you can catch SQL exceptions and print the stack trace.

```
try { <some code> }
catch(SQLException e) { e.printStackTrace (); }
```

To illustrate how the JDBC drivers handle errors, assume the following code uses an incorrect column index:

```
// Iterate through the result and print the employee names
// of the code

try {
  while (rset.next ())
      System.out.println (rset.getString (5));  // incorrect column index
}
catch(SQLException e) { e.printStackTrace (); }
```

Assuming the column index is incorrect, executing the program would produce the following error text:

```
java.sql.SQLException: Invalid column index
at oracle.jdbc.dbaccess.DBError.check_error(DBError.java:235)
at oracle.jdbc.OracleStatement.prepare_for_new_get(OracleStatemen
```

```
t.java:1560)
at oracle.jdbc.OracleStatement.getStringValue(OracleStatement.jav
a:1653)
at oracle.jdbc.OracleResultSet.getString(OracleResultSet.java:175
)
at Employee.main(Employee.java:41)
```

4

Overview of JDBC 2.0 Support

Oracle JDBC supports JDBC 2.0 functionality and standardizes functionality that was previously supported through Oracle extensions.

This chapter provides an overview of JDBC 2.0 support in the Oracle JDBC drivers, focusing in particular on any differences in support between the JDK 1.2.x and JDK 1.1.x environments. The following topics are discussed:

- Introduction
- JDBC 2.0 Support: JDK 1.2.x versus JDK 1.1.x
- Overview of JDBC 2.0 Features

Introduction

The Oracle JDBC drivers are compliant with the JDBC 2.0 specification. JDBC 2.0 functionality previously implemented through Oracle extensions in the `oracle.jdbc2` package—such as structured objects, object references, arrays, and LOBs—is now implemented through the standard `java.sql` package in JDK 1.2.

In a JDK 1.1.x environment, you can continue to use the `oracle.jdbc2` package. You can also use JDBC 2.0 features in connection objects, statement objects, result set objects, and database meta data objects under JDK 1.1.x by casting your objects to the Oracle types.

Furthermore, you can use features of the JDBC 2.0 Optional Package (also known as the JDBC 2.0 Standard Extension API) under either JDK 1.2.x or JDK 1.1.x. These features, including connection pooling and distributed transactions, are supported through the standard `javax.sql` package. This package and the classes that implement its interfaces are now included with the JDBC classes ZIP file for either JDK 1.2.x or JDK 1.1.x.

JDBC 2.0 Support: JDK 1.2.x versus JDK 1.1.x

Support for standard JDBC 2.0 features differs depending on whether you are using JDK 1.2.x or JDK 1.1.x. There are three areas to consider:

- datatype support—such as for objects, arrays, and LOBs—which is handled through the standard `java.sql` package under JDK 1.2.x and through the Oracle extension `oracle.jdbc2` package under JDK 1.1.x
- standard feature support—such as result set enhancements and update batching—which is handled through standard objects such as `Connection`, `ResultSet`, and `PreparedStatement` under JDK 1.2.x, but requires Oracle-specific functionality under JDK 1.1.x
- extended feature support—features of the JDBC 2.0 Optional Package (also known as the Standard Extension API), including data sources, connection pooling, and distributed transactions—which has the same support and functionality in either JDK 1.2.x or JDK 1.1.x

This section also discusses performance enhancements available under JDBC 2.0—update batching and fetch size—that are also still available as Oracle extensions, then concludes with a brief discussion about migration from JDK 1.1.x to JDK 1.2.x.

Datatype Support

Oracle JDBC fully supports JDK 1.2.x, which includes standard JDBC 2.0 functionality through implementation of interfaces in the standard `java.sql` package. These interfaces are implemented as appropriate by classes in the `oracle.sql` and `oracle.jdbc` packages.

For JDBC 2.0 functionality under JDK 1.2.x, where you are using `classes12.zip`, no special imports are required. The following imports, both of which you will likely need even if you are not using JDBC 2.0 features, will suffice:

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

JDBC 2.0 features are not supported by JDK 1.1.x; however, Oracle provides extensions that allow you to use a significant subset of JDBC 2.0 datatypes under JDK 1.1.x, where you are using `classes111.zip`. These extensions support database objects, object references, arrays, and LOBs.

The package `oracle.jdbc2` is included in `classes111.zip`. This package provides interfaces that mimic JDBC 2.0-related interfaces that became standard

with JDK 1.2.x for SQL3 and advanced datatypes. The interfaces in `oracle.jdbc2` are implemented as appropriate by classes in the `oracle.sql` package for a JDK 1.1.x environment.

The following imports are required for JDBC 2.0 datatypes under JDK 1.1.x:

```
import java.sql.*;
import oracle.jdbc2.*;
import oracle.sql.*;
```

Standard Feature Support

In a JDK 1.2.x environment (using the JDBC classes in `classes12.zip`), JDBC 2.0 features such as scrollable result sets, updatable result sets, and update batching are supported through methods specified by standard JDBC 2.0 interfaces. Therefore, under JDK 1.2.x, you can use standard objects such as `Connection`, `DatabaseMetaData`, `ResultSetMetaData`, `Statement`, `PreparedStatement`, `CallableStatement`, and `ResultSet` to use these features.

In a JDK 1.1.x environment (using the JDBC classes in `classes111.zip`), Oracle JDBC provides support for these JDBC 2.0 features as Oracle extensions. To use this functionality, you must cast your objects to the Oracle types:

- `OracleConnection`
- `OracleDatabaseMetaData`
- `OracleResultSetMetaData`
- `OracleStatement`
- `OraclePreparedStatement`
- `OracleCallableStatement`
- `OracleResultSet`

For example, to use JDBC 2.0 result set enhancements, you must do the following:

- Explicitly type or cast scrollable or updatable result sets as type `OracleResultSet`.
- Explicitly type or cast connection objects as type `OracleConnection` whenever the connection object will be required to produce a statement object that will in turn produce a scrollable or updatable result set.

In addition, you might have to cast statement objects to `OracleStatement`, `OraclePreparedStatement`, or `OracleCallableStatement`, and cast

database meta data objects to `OracleDatabaseMetaData`. This would be if you want to use JDBC 2.0 statement or database meta data methods described under "Summary of New Methods for Result Set Enhancements" on page 13-32.

Extended Feature Support

Features of the JDBC 2.0 Optional Package (also known as the Standard Extension API), including data sources, connection pooling, and distributed transactions, are supported equally in a JDK 1.2.x or 1.1.x environment.

The standard `javax.sql` package and classes that implement its interfaces are included in the JDBC classes ZIP file for either environment.

Standard versus Oracle Performance Enhancement APIs

There are two performance enhancements available under JDBC 2.0, which had previously been available as Oracle extensions:

- update batching
- fetch size / row prefetching

In each case, you have the option of using the standard model or the Oracle model. Do not, however, try to mix usage of the standard model and Oracle model within a single application for either of these features.

For more information, see the following sections:

- "Update Batching" on page 12-2
- "Fetch Size" on page 13-24
- "Oracle Row Prefetching" on page 12-20

Migration from JDK 1.1.x to JDK 1.2.x

The only migration requirements in going from JDK 1.1.x to JDK 1.2.x are as follows:

- Remove your imports of the `oracle.jdbc2` package, as discussed above under "Datatype Support" on page 4-3.
- Replace any direct references to `oracle.jdbc2.*` interfaces with references to the standard `java.sql.*` interfaces.
- Type map objects (for mapping SQL structured objects to Java types), which must extend the `java.util.Dictionary` class under JDK 1.1.x, must

implement the `java.util.Map` interface under JDK 1.2.x. Note, however, that the class `java.util.Hashtable` satisfies either requirement. If you used `Hashtable` objects for your type maps under JDK 1.1.x, then no change is necessary. For more information, see "Creating a Type Map Object and Defining Mappings for a SQLData Implementation" on page 9-12.

If these points do not apply to your code, then you do not need to make any code changes or recompile to run under JDK 1.2.x.

Overview of JDBC 2.0 Features

Table 4–1 lists key areas of JDBC 2.0 functionality and points to where you can go in this manual for more information about Oracle support.

Table 4–1 Key Areas of JDBC 2.0 Functionality

Feature	Comments and References
update batching	Also available previously as an Oracle extension. Under either JDK 1.2.x or JDK 1.1.x you can use either the standard update batching model or the Oracle model. See "Update Batching" on page 12-2 for information.
result set enhancements (scrollable and updatable result sets)	This is also available under JDK 1.1.x as an Oracle extension. See Chapter 13, "Result Set Enhancements" for information.
fetch size / row prefetching	The JDBC 2.0 fetch size feature is also available under JDK 1.1.x as an Oracle extension. Under either JDK 1.2.x or JDK 1.1.x, you can also use Oracle row prefetching, which is largely equivalent to the JDBC 2.0 fetch size feature but predates JDBC 2.0. See "Fetch Size" on page 13-24 and "Oracle Row Prefetching" on page 12-20 for information.
use of JNDI (Java Naming and Directory Interface) to specify and obtain database connections	This requires data sources, which are part of the JDBC 2.0 Optional Package (JDBC 2.0 Standard Extension API) in the `javax.sql` package. This is available under either JDK 1.2.x or JDK 1.1.x. See "A Brief Overview of Oracle Data Source Support for JNDI" on page 15-2 and "Creating a Data Source Instance, Registering with JNDI, and Connecting" on page 15-8 for information.
connection pooling (framework for connection caching)	This requires the JDBC 2.0 Optional Package (JDBC 2.0 Standard Extension API) in the `javax.sql` package. This is available under either JDK 1.2.x or 1.1.x. See "Connection Pooling" on page 15-11 for information.
connection caching (sample Oracle implementation)	This requires the JDBC 2.0 Optional Package (JDBC 2.0 Standard Extension API) in the `javax.sql` package. This is available under either JDK 1.2.x or 1.1.x. See "Connection Caching" on page 15-16 for information..

Table 4–1 Key Areas of JDBC 2.0 Functionality (Cont.)

Feature	Comments and References
distributed transactions / XA functionality	This requires the JDBC 2.0 Optional Package (JDBC 2.0 Standard Extension API) in the `javax.sql` package. This is available under either JDK 1.2.x or 1.1.x. See Chapter 14, "Distributed Transactions" for information.
miscellaneous `getXXX()` methods	See "Other getXXX() Methods" on page 7-7 for information about which `getXXX()` methods are Oracle extensions under JDK 1.2.x and 1.1.x, and about any differences in functionality with JDBC 2.0.
miscellaneous `setXXX()` methods	See "Other setXXX() Methods" on page 7-12 for information about which `setXXX()` methods are Oracle extensions under JDK 1.2.x and 1.1.x, and about any differences in functionality with JDBC 2.0.

Note: The Oracle JDBC drivers do not support the `Calendar` datatype because it is not yet feasible to support `java.sql.Date` timezone information. `Calendar` input to `setXXX()` or `getXXX()` method calls for `Date`, `Time`, and `Timestamp` is ignored. The `Calendar` type will be supported in a future Oracle release.

5

Overview of Supported JDBC 3.0 Features

This chapter provides an overview of the JDBC 3.0 features supported in the Oracle JDBC drivers, focusing in particular on any differences in support between the JDK 1.4 environment and previous JDK environments. The following topics are discussed:

- Introduction
- JDBC 3.0 Support: JDK 1.4 and Previous Releases
- Overview of Supported JDBC 3.0 Features
- Transaction Savepoints

Introduction

The Oracle JDBC drivers support the following JDBC 3.0 features:

- Using global and distributed transactions on the same connection (see "Oracle XA Packages" on page 14-5)
- Transaction savepoints (see "Transaction Savepoints" on page 5-5)
- Re-use of prepared statements by connection pools (also known as statement caching; see Chapter 18, "Statement Caching")
- Full support for JDK1.4 (see "JDBC 3.0 Support: JDK 1.4 and Previous Releases" in this chapter)

All of these features are provided in the package `oracle.jdbc`. This package supports all JDK releases from 1.1.x through 1.4; JDBC 3.0 features that depend on JDK1.4 are made available to earlier JDK versions through Oracle extensions.

JDBC 3.0 Support: JDK 1.4 and Previous Releases

This release adds or extends the following interfaces and classes.

Table 5–1 JDBC 3.0 Feature Support

New feature	JDK1.4 implementation	Pre-JDK1.4 implementation
Savepoints (new class)	`java.sql.Savepoint`	`oracle.jdbc.OracleSavepoint`
Savepoints (connection extensions)	`java.sql.connection`	`oracle.jdbc.OracleConnection`
Querying parameter capacities (new class)	`java.sql.ParameterMetaData`	`oracle.jdbc.OracleParameterMetaData`
Querying parameter capacities (interface change)	Not applicable	`oracle.jdbc.OraclePreparedStatement`

Overview of Supported JDBC 3.0 Features

Table 5–2 lists the JDBC 3.0 features supported at this release and gives references to a detailed discussion of each feature.

Table 5–2 Key Areas of JDBC 3.0 Functionality

Feature	Comments and References
Transaction savepoints	See "Transaction Savepoints" on page 5-5 for information.
Connection sharing	Re-use of prepared statements by connection pools (see Chapter 18, "Statement Caching".
Switching between local and global transactions	See "Switching Between Global and Local Transactions" on page 14-5 for information.

Transaction Savepoints

The JDBC 3.0 specification supports ***savepoints***, which offer finer demarcation within transactions. Applications can set a savepoint within a transaction and then roll back (but **not** commit) all work done after the savepoint. Savepoints relax the atomicity property of transactions. A transaction with a savepoint is atomic in the sense that it appears to be a single unit outside the context of the transaction, but code operating within the transaction can preserve partial states.

Note: Savepoints are supported for local transactions only. Specifying a savepoint within a global transaction causes `SQLException` to be thrown.

JDK1.4 specifies a standard savepoint API. Oracle JDBC provides two different savepoint interfaces: one (`java.sql.Savepoint`) for JDK1.4 and one (`oracle.jdbc.OracleSavepoint`) that works across all supported JDK versions. JDK1.4 adds savepoint-related APIs to `java.sql.Connection`; the Oracle JDK version-independent interface `oracle.jdbc.OracleConnection` provides equivalent functionality.

Creating a Savepoint

You create a savepoint using either `Connection.setSavepoint()`, which returns a `java.sql.Savepoint` instance, or `OracleConnection.oracleSetSavepoint()`, which returns an `oracle.jdbc.OracleSavepoint` instance.

A savepoint is either named or unnamed. You specify a savepoint's name by supplying a string to the `setSavepoint()` method; if you do not specify a name, the savepoint is assigned an integer ID. You retrieve a name using `getSavepointName()`; you retrieve an ID using `getSavepointId()`.

Note: Attempting to retrieve a name from an unnamed savepoint or attempting to retrieve an ID from a named savepoint throws an SQLException.

Rolling back to a Savepoint

You roll back to a savepoint using `Connection.rollback(Savepoint svpt)` or `OracleConnection.oracleRollback(OracleSavepoint svpt)`. If you try to roll back to a savepoint that has been released, `SQLException` is thrown.

Releasing a Savepoint

You remove a savepoint using `Connection.releaseSavepoint(Savepoint svpt)` or `OracleConnection.oracleReleaseSavepoint(OracleSavepoint svpt)`.

Note: As of Release 2 (9.2), `releaseSavepoint()` and `oracleReleaseSavepoint()` are not supported; if you invoke either message, `SQLException` is thrown with the message "Unsupported feature".

Checking Savepoint Support

You find out whether savepoints are supported by your database by calling `oracle.jdbc.OracleDatabaseMetaData.supportsSavepoints()`, which returns `True` if savepoints are available.

Savepoint Notes

- After a savepoint has been released, attempting to reference it in a rollback operation will cause an `SQLException` to be thrown.
- When a transaction is committed or rolled back, all savepoints created in that transaction are automatically released and become invalid.
- Rolling a transaction back to a savepoint automatically releases and makes invalid any savepoints created after the savepoint in question.

Savepoint Interfaces

The following methods are used to get information from savepoints. These methods are defined within both the `java.sql.Connection` and **`oracle.jdbc.OracleSavepoint`** interfaces:

public int getSavepointId() throws SQLException;

Return the savepoint ID for an unnamed savepoint.

Exceptions:

- `SQLException`: Thrown if `self` is a named savepoint.

public String getSavepointName() throws SQLException;

Return the name of a named savepoint.

Exceptions:

- `SQLException`: Thrown if `self` is an unnamed savepoint.

These methods are defined within the **`java.sql.Connection`** interface:

public Savepoint setSavepoint() throws SQLException;

Create an unnamed savepoint.

Exceptions:

- `SQLException`: Thrown on database error, or if Connection is in auto-commit mode or participating in a global transaction.

publicSavepoint setSavepoint(String name) throws SQLException;

Create a named savepoint. If a `Savepoint` by this name already exists, this instance replaces it.

Exceptions:

- `SQLException`: Thrown on database error or if Connection is in auto-commit mode or participating in a global transaction.

public void rollback(Savepoint savepoint) throws SQLException;

Remove specified Savepoint from current transaction. Any references to the savepoint after it is removed cause an `SQLException` to be thrown.

Exceptions:

- `SQLException`: Thrown on database error or if Connection is in auto-commit mode or participating in a global transaction.

public void releaseSavepoint(Savepoint savepoint) throws SQLException;

Not supported at this release. Always throws `SQLException`.

Pre-JDK1.4 Savepoint Support

These methods are defined within the `oracle.jdbc.OracleConnection` interface; except for using `OracleSavepoint` in the signatures, they are identical to the methods above.

public OracleSavepoint oracleSetSavepoint() throws SQLException;

public OracleSavepoint oracleSetSavepoint(String name) throws SQLException;

public void oracleRollback(OracleSavepoint savepoint) throws SQLException;

public void oracleReleaseSavepoint(OracleSavepoint savepoint) throws SQLException;

6

Overview of Oracle Extensions

Oracle's extensions to the JDBC standard include Java packages and interfaces that let you access and manipulate Oracle datatypes and use Oracle performance extensions. Compared to standard JDBC, the extensions offer you greater flexibility in how you can manipulate the data. This chapter presents an overview of the packages and classes included in Oracle's extensions to standard JDBC. It also describes some of the key support features of the extensions.

This chapter includes these topics:

- Introduction to Oracle Extensions
- Support Features of the Oracle Extensions
- Oracle JDBC Packages and Classes
- Oracle Character Datatypes Support
- Additional Oracle Type Extensions

Note: This chapter focuses on type extensions, as opposed to performance extensions, which are discussed in detail in Chapter 12, "Performance Extensions".

Introduction to Oracle Extensions

Oracle provides two implementations of its JDBC drivers—one that supports Sun Microsystems JDK versions 1.2.x through 1.4 and complies with the Sun JDBC 2.0 standard, and one that supports JDK 1.1.x and complies with the Sun JDBC 1.22 standard.

Beyond standard features, Oracle JDBC drivers provide Oracle-specific type extensions and performance extensions.

> **Note:** The JDBC OCI, Thin, and server-side internal drivers support the same functionality and all Oracle extensions.

Both implementations include the following Java packages:

- `oracle.sql` (classes to support all Oracle type extensions)
- `oracle.jdbc` (interfaces to support database access and updates in Oracle type formats)

In addition to these packages, the implementation for JDK 1.1.x includes the following Java package. This package supports some JDBC 2.0 and JDBC 3.0 features by providing interfaces that mimic the new interfaces in the standard `java.sql` package:

- `oracle.jdbc2` (interfaces equivalent to standard JDBC 2.0 interfaces)

(For example, `oracle.jdbc2.Struct` mimics `java.sql.Struct`, which exists in JDK 1.2.)

"Oracle JDBC Packages and Classes" on page 6-7 further describes the preceding packages and their classes.

Support Features of the Oracle Extensions

The Oracle extensions to JDBC include a number of features that enhance your ability to work with Oracle databases. Among these are support for Oracle datatypes, Oracle objects, and specific schema naming.

Support for Oracle Datatypes

A key feature of the Oracle JDBC extensions is the type support in the `oracle.sql` package. This package includes classes that map to all the Oracle SQL datatypes, acting as wrappers for raw SQL data. This functionality provides two significant advantages in manipulating SQL data:

- Accessing data directly in SQL format is more efficient than first converting it to Java format.
- Performing mathematical manipulations of the data directly in SQL format avoids the loss of precision that occurs in converting between SQL and Java formats.

Once manipulations are complete and it is time to output the information, each of the `oracle.sql.*` type support classes has all the necessary methods to convert data to appropriate Java formats. For a more detailed description of these general issues, see "Package oracle.sql" on page 6-7.

See the following for more information on specific `oracle.sql.*` datatype classes:

- "Oracle Character Datatypes Support" on page 6-28 for information on `oracle.sql.*` character datatypes which includes the SQL CHAR and SQL NCHAR datatypes
- "Additional Oracle Type Extensions" on page 6-33 for information on the `oracle.sql.*` datatype classes for ROWIDs and `REF CURSOR` types
- Chapter 8, "Working with LOBs and BFILEs" for information on `oracle.sql.*` datatype support for BLOBs, CLOBs, and BFILEs
- Chapter 9, "Working with Oracle Object Types" for information on `oracle.sql.*` datatype support for composite data structures (Oracle objects) in the database
- Chapter 10, "Working with Oracle Object References" for information on `oracle.sql.*` datatype support for object references

- Chapter 11, "Working with Oracle Collections" for information on `oracle.sql.*` datatype support for collections (VARRAYs and nested tables)

Support for Oracle Objects

Oracle JDBC supports the use of structured objects in the database, where an object datatype is a user-defined type with nested attributes. For example, a user application could define an `Employee` object type, where each `Employee` object has a `firstname` attribute (a character string), a `lastname` attribute (another character string), and an `employeenumber` attribute (integer).

Oracle's JDBC implementation supports Oracle object datatypes. When you work with Oracle object datatypes in a Java application, you must consider the following:

- how to map between Oracle object datatypes and Java classes
- how to store Oracle object attributes in corresponding Java objects (they can be stored in standard Java types or in `oracle.sql.*` types)
- how to convert attribute data between SQL and Java formats
- how to access data

Oracle objects can be mapped either to the weak `java.sql.Struct` or `oracle.sql.STRUCT` types or to strongly typed customized classes. These strong types are referred to as *custom Java classes*, which must implement either the standard `java.sql.SQLData` interface or the Oracle extension `oracle.sql.ORAData` interface. (Chapter 9, "Working with Oracle Object Types" provides more detail regarding these interfaces.) Each interface specifies methods to convert data between SQL and Java.

Note: The `ORAData` interface has replaced the `CustomDatum` interface. While the latter interface is deprecated for Oracle9*i*, it is still supported for backward compatibility.

To create custom Java classes to correspond to your Oracle objects, Oracle recommends that you use the Oracle9*i* JPublisher utility to create the classes. To do this, you must define attributes according to how you want to store the data. JPublisher performs this task seamlessly with command-line options and can generate either `SQLData` or `ORAData` implementations.

For `SQLData` implementations, a *type map* defines the correspondence between Oracle object datatypes and Java classes. Type maps are objects of a special Java class that specify which Java class corresponds to each Oracle object datatype.

Oracle JDBC uses these type maps to determine which Java class to instantiate and populate when it retrieves Oracle object data from a result set.

> **Note:** Oracle recommends using the `ORAData` interface, instead of the `SQLData` interface, in situations where portability is not a concern. `ORAData` works more easily and flexibly in conjunction with other features of the Oracle Java platform offerings.

JPublisher automatically defines `getXXX()` methods of the custom Java classes, which retrieve data into your Java application. For more information on the JPublisher utility, see the *Oracle9i JPublisher User's Guide.*

Chapter 9, "Working with Oracle Object Types" describes Oracle JDBC support for Oracle objects.

Support for Schema Naming

Oracle JDBC classes have the ability to accept and return fully qualified schema names. A fully qualified schema name has this syntax:

{[*schema_name*].}[*sql_type_name*]

Where *schema_name* is the name of the schema and *sql_type_name* is the SQL type name of the object. Notice that *schema_name* and *sql_type_name* are separated by a dot (".").

To specify an object type in JDBC, you use its fully qualified name (that is, a schema name and SQL type name). It is not necessary to enter a schema name if the type name is in current naming space (that is, the current schema). Schema naming follows these rules:

- Both the schema name and the type name may or may not be quoted. However, if the SQL type name has a dot in it, such as `CORPORATE.EMPLOYEE`, the type name must be quoted.
- The JDBC driver looks for the first unquoted dot in the object's name and uses the string before the dot as the schema name and the string following the dot as the type name. If no dot is found, the JDBC driver takes the current schema as default. That is, you can specify only the type name (without indicating a schema) instead of specifying the fully qualified name if the object type name belongs to the current schema. This also explains why you must quote the type name if the type name has a dot in it.

For example, assume that user Scott creates a type called `person.address` and then wants to use it in his session. Scott might want to skip the schema name and pass in `person.address` to the JDBC driver. In this case, if `person.address` is not quoted, then the dot will be detected, and the JDBC driver will mistakenly interpret `person` as the schema name and `address` as the type name.

- JDBC passes the object type name string to the database unchanged. That is, the JDBC driver will not change the character case even if it is quoted.

  For example, if `ScOtT.PersonType` is passed to the JDBC driver as an object type name, the JDBC driver will pass the string to the database unchanged. As another example, if there is white space between characters in the type name string, then the JDBC driver will not remove the white space.

OCI Extensions

See Chapter 16, "JDBC OCI Extensions" for the following OCI driver-specific information:

- OCI Driver Connection Pooling
- Middle-Tier Authentication Through Proxy Connections
- OCI Driver Transparent Application Failover
- OCI HeteroRM XA
- Accessing PL/SQL Index-by Tables

Oracle JDBC Packages and Classes

This section describes the Java packages that support the Oracle JDBC extensions and the key classes that are included in these packages:

- Package oracle.sql
- Package oracle.jdbc
- Package oracle.jdbc2 (for JDK 1.1.x only)

You can refer to the Oracle JDBC Javadoc for more information about all the classes mentioned in this section.

Package oracle.sql

The `oracle.sql` package supports direct access to data in SQL format. This package consists primarily of classes that provide Java mappings to SQL datatypes.

Essentially, the classes act as Java wrappers for the raw SQL data. Because data in an `oracle.sql.*` object remains in SQL format, no information is lost. For SQL primitive types, these classes simply wrap the SQL data. For SQL structured types (objects and arrays), they provide additional information such as conversion methods and details of structure.

Each of the `oracle.sql.*` datatype classes extends `oracle.sql.Datum`, a superclass that encapsulates functionality common to all the datatypes. Some of the classes are for JDBC 2.0-compliant datatypes. These classes, as Table 6–1 indicates, implement standard JDBC 2.0 interfaces in the `java.sql` package (`oracle.jdbc2` for JDK 1.1.x), as well as extending the `oracle.sql.Datum` class.

Classes of the oracle.sql Package

Table 6–1 lists the `oracle.sql` datatype classes and their corresponding Oracle SQL types.

Table 6–1 Oracle Datatype Classes

Java Class	Oracle SQL Types and Interfaces Implemented
`oracle.sql.STRUCT`	`STRUCT` (objects) implements `java.sql.Struct` (`oracle.jdbc2.Struct` under JDK 1.1.x)
`oracle.sql.REF`	`REF` (object references) implements `java.sql.Ref` (`oracle.jdbc2.Ref` under JDK 1.1.x)
`oracle.sql.ARRAY`	`VARRAY` or nested table (collections) implements `java.sql.Array` (`oracle.jdbc2.Array` under JDK 1.1.x)
`oracle.sql.BLOB`	`BLOB` (binary large objects) implements java.sql.Blob (`oracle.jdbc2.Blob` under JDK 1.1.x)
`oracle.sql.CLOB`	SQL `CLOB` (character large objects) and globalization support `NCLOB` datatypes both implement `java.sql.Clob` (`oracle.jdbc2.Clob` under JDK 1.1.x)
`oracle.sql.BFILE`	`BFILE` (external files)
`oracle.sql.CHAR`	`CHAR, NCHAR, VARCHAR2, NVARCHAR2`
`oracle.sql.DATE`	`DATE`
`oracle.sql.TIMESTAMP`	`TIMESTAMP`
`oracle.sql.TIMESTAMPTZ`	`TIMESTAMPTZ` (Timestamp with Time Zone)
`oracle.sql.TIMESTAMPLTZ`	`TIMESTAMPLTZ` (Timestamp with Local Time Zone)
`oracle.sql.NUMBER`	`NUMBER`
`oracle.sql.RAW`	`RAW`
`oracle.sql.ROWID`	`ROWID` (row identifiers)
`oracle.sql.OPAQUE`	`OPAQUE`

You can find more detailed information about each of these classes later in this chapter. Additional details about use of the Oracle extended types (`STRUCT`, `REF`, `ARRAY`, `BLOB`, `CLOB`, `BFILE`, and `ROWID`) are described in the following locations:

- "Oracle Character Datatypes Support" on page 6-28

- "Additional Oracle Type Extensions" on page 6-33
- Chapter 8, "Working with LOBs and BFILEs"
- Chapter 9, "Working with Oracle Object Types"
- Chapter 10, "Working with Oracle Object References"
- Chapter 11, "Working with Oracle Collections"

Notes:

- For information about retrieving data from a result set or callable statement object into `oracle.sql.*` types, as opposed to Java types, see Chapter 7, "Accessing and Manipulating Oracle Data".
- The `LONG` and `LONG RAW` SQL types and `REF CURSOR` type category have no `oracle.sql.*` classes. Use standard JDBC functionality for these types. For example, retrieve `LONG` or `LONG RAW` data as input streams using the standard JDBC result set and callable statement methods `getBinaryStream()` and `getCharacterStream()`. Use the `getCursor()` method for `REF CURSOR` types.

In addition to the datatype classes, the `oracle.sql` package includes the following support classes and interfaces, primarily for use with objects and collections:

- `oracle.sql.ArrayDescriptor` class: Used in constructing `oracle.sql.ARRAY` objects; describes the SQL type of the array. (See "Creating ARRAY Objects and Descriptors" on page 11-11.)
- `oracle.sql.StructDescriptor` class: Used in constructing `oracle.sql.STRUCT` objects, which you can use as a default mapping to Oracle objects in the database. (See "Creating STRUCT Objects and Descriptors" on page 9-4.)
- `oracle.sql.ORAData` and `oracle.sql.ORADataFactory` interfaces: Used in Java classes implementing the Oracle `ORAData` scenario of Oracle object support. (The other possible scenario is the JDBC-standard `SQLData` implementation.) See "Understanding the ORAData Interface" on page 9-21 for more information on `ORAData`.

- `oracle.sql.OpaqueDescriptor` class: Used to obtain the meta data for an instance of the `oracle.sql.OPAQUE` class.

General oracle.sql.* Datatype Support

Each of the Oracle datatype classes provides, among other things, the following:

- one or more constructors, typically with a constructor that uses raw bytes as input and a constructor that takes a Java type as input
- data storage as Java byte arrays for SQL data
- a `getBytes()` method, which returns the SQL data as a byte array (in the raw format in which JDBC received the data from the database)
- a `toJdbc()` method that converts the data into an object of a corresponding Java class as defined in the JDBC specification

  The JDBC driver does not convert Oracle-specific datatypes that are not part of the JDBC specification, such as `ROWID`; the driver returns the object in the corresponding `oracle.sql.*` format. For example, it returns an Oracle ROWID as an `oracle.sql.ROWID`.
- appropriate `xxxValue()` methods to convert SQL data to Java typed—for example: `stringValue()`, `intValue()`, `booleanValue()`, `dateValue()`, `bigDecimalValue()`
- additional conversion, `getXXX()` and `setXXX()` methods as appropriate for the functionality of the datatype (such as methods in the LOB classes that get the data as a stream, and methods in the `REF` class that get and set object data through the object reference)

Refer to the Oracle JDBC Javadoc for additional information about these classes. See "Class oracle.sql.CHAR" on page 6-29 to learn how the `oracle.sql.CHAR` class supports character data.

Overview of Class oracle.sql.STRUCT

For any given Oracle object type, it is usually desirable to define a custom mapping between SQL and Java. (If you use a `SQLData` custom Java class, the mapping must be defined in a type map.)

If you choose not to define a mapping, however, then data from the object type will be materialized in Java in an instance of the `oracle.sql.STRUCT` class.

The STRUCT class implements the standard JDBC 2.0 `java.sql.Struct` interface (`oracle.jdbc2.Struct` under JDK 1.1.x) and extends the `oracle.sql.Datum` class.

In the database, Oracle stores the raw bytes of object data in a linearized form. A STRUCT object is a wrapper for the raw bytes of an Oracle object. It contains the SQL type name of the Oracle object and a "values" array of `oracle.sql.Datum` objects that hold the attribute values in SQL format.

You can materialize a STRUCT's attributes as `oracle.sql.Datum[]` objects if you use the `getOracleAttributes()` method, or as `java.lang.Object[]` objects if you use the `getAttributes()` method. Materializing the attributes as `oracle.sql.*` objects gives you all the advantages of the `oracle.sql.*` format:

- Materializing `oracle.sql.STRUCT` data in `oracle.sql.*` format completely preserves data by maintaining it in SQL format. No translation is performed. This is useful if you want to access data but not necessarily display it.
- It allows complete flexibility in how your Java application unpacks data.

Notes:

- Elements of the values array, although of the generic `Datum` type, actually contain data associated with the relevant `oracle.sql.*` type appropriate for the given attribute. You can cast the element to the appropriate `oracle.sql.*` type as desired. For example, a CHAR data attribute within the STRUCT is materialized as `oracle.sql.Datum`. To use it as CHAR data, you must cast it to the `oracle.sql.CHAR` type.
- Nested objects in the values array of a STRUCT object are materialized by the JDBC driver as instances of STRUCT.

In some cases, you might want to manually create a STRUCT object and pass it to a prepared statement or callable statement. To do this, you must also create a `StructDescriptor` object.

For more information about working with Oracle objects using the `oracle.sql.STRUCT` and `StructDescriptor` classes, see "Using the Default STRUCT Class for Oracle Objects" on page 9-3.

Overview of Class oracle.sql.REF

The `oracle.sql.REF` class is the generic class that supports Oracle object references. This class, as with all `oracle.sql.*` datatype classes, is a subclass of the `oracle.sql.Datum` class. It implements the standard JDBC 2.0 `java.sql.Ref` interface (`oracle.jdbc2.Ref` under JDK 1.1.x).

The REF class has methods to retrieve and pass object references. Be aware, however, that selecting an object reference retrieves only a pointer to an object. This does not materialize the object itself. But the REF class also includes methods to retrieve and pass the object data.

You cannot create REF objects in your JDBC application—you can only retrieve existing REF objects from the database.

For more information about working with Oracle object references using the `oracle.sql.REF` class, see Chapter 10, "Working with Oracle Object References".

Overview of Class oracle.sql.ARRAY

The `oracle.sql.ARRAY` class supports Oracle collections—either VARRAYs or nested tables. If you select either a VARRAY or nested table from the database, then the JDBC driver materializes it as an object of the ARRAY class; the structure of the data is equivalent in either case. The `oracle.sql.ARRAY` class extends `oracle.sql.Datum` and implements the standard JDBC 2.0 `java.sql.Array` interface (`oracle.jdbc2.Array` under JDK 1.1.x).

You can use the `setARRAY()` method of the `OraclePreparedStatement` or `OracleCallableStatement` class to pass an array as an input parameter to a prepared statement. Similarly, you might want to manually create an ARRAY object to pass it to a prepared statement or callable statement, perhaps to insert into the database. This involves the use of `ArrayDescriptor` objects.

For more information about working with Oracle collections using the `oracle.sql.ARRAY` and `ArrayDescriptor` classes, see "Overview of Collection (Array) Functionality" on page 11-5.

Overview of Classes oracle.sql.BLOB, oracle.sql.CLOB, oracle.sql.BFILE

BLOBs and CLOBs (referred to collectively as "LOBs"), and BFILEs (for external files) are for data items that are too large to store directly in a database table. Instead, the database table stores a locator that points to the location of the actual data.

The `oracle.sql` package supports these datatypes in several ways:

- BLOBs point to large unstructured binary data items and are supported by the `oracle.sql.BLOB` class.
- CLOBs point to large fixed-width character data items (that is, characters that require a fixed number of bytes per character) and are supported by the `oracle.sql.CLOB` class.
- BFILEs point to the content of external files (operating system files) and are supported by the `oracle.sql.BFILE` class.

You can select a BLOB, CLOB, or BFILE locator from the database using a standard `SELECT` statement, but bear in mind that you are receiving only the locator, not the data itself. Additional steps are necessary to retrieve the data.

For information about how to access and manipulate locators and data for LOBs and BFILEs, see Chapter 8, "Working with LOBs and BFILEs".

Classes oracle.sql.DATE, oracle.sql.NUMBER, and oracle.sql.RAW

These classes map to primitive SQL datatypes, which are a part of standard JDBC, and supply conversions to and from the corresponding JDBC Java types. For more information, see the Javadoc.

Classes oracle.sql.TIMESTAMP, oracle.sql.TIMESTAMPTZ, and oracle.sql.TIMESTAMPLTZ

The Oracle9*i* JDBC drivers support the following date/time datatypes:

- Timestamp (`TS`)
- Timestamp with Time Zone (`TSTZ`)
- TIMESTAMP with Local Time Zone (`TSLTZ`)

Oracle9*i* JDBC drivers allow conversions among `DATE` and date/time datatypes. For example, you can access a `TIMESTAMPTZ` column as a `DATE` value.

Oracle9*i* JDBC drivers support the most popular time zone names used in the industry as well as most of the time zone names defined in the JDK from Sun Microsystems. Time zones are specified by using the `java.util.Calendar` class.

Note: Do not use `TimeZone.getTimeZone()` to create timezone objects; the Oracle timezone datatypes support more time zone names than does the JDK.

The following code shows how the `TimeZone` and `Calendar` objects are created for `US_PACIFIC`, which is a time zone name not defined in the JDK:

```
TimeZone tz = TimeZone.getDefault();
tz.setID("US_PACIFIC");
GregorianCalendar gcal = new GregorianCalendar(tz);
```

The following Java classes represent the SQL date/time types:

- `oracle.sql.TIMESTAMP`
- `oracle.sql.TIMESTAMPTZ`
- `oracle.sql.TIMESTAMPLTZ`

Use the following methods from the `oracle.jdbc.OraclePreparedStatement` interface to set a date/time:

- `setTIMESTAMP(int paramIdx,TIMESTAMP x)`
- `setTIMESTAMPTZ(int paramIdx,TIMESTAMPTZ x)`
- `setTIMESTAMPLTZ(int paramIdx,TIMESTAMPLTZ x)`

Use the following methods from the `oracle.jdbc.OracleCallableStatement` interface to get a date/time:

- `TIMESTAMP getTIMESTAMP (int paramIdx)`
- `TIMESTAMPTZ getTIMESTAMPTZ(int paramIdx)`
- `TIMESTAMPLTZ getTIMESTAMPLTZ(int paramIdx)`

Use the following methods from the `oracle.jdbc.OracleResultSet` interface to get a date/time:

- `TIMESTAMP getTIMESTAMP(int paramIdx)`
- `TIMESTAMP getTIMESTAMP(java.lang.String colName)`
- `TIMESTAMPTZ getTIMESTAMPTZ(int paramIdx)`
- `TIMESTAMPTZ getTIMESTAMPTZ(java.lang.String colName)`
- `TIMESTAMPLTZ getTIMESTAMPLTZ(int paramIdx)`
- `TIMESTAMPLTZ getTIMESTAMPLTZ(java.lang.String colName)`
- `TIMESTAMPLTZ getTIMESTAMPLTZ(int paramIdx)`

Use the following methods from the `oracle.jdbc.OracleResultSet` interface to update a date/time:

- `updateTIMESTAMP(int paramIdx)`
- `updateTIMESTAMPTZ(int paramIdx)`
- `updateTIMESTAMPLTZ(int paramIdx)`

Before accessing `TIMESTAMPLTZ` data, call the `OracleConnection.setSessionTime()` method to set the session time zone. When this method is called, the JDBC driver sets the session time zone of the connection and saves the session time zone so that any `TIMESTAMPLTZ` data accessed through JDBC can be adjusted using the session time zone.

Overview of Class oracle.sql.ROWID

This class supports Oracle ROWIDs, which are unique identifiers for rows in database tables. You can select a ROWID as you would select any column of data from the table. Note, however, that you cannot manually update ROWIDs—the Oracle database updates them automatically as appropriate.

The `oracle.sql.ROWID` class does not implement any noteworthy functionality beyond what is in the `oracle.sql.Datum` superclass. However, `ROWID` does provide a `stringValue()` method that overrides the `stringValue()` method in the `oracle.sql.Datum` class and returns the hexadecimal representation of the `ROWID` bytes.

For information about accessing ROWID data, see "Oracle ROWID Type" on page 6-33.

Class oracle.sql.OPAQUE

The `oracle.sql.OPAQUE` class gives you the name and characteristics of the OPAQUE type and any attributes. OPAQUE types provide access only to the uninterrupted bytes of the instance.

Note: For Oracle9*i* 9.0.1, there is minimal support for OPAQUE types.

The following are the methods of the `oracle.sql.OPAQUE` class:

- `getBytesValue()`: Returns a byte array that represents the value of the OPAQUE object, in the format used in the database.
- `public boolean isConvertibleTo(Class jClass)`: Determines if a `Datum` object can be converted to a particular class, where `Class` is any class

and `jClass` is the class to convert. `true` is returned if conversion to `jClass` is permitted and `false` if conversion to `jClass` is not permitted.

- `getDescriptor()`: Returns the `OpaqueDescriptor` object that contains the type information.
- `getJavaSqlConnection()`: Returns the connection associated with the receiver. Because methods that use the `oracle.jdbc.driver` package are deprecated, the `getConnection()` method has been deprecated in favor of the `getJavaSqlConnection()` method.
- `getSQLTypeName()`: Implements the `java.sql.Struct` interface function and retrieves the SQL type name of the SQL structured type that this `Struct` object represents. This method returns the fully-qualified type name of the SQL structured type which this `STRUCT` object represents.
- `getValue()`: Returns a Java object that represents the value (raw bytes).
- `toJdbc()`: Returns the JDBC representation of the `Datum` object.

Package oracle.jdbc

The interfaces of the `oracle.jdbc` package provide Oracle-specific extensions to allow access to raw SQL format data by using `oracle.sql.*` objects.

Note: The interfaces of the `oracle.jdbc` package replace the deprecated classes of the `oracle.jdbc.driver` package found in previous releases. (See "Package oracle.jdbc" on page 1-11 for more information.)

For the `oracle.jdbc` package, Table 6–2 lists key interfaces and classes used for connections, statements, and result sets.

Table 6–2 Key Interfaces and Classes of the oracle.jdbc Package

Name	Interface or Class	Key Functionality
`OracleDriver`	Class	implements `java.sql.Driver`
`OracleConnection`	Interface	methods to return Oracle statement objects; methods to set Oracle performance extensions for any statement executed in the current connection (implements `java.sql.Connection`)
`OracleStatement`	Interface	methods to set Oracle performance extensions for individual statement; superclass of `OraclePreparedStatement` and `OracleCallableStatement` (implements `java.sql.Statement`)
`OraclePreparedStatement`	Interface	`setXXX()` methods to bind `oracle.sql.*` types into a prepared statement (implements `java.sql.PreparedStatement`; extends `OracleStatement`; superclass of `OracleCallableStatement`)
`OracleCallableStatement`	Interface	`getXXX()` methods to retrieve data in `oracle.sql` format; `setXXX()` methods to bind `oracle.sql.*` types into a callable statement (implements `java.sql.CallableStatement`; extends `OraclePreparedStatement`)
`OracleResultSet`	Interface	`getXXX()` methods to retrieve data in `oracle.sql` format (implements `java.sql.ResultSet`)
`OracleResultSetMetaData`	Interface	methods to get meta information about Oracle result sets, such as column names and datatypes (implements `java.sql.ResultSetMetaData`)

Table 6–2 Key Interfaces and Classes of the oracle.jdbc Package (Cont.)

Name	Interface or Class	Key Functionality
`OracleDatabaseMetaData`	Class	methods to get meta information about the database, such as database product name / version, table information, and default transaction isolation level (implements `java.sql.DatabaseMetaData`)
OracleTypes	Class	defines integer constants used to identify SQL types. For standard types, it uses the same values as the standard `java.sql.Types` class. In addition, it adds constants for Oracle extended types.

The remainder of this section describes the interfaces and classes of the `oracle.jdbc` package. For more information about using these interfaces and classes to access Oracle type extensions, see Chapter 7, "Accessing and Manipulating Oracle Data".

Class oracle.jdbc.OracleDriver

Use this class to register the Oracle JDBC drivers for use by your application. You can input a new instance of this class to the static `registerDriver()` method of the `java.sql.DriverManager` class so that your application can access and use the Oracle drivers. The `registerDriver()` method takes as input a "driver" class, that is, a class that implements the `java.sql.Driver` interface, as is the case with `OracleDriver`.

Once you register the Oracle JDBC drivers, you can create your connection using the `DriverManager` class. For more information on registering drivers and writing a connection string, see "First Steps in JDBC" on page 3-2.

Interface oracle.jdbc.OracleConnection

This interface extends standard JDBC connection functionality to create and return Oracle statement objects, set flags and options for Oracle performance extensions, support type maps for Oracle objects, and support client identifiers.

"Additional Oracle Performance Extensions" on page 12-20 describes the performance extensions, including row prefetching, update batching, and metadata `TABLE_REMARKS` reporting.

Client Identifiers In a connection pooling environment, the client identifier can be used to identify which light-weight user is currently using the database session. A client identifier can also be used to share the Globally Accessed Application Context between different database sessions. The client identifier set in a database session is audited when database auditing is turned on.

> **Note:** See the *Oracle9i Application Developer's Guide - Fundamentals* for a full discussion of Globally Accessed Contexts.

Key methods include:

- `createStatement()`: Allocates a new `OracleStatement` object.
- `prepareStatement()`: Allocates a new `OraclePreparedStatement` object.
- `prepareCall()`: Allocates a new `OracleCallableStatement` object.
- `getTypeMap()`: Retrieves the type map for this connection (for use in mapping Oracle object types to Java classes).
- `setTypeMap()`: Initializes or updates the type map for this connection (for use in mapping Oracle object types to Java classes).
- `getTransactionIsolation()`: Gets this connection's current isolation mode.
- `setTransactionIsolation()`: Changes the transaction isolation level using one of the `TRANSACTION_*` values.

These `oracle.jdbc.OracleConnection` methods are Oracle-defined extensions:

- `setClientIdentifier()`: Sets the client identifier for this connection.
- `clearClientIdentifier()`: Clears the client identifier for this connection.
- `getDefaultExecuteBatch()`: Retrieves the default update-batching value for this connection.
- `setDefaultExecuteBatch()`: Sets the default update-batching value for this connection.
- `getDefaultRowPrefetch()`: Retrieves the default row-prefetch value for this connection.
- `setDefaultRowPrefetch()`: Sets the default row-prefetch value for this connection.

- `getRemarksReporting()`: Returns true if `TABLE_REMARKS` reporting is enabled.
- `setRemarksReporting()`: Enables or disables `TABLE_REMARKS` reporting.

Interface oracle.jdbc.OracleStatement

This interface extends standard JDBC statement functionality and is the superinterface of the `OraclePreparedStatement` and `OracleCallableStatement` classes. Extended functionality includes support for setting flags and options for Oracle performance extensions on a statement-by-statement basis, as opposed to the `OracleConnection` interface that sets these on a connection-wide basis.

"Additional Oracle Performance Extensions" on page 12-20 describes the performance extensions, including row prefetching and column type definitions.

Key methods include:

- `executeQuery()`: Executes a database query and returns an `OracleResultSet` object.
- `getResultSet()`: Retrieves an `OracleResultSet` object.
- `close()`: Closes the current statement.

These `oracle.jdbc.OracleStatement` methods are Oracle-defined extensions:

- `defineColumnType()`: Defines the type you will use to retrieve data from a particular database table column.
- `getRowPrefetch()`: Retrieves the row-prefetch value for this statement.
- `setRowPrefetch()`: Sets the row-prefetch value for this statement.

Interface oracle.jdbc.OraclePreparedStatement

This interface extends the `OracleStatement` interface and extends standard JDBC prepared statement functionality. Also, the `oracle.jdbc.OraclePreparedStatement` interface is extended by the `OracleCallableStatement` interface. Extended functionality consists of `setXXX()` methods for binding `oracle.sql.*` types and objects into prepared statements, and methods to support Oracle performance extensions on a statement-by-statement basis.

"Additional Oracle Performance Extensions" on page 12-20 describes the performance extensions, including database update batching.

Key methods include:

- `getExecuteBatch()`: Retrieves the update-batching value for this statement.
- `setExecuteBatch()`: Sets the update-batching value for this statement.
- `setOracleObject()`: This is a generic `setXXX()` method for binding `oracle.sql.*` data into a prepared statement as an `oracle.sql.Datum` object.
- `setXXX()`: These methods, such as `setBLOB()`, are for binding specific `oracle.sql.*` types into prepared statements.
- `setORAData()`: Binds an `ORAData` object (for use in mapping Oracle object types to Java) into a prepared statement.
- `setNull()`: Sets the value of the object specified by its SQL type name to `NULL`. For `setNull(`*`param_index`*`, `*`type_code`*`, `*`sql_type_name`*`)`, if `type_code` is `REF`, `ARRAY`, or `STRUCT`, then *`sql_type_name`* is the fully qualified name (*`schema.sql_type_name`*) of the SQL type.
- `setFormOfUse()`: Sets which form of use this method is going to use. There are two constants that specify the form of use: `FORM_CHAR` and `FORM_NCHAR`, where `FORM_CHAR` is the default. If the form of use is set to `FORM_NCHAR`, the JDBC driver will represent the provided data in the national character set of the server. The following code show how the `FORM_NCHAR` is used:

  ```
  pstmt.setFormOfUse
    (parameter index,
    oracle.jdbc.OraclePreparedStatement.FORM_NCHAR)
  ```

- `close()`: Closes the current statement.

Interface oracle.jdbc.OracleCallableStatement

This interface extends the `OraclePreparedStatement` interface (which extends the `OracleStatement` interface) and incorporates standard JDBC callable statement functionality.

Key methods include:

- `getOracleObject()`: This is a generic `getXXX()` method for retrieving data into an `oracle.sql.Datum` object, which can be cast to the specific `oracle.sql.*` type as necessary.
- `getXXX()`: These methods, such as `getCLOB()`, are for retrieving data into specific `oracle.sql.*` objects.

- `setOracleObject()`: This is a generic `setXXX()` method for binding `oracle.sql.*` data into a callable statement as an `oracle.sql.Datum` object.
- `setXXX()`: These methods, such as `setBLOB()`, are inherited from `OraclePreparedStatement` for binding specific `oracle.sql.*` objects into callable statements.
- `setNull()`: Sets the value of the object specified by its SQL type name to `NULL`. For `setNull(`*`param_index`*`, `*`type_code`*`, `*`sql_type_name`*`)`, if *`type_code`* is `REF`, `ARRAY`, or `STRUCT`, then *`sql_type_name`* is the fully qualified (*`schema.type`*) name of the SQL type.
- `setFormOfUse()`: Sets which form of use this method is going to use. There are two constants that specify the form of use: `FORM_CHAR` and `FORM_NCHAR`, where `FORM_CHAR` is the default. If the form of use is set to `FORM_NCHAR`, the JDBC driver will represent the provided data in the national character set of the server. The following code show how the `FORM_NCHAR` is used:

  ```
  pstmt.setFormOfUse
    (parameter index,
    oracle.jdbc.OraclePreparedStatement.FORM_NCHAR)
  ```

- `registerOutParameter()`: Registers the SQL typecode of the statement's output parameter. JDBC requires this for any callable statement with an `OUT` parameter. It takes an integer parameter index (the position of the output variable in the statement, relative to the other parameters) and an integer SQL type (the type constant defined in `oracle.jdbc.OracleTypes`).

  This is an overloaded method. One version of this method is for named types only—when the SQL typecode is `OracleTypes.REF`, `STRUCT`, or `ARRAY`. In this case, in addition to a parameter index and SQL type, the method also takes a `String` SQL type name (the name of the Oracle user-defined type in the database, such as `EMPLOYEE`).
- `close()`: Closes the current result set, if any, and the current statement.

Interface oracle.jdbc.OracleResultSet

This interface extends standard JDBC result set functionality, implementing `getXXX()` methods for retrieving data into `oracle.sql.*` objects.

Key methods include:

- `getOracleObject()`: This is a generic `getXXX()` method for retrieving data into an `oracle.sql.Datum` object. It can be cast to the specific `oracle.sql.*` type as necessary.

- `getXXX()`: These methods, such as `getCLOB()`, are for retrieving data into `oracle.sql.*` objects.

Interface oracle.jdbc.OracleResultSetMetaData

This interface extends standard JDBC result set metadata functionality to retrieve information about Oracle result set objects. See "Using Result Set Meta Data Extensions" on page 7-19 for information on the functionality of the `OracleResultSetMetadata` interface.

Class oracle.jdbc.OracleTypes

The `OracleTypes` class defines constants that JDBC uses to identify SQL types. Each variable in this class has a constant integer value. The `oracle.jdbc.OracleTypes` class duplicates the typecode definitions of the standard Java `java.sql.Types` class and contains these additional typecodes for Oracle extensions:

- `OracleTypes.BFILE`
- `OracleTypes.ROWID`
- `OracleTypes.CURSOR` (for `REF CURSOR` types)

As in `java.sql.Types`, all the variable names are in all-caps.

JDBC uses the SQL types identified by the elements of the `OracleTypes` class in two main areas: registering output parameters, and in the `setNull()` method of the `PreparedStatement` class.

OracleTypes and Registering Output Parameters The typecodes in `java.sql.Types` or `oracle.jdbc.OracleTypes` identify the SQL types of the output parameters in the `registerOutParameter()` method of the `java.sql.CallableStatement` interface and `oracle.jdbc.OracleCallableStatement` interface.

These are the forms that `registerOutputParameter()` can take for `CallableStatement` and `OracleCallableStatement` (assume a standard callable statement object `cs`):

```
cs.registerOutParameter(int index, int sqlType);

cs.registerOutParameter(int index, int sqlType, String sql_name);

cs.registerOutParameter(int index, int sqlType, int scale);
```

In these signatures, *index* represents the parameter index, *sqlType* is the typecode for the SQL datatype, *sql_name* is the name given to the datatype (for user-defined types, when *sqlType* is a STRUCT, REF, or ARRAY typecode), and *scale* represents the number of digits to the right of the decimal point (when *sqlType* is a NUMERIC or DECIMAL typecode).

Note: The second signature is standard under JDBC 2.0 in a JDK 1.2.x environment, but is an Oracle extension under JDK 1.1.x.

The following example uses a CallableStatement to call a procedure named charout, which returns a CHAR datatype. Note the use of the OracleTypes.CHAR typecode in the registerOutParameter() method (although java.sql.Types.CHAR could have been used as well).

```
CallableStatement cs = conn.prepareCall ("BEGIN charout (?); END;");
cs.registerOutParameter (1, OracleTypes.CHAR);
cs.execute ();
System.out.println ("Out argument is: " + cs.getString (1));
```

The next example uses a CallableStatement to call structout, which returns a STRUCT datatype. The form of registerOutParameter() requires you to specify the typecode (Types.STRUCT or OracleTypes.STRUCT), as well as the SQL name (EMPLOYEE).

The example assumes that no type mapping has been declared for the EMPLOYEE type, so it is retrieved into a STRUCT datatype. To retrieve the value of EMPLOYEE as an oracle.sql.STRUCT object, the statement object cs is cast to an OracleCallableStatement and the Oracle extension getSTRUCT() method is invoked.

```
CallableStatement cs = conn.prepareCall ("BEGIN structout (?); END;");
cs.registerOutParameter (1, OracleTypes.STRUCT, "EMPLOYEE");
cs.execute ();

// get the value into a STRUCT because it
// is assumed that no type map has been defined
STRUCT emp = ((OracleCallableStatement)cs).getSTRUCT (1);
```

OracleTypes and the setNull() Method The typecodes in Types and OracleTypes identify the SQL type of the data item, which the setNull() method sets to NULL. The setNull() method can be found in the java.sql.PreparedStatement interface and the oracle.jdbc.OraclePreparedStatement interface.

These are the forms that `setNull()` can take for `PreparedStatement` and `OraclePreparedStatement` objects (assume a standard prepared statement object `ps`):

```
ps.setNull(int index, int sqlType);

ps.setNull(int index, int sqlType, String sql_name);
```

In these signatures, *`index`* represents the parameter index, *`sqlType`* is the typecode for the SQL datatype, and *`sql_name`* is the name given to the datatype (for user-defined types, when *`sqlType`* is a `STRUCT`, `REF`, or `ARRAY` typecode). If you enter an invalid *`sqlType`*, a `Parameter Type Conflict` exception is thrown.

Note: The second signature is standard under JDBC 2.0 in a JDK 1.2.x environment, but is an Oracle extension under JDK 1.1.x.

The following example uses a `PreparedStatement` to insert a `NULL` numeric value into the database. Note the use of `OracleTypes.NUMERIC` to identify the numeric object set to `NULL` (although `Types.NUMERIC` could have been used as well).

```
PreparedStatement pstmt =
    conn.prepareStatement ("INSERT INTO num_table VALUES (?)");

pstmt.setNull (1, OracleTypes.NUMERIC);
pstmt.execute ();
```

In this example, the prepared statement inserts a `NULL STRUCT` object of type `EMPLOYEE` into the database.

```
PreparedStatement pstmt = conn.prepareStatement
                                ("INSERT INTO employee_table VALUES (?)");

pstmt.setNull (1, OracleTypes.STRUCT, "EMPLOYEE");
pstmt.execute ();
```

Oracle Interfaces for Oracle-specific Features

The `oracle.jdbc` interfaces introduced in Oracle9*i* are recommended alternatives to the classes by the same name in the `oracle.jdbc.driver` package in older

releases. These interfaces essentially duplicate the functionality in the `oracle.jdbc.driver` package.

The following example shows how the `oracle.jdbc` package is used to cast `pstmt` as an Oracle type:

```
java.sql.PreparedStatement pstmt
  = conn.prepareStatement(...);

((oracle.jdbc.OraclePreparedStatement) pstmt)
  .setExecuteBatch(10);   // Oracle-specific method
```

Method getJavaSqlConnection()

The `getJavaSqlConnection()` method of the oracle.sql.* classes returns `java.sql.Connection` while the `getConnection()` method returns `oracle.jdbc.driver.OracleConnection`. Because the methods that use the `oracle.jdbc.driver` package are deprecated, the `getConnection()` method is also deprecated in favor of the `getJavaSqlConnection()` method.

For the following Oracle datatype classes, the `getJavaSqlConnection()` method was added:

- `oracle.sql.ARRAY`
- `oracle.sql.BFILE`
- `oracle.sql.BLOB`
- `oracle.sql.CLOB`
- `oracle.sql.OPAQUE`
- `oracle.sql.REF`
- `oracle.sql.STRUCT`

The following shows the `getJavaSqlConnection()` and the `getConnection()` methods in the `Array` class:

```
public class ARRAY
{
  // New API
  //
  java.sql.Connection getJavaSqlConnection()
    throws SQLException;

  // Deprecated API.
```

```
  //
  oracle.jdbc.driver.OracleConnection
    getConnection() throws SQLException;

  ...
}
```

Package oracle.jdbc2 (for JDK 1.1.x only)

The `oracle.jdbc2` package is an Oracle implementation for use with JDK 1.1.x, containing classes and interfaces that mimic a subset of standard JDBC 2.0 classes and interfaces (which exist in the JDK 1.2 version of the standard `java.sql` package).

The following interfaces are implemented by `oracle.sql.*` type classes for JDBC 2.0-compliant Oracle type extensions under JDK 1.1.x.

- `oracle.jdbc2.Array` is implemented by `oracle.sql.ARRAY`
- `oracle.jdbc2.Struct` is implemented by `oracle.sql.STRUCT`
- `oracle.jdbc2.Ref` is implemented by `oracle.sql.REF`
- `oracle.jdbc2.Clob` is implemented by `oracle.sql.CLOB`
- `oracle.jdbc2.Blob` is implemented by `oracle.sql.BLOB`

In addition, the `oracle.jdbc2` package includes the following interfaces for users employing the JDBC-standard `SQLData` interface to create Java classes that map to Oracle objects. Again, these interfaces mimic `java.sql` interfaces available with JDK 1.2:

- `oracle.jdbc2.SQLData` is implemented by classes that map to Oracle objects; users must provide this implementation
- `oracle.jdbc2.SQLInput` is implemented by classes that read object data; Oracle provides a `SQLInput` class that the JDBC drivers use
- `oracle.jdbc2.SQLOutput` is implemented by classes that write object data; Oracle provides a `SQLOutput` class that the JDBC drivers use

The `SQLData` interface is one of the two facilities you can use to support Oracle objects in Java. (The other choice is the Oracle `ORAData` interface, included in the `oracle.sql` package.) See "Understanding the SQLData Interface" on page 9-15 for more information about `SQLData`, `SQLInput`, and `SQLOutput`.

Oracle Character Datatypes Support

Oracle character datatypes include the SQL CHAR and SQL NCHAR datatypes. The following sections describe how these datatypes can be accessed using the Oracle JDBC drivers.

SQL CHAR Datatypes

The SQL CHAR datatypes include CHAR, VARCHAR2, and CLOB. These datatypes allow you to store character data in the database character set encoding scheme. The character set of the database is established when you create the database.

SQL NCHAR Datatypes

SQL NCHAR datatypes were created for Globalization Support (formerly NLS). SQL NCHAR datatypes include NCHAR, NVARCHAR2, and NCLOB. These datatypes allow you to store unicode data in the database NCHAR character set encoding. The NCHAR character set, which never changes, is established when you create the database. See the *Oracle9i Database Globalization Support Guide* for information on SQL NCHAR datatypes.

Note: Because the `UnicodeStream` class is deprecated in favor of the `CharacterStream` class, the `setUnicodeStream()` and `getUnicodeStream()` methods are not supported for NCHAR datatype access. Use the `setCharacterStream()` method and the `getCharacterStream()` method if you want to use stream access.

The usage of SQL NCHAR datatypes is similar to that of the SQL CHAR (CHAR, VARCHAR2, and CLOB) datatypes. JDBC uses the same classes and methods to access SQL NCHAR datatypes that are used for the corresponding SQL CHAR datatypes. Therefore, there are no separate, corresponding classes defined in the `oracle.sql` package for SQL NCHAR datatypes. Likewise, there is no separate, corresponding constant defined in the `oracle.jdbc.OracleTypes` class for SQL NCHAR datatypes. The only difference in usage between the two datatypes occur in a data bind situation: a JDBC program must call the `setFormOfUse()` method to specify if the data is bound for a SQL NCHAR datatype.

> **Note:** For Oracle9*i* 9.0.1, the `setFormOfUse()` method must be called before the `registerOutParameter()` method is called in order to avoid unpredictable results.

The following code shows how to access SQL NCHAR data:

```
//
// Table TEST has the following columns:
// - NUMBER
// - NVARCHAR2
// - NCHAR
//
oracle.jdbc.OraclePreparedStatement pstmt =
  (oracle.jdbc.OraclePreparedStatement)
conn.prepareStatement("insert into TEST values(?, ?, ?)");

//
// oracle.jdbc.OraclePreparedStatement.FORM_NCHAR should be used for all NCHAR,
// NVARCHAR2 and NCLOB data types.
//
pstmt.setFormOfUse(2, Const.NCHAR);
pstmt.setFormOfUse(3, Const.NCHAR);

pstmt.setInt(1, 1);                    // NUMBER column
pstmt.setString(2, myUnicodeString1);  // NVARCHAR2 column
pstmt.setString(3, myUnicodeString2);  // NCHAR column
pstmt.execute();
```

Class oracle.sql.CHAR

The CHAR class is used by Oracle JDBC in handling and converting character data. The JDBC driver constructs and populates `oracle.sql.CHAR` objects once character data has been read from the database.

> **Note:** The `oracle.sql.CHAR` class is used for both SQL CHAR and SQL NCHAR datatypes.

The CHAR objects constructed and returned by the JDBC driver can be in the database character set, `UTF-8`, or `ISO-Latin-1` (`WE8ISO8859P1`). The CHAR objects that are Oracle object attributes are returned in the database character set.

JDBC application code rarely needs to construct CHAR objects directly, since the JDBC driver automatically creates CHAR objects as character data are obtained from the database. There may be circumstances, however, where constructing CHAR objects directly in application code is useful—for example, to repeatedly pass the same character data to one or more prepared statements without the overhead of converting from Java strings each time.

oracle.sql.CHAR Objects and Character Sets

The CHAR class provides Globalization Support functionality to convert character data. This class has two key attributes: (1) Globalization Support character set and (2) the character data. The Globalization Support character set defines the encoding of the character data. It is a parameter that is always passed when a CHAR object is constructed. Without the Globalization Support character set being know, the bytes of data in the CHAR object are meaningless.

The `oracle.sql.CharacterSet` class is instantiated to represent character sets. To construct a CHAR object, you must provide character set information to the CHAR object by way of an instance of the `CharacterSet` class. Each instance of this class represents one of the Globalization Support character sets that Oracle supports. A `CharacterSet` instance encapsulates methods and attributes of the character set, mainly involving functionality to convert to or from other character sets. You can find a complete list of the character sets that Oracle supports in the *Oracle9i Database Globalization Support Guide.*

Constructing an oracle.sql.CHAR Object

Follow these general steps to construct a CHAR object:

1. Create a `CharacterSet` object by calling the static `CharacterSet.make()` method.

   This method is a factory for the character set instance. The `make()` method takes an integer as input, which corresponds to a character set ID that Oracle supports. For example:

   ```
   int oracleId = CharacterSet.JA16SJIS_CHARSET; // this is character set ID,
                                                 // 832
   ...
   CharacterSet mycharset = CharacterSet.make(oracleId);
   ```

   Each character set that Oracle supports has a unique, predefined Oracle ID.

   For more information on character sets and character set IDs, see the *Oracle9i Database Globalization Support Guide.*

2. Construct a CHAR object.

   Pass a string (or the bytes that represent the string) to the constructor along with the `CharacterSet` object that indicates how to interpret the bytes based on the character set. For example:

   ```
   String mystring = "teststring";
   ...
   CHAR mychar = new CHAR(teststring, mycharset);
   ```

   The CHAR class has multiple constructors—they can take a string, a byte array, or an object as input along with the `CharacterSet` object. In the case of a string, the string is converted to the character set indicated by the `CharacterSet` object before being placed into the CHAR object.

   See the `oracle.sql.CHAR` class Javadoc for more information.

   Notes:

   - The `CharacterSet` object cannot be null.
   - The `CharacterSet` class is an abstract class, therefore it has no constructor. The only way to create instances is to use the `make()` method.
   - The server recognizes the special value `CharacterSet.DEFAULT_CHARSET` as the database character set. For the client, this value is not meaningful.
   - Oracle does not intend or recommend that users extend the `CharacterSet` class.

oracle.sql.CHAR Conversion Methods

The CHAR class provides the following methods for translating character data to strings:

- `getString()`: Converts the sequence of characters represented by the CHAR object to a string, returning a Java `String` object. If you enter an invalid `OracleID`, then the character set will not be recognized and the `getString()` method throws a `SQLException`.
- `toString()`: Identical to the `getString()` method. But if you enter an invalid `OracleID`, then the character set will not be recognized and the `toString()` method returns a hexadecimal representation of the CHAR data and does *not* throw a `SQLException`.

- `getStringWithReplacement()`: Identical to `getString()`, except a default replacement character replaces characters that have no unicode representation in the CHAR object character set. This default character varies from character set to character set, but is often a question mark ("?").

The server (a database) and the client, or application running on the client, can use different character sets. When you use the methods of the CHAR class to transfer data between the server and the client, the JDBC drivers must convert the data from the server character set to the client character set or vice versa. To convert the data, the drivers use Globalization Support. For more information on how the JDBC drivers convert between character sets, see "JDBC and Globalization Support" on page 17-2.

Additional Oracle Type Extensions

See other chapters in this book for information about key Oracle type extensions:

- Chapter 8, "Working with LOBs and BFILEs"
- Chapter 9, "Working with Oracle Object Types"
- Chapter 10, "Working with Oracle Object References"
- Chapter 11, "Working with Oracle Collections"

This section covers additional Oracle type extensions and concludes with a discussion of differences between the current Oracle JDBC drivers and the Oracle 8.0.x and 7.3.x drivers regarding support of Oracle extensions.

Oracle JDBC drivers support the Oracle-specific `BFILE` and `ROWID` datatypes and `REF CURSOR` types, which were introduced in Oracle7 and are not part of the standard JDBC specification. This section describes the `ROWID` and `REF CURSOR` type extensions. See Chapter 8 for information about BFILEs.

`ROWID` is supported as a Java string, and `REF CURSOR` types are supported as JDBC result sets.

Oracle ROWID Type

A ROWID is an identification tag unique for each row of an Oracle database table. The ROWID can be thought of as a virtual column, containing the ID for each row.

The `oracle.sql.ROWID` class is supplied as a wrapper for type `ROWID` SQL data.

ROWIDs provide functionality similar to the `getCursorName()` method specified in the `java.sql.ResultSet` interface, and the `setCursorName()` method specified in the `java.sql.Statement` interface.

If you include the ROWID pseudo-column in a query, then you can retrieve the ROWIDs with the result set `getString()` method (passing in either the column index or the column name). You can also bind a ROWID to a `PreparedStatement` parameter with the `setString()` method. This allows in-place updates, as in the example that follows.

Note: The `oracle.sql.ROWID` class replaces `oracle.jdbc.driver.ROWID`, which was used in previous releases of Oracle JDBC.

Example: ROWID The following example shows how to access and manipulate `ROWID` data.

```
Statement stmt = conn.createStatement();

// Query the employee names with "FOR UPDATE" to lock the rows.
// Select the ROWID to identify the rows to be updated.

ResultSet rset =
   stmt.executeQuery ("SELECT ename, rowid FROM emp FOR UPDATE");

// Prepare a statement to update the ENAME column at a given ROWID

PreparedStatement pstmt =
   conn.prepareStatement ("UPDATE emp SET ename = ? WHERE rowid = ?");

// Loop through the results of the query
while (rset.next ())
{
    String ename = rset.getString (1);
    oracle.sql.ROWID rowid = rset.getROWID (2);  // Get the ROWID as a String
    pstmt.setString (1, ename.toLowerCase ());
    pstmt.setROWID (2, rowid); // Pass ROWID to the update statement
    pstmt.executeUpdate ();     // Do the update
}
```

Oracle REF CURSOR Type Category

A cursor variable holds the memory location (address) of a query work area, rather than the contents of the area. Declaring a cursor variable creates a pointer. In SQL, a pointer has the datatype REF *x* , where REF is short for REFERENCE and *x* represents the entity being referenced. A REF CURSOR, then, identifies a reference to a cursor variable. Because many cursor variables might exist to point to many work areas, REF CURSOR can be thought of as a category or "datatype specifier" that identifies many different types of cursor variables.

To create a cursor variable, begin by identifying a type that belongs to the REF CURSOR category. For example:

```
DECLARE TYPE DeptCursorTyp IS REF CURSOR
```

Then create the cursor variable by declaring it to be of the type `DeptCursorTyp`:

```
dept_cv DeptCursorTyp  - - declare cursor variable
...
```

`REF CURSOR`, then, is a *category* of datatypes, rather than a particular datatype.

Stored procedures can return cursor variables of the `REF CURSOR` category. This output is equivalent to a database cursor or a JDBC result set. A REF CURSOR essentially encapsulates the results of a query.

In JDBC, REF CURSORs are materialized as `ResultSet` objects and can be accessed as follows:

1. Use a JDBC callable statement to call a stored procedure. It must be a callable statement, as opposed to a prepared statement, because there is an output parameter.
2. The stored procedure returns a REF CURSOR.
3. The Java application casts the callable statement to an Oracle callable statement and uses the `getCursor()` method of the `OracleCallableStatement` class to materialize the REF CURSOR as a JDBC `ResultSet` object.
4. The result set is processed as requested.

Important: The cursor associated with a REF CURSOR is closed whenever the statement object that produced the REF CURSOR is closed.

Unlike in past releases, the cursor associated with a REF CURSOR is *not* closed when the result set object in which the REF CURSOR was materialized is closed.

Example: Accessing REF CURSOR Data This example shows how to access REF CURSOR data.

```
import oracle.jdbc.*;
...
CallableStatement cstmt;
ResultSet cursor;

// Use a PL/SQL block to open the cursor
```

```
cstmt = conn.prepareCall
         ("begin open ? for select ename from emp; end;");

cstmt.registerOutParameter(1, OracleTypes.CURSOR);
cstmt.execute();
cursor = ((OracleCallableStatement)cstmt).getCursor(1);

// Use the cursor like a normal ResultSet
while (cursor.next ())
    {System.out.println (cursor.getString(1));}
```

In the preceding example:

- A `CallableStatement` object is created by using the `prepareCall()` method of the connection class.
- The callable statement implements a PL/SQL procedure that returns a REF CURSOR.
- As always, the output parameter of the callable statement must be registered to define its type. Use the typecode `OracleTypes.CURSOR` for a REF CURSOR.
- The callable statement is executed, returning the REF CURSOR.
- The `CallableStatement` object is cast to an `OracleCallableStatement` object to use the `getCursor()` method, which is an Oracle extension to the standard JDBC API, and returns the REF CURSOR into a `ResultSet` object.

Support for Oracle Extensions in 8.0.x and 7.3.x JDBC Drivers

Some of the Oracle type extensions supported by the current Oracle JDBC drivers are either not supported or are supported differently by the Oracle 8.0.x and 7.3.x JDBC drivers. The following are the key points:

- The 8.0.x and 7.3.x drivers have no `oracle.sql` package, meaning there are no wrapper types such as `oracle.sql.NUMBER` and `oracle.sql.CHAR` that you can use to wrap raw SQL data.
- The 8.0.x and 7.3.x drivers do not support Oracle object and collection types.
- The 8.0.x and 7.3.x drivers support the Oracle `ROWID` datatype with the `OracleRowid` class in the `oracle.jdbc` package.
- The 8.0.x drivers support the Oracle `BLOB`, `CLOB`, and `BFILE` datatypes with the `OracleBlob`, `OracleClob`, and `OracleBfile` classes in the `oracle.jdbc` package. These classes do not include LOB and BFILE manipulation methods—you must instead use the PL/SQL `DBMS_LOB` package.

- The 7.3.x drivers do not support `BLOB`, `CLOB`, and `BFILE`.

Table 6–3 summarizes these differences. "OracleTypes Definition" refers to static typecode constants defined in the `oracle.jdbc.OracleTypes` class.

Table 6–3 Support for Oracle Type Extensions, 8.0.x and 7.3.x JDBC Drivers

Oracle Datatype	OracleTypes Definition	Type Extension, Current Drivers	Type Extension, 8.0.x/7.3.x drivers
NUMBER	OracleTypes.NUMBER	oracle.sql.NUMBER	no type extension for wrapper class
CHAR	OracleTypes.CHAR	oracle.sql.CHAR	no type extension for wrapper class
RAW	OracleTypes.RAW	oracle.sql.RAW	no type extension for wrapper class
DATE	OracleTypes.DATE	oracle.sql.DATE	no type extension for wrapper class
ROWID	OracleTypes.ROWID	oracle.sql.ROWID	oracle.jdbc.driver.OracleRowid
BLOB	OracleTypes.BLOB	oracle.sql.BLOB	oracle.jdbc.driver.OracleBlob in 8.0.x; not supported in 7.3.x
CLOB	OracleTypes.CLOB	oracle.sql.CLOB	oracle.jdbc.driver.OracleClob in 8.0.x; not supported in 7.3.x
BFILE	n/a	oracle.sql.BFILE	oracle.jdbc.driver.OracleBfile in 8.0.x; not supported in 7.3.x
structured object	OracleTypes.STRUCT	oracle.sql.STRUCT or custom class	not supported
object reference	OracleTypes.REF	oracle.sql.REF or custom class	not supported
collection (array)	OracleTypes.ARRAY	oracle.sql.ARRAY or custom class	not supported
OPAQUE	OracleTypes.OPAQUE	oracle.sql.OPAQUE	not supported

7

Accessing and Manipulating Oracle Data

This chapter describes data access in `oracle.sql.*` formats, as opposed to standard Java formats. As described in the previous chapter, the `oracle.sql.*` formats are a key factor of the Oracle JDBC extensions, offering significant advantages in efficiency and precision in manipulating SQL data.

Using `oracle.sql.*` formats involves casting your result sets and statements to `OracleResultSet`, `OracleStatement`, `OraclePreparedStatement`, and `OracleCallableStatement` objects, as appropriate, and using the `getOracleObject()`, `setOracleObject()`, `getXXX()`, and `setXXX()` methods of these classes (where `XXX` corresponds to the types in the `oracle.sql` package).

This chapter covers the following topics:

- Data Conversion Considerations
- Result Set and Statement Extensions
- Comparison of Oracle get and set Methods to Standard JDBC
- Using Result Set Meta Data Extensions

Data Conversion Considerations

When JDBC programs retrieve SQL data into Java, you can use standard Java types, or you can use types of the `oracle.sql` package. The classes in this package simply wrap the raw SQL data.

Standard Types versus Oracle Types

In processing speed and effort, the `oracle.sql.*` classes provide the most efficient way of representing SQL data. These classes store the usual representations of SQL data as byte arrays. They do not reformat the data or perform any character-set conversions (aside from the usual network conversions) on it. The data remains in SQL format, and therefore no information is lost. For SQL primitive types (such as `NUMBER`, and `CHAR`), the `oracle.sql.*` classes simply wrap the SQL data. For SQL structured types (such as objects and arrays), the classes provide additional information such as conversion methods and structure details.

If you are moving data within the database, then you will probably want to keep your data in `oracle.sql.*` format. If you are displaying the data or performing calculations on it in a Java application running outside the database, then you will probably want to materialize the data as instances of standard types such as `java.sql.*` or `java.lang.*` types. Similarly, if you are using a parser that expects the data to be in a standard Java format, then you must use one of the standard formats instead of `oracle.sql.*` format.

Converting SQL NULL Data

Java represents a SQL `NULL` datum by the Java value `null`. Java datatypes fall into two categories: primitive types (such as `byte`, `int`, `float`) and object types (class instances). The primitive types cannot represent `null`. Instead, they store the null as the value zero (as defined by the JDBC specification). This can lead to ambiguity when you try to interpret your results.

In contrast, Java object types can represent `null`. The Java language defines an object wrapper type corresponding to every primitive type (for example, `Integer` for `int`, `Float` for `float`) that can represent `null`. The object wrapper types must be used as the targets for SQL data to detect SQL `NULL` without ambiguity.

Result Set and Statement Extensions

The JDBC `Statement` object returns an `OracleResultSet` object, typed as a `java.sql.ResultSet`. If you want to apply only standard JDBC methods to the object, keep it as a `ResultSet` type. However, if you want to use the Oracle extensions on the object, you must cast it to an `OracleResultSet` type. Although the type by which the Java compiler will identify the object is changed, the object itself is unchanged.

For example, assuming you have a standard `Statement` object `stmt`, do the following if you want to use only standard JDBC `ResultSet` methods:

```
ResultSet rs = stmt.executeQuery("SELECT * FROM emp");
```

If you need the extended functionality provided by the Oracle extensions to JDBC, you can select the results into a standard `ResultSet` object, as above, and then cast that object into an `OracleResultSet` object later.

Similarly, when you want to execute a stored procedure using a callable statement, the JDBC drivers will return an `OracleCallableStatement` object typed as a `java.sql.CallableStatement`. If you want to apply only standard JDBC methods to the object, then keep it as a `CallableStatement` type. However, if you want to use the Oracle extensions on the object, you must cast it to an `OracleCallableStatement` type. Although the type by which the Java compiler will identify the object is changed, the object itself is unchanged.

You use the standard JDBC `java.sql.Connection.prepareStatement()` method to create a `PreparedStatement` object. If you want to apply only standard JDBC methods to the object, keep it as a `PreparedStatement` type. However, if you want to use the Oracle extensions on the object, you must cast it to an `OraclePreparedStatement` type. While the type by which the Java compiler will identify the object is changed, the object itself is unchanged.

Key extensions to the result set and statement classes include `getOracleObject()` and `setOracleObject()` methods that you can use to access and manipulate data in `oracle.sql.*` formats, instead of standard Java formats. For more information, see the next section: "Comparison of Oracle get and set Methods to Standard JDBC".

Comparison of Oracle get and set Methods to Standard JDBC

This section describes `get` and `set` methods, particularly the JDBC standard `getObject()` and `setObject()` methods and the Oracle-specific `getOracleObject()` and `setOracleObject()` methods, and how to access data in `oracle.sql.*` format compared with Java format.

Although there are specific `getXXX()` methods for all the Oracle SQL types (as described in "Other getXXX() Methods" on page 7-7), you can use the general `get` methods for convenience or simplicity, or if you are not certain in advance what type of data you will receive.

Standard getObject() Method

The standard JDBC `getObject()` method of a result set or callable statement returns data into a `java.lang.Object` object. The format of the data returned is based on its original type, as follows:

- For SQL datatypes that are not Oracle-specific, `getObject()` returns the default Java type corresponding to the column's SQL type, following the mapping specified in the JDBC specification.
- For Oracle-specific datatypes (such as `ROWID`, discussed in "Oracle ROWID Type" on page 6-33), `getObject()` returns an object of the appropriate `oracle.sql.*` class (such as `oracle.sql.ROWID`).
- For Oracle objects, `getObject()` returns an object of the Java class specified in your type map. (Type maps specify the correlation between Java classes and database SQL types and are discussed in "Understanding Type Maps for SQLData Implementations" on page 9-11.) The `getObject(`*`parameter_index`*`)` method uses the connection's default type map. The `getObject(`*`parameter_index, map`*`)` enables you to pass in a type map. If the type map does not provide a mapping for a particular Oracle object, then `getObject()` returns an `oracle.sql.STRUCT` object.

For more information on `getObject()` return types, see Table 7–1, "Summary of getObject() and getOracleObject() Return Types" on page 7-6.

Oracle getOracleObject() Method

If you want to retrieve data from a result set or callable statement into an `oracle.sql.*` object, then cast your result set to an `OracleResultSet` type or your callable statement to an `OracleCallableStatement` type, and use the `getOracleObject()` method.

When you use `getOracleObject()`, the data will be of the appropriate `oracle.sql.*` type and is returned into an `oracle.sql.Datum` object (the `oracle.sql` type classes extend `Datum`). The signature for the method is:

```
public oracle.sql.Datum getOracleObject(int parameter_index)
```

When you have retrieved data into a `Datum` object, you can use the standard Java `instanceof` operator to determine which `oracle.sql.*` type it really is.

For more information on `getOracleObject()` return types, see Table 7–1, "Summary of getObject() and getOracleObject() Return Types" on page 7-6.

Example: Using getOracleObject() with a ResultSet The following example creates a table that contains a column of character data (in this case, a row number) and a column containing a `BFILE` locator. A `SELECT` statement retrieves the contents of the table into a result set. The `getOracleObject()` then retrieves the `CHAR` data into the `char_datum` variable and the `BFILE` locator into the `bfile_datum` variable. Note that because `getOracleObject()` returns a `Datum` object, the results must be cast to `CHAR` and `BFILE`, respectively.

```
stmt.execute ("CREATE TABLE bfile_table (x varchar2 (30), b bfile)");
stmt.execute
    ("INSERT INTO bfile_table VALUES ('one', bfilename ('TEST_DIR', 'file1'))");

ResultSet rset = stmt.executeQuery ("SELECT * FROM bfile_table");
while (rset.next ())
{
   CHAR char_datum = (CHAR) ((OracleResultSet)rset).getOracleObject (1);
   BFILE bfile_datum = (BFILE) ((OracleResultSet)rset).getOracleObject (2);
   ...
}
```

Example: Using getOracleObject() in a Callable Statement The following example prepares a call to the procedure `myGetDate()`, which associates a character string (in this case a name) with a date. The program passes the string `SCOTT` to the prepared call and registers the `DATE` type as an output parameter. After the call is executed, `getOracleObject()` retrieves the date associated with the name `SCOTT`. Note that because `getOracleObject()` returns a `Datum` object, the results are cast to a `DATE` object.

```
OracleCallableStatement cstmt = (OracleCallableStatement)conn.prepareCall
                                   ("begin myGetDate (?, ?); end;");

cstmt.setString (1, "SCOTT");
cstmt.registerOutParameter (2, Types.DATE);
```

```
cstmt.execute ();

DATE date = (DATE) ((OracleCallableStatement)cstmt).getOracleObject (2);
...
```

Summary of getObject() and getOracleObject() Return Types

Table 7–1 summarizes the information in the preceding sections, "Standard getObject() Method" and "Oracle getOracleObject() Method" on page 7-4.

This table lists the underlying return types for each method for each Oracle SQL type, but keep in mind the signatures of the methods when you write your code:

- `getObject()`: Always returns data into a `java.lang.Object` instance.
- `getOracleObject()`: Always returns data into an `oracle.sql.Datum` instance.

You must cast the returned object to use any special functionality (see "Casting Your get Method Return Values" on page 7-10).

Table 7–1 Summary of getObject() and getOracleObject() Return Types

Oracle SQL Type	getObject() Underlying Return Type	getOracleObject() Underlying Return Type
CHAR	String	oracle.sql.CHAR
VARCHAR2	String	oracle.sql.CHAR
LONG	String	oracle.sql.CHAR
NUMBER	java.math.BigDecimal	oracle.sql.NUMBER
RAW	byte[]	oracle.sql.RAW
LONGRAW	byte[]	oracle.sql.RAW
DATE	java.sql.Timestamp	oracle.sql.DATE
ROWID	oracle.sql.ROWID	oracle.sql.ROWID
REF CURSOR	java.sql.ResultSet	(not supported)
BLOB	oracle.sql.BLOB	oracle.sql.BLOB
CLOB	oracle.sql.CLOB	oracle.sql.CLOB
BFILE	oracle.sql.BFILE	oracle.sql.BFILE

Table 7–1 Summary of getObject() and getOracleObject() Return Types (Cont.)

Oracle SQL Type	getObject() Underlying Return Type	getOracleObject() Underlying Return Type
Oracle object	class specified in type map or oracle.sql.STRUCT (if no type map entry)	oracle.sql.STRUCT
Oracle object reference	oracle.sql.REF	oracle.sql.REF
collection (varray or nested table)	oracle.sql.ARRAY	oracle.sql.ARRAY

For information on type compatibility between all SQL and Java types, see Table 19–1, "Valid SQL Datatype-Java Class Mappings" on page 19-2.

Other getXXX() Methods

Standard JDBC provides a `getXXX()` for each standard Java type, such as `getByte()`, `getInt()`, `getFloat()`, and so on. Each of these returns exactly what the method name implies (a `byte`, an `int`, a `float`, and so on).

In addition, the `OracleResultSet` and `OracleCallableStatement` classes provide a full complement of `getXXX()` methods corresponding to all the `oracle.sql.*` types. Each `getXXX()` method returns an `oracle.sql.XXX` object. For example, `getROWID()` returns an `oracle.sql.ROWID` object.

Some of these extensions are taken from the JDBC 2.0 specification. They return objects of type `java.sql.*` (or `oracle.jdbc2.*` under JDK 1.1.x), instead of `oracle.sql.*`. For example, compare the following method names and return types:

```
java.sql.Blob getBlob(int parameter_index)

oracle.sql.BLOB getBLOB(int parameter_index)
```

Although there is no particular performance advantage in using the specific `getXXX()` methods, they can save you the trouble of casting, because they return specific object types.

Return Types and Input Parameter Types of getXXX() Methods

Table 7–2 summarizes the underlying return types and the input parameter types for each `getXXX()` method, and notes which are Oracle extensions under JDK 1.2.x

and JDK 1.1.x. You must cast to an `OracleResultSet` or `OracleCallableStatement` to use methods that are Oracle extensions.

Table 7–2 Summary of getXXX() Return Types

Method	Underlying Return Type	Signature Type	Oracle Ext for JDK 1.2.x?	Oracle Ext for JDK 1.1.x?
getArray()	oracle.sql.ARRAY	java.sql.Array (oracle.jdbc2.Array under JDK 1.1.x)	No	Yes
getARRAY()	oracle.sql.ARRAY	oracle.sql.ARRAY	Yes	Yes
getAsciiStream()	java.io.InputStream	java.io.InputStream	No	No
getBfile()	oracle.sql.BFILE	oracle.sql.BFILE	Yes	Yes
getBFILE()	oracle.sql.BFILE	oracle.sql.BFILE	Yes	Yes
getBigDecimal() (see Notes section below)	java.math.BigDecimal	java.math.BigDecimal	No	No
getBinaryStream()	java.io.InputStream	java.io.InputStream	No	No
getBlob()	oracle.sql.BLOB	java.sql.Blob (oracle.jdbc2.Blob under JDK 1.1.x)	No	Yes
getBLOB	oracle.sql.BLOB	oracle.sql.BLOB	Yes	Yes
getBoolean()	boolean	boolean	No	No
getByte()	byte	byte	No	No
getBytes()	byte[]	byte[]	No	No
getCHAR()	oracle.sql.CHAR	oracle.sql.CHAR	Yes	Yes
getCharacterStream() (new with 8.1.6)	java.io.Reader	java.io.Reader	No	Yes
getClob()	oracle.sql.CLOB	java.sql.Clob (oracle.jdbc2.Clob under JDK 1.1.x)	No	Yes
getCLOB()	oracle.sql.CLOB	oracle.sql.CLOB	Yes	Yes
getDate() (see Notes section below)	java.sql.Date	java.sql.Date	No	No

Table 7–2 Summary of getXXX() Return Types (Cont.)

Method	Underlying Return Type	Signature Type	Oracle Ext for JDK 1.2.x?	Oracle Ext for JDK 1.1.x?
getDATE()	oracle.sql.DATE	oracle.sql.DATE	Yes	Yes
getDouble()	double	double	No	No
getFloat()	float	float	No	No
getInt()	int	int	No	No
getLong()	long	long	No	No
getNUMBER()	oracle.sql.NUMBER	oracle.sql.NUMBER	Yes	Yes
getOracleObject()	subclasses of oracle.sql.Datum	oracle.sql.Datum	Yes	Yes
getRAW()	oracle.sql.RAW	oracle.sql.RAW	Yes	Yes
getRef()	oracle.sql.REF	java.sql.Ref (oracle.jdbc2.Ref under JDK 1.1.x)	No	Yes
getREF()	oracle.sql.REF	oracle.sql.REF	Yes	Yes
getROWID()	oracle.sql.ROWID	oracle.sql.ROWID	Yes	Yes
getShort()	short	short	No	No
getString()	String	String	No	No
getSTRUCT()	oracle.sql.STRUCT.	oracle.sql.STRUCT	Yes	Yes
getTime() (see Notes section below)	java.sql.Time	java.sql.Time	No	No
getTimestamp() (see Notes section below)	java.sql.Timestamp	java.sql.Timestamp	No	No
getUnicodeStream()	java.io.InputStream	java.io.InputStream	No	No

Special Notes about getXXX() Methods

This section provides additional details about some of the `getXXX()` methods.

getBigDecimal() Note

JDBC 2.0 supports a simplified method signature for the `getBigDecimal()` method. The previous input signature was:

`(int columnIndex, int scale)` or `(String columnName, int scale)`

The new input signature is simply:

`(int columnIndex)` or `(String columnName)`

The `scale` parameter, used to specify the number of digits to the right of the decimal, is no longer necessary. The Oracle JDBC drivers retrieve numeric values with full precision.

getDate(), getTime(), and getTimestamp() Note

In JDBC 2.0, the `getDate()`, `getTime()`, and `getTimestamp()` methods have the following input signatures:

```
(int columnIndex, Calendar cal)
```

or:

```
(String columnName, Calendar cal)
```

The Oracle JDBC drivers ignore the `Calendar` object input, because it is not currently feasible to support `java.sql.Date` timezone information together with the data. You should continue to use previous input signatures that take only the column index or column name. Calendar input will be supported in a future Oracle JDBC release.

Casting Your get Method Return Values

As described in "Standard getObject() Method" on page 7-4, Oracle's implementation of `getObject()` always returns a `java.lang.Object` instance, and `getOracleObject()` always returns an `oracle.sql.Datum` instance. Usually, you would cast the returned object to the appropriate class so that you could use particular methods and functionality of that class.

In addition, you have the option of using a specific `getXXX()` method instead of the generic `getObject()` or `getOracleObject()` methods. The `getXXX()` methods enable you to avoid casting, because the return type of `getXXX()` corresponds to the type of object returned. For example, `getCLOB()` returns an `oracle.sql.CLOB` instance, as opposed to a `java.lang.Object` instance.

Example: Casting Return Values This example assumes that you have fetched data of type CHAR into a result set (where it is in column 1). Because you want to

manipulate the CHAR data without losing precision, cast your result set to an OracleResultSet, and use getOracleObject() to return the CHAR data in oracle.sql.* format. If you do not cast your result set, you have to use getObject(), which returns your character data into a Java String and loses some of the precision of your SQL data.

The getOracleObject() method returns an oracle.sql.CHAR object into an oracle.sql.Datum return variable unless you cast the output. Cast the getOracleObject() output to oracle.sql.CHAR if you want to use a CHAR return variable and any of the special functionality of that class (such as the getCharacterSet() method that returns the character set used to represent the characters).

```
CHAR char = (CHAR)ors.getOracleObject(1);
CharacterSet cs = char.getCharacterSet();
```

Alternatively, you can return the object into a generic oracle.sql.Datum return variable and cast it later when you must use the CHAR getCharacterSet() method.

```
Datum rawdatum = ors.getOracleObject(1);
...
CharacterSet cs = ((CHAR)rawdatum).getCharacterSet();
```

This uses the getCharacterSet() method of oracle.sql.CHAR. The getCharacterSet() method is not defined on oracle.sql.Datum and would not be reachable without the cast.

Standard setObject() and Oracle setOracleObject() Methods

Just as there is a standard getObject() and Oracle-specific getOracleObject() in result sets and callable statements for retrieving data, there is also a standard setObject() and an Oracle-specific setOracleObject() in Oracle prepared statements and callable statements for updating data. The setOracleObject() methods take oracle.sql.* input parameters.

To bind standard Java types to a prepared statement or callable statement, use the setObject() method, which takes a java.lang.Object as input. The setObject() method does support a few of the oracle.sql.* types—it has been implemented so that you can also input instances of the oracle.sql.* classes that correspond to JDBC 2.0-compliant Oracle extensions: BLOB, CLOB, BFILE, STRUCT, REF, and ARRAY.

To bind `oracle.sql.*` types to a prepared statement or callable statement, use the `setOracleObject()` method, which takes an `oracle.sql.Datum` (or any subclass) as input. To use `setOracleObject()`, you must cast your prepared statement or callable statement to an `OraclePreparedStatement` or `OracleCallableStatement` object.

Example: Using setObject() and setOracleObject() in a Prepared Statement This example assumes that you have fetched character data into a standard result set (where it is in column 1), and you want to cast the results to an `OracleResultSet` so that you can use Oracle-specific formats and methods. Because you want to use the data as `oracle.sql.CHAR` format, cast the results of the `getOracleObject()` (which returns type `oracle.sql.Datum`) to `CHAR`. Similarly, because you want to manipulate the data in column 2 as strings, cast the data to a Java `String` type (because `getObject()` returns data of type `Object`). In this example, `rs` represents the result set, `charVal` represents the data from column 1 in `oracle.sql.CHAR` format, and `strVal` represents the data from column 2 in Java `String` format.

```
CHAR charVal=(CHAR)((OracleResultSet)rs).getOracleObject(1);
String strVal=(String)rs.getObject(2);
...
```

For a prepared statement object `ps`, the `setOracleObject()` method binds the `oracle.sql.CHAR` data represented by the `charVal` variable to the prepared statement. To bind the `oracle.sql.*` data, the prepared statement must be cast to an `OraclePreparedStatement`. Similarly, the `setObject()` method binds the Java `String` data represented by the variable `strVal`.

```
PreparedStatement ps= conn.prepareStatement("text_of_prepared_statement");
((OraclePreparedStatement)ps).setOracleObject(1,charVal);
ps.setObject(2,strVal);
```

Other setXXX() Methods

As with `getXXX()` methods, there are several specific `setXXX()` methods. Standard `setXXX()` methods are provided for binding standard Java types, and Oracle-specific `setXXX()` methods are provided for binding Oracle-specific types.

> **Note:** Under JDK 1.1.x, for compatibility with the JDBC 2.0 standard, `OraclePreparedStatement` and `OracleCallableStatement` classes provide `setXXX()` methods that take `oracle.jdbc2` input parameters for `BLOB`s, `CLOB`s, object references, and arrays. For example, a `setBlob()` method takes an `oracle.jdbc2.Blob` input parameter, where it would take a `java.sql.Blob` input parameter under JDK 1.2.x.

Similarly, there are two forms of the `setNull()` method:

- `void setNull(int` *`parameterIndex`*`, int` *`sqlType`*`)`

  This is specified in the standard `java.sql.PreparedStatement` interface. This signature takes a parameter index and a SQL typecode defined by the `java.sql.Types` or `oracle.jdbc.OracleTypes` class. Use this signature to set an object other than a `REF`, `ARRAY`, or `STRUCT` to `NULL`.

- `void setNull(int` *`parameterIndex`*`, int` *`sqlType`*`, String` *`sql_type_name`*`)`

  With JDBC 2.0, this signature is also specified in the standard `java.sql.PreparedStatement` interface. Under JDK 1.1.x, it is available as an Oracle extension. It takes a SQL type name in addition to a parameter index and a SQL type code. Use this method when the SQL typecode is `java.sql.Types.REF`, `ARRAY`, or `STRUCT`. (If the typecode is other than `REF`, `ARRAY`, or `STRUCT`, then the given SQL type name is ignored.)

Similarly, the `registerOutParameter()` method has a signature for use with `REF`, `ARRAY`, or `STRUCT` data:

```
void registerOutParameter
             (int parameterIndex, int sqlType, String sql_type_name)
```

For binding Oracle-specific types, using the appropriate specific `setXXX()` methods instead of methods for binding standard Java types may offer some performance advantage.

Input Parameter Types of setXXX() Methods

Table 7–3 summarizes the input types for all the `setXXX()` methods and notes which are Oracle extensions under JDK 1.2.x and JDK 1.1.x. To use methods that are Oracle extensions, you must cast your statement to an `OraclePreparedStatement` or `OracleCallableStatement`.

Table 7–3 Summary of setXXX() Input Parameter Types

Method	Input Parameter Type	Oracle Ext for JDK 1.2.x?	Oracle Ext for JDK 1.1.x?
setArray()	java.sql.Array (oracle.jdbc2.Array under JDK 1.1.x)	No	Yes
setARRAY()	oracle.sql.ARRAY	Yes	Yes
setAsciiStream() (see Notes section below)	java.io.InputStream	No	No
setBfile()	oracle.sql.BFILE	Yes	Yes
setBFILE()	oracle.sql.BFILE	Yes	Yes
setBigDecimal()	BigDecimal	No	No
setBinaryStream() (see Notes section below)	java.io.InputStream	No	No
setBlob()	java.sql.Blob (oracle.jdbc2.Blob under JDK 1.1.x)	No	Yes
setBLOB()	oracle.sql.BLOB	Yes	Yes
setBoolean()	boolean	No	No
setByte()	byte	No	No
setBytes()	byte[]	No	No
setCHAR() (also see setFixedCHAR() method)	oracle.sql.CHAR	Yes	Yes
setCharacterStream() (see Notes section below)	java.io.Reader	No	Yes
setClob()	java.sql.Clob (oracle.jdbc2.Clob under JDK 1.1.x)	No	Yes
setCLOB()	oracle.sql.CLOB	Yes	Yes
setDate() (see Notes section below)	java.sql.Date	No	No
setDATE()	oracle.sql.DATE	Yes	Yes

Table 7–3 Summary of setXXX() Input Parameter Types (Cont.)

Method	Input Parameter Type	Oracle Ext for JDK 1.2.x?	Oracle Ext for JDK 1.1.x?
setDouble()	double	No	No
setFixedCHAR() (see setFixedCHAR() section below)	java.lang.String	Yes	Yes
setFloat()	float	No	No
setInt()	int	No	No
setLong()	long	No	No
setNUMBER()	oracle.sql.NUMBER	Yes	Yes
setRAW()	oracle.sql.RAW	Yes	Yes
setRef()	java.sql.Ref	No	Yes
	(oracle.jdbc2.Ref under JDK 1.1.x)		
setREF()	oracle.sql.REF	Yes	Yes
setROWID()	oracle.sql.ROWID	Yes	Yes
setShort()	short	No	No
setString()	String	No	No
setSTRUCT()	oracle.sql.STRUCT	Yes	Yes
setTime() (see note below)	java.sql.Time	No	No
setTimestamp() (see note below)	java.sql.Timestamp	No	No
setUnicodeStream() (see note below)	java.io.InputStream	No	No

For information on all supported type mappings between SQL and Java, see Table 19–1, "Valid SQL Datatype-Java Class Mappings" on page 19-2.

Setter Method Size Limitations

Table 7–4 lists size limitations for the `setBytes()` and `setString()` methods for SQL binds to different Oracle databases. (These limitations do not apply to PL/SQL

binds.) For information about how to work around these limits using the stream API, see "Using Streams to Avoid Limits on setBytes() and setString()" on page 3-31.

Table 7–4 Size Limitations for setByes() and setString() Methods

	Oracle8 and Later	Oracle7
setBytes() size limitation	2000 bytes	255 bytes
setString() size limitation	4000 bytes	2000 bytes

Setter Methods That Take Additional Input

The following `setXXX()` methods take an additional input parameter other than the parameter index and the data item itself:

- `setAsciiStream(int paramIndex, InputStream istream, int length)`

  Takes the length of the stream, in bytes.

- `setBinaryStream(int paramIndex, InputStream istream, int length)`

  Takes the length of the stream, in bytes.

- `setCharacterStream(int paramIndex, Reader reader, int length)`

  Takes the length of the stream, in characters.

- `setUnicodeStream(int paramIndex, InputStream istream, int length)`

  Takes the length of the stream, in bytes.

The particular usefulness of the `setCharacterStream()` method is that when a very large `Unicode` value is input to a `LONGVARCHAR` parameter, it can be more practical to send it through a `java.io.Reader` object. JDBC will read the data from the stream as needed, until it reaches the end-of-file mark. The JDBC driver will do any necessary conversion from `Unicode` to the database character format.

Important: The preceding stream methods can also be used for LOBs. See "Reading and Writing BLOB and CLOB Data" on page 8-6 for more information.

- `setDate(int paramIndex, Date x, Calendar cal)`

- `setTime(int paramIndex, Time x, Calendar cal)`
- `setTimestamp(int paramIndex, Timestamp x, Calendar cal)`

  The JDBC 2.0 signatures for `setDate()`, `setTime()`, and `setTimestamp()` include a `Calendar` object, but in Oracle8*i* release 8.1.6 and higher the Oracle JDBC drivers ignore this input because it is not yet feasible to support `java.sql.Date` timezone information together with the data. You should continue to use the previous signatures that take only the parameter index and data item. Calendar input will be supported in a future release.

Method setFixedCHAR() for Binding CHAR Data into WHERE Clauses

`CHAR` data in the database is padded to the column width. This leads to a limitation in using the `setCHAR()` method to bind character data into the `WHERE` clause of a `SELECT` statement—the character data in the `WHERE` clause must also be padded to the column width to produce a match in the `SELECT` statement. This is especially troublesome if you do not know the column width.

To remedy this, Oracle has added the `setFixedCHAR()` method to the `OraclePreparedStatement` class. This method executes a non-padded comparison.

Note:

- Remember to cast your prepared statement object to `OraclePreparedStatement` to use the `setFixedCHAR()` method.
- There is no need to use `setFixedCHAR()` for an `INSERT` statement. The database always automatically pads the data to the column width as it inserts it.

Example The following example demonstrates the difference between the `setCHAR()` and `setFixedCHAR()` methods.

```
/* Schema is :
 create table my_table (col1 char(10));
 insert into my_table values ('JDBC');
*/
 PreparedStatement pstmt = conn.prepareStatement
                    ("select count(*) from my_table where col1 = ?");

 pstmt.setString (1, "JDBC");  // Set the Bind Value
```

```
runQuery (pstmt);             // This will print " No of rows are 0"

CHAR ch = new CHAR("JDBC      ", null);
((OraclePreparedStatement)pstmt).setCHAR(1, ch); // Pad it to 10 bytes
runQuery (pstmt);             // This will print "No of rows are 1"

((OraclePreparedStatement)pstmt).setFixedCHAR(1, "JDBC");
 runQuery (pstmt);            // This will print "No of rows are 1"

void runQuery (PreparedStatement ps)
{
  // Run the Query
  ResultSet rs = pstmt.executeQuery ();

  while (rs.next())
    System.out.println("No of rows are " + rs.getInt(1));

  rs.close();
  rs = null;
}
```

Limitations of the Oracle 8.0.x and 7.3.x JDBC Drivers

The Oracle 8.0.x JDBC drivers use the same protocol as the Oracle 7.3.x JDBC drivers. In both cases, Oracle datatypes are as defined for an Oracle 7.3.x database, and data items longer than 2K bytes must be `LONG`.

As with any `LONG` data, use the stream APIs to read and write data between your application and the database. Essentially, this means that you cannot use the normal `getString()` and `setString()` methods to read or write data longer than 2K bytes when using the 8.0.x and 7.3.x drivers.

The stream APIs include methods such as `getBinaryStream()`, `setBinaryStream()`, `getAsciiStream()`, and `setAsciiStream()`. These methods are discussed under "Java Streams in JDBC" on page 3-20.

Using Result Set Meta Data Extensions

The `oracle.jdbc.OracleResultSetMetaData` interface is JDBC 2.0-compliant but does not implement the `getSchemaName()` and `getTableName()` methods because underlying protocol does not make this feasible. Oracle does implement many methods to retrieve information about an Oracle result set, however.

Key methods include the following:

- `int getColumnCount()`: Returns the number of columns in an Oracle result set.
- `String getColumnName(int column)`: Returns the name of a specified column in an Oracle result set.
- `int getColumnType(int column)`: Returns the SQL type of a specified column in an Oracle result set. If the column stores an Oracle object or collection, then this method returns `OracleTypes.STRUCT` or `OracleTypes.ARRAY` respectively.
- `String getColumnTypeName(int column)`: Returns the SQL type name for a specified column of type REF, STRUCT, or ARRAY. If the column stores an array or collection, then this method returns its SQL type name. If the column stores REF data, then this method returns the SQL type name of the objects to which the object reference points.

The following example uses several of the methods in the `OracleResultSetMetadata` interface to retrieve the number of columns from the EMP table, and each column's numerical type and SQL type name.

```
DatabaseMetaData dbmd = conn.getMetaData();
ResultSet rset = dbmd.getTables("", "SCOTT", "EMP", null);

 while (rset.next())
 {
   OracleResultSetMetaData orsmd = ((OracleResultSet)rset).getMetaData();
   int numColumns = orsmd.getColumnCount();
   System.out.println("Num of columns = " + numColumns);

   for (int i=0; i<numColumns; i++)
   {
     System.out.print ("Column Name=" + orsmd.getColumnName (i+1));
     System.out.print (" Type=" + orsmd.getColumnType (i + 1) );
     System.out.println (" Type Name=" + orsmd.getColumnTypeName (i + 1));
  }
}
```

The program returns the following output:

```
Num of columns = 5
Column Name=TABLE_CAT Type=12 Type Name=VARCHAR2
Column Name=TABLE_SCHEM Type=12 Type Name=VARCHAR2
Column Name=TABLE_NAME Type=12 Type Name=VARCHAR2
Column Name=TABLE_TYPE Type=12 Type Name=VARCHAR2
Column Name=TABLE_REMARKS Type=12 Type Name=VARCHAR2
```

8

Working with LOBs and BFILEs

This chapter describes how you use JDBC and the `oracle.sql.*` classes to access and manipulate LOB and BFILE locators and data, covering the following topics:

- Oracle Extensions for LOBs and BFILEs
- Working with BLOBs and CLOBs
- Working with BFILEs

Oracle Extensions for LOBs and BFILEs

LOBs ("large objects") are stored in a way that optimizes space and provides efficient access. The JDBC drivers provide support for two types of LOBs: BLOBs (unstructured binary data) and CLOBs (character data). BLOB and CLOB data is accessed and referenced by using a locator, which is stored in the database table and points to the BLOB or CLOB data, which is outside the table.

BFILEs are large binary data objects stored in operating system files outside of database tablespaces. These files use reference semantics. They can also be located on tertiary storage devices such as hard disks, CD-ROMs, PhotoCDs and DVDs. As with BLOBs and CLOBs, a BFILE is accessed and referenced by a locator which is stored in the database table and points to the BFILE data.

To work with LOB data, you must first obtain a LOB locator. Then you can read or write LOB data and perform data manipulation. The following sections also describe how to create and populate a LOB column in a table.

The JDBC drivers support these `oracle.sql.*` classes for BLOBs, CLOBs, and BFILEs:

- `oracle.sql.BLOB`
- `oracle.sql.CLOB`
- `oracle.sql.BFILE`

The `oracle.sql.BLOB` and `CLOB` classes implement the `java.sql.Blob` and `Clob` interfaces, respectively (`oracle.jdbc2.Blob` and `Clob` interfaces under JDK 1.1.x). By contrast, `BFILE` is an Oracle extension, without a corresponding `java.sql` (or `oracle.jdbc2`) interface.

Instances of these classes contain only the locators for these datatypes, not the data. After accessing the locators, you must perform some additional steps to access the data. These steps are described in "Reading and Writing BLOB and CLOB Data" on page 8-6 and "Reading BFILE Data" on page 8-22.

Note: You cannot construct `BLOB`, `CLOB`, or `BFILE` objects in your JDBC application—you can only retrieve existing BLOBs, CLOBs, or BFILEs from the database or create them using the `createTemporary()` and `empty_lob()` methods.

Working with BLOBs and CLOBs

This section describes how to read and write data to and from binary large objects (BLOBs) and character large objects (CLOBs) in an Oracle database, using LOB locators.

For general information about Oracle9i LOBs and how to use them, see the *Oracle9i Application Developer's Guide—Large Objects (LOBs)*.

Getting and Passing BLOB and CLOB Locators

Standard as well as Oracle-specific getter and setter methods are available for retrieving or passing LOB locators from or to the database.

Retrieving BLOB and CLOB Locators

Given a standard JDBC result set (`java.sql.ResultSet`) or callable statement (`java.sql.CallableStatement`) that includes BLOB or CLOB locators, you can access the locators by using standard getter methods, as follows. All the standard and Oracle-specific getter methods discussed here take either an `int` column index or a `String` column name as input.

- Under JDK 1.2.x and higher, you can use the standard `getBlob()` and `getClob()` methods, which return `java.sql.Blob` and `Clob` objects, respectively.
- Under JDK 1.1.x, there is no standard BLOB or CLOB functionality, but you can use the generic `getObject()` method, which returns `java.lang.Object`, and cast the output as desired.

If you retrieve or cast the result set or callable statement to an `OracleResultSet` or `OracleCallableStatement` object, then you can use Oracle extensions as follows:

- Under JDK 1.1.x and higher, you can use `getBLOB()` and `getCLOB()`, which return `oracle.sql.BLOB` and `CLOB` objects, respectively.
- Under JDK 1.1.x and higher, you can also use the `getOracleObject()` method, which returns an `oracle.sql.Datum` object, and cast the output appropriately.
- Under JDK 1.1.x, you also have the option of using the Oracle extensions `getBlob()` and `getClob()`, which return `oracle.jdbc2.Blob` and `Clob` objects, respectively. (These `Blob` and `Clob` interfaces mimic the standard interfaces available in JDK 1.2.x.)

> **Note:** If using `getObject()` or `getOracleObject()`, then remember to cast the output, as necessary. For more information, see "Casting Your get Method Return Values" on page 7-10.

Example: Getting BLOB and CLOB Locators from a Result Set Assume the database has a table called `lob_table` with a column for a BLOB locator, `blob_col`, and a column for a CLOB locator, `clob_col`. This example assumes that you have already created the `Statement` object, `stmt`.

First, select the LOB locators into a standard result set, then get the LOB data into appropriate Java classes:

```
// Select LOB locator into standard result set.
ResultSet rs =
   stmt.executeQuery ("SELECT blob_col, clob_col FROM lob_table");
while (rs.next())
{
   // Get LOB locators into Java wrapper classes.
   java.sql.Blob blob = (java.sql.Blob)rs.getObject(1);
   java.sql.Clob clob = (java.sql.Clob)rs.getObject(2);
   (...process...)
}
```

The output is cast to `java.sql.Blob` and `Clob`. As an alternative, you can cast the output to `oracle.sql.BLOB` and `CLOB` to take advantage of extended functionality offered by the `oracle.sql.*` classes. For example, you can rewrite the above code to get the LOB locators as:

```
   // Get LOB locators into Java wrapper classes.
   oracle.sql.BLOB blob = (BLOB)rs.getObject(1);
   oracle.sql.CLOB clob = (CLOB)rs.getObject(2);
   (...process...)
```

Example: Getting a CLOB Locator from a Callable Statement The callable statement methods for retrieving LOBs are identical to the result set methods.

For example, if you have an `OracleCallableStatement ocs` that calls a function `func` that has a CLOB output parameter, then set up the callable statement as in the following example.

This example registers `OracleTypes.CLOB` as the typecode of the output parameter.

```
OracleCallableStatement ocs =
   (OracleCallableStatement)conn.prepareCall("{? = call func()}");
ocs.registerOutParameter(1, OracleTypes.CLOB);
ocs.execute();
oracle.sql.CLOB clob = ocs.getCLOB(1);
```

Passing BLOB and CLOB Locators

Given a standard JDBC prepared statement (`java.sql.PreparedStatement`) or callable statement (`java.sql.CallableStatement`), you can use standard setter methods to pass LOB locators, as follows. All the standard and Oracle-specific setter methods discussed here take an `int` parameter index and the LOB locator as input.

- Under JDK 1.2.x and higher, you can use the standard `setBlob()` and `setClob()` methods, which take `java.sql.Blob` and `Clob` locators as input.
- Under JDK 1.1.x, there is no standard BLOB or CLOB functionality, but you can use the generic `setObject()` method, which simply specifies a `java.lang.Object` input.

Given an Oracle-specific `OraclePreparedStatement` or `OracleCallableStatement`, then you can use Oracle extensions as follows:

- Under JDK 1.1.x and higher, you can use `setBLOB()` and `setCLOB()`, which take `oracle.sql.BLOB` and `CLOB` locators as input, respectively.
- Under JDK 1.1.x and higher, you can also use the `setOracleObject()` method, which simply specifies an `oracle.sql.Datum` input.
- Under JDK 1.1.x, you also have the option of using the Oracle extensions `setBlob()` and `setClob()`, which take `oracle.jdbc2.Blob` and `Clob` locators as input, respectively. (These `Blob` and `Clob` interfaces mimic the standard interfaces available in JDK 1.2.x.)

Example: Passing a BLOB Locator to a Prepared Statement If you have an `OraclePreparedStatement` object `ops` and a BLOB named `my_blob`, then write the BLOB to the database as follows:

```
OraclePreparedStatement ops = (OraclePreparedStatement)conn.prepareStatement
                              ("INSERT INTO blob_table VALUES(?)");
ops.setBLOB(1, my_blob);
ops.execute();
```

Example: Passing a CLOB Locator to a Callable Statement If you have an `OracleCallableStatement` object `ocs` and a CLOB named `my_clob`, then input the CLOB to the stored procedure `proc` as follows:

```
OracleCallableStatement ocs =
   (OracleCallableStatement)conn.prepareCall("{call proc(?))}");
ocs.setClob(1, my_clob);
ocs.execute();
```

Reading and Writing BLOB and CLOB Data

Once you have a LOB locator, you can use JDBC methods to read and write the LOB data. LOB data is materialized as a Java array or stream. However, unlike most Java streams, a locator representing the LOB data is stored in the table. Thus, you can access the LOB data at any time during the life of the connection.

To read and write the LOB data, use the methods in the `oracle.sql.BLOB` or `oracle.sql.CLOB` class, as appropriate. These classes provide functionality such as reading from the LOB into an input stream, writing from an output stream into a LOB, determining the length of a LOB, and closing a LOB.

Notes:

- To write LOB data, the application must acquire a write lock on the LOB object. One way to accomplish this is through a `SELECT FOR UPDATE`. Also, disable auto-commit mode.
- The implementation of the data access API uses direct native calls in the JDBC OCI and server-side internal drivers, thereby providing better performance. You can use the same API on the LOB classes in all Oracle JDBC drivers.
- In the case of the JDBC Thin driver only, the implementation of the data access API uses the PL/SQL `DBMS_LOB` package internally. You never have to use `DBMS_LOB` directly. This is in contrast to the 8.0.*x* drivers. For more information on the `DBMS_LOB` package, see the *Oracle9i Supplied PL/SQL Packages Reference*.

To read and write LOB data, you can use these methods:

- To read from a BLOB, use the `getBinaryStream()` method of an `oracle.sql.BLOB` object to retrieve the entire `BLOB` as an input stream. This returns a `java.io.InputStream` object.

  As with any `InputStream` object, use one of the overloaded `read()` methods to read the LOB data, and use the `close()` method when you finish.

- To write to a BLOB, use the `getBinaryOutputStream()` method of an `oracle.sql.BLOB` object to retrieve the BLOB as an output stream. This returns a `java.io.OutputStream` object to be written back to the BLOB.

  As with any `OutputStream` object, use one of the overloaded `write()` methods to update the LOB data, and use the `close()` method when you finish.

- To read from a CLOB, use the `getAsciiStream()` or `getCharacterStream()` method of an `oracle.sql.CLOB` object to retrieve the entire CLOB as an input stream. The `getAsciiStream()` method returns an ASCII input stream in a `java.io.InputStream` object. The `getCharacterStream()` method returns a `Unicode` input stream in a `java.io.Reader` object.

  As with any `InputStream` or `Reader` object, use one of the overloaded `read()` methods to read the LOB data, and use the `close()` method when you finish.

  You can also use the `getSubString()` method of `oracle.sql.CLOB` object to retrieve a subset of the CLOB as a character string of type `java.lang.String`.

- To write to a CLOB, use the `getAsciiOutputStream()` or `getCharacterOutputStream()` method of an `oracle.sql.CLOB` object to retrieve the CLOB as an output stream to be written back to the CLOB. The `getAsciiOutputStream()` method returns an ASCII output stream in a `java.io.OutputStream` object. The `getCharacterOutputStream()` method returns a `Unicode` output stream in a `java.io.Writer` object.

  As with any `OutputStream` or `Writer` object, use one of the overloaded `write()` methods to update the LOB data, and use the `flush()` and `close()` methods when you finish.

Notes:

- The stream "write" methods described in this section write directly to the database when you write to the output stream. You do *not* need to execute an `UPDATE` to write the data. CLOBs and BLOBs are transaction controlled. After writing to either, you must commit the transaction for the changes to be permanent. BFILEs are not transaction controlled. Once you write to them the changes are permanent, even if the transaction is rolled back, unless the external file system does something else.
- When writing to or reading from a CLOB, the JDBC drivers perform all character set conversions for you.

Important: The JDBC 2.0 specification states that `PreparedStatement` methods `setBinaryStream()` and `setObject()` can be used to input a stream value as a BLOB, and that the `PreparedStatement` methods `setAsciiStream()`, `setUnicodeStream()`, `setCharacterStream()`, and `setObject()` can be used to input a stream value as a CLOB. This bypasses the LOB locator, going directly to the LOB data itself.

In the implementation of the Oracle JDBC drivers, this functionality is supported *only* for a configuration using an 8.1.6 and higher database and 8.1.6 and higher JDBC OCI driver. **Do not use this functionality for any other configuration, as data corruption may result.**

Example: Reading BLOB Data Use the `getBinaryStream()` method of the `oracle.sql.BLOB` class to read BLOB data. The `getBinaryStream()` method reads the BLOB data into a binary stream.

The following example uses the `getBinaryStream()` method to read BLOB data into a byte stream and then reads the byte stream into a byte array (returning the number of bytes read, as well).

```
// Read BLOB data from BLOB locator.
InputStream byte_stream = my_blob.getBinaryStream();
byte [] byte_array = new byte [10];
int bytes_read = byte_stream.read(byte_array);
```

```
...
```

Example: Reading CLOB Data The following example uses the `getCharacterStream()` method to read `CLOB` data into a `Unicode` character stream. It then reads the character stream into a character array (returning the number of characters read, as well).

```
// Read CLOB data from CLOB locator into Reader char stream.
Reader char_stream = my_clob.getCharacterStream();
char [] char_array = new char [10];
int chars_read = char_stream.read (char_array, 0, 10);
...
```

The next example uses the `getAsciiStream()` method of the `oracle.sql.CLOB` class to read CLOB data into an ASCII character stream. It then reads the ASCII stream into a byte array (returning the number of bytes read, as well).

```
// Read CLOB data from CLOB locator into Input ASCII character stream
Inputstream asciiChar_stream = my_clob.getAsciiStream();
byte[] asciiChar_array = new byte[10];
int asciiChar_read = asciiChar_stream.read(asciiChar_array,0,10);
```

Example: Writing BLOB Data Use the `getBinaryOutputStream()` method of an `oracle.sql.BLOB` object to write BLOB data.

The following example reads a vector of data into a byte array, then uses the `getBinaryOutputStream()` method to write an array of character data to a BLOB.

```
java.io.OutputStream outstream;

// read data into a byte array
byte[] data = {0, 1, 2, 3, 4, 5, 6, 7, 8, 9};

// write the array of binary data to a BLOB
outstream = ((BLOB)my_blob).getBinaryOutputStream();
outstream.write(data);
...
```

Example: Writing CLOB Data Use the `getCharacterOutputStream()` method or the `getAsciiOutputStream()` method to write data to a CLOB. The `getCharacterOutputStream()` method returns a `Unicode` output stream; the `getAsciiOutputStream()` method returns an ASCII output stream.

The following example reads a vector of data into a character array, then uses the `getCharacterOutputStream()` method to write the array of character data to a CLOB. The `getCharacterOutputStream()` method returns a `java.io.Writer` instance in an `oracle.sql.CLOB` object, not a `java.sql.Clob` object.

```
java.io.Writer writer;

// read data into a character array
char[] data = {'0','1','2','3','4','5','6','7','8','9'};

// write the array of character data to a CLOB
writer = ((CLOB)my_clob).getCharacterOutputStream();
writer.write(data);
writer.flush();
writer.close();
...
```

The next example reads a vector of data into a byte array, then uses the `getAsciiOutputStream()` method to write the array of ASCII data to a CLOB. Because `getAsciiOutputStream()` returns an ASCII output stream, you must cast the output to a `oracle.sql.CLOB` datatype.

```
java.io.OutputStream out;

// read data into a byte array
byte[] data = {'0','1','2','3','4','5','6','7','8','9'};

// write the array of ascii data to a CLOB
out = ((CLOB)clob).getAsciiOutputStream();
out.write(data);
out.flush();
out.close();
```

Creating and Populating a BLOB or CLOB Column

Create and populate a `BLOB` or `CLOB` column in a table by using SQL statements.

> **Note:** You cannot construct a new BLOB or CLOB locator in your application with a Java new statement. You must create the locator through a SQL operation, and then select it into your application or with the createTemporary() or empty_lob() methods.

Create a BLOB or CLOB column in a table with the SQL CREATE TABLE statement, then populate the LOB. This includes creating the LOB entry in the table, obtaining the LOB locator, creating a file handler for the data (if you are reading the data from a file), and then copying the data into the LOB.

Creating a BLOB or CLOB Column in a New Table

To create a BLOB or CLOB column in a new table, execute the SQL CREATE TABLE statement. The following example code creates a BLOB column in a new table. This example assumes that you have already created your Connection object conn and Statement object stmt:

```
String cmd = "CREATE TABLE my_blob_table (x varchar2 (30), c blob)";
stmt.execute (cmd);
```

In this example, the VARCHAR2 column designates a row number, such as 1 or 2, and the BLOB column stores the locator of the BLOB data.

Populating a BLOB or CLOB Column in a New Table

This example demonstrates how to populate a BLOB or CLOB column by reading data from a stream. These steps assume that you have already created your Connection object conn and Statement object stmt. The table my_blob_table is the table that was created in the previous section.

The following example writes the GIF file john.gif to a BLOB.

1. Begin by using SQL statements to create the BLOB entry in the table. Use the empty_blob syntax to create the BLOB locator.

   ```
   stmt.execute ("INSERT INTO my_blob_table VALUES ('row1', empty_blob())");
   ```

2. Get the BLOB locator from the table.

   ```
   BLOB blob;
   cmd = "SELECT * FROM my_blob_table WHERE X='row1'";
   ResultSet rset = stmt.executeQuery(cmd);
   rset.next();
   BLOB blob = ((OracleResultSet)rset).getBLOB(2);
   ```

3. Declare a file handler for the `john.gif` file, then print the length of the file. This value will be used later to ensure that the entire file is read into the BLOB. Next, create a `FileInputStream` object to read the contents of the `GIF` file, and an `OutputStream` object to retrieve the BLOB as a stream.

```
File binaryFile = new File("john.gif");
System.out.println("john.gif length = " + binaryFile.length());
FileInputStream instream = new FileInputStream(binaryFile);
OutputStream outstream = blob.getBinaryOutputStream();
```

4. Call `getBufferSize()` to retrieve the ideal buffer size (according to calculations by the JDBC driver) to use in writing to the BLOB, then create the `buffer` byte array.

```
int size = blob.getBufferSize();
byte[] buffer = new byte[size];
int length = -1;
```

5. Use the `read()` method to read the `GIF` file to the byte array `buffer`, then use the `write()` method to write it to the BLOB. When you finish, close the input and output streams.

```
while ((length = instream.read(buffer)) != -1)
   outstream.write(buffer, 0, length);
instream.close();
outstream.close();
```

Once your data is in the BLOB or CLOB, you can manipulate the data. This is described in the next section, "Accessing and Manipulating BLOB and CLOB Data".

Accessing and Manipulating BLOB and CLOB Data

Once you have your BLOB or CLOB locator in a table, you can access and manipulate the data to which it points. To access and manipulate the data, you first must select their locators from a result set or from a callable statement. "Getting and Passing BLOB and CLOB Locators" on page 8-3 describes these techniques in detail.

After you select the locators, you can retrieve the BLOB or CLOB data. You will usually want to cast the result set to the `OracleResultSet` datatype so that you can retrieve the data in `oracle.sql.*` format. After retrieving the BLOB or CLOB data, you can manipulate it however you want.

This example is a continuation of the example in the previous section. It uses the SQL `SELECT` statement to select the BLOB locator from the table `my_blob_table`

into a result set. The result of the data manipulation is to print the length of the BLOB in bytes.

```
// Select the blob - what we are really doing here
// is getting the blob locator into a result set
BLOB blob;
cmd = "SELECT *  FROM my_blob_table";
ResultSet rset = stmt.executeQuery (cmd);

// Get the blob data - cast to OracleResult set to
// retrieve the data in oracle.sql format
String index = ((OracleResultSet)rset).getString(1);
blob = ((OracleResultSet)rset).getBLOB(2);

// get the length of the blob
int length = blob.length();

// print the length of the blob
System.out.println("blob length" + length);

// read the blob into a byte array
// then print the blob from the array
byte bytes[] = blob.getBytes(1, length);
printBytes(bytes, length);
```

Additional BLOB and CLOB Features

In addition to what has already been discussed in this chapter, the `oracle.sql.BLOB` and `CLOB` classes have a number of methods for further functionality.

Note: The `oracle.sql.CLOB` class supports all the character sets that the Oracle data server supports for CLOB types.

Additional BLOB Methods

The `oracle.sql.BLOB` class includes the following methods:

- `close()`: Closes the BLOB associated with the locator. (See "Using Open and Close With LOBs" on page 8-19 for more information.)
- `freeTemporary()`: Frees the storage used by a temporary BLOB. (See "Working With Temporary LOBs" on page 8-18 for more information.)

- `getBinaryOutputStream()`: Returns a `java.io.OutputStream` to write data to the BLOB as a stream.
- `getBinaryOutputStream(long)`: Returns a `java.io.OutputStream` to write data to the BLOB as a stream. The data is written beginning at the position in the BLOB specified in the argument.
- `getBinaryStream()`: Returns the BLOB data for this `Blob` instance as a stream of bytes.
- `getBinaryStream(long)`: Returns the BLOB data for this Blob instance as a stream of bytes beginning at the position in the BLOB specified in the argument.
- `getBufferSize()`: Returns the ideal buffer size, according to calculations by the JDBC driver, to use in reading and writing BLOB data. This value is a multiple of the chunk size (see `getChunkSize()` below) and is close to 32K.
- `getBytes()`: Reads from the BLOB data, starting at a specified point, into a supplied buffer.
- `getChunkSize()`: Returns the Oracle chunking size, which can be specified by the database administrator when the LOB column is first created. This value, in Oracle blocks, determines the size of the chunks of data read or written by the LOB data layer in accessing or modifying the BLOB value. Part of each chunk stores system-related information, and the rest stores LOB data. Performance is enhanced if read and write requests use some multiple of the chunk size.
- `isOpen()`: Returns `true` if the BLOB was opened by calling the `open()` method; otherwise, it returns `false`. (See "Using Open and Close With LOBs" on page 8-19 for more information.)
- `isTemporary()`: Returns true if the BLOB is a temporary BLOB. (See "Working With Temporary LOBs" on page 8-18 for more information.)
- `length()`: Returns the length of the BLOB in bytes.
- `open()`: Opens the BLOB associated with the locator. (See "Using Open and Close With LOBs" on page 8-19 for more information.)
- `open(int)`: Opens the BLOB associated with the locator in the mode specified by the argument. (See "Using Open and Close With LOBs" on page 8-19 for more information.)
- `position()`: Determines the byte position in the BLOB where a given pattern begins.
- `putBytes()`: Writes BLOB data, starting at a specified point, from a supplied buffer.

- `trim(long)`: Trims the value of the BLOB to the length specified by the argument.

Additional CLOB Methods

The `oracle.sql.CLOB` class includes the following methods:

- `close()`: Closes the CLOB associated with the locator. (See "Using Open and Close With LOBs" on page 8-19 for more information.)
- `freeTemporary()`: Frees the storage used by a temporary CLOB. (See "Working With Temporary LOBs" on page 8-18 for more information.)
- `getAsciiOutputStream()`: Returns a `java.io.OutputStream` to write data to the CLOB as a stream.
- `getAsciiOutputStream(long)`: Returns a `java.io.OutputStream` object to write data to the CLOB as a stream. The data is written beginning at the position in the CLOB specified by the argument.
- `getAsciiStream()`: Returns the CLOB value designated by the `Clob` object as a stream of ASCII bytes.
- `getAsciiStream(long)`: Returns the CLOB value designated by the CLOB object as a stream of ASCII bytes, beginning at the position in the CLOB specified by the argument.
- `getBufferSize()`: Returns the ideal buffer size, according to calculations by the JDBC driver, to use in reading and writing CLOB data. This value is a multiple of the chunk size (see `getChunkSize()` below) and is close to 32K.
- `getCharacterOutputStream()`: Returns a `java.io.Writer` to write data to the CLOB as a stream.
- `getCharacterOutputStream(long)`: Returns a `java.io.Writer` object to write data to the CLOB as a stream. The data is written beginning at the position in the CLOB specified by the argument.
- `getCharacterStream()`: Returns the CLOB data as a stream of `Unicode` characters.
- `getCharacterStream(long)`: Returns the CLOB data as a stream of Unicode characters beginning at the position in the CLOB specified by the argument.
- `getChars()`: Retrieves characters from a specified point in the CLOB data into a character array.

- `getChunkSize()`: Returns the Oracle chunking size, which can be specified by the database administrator when the LOB column is first created. This value, in Oracle blocks, determines the size of the chunks of data read or written by the LOB data layer in accessing or modifying the CLOB value. Part of each chunk stores system-related information and the rest stores LOB data. Performance is enhanced if you make read and write requests using some multiple of the chunk size.
- `isOpen()`: Returns `true` if the CLOB was opened by calling the open() method; otherwise, it returns `false`. (See "Using Open and Close With LOBs" on page 8-19 for more information.)
- `isTemporary()`: Returns true if and only if the CLOB is a temporary CLOB. (See "Working With Temporary LOBs" on page 8-18 for more information.)
- `length()`: Returns the length of the CLOB in characters.
- `open()`: Opens the CLOB associated with the locator. (See "Using Open and Close With LOBs" on page 8-19 for more information.)
- `open(int)`: Opens the CLOB associated with the locator in the mode specified by the argument. (See "Using Open and Close With LOBs" on page 8-19 for more information.)
- `position()`: Determines the character position in the CLOB at which a given substring begins.
- `putChars()`: Writes characters from a character array to a specified point in the CLOB data.
- `getSubString()`: Retrieves a substring from a specified point in the CLOB data.
- `putString()`: Writes a string to a specified point in the CLOB data.
- `trim(long)`: Trims the value of the CLOB to the length specified by the argument.

Creating Empty LOBs

Before writing data to an internal LOB, you must make sure the LOB column/attribute is not `null`: it must contain a locator. You can accomplish this by initializing the internal LOB as an empty LOB in an `INSERT` or `UPDATE` statement, using the `empty_lob()` method defined in the `oracle.sql.BLOB` and `oracle.sql.CLOB` classes:

- `public static BLOB empty_lob() throws SQLException`

- `public static CLOB empty_lob() throws SQLException`

A JDBC driver creates an empty `LOB` instance without making database round trips. You can use empty LOBs in the following:

- `setXXX()` methods of the `OraclePreparedStatement` class
- `updateXXX()` methods of updatable result sets
- attributes of `STRUCT` objects
- elements of `ARRAY` objects

Note: Because an `empty_lob()` method creates a special marker that does not contain a locator, a JDBC application cannot read or write to it. The JDBC driver throws the exception `ORA-17098 Invalid empty LOB operation` if a JDBC application attempts to read or write to an empty LOB before it is stored in the database.

Working With Temporary LOBs

You can use temporary LOBs to transient data. The data is stored in temporary table space rather than regular table space. You should free temporary LOBs after you no longer need them. If you do not, the space the LOB consumes in temporary table space will not be reclaimed.

You create a temporary LOB with the static method, `createTemporary(Connection, boolean, int)`, defined in the `oracle.sql.BLOB` and `oracle.sql.CLOB` classes. You free a temporary LOB with the `freeTemporary()` method.

```
public static BLOB createTemporary(Connection conn, boolean isCached, int
duration);
public static CLOB createTemporary(Connection conn, boolean isCached, int
duration);
```

The duration must be either `DURATION_SESSION` or `DURATION_CALL` as defined in the `oracle.sql.BLOB` or `oracle.sql.CLOB` class. In client applications `DURATION_SESSION` is appropriate. In Java stored procedures you can use either `DURATION_SESSION` or `DURATION_CALL`, which ever is appropriate.

You can test whether a LOB is temporary by calling the `isTemporary()` method. If the LOB was created by calling the `createTemporary()`method, the `isTemporary()` method returns `true`; otherwise, it returns `false`.

You can free a temporary LOB by calling the `freeTemporary()` method. Free any temporary LOBs before ending the session or call. Otherwise, the storage used by the temporary LOB will not be reclaimed.

Note: Failure to free a temporary LOB will result in the storage used by that LOB being unavailable. Frequent failure to free temporary LOBs will result in filling up temporary table space with unavailable LOB storage.

Using Open and Close With LOBs

You do not have to open and close your LOBs. You might choose to open and close them for performance reasons.

If you do not wrap LOB operations inside an Open / Close call operation: Each modification to the LOB will implicitly open and close the LOB thereby firing any triggers on an domain index. Note that in this case, any domain indexes on the LOB will become updated as soon as LOB modifications are made. Therefore, domain LOB indexes are always valid and may be used at any time.

If you wrap your LOB operations inside the Open / Close operation, triggers will not be fired for each LOB modification. Instead, the trigger on domain indexes will be fired at the Close call. For example, you might design your application so that domain indexes are not be updated until you call the `close()` method. However, this means that any domain indexes on the LOB will not be valid in-between the Open / Close calls.

You open a LOB by calling the `open()` or `open(int)` method. You may then read and write the LOB without any triggers associated with that LOB firing. When you are done accessing the LOB, close the LOB by calling the `close()` method. When you close the LOB, any triggers associated with the LOB will fire. You can see if a LOB is open or closed by calling the `isOpen()` method. If you open the LOB by calling the `open(int)` method, the value of the argument must be either `MODE_READONLY` or `MODE_READWRITE`, as defined in the `oracle.sql.BLOB` and `oracle.sql.CLOB` classes. If you open the LOB with `MODE_READONLY`, any attempt to write to the LOB will result in a SQL exception.

Note: An error occurs if you commit the transaction before closing all opened LOBs that were opened by the transaction. The openness of the open LOBs is discarded, but the transaction is successfully committed. Hence, all the changes made to the LOB and non-LOB data in the transaction are committed but the triggers for domain indexing are not fixed.

Working with BFILEs

This section describes how to read and write data to and from external binary files (BFILEs), using file locators.

Getting and Passing BFILE Locators

Getter and setter methods are available for retrieving or passing BFILE locators from or to the database.

Retrieving BFILE Locators

Given a standard JDBC result set or callable statement object that includes BFILE locators, you can access the locators by using the standard result set `getObject()` method. This method returns an `oracle.sql.BFILE` object.

You can also access the locators by casting your result set to `OracleResultSet` or your callable statement to `OracleCallableStatement` and using the `getOracleObject()` or `getBFILE()` method.

Notes:

- In the `OracleResultSet` and `OracleCallableStatement` classes, `getBFILE()` and `getBfile()` both return `oracle.sql.BFILE`. There is no `java.sql` interface (or `oracle.jdbc2` interface) for BFILEs.
- If using `getObject()` or `getOracleObject()`, remember to cast the output, as necessary. For more information, see "Casting Your get Method Return Values" on page 7-10.

Example: Getting a BFILE locator from a Result Set Assume that the database has a table called `bfile_table` with a single column for the BFILE locator `bfile_col`. This example assumes that you have already created your `Statement` object `stmt`.

Select the BFILE locator into a standard result set. If you cast the result set to an `OracleResultSet`, you can use `getBFILE()` to get the BFILE locator:

```
// Select the BFILE locator into a result set
ResultSet rs = stmt.executeQuery("SELECT bfile_col FROM bfile_table");
while (rs.next())
{
   oracle.sql.BFILE my_bfile = ((OracleResultSet)rs).getBFILE(1);
}
```

Note that as an alternative, you can use `getObject()` to return the BFILE locator. In this case, because `getObject()` returns a `java.lang.Object`, cast the results to `BFILE`. For example:

```
oracle.sql.BFILE my_bfile = (BFILE)rs.getObject(1);
```

Example: Getting a BFILE Locator from a Callable Statement Assume you have an `OracleCallableStatement` object `ocs` that calls a function `func` that has a `BFILE` output parameter. The following code example sets up the callable statement, registers the output parameter as `OracleTypes.BFILE`, executes the statement, and retrieves the BFILE locator:

```
OracleCallableStatement ocs =
   (OracleCallableStatement)conn.prepareCall("{? = call func()}");
ocs.registerOutParameter(1, OracleTypes.BFILE);
ocs.execute();
oracle.sql.BFILE bfile = ocs.getBFILE(1);
```

Passing BFILE Locators

To pass a BFILE locator to a prepared statement or callable statement (to update a BFILE locator, for example), you can do one of the following:

- Use the standard `setObject()` method.

or:

- Cast the statement to `OraclePreparedStatement` or `OracleCallableStatement`, and use the `setOracleObject()` or `setBFILE()` method.

These methods take the parameter index and an `oracle.sql.BFILE` object as input.

Example: Passing a BFILE Locator to a Prepared Statement Assume you want to insert a BFILE locator into a table, and you have an `OraclePreparedStatement` object `ops` to insert data into a table. The first column is a string (to designate a row number), the second column is a BFILE, and you have a valid `oracle.sql.BFILE` object (`bfile`). Write the BFILE to the database as follows:

```
OraclePreparedStatement ops = (OraclePreparedStatement)conn.prepareStatement
                              ("INSERT INTO my_bfile_table VALUES (?,?)");
ops.setString(1,"one");
ops.setBFILE(2, bfile);
ops.execute();
```

Example: Passing a BFILE Locator to a Callable Statement Passing a BFILE locator to a callable statement is similar to passing it to a prepared statement. In this case, the BFILE locator is passed to the `myGetFileLength()` procedure, which returns the BFILE length as a numeric value.

```
OracleCallableStatement cstmt = (OracleCallableStatement)conn.prepareCall
                               ("begin ? := myGetFileLength (?); end;");
try
{
   cstmt.registerOutParameter (1, Types.NUMERIC);
   cstmt.setBFILE (2, bfile);
   cstmt.execute ();
   return cstmt.getLong (1);
}
```

Reading BFILE Data

To read BFILE data, you must first get the BFILE locator. You can get the locator from either a callable statement or a result set. "Getting and Passing BFILE Locators" on page 8-20 describes this.

Once you obtain the locator, you can invoke a number of methods on the BFILE without opening it. For example, you can use the `oracle.sql.BFILE` methods `fileExists()` and `isFileOpen()` to determine whether the BFILE exists and if it is open. If you want to read and manipulate the data, however, you must open and close the BFILE, as follows:

- Use the `openFile()` method of the `oracle.sql.BFILE` class to open a BFILE.
- When you are done, use the `closeFile()` method of the `BFILE` class.

BFILE data is materialized as a Java stream. To read from a BFILE, use the `getBinaryStream()` method of an `oracle.sql.BFILE` object to retrieve the entire file as an input stream. This returns a `java.io.InputStream` object.

As with any `InputStream` object, use one of the overloaded `read()` methods to read the file data, and use the `close()` method when you finish.

Notes:

- BFILEs are read-only. You cannot insert data or otherwise write to a BFILE.
- You cannot use JDBC to create a new BFILE. They are created only externally.

Example: Reading BFILE Data The following example uses the `getBinaryStream()` method of an `oracle.sql.BFILE` object to read BFILE data into a byte stream and then read the byte stream into a byte array. The example assumes that the BFILE has already been opened.

```
// Read BFILE data from a BFILE locator
Inputstream in = bfile.getBinaryStream();
byte[] byte_array = new byte{10};
int byte_read = in.read(byte_array);
```

Creating and Populating a BFILE Column

This section discusses how to create a `BFILE` column in a table with SQL operations and specify the location where the BFILE resides. The examples below assume that you have already created your `Connection` object `conn` and `Statement` object `stmt`.

Creating a BFILE Column in a New Table

To work with BFILE data, create a `BFILE` column in a table, and specify the location of the BFILE. To specify the location of the BFILE, use the SQL `CREATE DIRECTORY...AS` statement to specify an alias for the directory where the BFILE resides. Then execute the statement. In this example, the directory alias is `test_dir`, and the BFILE resides in the `/home/work` directory.

```
String cmd;
cmd = "CREATE DIRECTORY test_dir AS '/home/work'";
stmt.execute (cmd);
```

Use the SQL `CREATE TABLE` statement to create a table containing a `BFILE` column, then execute the statement. In this example, the name of the table is `my_bfile_table`.

```
// Create a table containing a BFILE field
cmd = "CREATE TABLE my_bfile_table (x varchar2 (30), b bfile)";
```

```
stmt.execute (cmd);
```

In this example, the VARCHAR2 column designates a row number, and the BFILE column stores the locator of the BFILE data.

Populating a BFILE Column

Use the SQL INSERT INTO...VALUES statement to populate the VARCHAR2 and BFILE fields, then execute the statement. The BFILE column is populated with the locator to the BFILE data. To populate the BFILE column, use the bfilename function to specify the directory alias and the name of the BFILE file.

```
cmd ="INSERT INTO my_bfile_table VALUES ('one', bfilename(test_dir,
                                         'file1.data'))";
stmt.execute (cmd);
cmd ="INSERT INTO my_bfile_table VALUES ('two', bfilename(test_dir,
                                         'jdbcTest.data'))";
stmt.execute (cmd);
```

In this example, the name of the directory alias is test_dir. The locator of the BFILE file1.data is loaded into the BFILE column on row one, and the locator of the BFILE jdbcTest.data is loaded into the bfile column on row two.

As an alternative, you might want to create the row for the row number and BFILE locator now, but wait until later to insert the locator. In this case, insert the row number into the table, and null as a place holder for the BFILE locator.

```
cmd ="INSERT INTO my_bfile_table VALUES ('three', null)";
stmt.execute(cmd);
```

Here, three is inserted into the row number column, and null is inserted as the place holder. Later in your program, insert the BFILE locator into the table by using a prepared statement.

First get a valid BFILE locator into the bfile object:

```
rs = stmt.executeQuery("SELECT b FROM my_bfile_table WHERE x='two'");
rs.next();
oracle.sql.BFILE bfile = ((OracleResultSet)rs).getBFILE(1);
```

Then, create your prepared statement. Note that because this example uses the `setBFILE()` method to identify the BFILE, the prepared statement must be cast to an `OraclePreparedStatement`:

```
OraclePreparedStatement ops = (OraclePreparedStatement)conn.prepareStatement
                     (UPDATE my_bfile_table SET b=? WHERE x = 'three');
ops.setBFILE(1, bfile);
ops.execute();
```

Now row `two` and row `three` contain the same BFILE.

Once you have the BFILE locators available in a table, you can access and manipulate the BFILE data. The next section, "Accessing and Manipulating BFILE Data", describes this.

Accessing and Manipulating BFILE Data

Once you have the BFILE locator in a table, you can access and manipulate the data to which it points. To access and manipulate the data, you must first select its locator from a result set or a callable statement.

The following code continues the example from "Populating a BFILE Column" on page 8-24, getting the locator of the BFILE from row `two` of a table into a result set. The result set is cast to an `OracleResultSet` so that `oracle.sql.*` methods can be used on it. Several of the methods applied to the BFILE, such as `getDirAlias()` and `getName()`, do not require you to open the BFILE. Methods that manipulate the BFILE data, such as reading, getting the length, and displaying, *do* require you to open the BFILE.

When you finish manipulating the BFILE data, you must close the BFILE.

```
// select the bfile locator
cmd = "SELECT *  FROM my_bfile_table WHERE x = 'two'";
rset = stmt.executeQuery (cmd);

if (rset.next ())
    BFILE bfile = ((OracleResultSet)rset).getBFILE (2);

// for these methods, you do not have to open the bfile
println("getDirAlias() = " + bfile.getDirAlias());
println("getName() = " + bfile.getName());
println("fileExists() = " + bfile.fileExists());
println("isFileOpen() = " + bfile.isFileOpen());

// now open the bfile to get the data
```

```
bfile.openFile();

// get the BFILE data as a binary stream
InputStream in = bfile.getBinaryStream();
int length ;

// read the bfile data in 6-byte chunks
byte[] buf = new byte[6];

while ((length = in.read(buf)) != -1)
{
    // append and display the bfile data in 6-byte chunks
   StringBuffer sb = new StringBuffer(length);
   for (int i=0; i<length; i++)
      sb.append( (char)buf[i] );
   System.out.println(sb.toString());
}

// we are done working with the input stream. Close it.
in.close();

// we are done working with the BFILE. Close it.
bfile.closeFile();
```

Additional BFILE Features

In addition to the features already discussed in this chapter, the `oracle.sql.BFILE` class has a number of methods for further functionality, including the following:

- `openFile()`: Opens the external file for read-only access.
- `closeFile()`: Closes the external file.
- `getBinaryStream()`: Returns the contents of the external file as a stream of bytes.
- `getBinaryStream(long)`: Returns the contents of the external file as a stream of bytes beginning at the position in the external file specified by the argument.
- `getBytes()`: Reads from the external file, starting at a specified point, into a supplied buffer.
- `getName()`: Gets the name of the external file.

- `getDirAlias()`: Gets the directory alias of the external file.
- `length()`: Returns the length of the BFILE in bytes.
- `position()`: Determines the byte position at which the given byte pattern begins.
- `isFileOpen()`: Determines whether the BFILE is open (for read-only access).

9

Working with Oracle Object Types

This chapter describes JDBC support for user-defined object types. It discusses functionality of the generic, weakly typed `oracle.sql.STRUCT` class, as well as how to map to custom Java classes that implement either the JDBC standard `SQLData` interface or the Oracle `ORAData` interface. This chapter also describes how JDBC drivers access SQLJ object types in SQL representation.

The following topics are covered:

- Mapping Oracle Objects
- Using the Default STRUCT Class for Oracle Objects
- Creating and Using Custom Object Classes for Oracle Objects
- Object-Type Inheritance
- Using JPublisher to Create Custom Object Classes
- Describing an Object Type
- SQLJ Object Types

> **Note:** For general information about Oracle object features and functionality, see the *Oracle9i Application Developer's Guide - Object-Relational Features.*

Mapping Oracle Objects

Oracle object types provide support for composite data structures in the database. For example, you can define a type `Person` that has attributes such as name (type `CHAR`), phone number (type `CHAR`), and employee number (type `NUMBER`).

Oracle provides tight integration between its Oracle object features and its JDBC functionality. You can use a standard, generic JDBC type to map to Oracle objects, or you can customize the mapping by creating custom Java type definition classes. In this book, Java classes that you create to map to Oracle objects will be referred to as *custom Java classes* or, more specifically, *custom object classes*. This is as opposed to *custom references classes* to map to object references, and *custom collection classes* to map to Oracle collections. Custom object classes can implement either a standard JDBC interface or an Oracle extension interface to read and write data.

JDBC materializes Oracle objects as instances of particular Java classes. Two main steps in using JDBC to access Oracle objects are: 1) creating the Java classes for the Oracle objects, and 2) populating these classes. You have two options:

- Let JDBC materialize the object as a `STRUCT`. This is described in "Using the Default STRUCT Class for Oracle Objects" on page 9-3.

or:

- Explicitly specify the mappings between Oracle objects and Java classes. This includes customizing your Java classes for object data. The driver then must be able to populate instances of the custom object classes that you specify. This imposes a set of constraints on the Java classes. To satisfy these constraints, you can define your classes to implement either the JDBC standard `java.sql.SQLData` interface or the Oracle extension `oracle.sql.ORAData` interface. This is described in "Creating and Using Custom Object Classes for Oracle Objects" on page 9-10.

  You can use the Oracle JPublisher utility to generate custom Java classes.

Note: When you use the `SQLData` interface, you must use a Java type map to specify your SQL-Java mapping, unless weakly typed `java.sql.Struct` objects will suffice. See "Understanding Type Maps for SQLData Implementations" on page 9-11.

Using the Default STRUCT Class for Oracle Objects

If you choose not to supply a custom Java class for your SQL-Java mapping for an Oracle object, then Oracle JDBC will materialize the object as an instance of the `oracle.sql.STRUCT` class.

You would typically want to use `STRUCT` objects, instead of custom Java objects, in situations where you are manipulating SQL data. For example, your Java application might be a tool to manipulate arbitrary object data within the database, as opposed to being an end-user application. You can select data from the database into `STRUCT` objects and create `STRUCT` objects for inserting data into the database. `STRUCT` objects completely preserve data, because they maintain the data in SQL format. Using `STRUCT` objects is more efficient and more precise in these situations where you don't need the information in a convenient form.

STRUCT Class Functionality

This section discusses standard versus Oracle-specific features of the `oracle.sql.STRUCT` class, introduces `STRUCT` descriptors, and lists methods of the `STRUCT` class to give an overview of its functionality.

Standard java.sql.Struct Methods

If your code must comply with standard JDBC 2.0, then use a `java.sql.Struct` instance (`oracle.jdbc2.Struct` under JDK 1.1.x), and use the following standard methods:

- `getAttributes(map)`: Retrieves the values of the attributes, using entries in the specified type map to determine the Java classes to use in materializing any attribute that is a structured object type. The Java types for other attribute values would be the same as for a `getObject()` call on data of the underlying SQL type (the default JDBC types).
- `getAttributes()`: This is the same as the preceding `getAttributes(map)` method, except it uses the default type map for the connection.
- `getSQLTypeName()`: Returns a Java `String` that represents the fully qualified name (*`schema.sql_type_name`*) of the Oracle object type that this `Struct` represents (such as `SCOTT.EMPLOYEE`).

Oracle oracle.sql.STRUCT Class Methods

If you want to take advantage of the extended functionality offered by Oracle-defined methods, then use an `oracle.sql.STRUCT` instance.

The `oracle.sql.STRUCT` class implements the `java.sql.Struct` interface (`oracle.jdbc2.Struct` interface under JDK 1.1.x) and provides extended functionality beyond the JDBC 2.0 standard.

The `STRUCT` class includes the following methods in addition to standard `Struct` functionality:

- `getOracleAttributes()`: Retrieves the values of the values array as `oracle.sql.*` objects.
- `getDescriptor()`: Returns the `StructDescriptor` object for the SQL type that corresponds to this `STRUCT` object.
- `getJavaSQLConnection()`: Returns the current connection instance (`java.sql.Connection`).
- `toJdbc()`: Consults the default type map of the connection, to determine what class to map to, and then uses `toClass()`.
- `toJdbc(map)`: Consults the specified type map to determine what class to map to, and then uses `toClass()`.

STRUCT Descriptors

Creating and using a `STRUCT` object requires a descriptor—an instance of the `oracle.sql.StructDescriptor` class—to exist for the SQL type (such as `EMPLOYEE`) that will correspond to the `STRUCT` object. You need only one `StructDescriptor` object for any number of `STRUCT` objects that correspond to the same SQL type.

`STRUCT` descriptors are further discussed in "Creating STRUCT Objects and Descriptors" on page 9-4.

Creating STRUCT Objects and Descriptors

This section describes how to create `STRUCT` objects and descriptors and lists useful methods of the `StructDescriptor` class.

Steps in Creating StructDescriptor and STRUCT Objects

This section describes how to construct an `oracle.sql.STRUCT` object for a given Oracle object type. To create a `STRUCT` object, you must:

1. Create a `StructDescriptor` object (if one does not already exist) for the given Oracle object type.
2. Use the `StructDescriptor` to construct the `STRUCT` object.

A StructDescriptor is an instance of the oracle.sql.StructDescriptor class and describes a type of Oracle object (SQL structured object). Only one StructDescriptor is necessary for each Oracle object type. The driver caches StructDescriptor objects to avoid recreating them if the type has already been encountered.

Before you can construct a STRUCT object, a StructDescriptor must first exist for the given Oracle object type. If a StructDescriptor object does not exist, you can create one by calling the static StructDescriptor.createDescriptor() method. This method requires you to pass in the SQL type name of the Oracle object type and a connection object:

```
StructDescriptor structdesc = StructDescriptor.createDescriptor
                                          (sql_type_name, connection);
```

Where *sql_type_name* is a Java string containing the name of the Oracle object type (such as EMPLOYEE) and connection is your connection object.

Once you have your StructDescriptor object for the Oracle object type, you can construct the STRUCT object. To do this, pass in the StructDescriptor, your connection object, and an array of Java objects containing the attributes you want the STRUCT to contain.

```
STRUCT struct = new STRUCT(structdesc, connection, attributes);
```

Where structdesc is the StructDescriptor created previously, connection is your connection object, and attributes is an array of type java.lang.Object[].

Using StructDescriptor Methods

A StructDescriptor can be thought of as a "type object". This means that it contains information about the object type, including the typecode, the type name, and how to convert to and from the given type. Remember, there should be only one StructDescriptor object for any one Oracle object type. You can then use that descriptor to create as many STRUCT objects as you need for that type.

The StructDescriptor class includes the following methods:

- getName(): Returns the fully qualified SQL type name of the Oracle object (that is, in *schema.sql_type_name* format, such as CORPORATE.EMPLOYEE).
- getLength(): Returns the number of fields in the object type.
- getMetaData(): Returns the meta data regarding this type (like the getMetaData() method of a result set object). The returned

`ResultSetMetaData` object contains the attribute name, attribute typecode, and attribute type precision information. The "column" index in the `ResultSetMetaData` object maps to the position of the attribute in the `STRUCT`, with the first attribute being at index 1.

The `getMetaData()` method is further discussed in "Functionality for Getting Object Meta Data" on page 9-49.

Serializable STRUCT Descriptors

As "Steps in Creating StructDescriptor and STRUCT Objects" on page 9-4 explains, when you create a `STRUCT` object, you first must create a `StructDescriptor` object. Do this by calling the `StructDescriptor.createDescriptor()` method. The `oracle.sql.StructDescriptor` class is serializable, meaning that you can write the complete state of a `StructDescriptor` object to an output stream for later use. Recreate the `StructDescriptor` object by reading its serialized state from an input stream. This is referred to as *deserializing*. With the `StructDescriptor` object serialized, you do not need to call the `StructDescriptor.createDescriptor()` method—you simply deserialize the `StructDescriptor` object.

It is advisable to serialize a `StructDescriptor` object when the object type is complex but not changed often.

If you create a `StructDescriptor` object through deserialization, you must supply the appropriate database connection instance for the `StructDescriptor` object, using the `setConnection()` method.

The following code provides the connection instance for a `StructDescriptor` object:

```
public void setConnection (Connection conn) throws SQLException
```

Note: The JDBC driver does not verify that the connection object from the `setConnection()` method connects to the same database from which the type descriptor was initially derived.

Retrieving STRUCT Objects and Attributes

This section discusses how to retrieve and manipulate Oracle objects and their attributes, using either Oracle-specific features or JDBC 2.0 standard features.

Note: The JDBC driver seamlessly handles embedded objects (STRUCT objects that are attributes of STRUCT objects) in the same way that it normally handles objects. When the JDBC driver retrieves an attribute that is an object, it follows the same rules of conversion, using the type map if it is available, or using default mapping if it is not.

Retrieving an Oracle Object as an oracle.sql.STRUCT Object

You can retrieve an Oracle object directly into an `oracle.sql.STRUCT` instance. In the following example, `getObject()` is used to get a `NUMBER` object from column 1 (`col1`) of the table `struct_table`. Because `getObject()` returns an `Object` type, the return is cast to an `oracle.sql.STRUCT`. This example assumes that the `Statement` object `stmt` has already been created.

```
String cmd;
cmd = "CREATE TYPE type_struct AS object (field1 NUMBER,field2 DATE)";
stmt.execute(cmd);

cmd = "CREATE TABLE struct_table (col1 type_struct)";
stmt.execute(cmd);

cmd = "INSERT INTO struct_table VALUES (type_struct(10,'01-apr-01'))";
stmt.execute(cmd);

cmd = "INSERT INTO struct_table VALUES (type_struct(20,'02-may-02'))";
stmt.execute(cmd);

ResultSet rs= stmt.executeQuery("SELECT * FROM struct_table");
oracle.sql.STRUCT oracleSTRUCT=(oracle.sql.STRUCT)rs.getObject(1);
```

Another way to return the object as a `STRUCT` object is to cast the result set to an `OracleResultSet` object and use the Oracle extension `getSTRUCT()` method:

```
oracle.sql.STRUCT oracleSTRUCT=((OracleResultSet)rs).getSTRUCT(1);
```

Retrieving an Oracle Object as a java.sql.Struct Object

Alternatively, referring back to the previous example, you can use standard JDBC functionality such as `getObject()` to retrieve an Oracle object from the database as an instance of `java.sql.Struct` (`oracle.jdbc2.Struct` under JDK 1.1.x). Because `getObject()` returns a `java.lang.Object`, you must cast the output of the method to a `Struct`. For example:

```
ResultSet rs= stmt.executeQuery("SELECT * FROM struct_table");
java.sql.Struct jdbcStruct = (java.sql.Struct)rs.getObject(1);
```

Retrieving Attributes as oracle.sql Types

If you want to retrieve Oracle object attributes from a STRUCT or Struct instance as oracle.sql types, use the getOracleAttributes() method of the oracle.sql.STRUCT class (for a Struct instance, you will have to cast to a STRUCT instance):

Referring back to the previous examples:

```
oracle.sql.Datum[] attrs = oracleSTRUCT.getOracleAttributes();
```

or:

```
oracle.sql.Datum[] attrs =
        ((oracle.sql.STRUCT)jdbcStruct).getOracleAttributes();
```

Retrieving Attributes as Standard Java Types

If you want to retrieve Oracle object attributes as standard Java types from a STRUCT or Struct instance, use the standard getAttributes() method:

```
Object[] attrs = jdbcStruct.getAttributes();
```

Binding STRUCT Objects into Statements

To bind an oracle.sql.STRUCT object to a prepared statement or callable statement, you can either use the standard setObject() method (specifying the typecode), or cast the statement object to an Oracle statement object and use the Oracle extension setOracleObject() method. For example:

```
PreparedStatement ps= conn.prepareStatement("text_of_prepared_statement");
STRUCT mySTRUCT = new STRUCT (...);
ps.setObject(1, mySTRUCT, Types.STRUCT); //OracleTypes.STRUCT under JDK 1.1.x
```

or:

```
PreparedStatement ps= conn.prepareStatement("text_of_prepared_statement");
STRUCT mySTRUCT = new STRUCT (...);
((OraclePreparedStatement)ps).setOracleObject(1, mySTRUCT);
```

STRUCT Automatic Attribute Buffering

The Oracle JDBC driver furnishes public methods to enable and disable buffering of STRUCT attributes. (See "ARRAY Automatic Element Buffering" on page 11-9 for a discussion of how to buffer ARRAY elements.)

The following methods are included with the `oracle.sql.STRUCT` class:

- `public void setAutoBuffering(boolean enable)`
- `public boolean getAutoBuffering()`

The `setAutoBuffering(boolean)` method enables or disables auto-buffering. The `getAutoBuffering()` method returns the current auto-buffering mode. By default, auto-buffering is disabled.

It is advisable to enable auto-buffering in a JDBC application when the STRUCT attributes will be accessed more than once by the `getAttributes()` and `getArray()` methods (presuming the ARRAY data is able to fit into the JVM memory without overflow).

Important: Buffering the converted attributes may cause the JDBC application to consume a significant amount of memory.

When you enable auto-buffering, the `oracle.sql.STRUCT` object keeps a local copy of all the converted attributes. This data is retained so that a second access of this information does not require going through the data format conversion process.

Creating and Using Custom Object Classes for Oracle Objects

If you want to create custom object classes for your Oracle objects, then you must define entries in the type map that specify the custom object classes that the drivers will instantiate for the corresponding Oracle objects.

You must also provide a way to create and populate instances of the custom object class from the Oracle object and its attribute data. The driver must be able to read from a custom object class and write to it. In addition, the custom object class can provide `getXXX()` and `setXXX()` methods corresponding to the Oracle object's attributes, although this is not necessary. To create and populate the custom classes and provide these read / write capabilities, you can choose between these two interfaces:

- the JDBC standard `SQLData` interface
- the `ORAData` and `ORADataFactory` interfaces provided by Oracle

The custom object class you create must implement one of these interfaces. The `ORAData` interface can also be used to implement the custom reference class corresponding to the custom object class. If you are using the `SQLData` interface, however, you can only use weak reference types in Java (`java.sql.Ref` or `oracle.sql.REF`). The `SQLData` interface is for mapping SQL objects only.

As an example, assume you have an Oracle object type, `EMPLOYEE`, in the database that consists of two attributes: `Name` (which is type `CHAR`) and `EmpNum` (employee number, which is type `NUMBER`). You use the type map to specify that the `EMPLOYEE` object should map to a custom object class that you call `JEmployee`. You can implement either the `SQLData` or `ORAData` interface in the `JEmployee` class.

You can create custom object classes yourself, but the most convenient way to create them is to employ the Oracle JPublisher utility to create them for you. JPublisher supports the standard `SQLData` interface as well as the Oracle-specific `ORAData` interface, and is able to generate classes that implement either one. See "Using JPublisher to Create Custom Object Classes" on page 9-45 for more information.

Note: If you need to create a custom object class in order to have object-type inheritance, then see "Object-Type Inheritance" on page 9-29.

The following section compares `ORAData` and `SQLData` functionality.

Relative Advantages of ORAData versus SQLData

In deciding which of these two interface implementations to use, consider the following:

Advantages of `ORAData`:

- It does not require an entry in the type map for the Oracle object.
- It has awareness of Oracle extensions.
- You can construct a `ORAData` from an `oracle.sql.STRUCT`. This is more efficient because it avoids unnecessary conversions to native Java types.
- You can obtain the corresponding `Datum` object (which is in `oracle.sql` format) from the `ORAData` object, using the `toDatum()` method.
- It provides better performance: `ORAData` works directly with `Datum` types, which is the internal format used by the driver to hold Oracle objects.

Advantages of `SQLData`:

- It is a JDBC standard, making your code more portable.

The `SQLData` interface is for mapping SQL objects only. The `ORAData` interface is more flexible, enabling you to map SQL objects as well as any other SQL type for which you want to customize processing. You can create a `ORAData` object from any datatype found in an Oracle database. This could be useful, for example, for serializing `RAW` data in Java.

Understanding Type Maps for SQLData Implementations

If you use the `SQLData` interface in a custom object class, then you must create type map entries that specify the custom object class to use in mapping the Oracle object type (SQL object type) to Java. You can either use the default type map of the connection object, or a type map that you specify when you retrieve the data from the result set. The `ResultSet` interface `getObject()` method has a signature that lets you specify a type map:

```
rs.getObject(int columnIndex);
```

or:

```
rs.getObject(int columnIndex, Map map);
```

For a description of how to create these custom object classes with `SQLData`, see "Creating and Using Custom Object Classes for Oracle Objects" on page 9-10.

When using a SQLData implementation, if you do not include a type map entry, then the object will map to the `oracle.sql.STRUCT` class by default. (`ORAData` implementations, by contrast, have their own mapping functionality so that a type map entry is not required. When using a `ORAData` implementation, use the Oracle `getORAData()` method instead of the standard `getObject()` method.)

The type map relates a Java class to the SQL type name of an Oracle object. This one-to-one mapping is stored in a hash table as a keyword-value pair. When you read data from an Oracle object, the JDBC driver considers the type map to determine which Java class to use to materialize the data from the Oracle object type (SQL object type). When you write data to an Oracle object, the JDBC driver gets the SQL type name from the Java class by calling the `getSQLTypeName()` method of the `SQLData` interface. The actual conversion between SQL and Java is performed by the driver.

The attributes of the Java class that corresponds to an Oracle object can use either Java native types or Oracle native types (instances of the `oracle.sql.*` classes) to store attributes.

Creating a Type Map Object and Defining Mappings for a SQLData Implementation

When using a `SQLData` implementation, the JDBC applications programmer is responsible for providing a type map, which must be an instance of a class as follows:

- under JDK 1.2.x, an instance of a class that implements the standard `java.util.Map` interface

or:

- under JDK 1.1.x, an instance of a class that extends the standard `java.util.Dictionary` class (or an instance of the `Dictionary` class itself)

You have the option of creating your own class to accomplish this, but under either JDK 1.2.x or JDK 1.1.x, the standard class `java.util.Hashtable` meets the requirement.

Note: If you are migrating from JDK 1.1.x to JDK 1.2.x, you must ensure that your code uses a class that implements the `Map` interface. If you were using the `java.util.Hashtable` class under 1.1.x, then no change is necessary.

`Hashtable` and other classes used for type maps implement a `put()` method that takes keyword-value pairs as input, where each key is a fully qualified SQL type name and the corresponding value is an instance of a specified Java class.

A type map is associated with a connection instance. The standard `java.sql.Connection` interface and the Oracle-specific `oracle.jdbc.OracleConnection` interface include a `getTypeMap()` method. Under JDK 1.2.x, both return a `Map` object; under JDK 1.1.x, both return a `Dictionary` object.

The remainder of this section covers the following topics:

- Adding Entries to an Existing Type Map
- Creating a New Type Map

Adding Entries to an Existing Type Map

When a connection instance is first established, the default type map is empty. You must populate it to use any SQL-Java mapping functionality.

Follow these general steps to add entries to an existing type map.

1. Use the `getTypeMap()` method of your `OracleConnection` object to return the connection's type map object. The `getTypeMap()` method returns a `java.util.Map` object (or `java.util.Dictionary` under JDK 1.1.x). For example, presuming an `OracleConnection` instance `oraconn`:

   ```
   java.util.Map myMap = oraconn.getTypeMap();
   ```

   Note: If the type map in the `OracleConnection` instance has not been initialized, then the first call to `getTypeMap()` returns an empty map.

2. Use the type map's `put()` method to add map entries. The `put()` method takes two arguments: a SQL type name string and an instance of a specified Java class that you want to map to.

   ```
   myMap.put(sqlTypeName, classObject);
   ```

   The *`sqlTypeName`* is a string that represents the fully qualified name of the SQL type in the database. The *`classObject`* is the Java class object to which you want to map the SQL type. Get the class object with the `Class.forName()` method, as follows:

```
myMap.put(sqlTypeName, Class.forName(className));
```

For example, if you have a PERSON SQL datatype defined in the CORPORATE database schema, then map it to a Person Java class defined as Person with this statement:

```
myMap.put("CORPORATE.PERSON", Class.forName("Person"));
```

The map has an entry that maps the PERSON SQL datatype in the CORPORATE database to the Person Java class.

Note: SQL type names in the type map must be all uppercase, because that is how the Oracle database stores SQL names.

Creating a New Type Map

Follow these general steps to create a new type map. This example uses an instance of java.util.Hashtable, which extends java.util.Dictionary and, under JDK 1.2.x, also implements java.util.Map.

1. Create a new type map object.

   ```
   Hashtable newMap = new Hashtable();
   ```

2. Use the put() method of the type map object to add entries to the map. For more information on the put() method, see Step 2 under "Adding Entries to an Existing Type Map" on page 9-13. For example, if you have an EMPLOYEE SQL type defined in the CORPORATE database, then you can map it to an Employee class object defined by Employee.java, with this statement:

   ```
   newMap.put("CORPORATE.EMPLOYEE", class.forName("Employee"));
   ```

3. When you finish adding entries to the map, use the OracleConnection object's setTypeMap() method to overwrite the connection's existing type map. For example:

   ```
   oraconn.setTypeMap(newMap);
   ```

   In this example, setTypeMap() overwrites the oraconn connection's original map with newMap.

Note: The default type map of a connection instance is used when mapping is required but no map name is specified, such as for a result set `getObject()` call that does not specify the map as input.

Materializing Object Types not Specified in the Type File

If you do not provide a type map with an appropriate entry when using a `getObject()` call, then the JDBC driver will materialize an Oracle object as an instance of the `oracle.sql.STRUCT` class. If the Oracle object type contains embedded objects, and they are not present in the type map, the driver will materialize the embedded objects as instances of `oracle.sql.STRUCT` as well. If the embedded objects are present in the type map, a call to the `getAttributes()` method will return embedded objects as instances of the specified Java classes from the type map.

Understanding the SQLData Interface

One of the choices in making an Oracle object and its attribute data available to Java applications is to create a custom object class that implements the `SQLData` interface. Note that if you use this interface, you must supply a type map that specifies the Oracle object types in the database and the names of the corresponding custom object classes that you will create for them.

The `SQLData` interface defines methods that translate between SQL and Java for Oracle database objects. Standard JDBC provides a `SQLData` interface and companion `SQLInput` and `SQLOutput` interfaces in the `java.sql` package (`oracle.jdbc2` package under JDK 1.1.x).

If you create a custom object class that implements `SQLData`, then you must provide a `readSQL()` method and a `writeSQL()` method, as specified by the `SQLData` interface.

The JDBC driver calls your `readSQL()` method to read a stream of data values from the database and populate an instance of your custom object class. Typically, the driver would use this method as part of an `OracleResultSet` object `getObject()` call.

Similarly, the JDBC driver calls your `writeSQL()` method to write a sequence of data values from an instance of your custom object class to a stream that can be written to the database. Typically, the driver would use this method as part of an `OraclePreparedStatement` object `setObject()` call.

Understanding the SQLInput and SQLOutput Interfaces

The JDBC driver includes classes that implement the `SQLInput` and `SQLOutput` interfaces. It is not necessary to implement the `SQLOutput` or `SQLInput` objects—the JDBC drivers will do this for you.

The `SQLInput` implementation is an input stream class, an instance of which must be passed in to the `readSQL()` method. `SQLInput` includes a `readXXX()` method for every possible Java type that attributes of an Oracle object might be converted to, such as `readObject()`, `readInt()`, `readLong()`, `readFloat()`, `readBlob()`, and so on. Each `readXXX()` method converts SQL data to Java data and returns it into an output parameter of the corresponding Java type. For example, `readInt()` returns an integer.

The `SQLOutput` implementation is an output stream class, an instance of which must be passed in to the `writeSQL()` method. `SQLOutput` includes a `writeXXX()` method for each of these Java types. Each `writeXXX()` method converts Java data to SQL data, taking as input a parameter of the relevant Java type. For example, `writeString()` would take as input a string attribute from your Java class.

Implementing readSQL() and writeSQL() Methods

When you create a custom object class that implements `SQLData`, you must implement the `readSQL()` and `writeSQL()` methods, as described here.

You must implement `readSQL()` as follows:

```
public void readSQL(SQLInput stream, String sql_type_name) throws SQLException
```

- The `readSQL()` method takes as input a `SQLInput` stream and a string that indicates the SQL type name of the data (in other words, the name of the Oracle object type, such as `EMPLOYEE`).

  When your Java application calls `getObject()`, the JDBC driver creates a `SQLInput` stream object and populates it with data from the database. The driver can also determine the SQL type name of the data when it reads it from the database. When the driver calls `readSQL()`, it passes in these parameters.

- For each Java datatype that maps to an attribute of the Oracle object, `readSQL()` must call the appropriate `readXXX()` method of the `SQLInput` stream that is passed in.

  For example, if you are reading `EMPLOYEE` objects that have an employee name as a `CHAR` variable and an employee number as a `NUMBER` variable, you must have a `readString()` call and a `readInt()` call in your `readSQL()` method.

JDBC calls these methods according to the order in which the attributes appear in the SQL definition of the Oracle object type.

- The `readSQL()` method takes the data that the `readXXX()` methods read and convert, and assigns them to the appropriate fields or elements of a custom object class instance.

You must implement `writeSQL()` as follows:

```
public void writeSQL(SQLOutput stream) throws SQLException
```

- The `writeSQL()` method takes as input a `SQLOutput` stream.

  When your Java application calls `setObject()`, the JDBC driver creates a `SQLOutput` stream object and populates it with data from a custom object class instance. When the driver calls `writeSQL()`, it passes in this stream parameter.

- For each Java datatype that maps to an attribute of the Oracle object, `writeSQL()` must call the appropriate `writeXXX()` method of the `SQLOutput` stream that is passed in.

  For example, if you are writing to `EMPLOYEE` objects that have an employee name as a `CHAR` variable and an employee number as a `NUMBER` variable, then you must have a `writeString()` call and a `writeInt()` call in your `writeSQL()` method. These methods must be called according to the order in which attributes appear in the SQL definition of the Oracle object type.

- The `writeSQL()` method then writes the data converted by the `writeXXX()` methods to the `SQLOutput` stream so that it can be written to the database once you execute the prepared statement.

Reading and Writing Data with a SQLData Implementation

This section describes how to read data from an Oracle object or write data to an Oracle object if your corresponding Java class implements `SQLData`.

Reading SQLData Objects from a Result Set

This section summarizes the steps to read data from an Oracle object into your Java application when you choose the `SQLData` implementation for your custom object class.

These steps assume you have already defined the Oracle object type, created the corresponding custom object class, updated the type map to define the mapping between the Oracle object and the Java class, and defined a statement object `stmt`.

1. Query the database to read the Oracle object into a JDBC result set.

   ```
   ResultSet rs = stmt.executeQuery("SELECT emp_col FROM personnel");
   ```

   The PERSONNEL table contains one column, EMP_COL, of SQL type EMP_OBJECT. This SQL type is defined in the type map to map to the Java class Employee.

2. Use the `getObject()` method of your result set to populate an instance of your custom object class with data from one row of the result set. The `getObject()` method returns the user-defined `SQLData` object because the type map contains an entry for `Employee`.

   ```
   if (rs.next())
      Employee emp = (Employee)rs.getObject(1);
   ```

   Note that if the type map did not have an entry for the object, then `getObject()` would return an `oracle.sql.STRUCT` object. Cast the output to type STRUCT, because the `getObject()` method signature returns the generic `java.lang.Object` type.

   ```
   if (rs.next())
      STRUCT empstruct = (STRUCT)rs.getObject(1);
   ```

   The `getObject()` call triggers `readSQL()` and `readXXX()` calls from the `SQLData` interface, as described above.

   Note: If you want to avoid using a type map, then use the `getSTRUCT()` method. This method always returns a `STRUCT` object, even if there is a mapping entry in the type map.

3. If you have `get` methods in your custom object class, then use them to read data from your object attributes. For example, if EMPLOYEE has an `EmpName` (employee name) of type CHAR, and an `EmpNum` (employee number) of type NUMBER, then provide a `getEmpName()` method that returns a Java `String` and a `getEmpNum()` method that returns an integer (`int`). Then invoke them in your Java application, as follows:

   ```
   String empname = emp.getEmpName();
   int empnumber = emp.getEmpNum();
   ```

Note: Alternatively, fetch data by using a callable statement object, which also has a `getObject()` method.

Retrieving SQLData Objects from a Callable Statement OUT Parameter

Suppose you have an `OracleCallableStatement ocs` that calls a PL/SQL function `GETEMPLOYEE()`. The program passes an employee number (`empnumber`) to the function; the function returns the corresponding `Employee` object.

1. Prepare an `OracleCallableStatement` to call the `GETEMPLOYEE()` function.

```
OracleCallableStatement ocs =
  (OracleCallableStatement)conn.prepareCall("{ ? = call GETEMPLOYEE(?) }");
```

2. Declare the `empnumber` as the input parameter to `GETEMPLOYEE()`. Register the `SQLData` object as the `OUT` parameter, with typecode `OracleTypes.STRUCT`. Then, execute the statement.

```
ocs.setInt(2, empnumber);
ocs.registerOutParameter(1, OracleTypes.STRUCT, "EMP_OBJECT");
ocs.execute();
```

3. Use the `getObject()` method to retrieve the employee object. The following code assumes that there is a type map entry to map the Oracle object to Java type `Employee`:

```
Employee emp = (Employee)ocs.getObject(1);
```

   If there is no type map entry, then `getObject()` would return an `oracle.sql.STRUCT` object. Cast the output to type `STRUCT`, because the `getObject()` method signature returns the generic `java.lang.Object` type:

```
STRUCT emp = (STRUCT)ocs.getObject(1);
```

Passing SQLData Objects to a Callable Statement as an IN Parameter

Suppose you have a PL/SQL function `addEmployee(?)` that takes an `Employee` object as an `IN` parameter and adds it to the `PERSONNEL` table. In this example, `emp` is a valid `Employee` object.

1. Prepare an `OracleCallableStatement` to call the `addEmployee(?)` function.

```
OracleCallableStatement ocs =
  (OracleCallableStatement) conn.prepareCall("{ call addEmployee(?) }");
```

2. Use `setObject()` to pass the `emp` object as an `IN` parameter to the callable statement. Then, execute the statement.

```
ocs.setObject(1, emp);
ocs.execute();
```

Writing Data to an Oracle Object Using a SQLData Implementation

This section describes the steps in writing data to an Oracle object from your Java application when you choose the `SQLData` implementation for your custom object class.

This description assumes you have already defined the Oracle object type, created the corresponding Java class, and updated the type map to define the mapping between the Oracle object and the Java class.

1. If you have `set` methods in your custom object class, then use them to write data from Java variables in your application to attributes of your Java datatype object.

```
emp.setEmpName(empname);
emp.setEmpNum(empnumber);
```

   This statement uses the `emp` object and the `empname` and `empnumber` variables assigned in "Reading SQLData Objects from a Result Set" on page 9-17.

2. Prepare a statement that updates an Oracle object in a row of a database table, as appropriate, using the data provided in your Java datatype object.

```
PreparedStatement pstmt = conn.prepareStatement
                          ("INSERT INTO PERSONNEL VALUES (?)");
```

   This assumes `conn` is your connection object.

3. Use the `setObject()` method of the prepared statement to bind your Java datatype object to the prepared statement.

```
pstmt.setObject(1, emp);
```

4. Execute the statement, which updates the database.

```
pstmt.executeUpdate();
```

Understanding the ORAData Interface

One of the choices in making an Oracle object and its attribute data available to Java applications is to create a custom object class that implements the `oracle.sql.ORAData` and `oracle.sql.ORADataFactory` interfaces (or you can implement `ORADataFactory` in a separate class). The `ORAData` and `ORADataFactory` interfaces are supplied by Oracle and are not a part of the JDBC standard.

> **Note:** The JPublisher utility supports the generation of classes that implement the `ORAData` and `ORADataFactory` interfaces. See "Using JPublisher to Create Custom Object Classes" on page 9-45.

Understanding ORAData Features

The `ORAData` interface has these advantages:

- It recognizes Oracle extensions to the JDBC; `ORAData` uses `oracle.sql.Datum` types directly.
- It does not require a type map to specify the names of the Java custom classes you want to create.
- It provides better performance: `ORAData` works directly with `Datum` types, the internal format the driver uses to hold Oracle objects.

The `ORAData` and `ORADataFactory` interfaces do the following:

- The `toDatum()` method of the `ORAData` class transforms the data into an `oracle.sql.*` representation.
- `ORADataFactory` specifies a `create()` method equivalent to a constructor for your custom object class. It creates and returns a `ORAData` instance. The JDBC driver uses the `create()` method to return an instance of the custom object class to your Java application or applet. It takes as input an `oracle.sql.Datum` object and an integer indicating the corresponding SQL typecode as specified in the `OracleTypes` class.

`ORAData` and `ORADataFactory` have the following definitions:

```
public interface ORAData
{
    Datum toDatum (OracleConnection conn) throws SQLException;
}

public interface ORADataFactory
```

```
{
    ORAData create (Datum d, int sql_Type_Code) throws SQLException;
}
```

Where *conn* represents the Connection object, *d* represents an object of type `oracle.sql.Datum`, and *sql_Type_Code* represents the SQL typecode (from the standard `Types` or `OracleTypes` class) of the `Datum` object.

Retrieving and Inserting Object Data

The JDBC drivers provide the following methods to retrieve and insert object data as instances of `ORAData`.

To retrieve object data:

- Use the Oracle-specific `OracleResultSet` class `getORAData()` method (assume an `OracleResultSet` object `ors`):

  ```
  ors.getORAData (int col_index, ORADataFactory factory);
  ```

  This method takes as input the column index of the data in your result set, and a `ORADataFactory` instance. For example, you can implement a `getORAFactory()` method in your custom object class to produce the `ORADataFactory` instance to input to `getORAData()`. The type map is not required when using Java classes that implement `ORAData`.

or:

- Use the standard `getObject(`*`index, map`*`)` method specified by the `ResultSet` interface to retrieve data as instances of `ORAData`. In this case, you must have an entry in the type map that identifies the factory class to be used for the given object type, and its corresponding SQL type name.

To insert object data:

- Use the Oracle-specific `OraclePreparedStatement` class `setORAData()` method (assume an `OraclePreparedStatement` object `ops`):

  ```
  ops.setORAData (int bind_index, ORAData custom_obj);
  ```

  This method takes as input the parameter index of the bind variable and the name of the object containing the variable.

or:

- Use the standard `setObject()` method specified by the `PreparedStatement` interface. You can also use this method, in its different forms, to insert `ORAData` instances without requiring a type map.

The following sections describe the `getORAData()` and `setORAData()` methods.

To continue the example of an Oracle object `EMPLOYEE`, you might have something like the following in your Java application:

```
ORAData datum = ors.getORAData(1, Employee.getORAFactory());
```

In this example, `ors` is an Oracle result set, `getORAData()` is a method in the `OracleResultSet` class used to retrieve a `ORAData` object, and the `EMPLOYEE` is in column 1 of the result set. The static `Employee.getORAFactory()` method will return a `ORADataFactory` to the JDBC driver. The JDBC driver will call `create()` from this object, returning to your Java application an instance of the `Employee` class populated with data from the result set.

Notes:

- `ORAData` and `ORADataFactory` are defined as separate interfaces so that different Java classes can implement them if you wish (such as an `Employee` class and an `EmployeeFactory` class).
- To use the `ORAData` interface, your custom object classes must import `oracle.sql.*` (or at least `ORAData`, `ORADataFactory`, and `Datum`).

Reading and Writing Data with a ORAData Implementation

This section describes how to read data from an Oracle object or write data to an Oracle object if your corresponding Java class implements `ORAData`.

Reading Data from an Oracle Object Using a ORAData Implementation

This section summarizes the steps in reading data from an Oracle object into your Java application. These steps apply whether you implement `ORAData` manually or use JPublisher to produce your custom object classes.

These steps assume you have already defined the Oracle object type, created the corresponding custom object class or had JPublisher create it for you, and defined a statement object `stmt`.

1. Query the database to read the Oracle object into a result set, casting to an Oracle result set.

```
OracleResultSet ors = (OracleResultSet)stmt.executeQuery
                      ("SELECT Emp_col FROM PERSONNEL");
```

   Where `PERSONNEL` is a one-column table. The column name is `Emp_col` of type `Employee_object`.

2. Use the `getORAData()` method of your Oracle result set to populate an instance of your custom object class with data from one row of the result set. The `getORAData()` method returns an `oracle.sql.ORAData` object, which you can cast to your specific custom object class.

```
if (ors.next())
   Employee emp = (Employee)ors.getORAData(1, Employee.getORAFactory());
```

   or:

```
if (ors.next())
   ORAData datum = ors.getORAData(1, Employee.getORAFactory());
```

   This example assumes that `Employee` is the name of your custom object class and `ors` is the name of your `OracleResultSet` object.

   In case you do not want to use `getORAData()`, the JDBC drivers let you use the `getObject()` method of a standard JDBC `ResultSet` to retrieve `ORAData` data. However, you must have an entry in the type map that identifies the factory class to be used for the given object type, and its corresponding SQL type name.

   For example, if the SQL type name for your object is `EMPLOYEE`, then the corresponding Java class is `Employee`, which will implement `ORAData`. The corresponding Factory class is `EmployeeFactory`, which will implement `ORADataFactory`.

   Use this statement to declare the `EmployeeFactory` entry for your type map:

```
map.put ("EMPLOYEE", Class.forName ("EmployeeFactory"));
```

   Then use the form of `getObject()` where you specify the map object:

```
Employee emp = (Employee) rs.getObject (1, map);
```

   If the connection's default type map already has an entry that identifies the factory class to be used for the given object type, and its corresponding SQL type name, then you can use this form of `getObject()`:

```
Employee emp = (Employee) rs.getObject (1);
```

3. If you have `get` methods in your custom object class, use them to read data from your object attributes into Java variables in your application. For example, if `EMPLOYEE` has `EmpName` of type `CHAR` and `EmpNum` (employee number) of type `NUMBER`, provide a `getEmpName()` method that returns a Java string and a `getEmpNum()` method that returns an integer. Then invoke them in your Java application as follows:

   ```
   String empname = emp.getEmpName();
   int empnumber = emp.getEmpNum();
   ```

   Note: Alternatively, you can fetch data into a callable statement object. The `OracleCallableStatement` class also has a `getORAData()` method.

Writing Data to an Oracle Object Using a ORAData Implementation

This section summarizes the steps in writing data to an Oracle object from your Java application. These steps apply whether you implement `ORAData` manually or use JPublisher to produce your custom object classes.

These steps assume you have already defined the Oracle object type and created the corresponding custom object class (or had JPublisher create it for you).

Note: The type map is not used when you are performing database `INSERT` and `UPDATE` operations.

1. If you have `set` methods in your custom object class, then use them to write data from Java variables in your application to attributes of your Java datatype object.

   ```
   emp.setEmpName(empname);
   emp.setEmpNum(empnumber);
   ```

   This statement uses the `emp` object and the `empname` and `empnumber` variables defined in "Reading Data from an Oracle Object Using a ORAData Implementation" on page 9-23.

2. Write an Oracle prepared statement that updates an Oracle object in a row of a database table, as appropriate, using the data provided in your Java datatype object.

```
OraclePreparedStatement opstmt = conn.prepareStatement
   ("UPDATE PERSONNEL SET Employee = ? WHERE Employee.EmpNum = 28959);
```

This assumes `conn` is your `Connection` object.

3. Use the `setORAData()` method of the Oracle prepared statement to bind your Java datatype object to the prepared statement.

   ```
   opstmt.setORAData(1, emp);
   ```

   The `setORAData()` method calls the `toDatum()` method of the custom object class instance to retrieve an `oracle.sql.STRUCT` object that can be written to the database.

   In this step you could also use the `setObject()` method to bind the Java datatype. For example:

   ```
   opstmt.setObject(1,emp);
   ```

   Note: You can use your Java datatype objects as either `IN` or `OUT` bind variables.

Additional Uses for ORAData

The `ORAData` interface offers far more flexibility than the `SQLData` interface. The `SQLData` interface is designed to let you customize the mapping of only Oracle object types (SQL object types) to Java types of your choice. Implementing the `SQLData` interface lets the JDBC driver populate fields of a custom Java class instance from the original SQL object data, and the reverse, after performing the appropriate conversions between Java and SQL types.

The `ORAData` interface goes beyond supporting the customization of Oracle object types to Java types. It lets you provide a mapping between Java object types and *any* SQL type supported by the `oracle.sql` package.

It might be useful to provide custom Java classes to wrap `oracle.sql.*` types and perhaps implement customized conversions or functionality as well. The following are some possible scenarios:

- to perform encryption and decryption or validation of data
- to perform logging of values that have been read or are being written
- to parse character columns (such as character fields containing URL information) into smaller components

- to map character strings into numeric constants
- to map data into more desirable Java formats (such as mapping a DATE field to `java.util.Date` format)
- to customize data representation (for example, data in a table column is in feet but you want it represented in meters after it is selected)
- to serialize and deserialize Java objects—into or out of RAW fields, for example

For example, use `ORAData` to store instances of Java objects that do not correspond to a particular SQL Oracle9 object type in the database in columns of SQL type RAW. The `create()` method in `ORADataFactory` would have to implement a conversion from an object of type `oracle.sql.RAW` to the desired Java object. The `toDatum()` method in `ORAData` would have to implement a conversion from the Java object to an `oracle.sql.RAW` object. This can be done, for example, by using Java serialization.

Upon retrieval, the JDBC driver transparently retrieves the raw bytes of data in the form of an `oracle.sql.RAW` and calls the `ORADataFactory`'s `create()` method to convert the `oracle.sql.RAW` object to the desired Java class.

When you insert the Java object into the database, you can simply bind it to a column of type RAW to store it. The driver transparently calls the `ORAData.toDatum()` method to convert the Java object to an `oracle.sql.RAW` object. This object is then stored in a column of type RAW in the database.

Support for the `ORAData` interfaces is also highly efficient because the conversions are designed to work using `oracle.sql.*` formats, which happen to be the internal formats used by the JDBC drivers. Moreover, the type map, which is necessary for the `SQLData` interface, is not required when using Java classes that implement `ORAData`. For more information on why classes that implement `ORAData` do not need a type map, see "Understanding the ORAData Interface" on page 9-21.

The Deprecated CustomDatum Interface

As a result of the `oracle.jdbc` interfaces being introduced in Oracle9*i* as an alternative to the `oracle.jdbc.driver` classes, the `oracle.sql.CustomDatum` and `oracle.sql.CustomDatumFactory` interfaces, formerly used to access customized objects, have been deprecated by the new interfaces—`oracle.sql.ORAData` and `oracle.sql.ORADataFactory`.

The following are the specifications for the `CustomDatum` and `CustomDatumFactory` interfaces:

```
public interface CustomDatum
{
  oracle.sql.Datum toDatum(
    oracle.jdbc.driver.OracleConnection c
  ) throws SQLException ;

// The following is expected to be present in an
// implementation:
//
// - Definition of public static fields for
//   _SQL_TYPECODE, _SQL_NAME and  _SQL_BASETYPE.
//   (See Oracle Jdbc documentation for details.)
//
// - Definition of
//   public static CustomDatumFactory
//     getFactory();
//
}

public interface CustomDatumFactory
{
  oracle.sql.CustomDatum create(
    oracle.sql.Datum d, int sqlType
    ) throws SQLException;
}
```

Object-Type Inheritance

Object-type inheritance is an Oracle9*i* feature which allows a new object type to be created by extending another object type. (While Oracle9*i* does not yet support JDBC 3.0, object-type inheritance is supported and documented.) The new object type is then a subtype of the object type from which it extends. The subtype automatically inherits all the attributes and methods defined in the supertype. The subtype can add attributes and methods, and overload or override methods inherited from the supertype.

Object-type inheritance introduces *substitutability*. Substitutability is the ability of a slot declared to hold a value of type T to do so in addition to any subtype of type T. Oracle9*i* JDBC drivers handle substitutability transparently.

A database object is returned with its most specific type without losing information. For example, if the STUDENT_T object is stored in a PERSON_T slot, the Oracle JDBC driver returns a Java object that represents the STUDENT_T object.

Creating Subtypes

Create custom object classes if you want to have Java classes that explicitly correspond to the Oracle object types. (See "Creating and Using Custom Object Classes for Oracle Objects" on page 9-10.) If you have a hierarchy of object types, you may want a corresponding hierarchy of Java classes.

The most common way to create a database subtype in JDBC is to pass the extended SQL CREATE TYPE command to the `execute()` method of the `java.sql.Statement` interface. For example, to create a type inheritance hierarchy for:

```
PERSON_T
|
STUDENT_T
|
PARTTIMESTUDENT_T
```

the JDBC code can be:

```
statement s = conn.createStatement();
s.execute ("CREATE TYPE Person_T (SSN NUMBER, name VARCHAR2(30),
  address VARCHAR2(255))");
s.execute ("CREATE TYPE Student_T UNDER Person_t (deptid NUMBER,
  major VARCHAR2(100))");
s.execute ("CREATE TYPE PartTimeStudent_t UNDER Student_t (numHours NUMBER)");
```

In the following code, the "foo" member procedure in type ST is overloaded and the member procedure "print" overwrites the copy it inherits from type T.

```
CREATE TYPE T AS OBJECT (...,
  MEMBER PROCEDURE foo(x NUMBER),
  MEMBER PROCEDURE Print(),
  ...
  NOT FINAL;

CREATE TYPE ST UNDER T (...,
  MEMBER PROCEDURE foo(x DATE),         <-- overload "foo"
  OVERRIDING MEMBER PROCEDURE Print(),   <-- override "print"
  STATIC FUNCTION bar(...) ...
  ...
  );
```

Once the subtypes have been created, they can be used as both columns of a base table as well as attributes of a object type. For complete details on the syntax to create subtypes, see the *Oracle9i Application Developer's Guide - Object-Relational Features* for details.

Implementing Customized Classes for Subtypes

In most cases, a customized Java class represents a database object type. When you create a customized Java class for a subtype, the Java class can either mirror the database object type hierarchy or not.

You can use either the ORAData or SQLData solution in creating classes to map to the hierarchy of object types.

Use of ORAData for Type Inheritance Hierarchy

Customized mapping where Java classes implement the oracle.sql.ORAData interface is the recommended mapping. (See "Relative Advantages of ORAData versus SQLData" on page 9-11.) ORAData mapping requires the JDBC application to implement the ORAData and ORADataFactory interfaces. The class implementing the ORADataFactory interface contains a factory method that produces objects. Each object represents a database object.

The hierarchy of the class implementing the ORAData interface can mirror the database object type hierarchy. For example, the Java classes mapping to PERSON_T and STUDENT_T are as follows:

Person.java using ORAData Code for the `Person.java` class which implements the `ORAData` and `ORADataFactory` interfaces:

```
class Person implements ORAData, ORADataFactory
{
  static final Person _personFactory = new Person();

  public NUMBER ssn;
  public CHAR name;
  public CHAR address;

  public static ORADataFactory getORADataFactory()
  {
    return _personFactory;
  }

  public Person () {}

  public Person(NUMBER ssn, CHAR name, CHAR address)
  {
    this.ssn = ssn;
    this.name = name;
    this.address = address;
  }

  public Datum toDatum(OracleConnection c) throws SQLException
  {
    StructDescriptor sd =
      StructDescriptor.createDescriptor("SCOTT.PERSON_T", c);
    Object [] attributes = { ssn, name, address };
    return new STRUCT(sd, c, attributes);
  }

  public ORAData create(Datum d, int sqlType) throws SQLException
  {
    if (d == null) return null;
    Object [] attributes = ((STRUCT) d).getOracleAttributes();
    return new Person((NUMBER) attributes[0],
                      (CHAR) attributes[1],
                      (CHAR) attributes[2]);
  }
}
```

Student.java extending Person.java Code for the `Student.java` class which extends the `Person.java` class:

```
class Student extends Person
{
  static final Student _studentFactory = new Student ();

  public NUMBER deptid;
  public CHAR major;

  public static ORADataFactory getORADataFactory()
  {
    return _studentFactory;
  }

  public Student () {}

  public Student (NUMBER ssn, CHAR name, CHAR address,
                  NUMBER deptid, CHAR major)
  {
    super (ssn, name, address);
    this.deptid = deptid;
    this.major = major;
  }

  public Datum toDatum(OracleConnection c) throws SQLException
  {
    StructDescriptor sd =
      StructDescriptor.createDescriptor("SCOTT.STUDENT_T", c);
    Object [] attributes = { ssn, name, address, deptid, major };
    return new STRUCT(sd, c, attributes);
  }

  public CustomDatum create(Datum d, int sqlType) throws SQLException
  {
    if (d == null) return null;
    Object [] attributes = ((STRUCT) d).getOracleAttributes();
    return new Student((NUMBER) attributes[0],
                       (CHAR) attributes[1],
                       (CHAR) attributes[2],
                       (NUMBER) attributes[3],
                       (CHAR) attributes[4]);
  }
}
```

Customized classes that implement the ORAData interface do not have to mirror the database object type hierarchy. For example, you could have declared the above class, Student, without a superclass. In this case, Student would contain fields to hold the inherited attributes from PERSON_T as well as the attributes declared by STUDENT_T.

ORADataFactory Implementation The JDBC application uses the factory class in querying the database to return instances of Person or its subclasses, as in the following example:

```
ResultSet rset = stmt.executeQuery ("select person from tab1");
while (rset.next())
{
  Object s = rset.getORAData (1, PersonFactory.getORADataFactory());
  ...
}
```

A class implementing the ORADataFactory interface should be able to produce instances of the associated custom object type, as well as instances of any subtype, or at least all the types you expect to support.

In the following example, the PersonFactory.getORADataFactory() method returns a factory that can handle PERSON_T, STUDENT_T, and PARTTIMESTUDENT_T objects (by returning person, student, or parttimestudent Java instances).

```
class PersonFactory implements ORADataFactory
{
  static final PersonFactory _factory = new PersonFactory ();

  public static ORADataFactory getORADataFactory()
  {
    return _factory;
  }

  public ORAData create(Datum d, int sqlType) throws SQLException
  {
    STRUCT s = (STRUCT) d;
    if (s.getSQLTypeName ().equals ("SCOTT.PERSON_T"))
      return Person.getORADataFactory ().create (d, sqlType);
    else if (s.getSQLTypeName ().equals ("SCOTT.STUDENT_T"))
      return Student.getORADataFactory ().create(d, sqlType);
    else if (s.getSQLTypeName ().equals ("SCOTT.PARTTIMESTUDENT_T"))
      return ParttimeStudent.getORADataFactory ().create(d, sqlType);
    else
      return null;
```

```
  }
}
```

The following example assumes a table `tab1`, such as the following:

```
CREATE TABLE tab1 (idx NUMBER, person PERSON_T);
INSERT INTO tabl1 VALUES (1, PERSON_T (1000, 'Scott', '100 Oracle Parkway'));
INSERT INTO tabl1 VALUES (2, STUDENT_T (1001, 'Peter', '200 Oracle Parkway',
101, 'CS'));
INSERT INTO tabl1 VALUES (3, PARTTIMESTUDENT_T (1002, 'David', '300 Oracle
Parkway', 102, 'EE'));
```

Use of SQLData for Type Inheritance Hierarchy

The customized classes that implement the `java.sql.SQLData` interface can mirror the database object type hierarchy. The `readSQL()` and `writeSQL()` methods of a subclass cascade each call to the corresponding methods in the superclass in order to read or write the superclass attributes before reading or writing the subclass attributes. For example, the Java classes mapping to `PERSON_T` and `STUDENT_T` are as follows:

Person.java using SQLData Code for the `Person.java` class which implements the `SQLData` interface:

```
import java.sql.*;

public class Person implements SQLData
{
  private String sql_type;
  public int ssn;
  public String name;
  public String address;

  public Person () {}

  public String getSQLTypeName() throws SQLException { return sql_type; }

  public void readSQL(SQLInput stream, String typeName) throws SQLException
  {
    sql_type = typeName;
    ssn = stream.readInt();
    name = stream.readString();
    address = stream.readString();
  }
```

```
  public void writeSQL(SQLOutput stream) throws SQLException
  {
    stream.writeInt (ssn);
    stream.writeString (name);
    stream.writeString (address);
  }
}
```

Student.java extending Student.java Code for the `Student.java` class which extends the `Person.java` class:

```
import java.sql.*;

public class Student extends Person
{
  private String sql_type;
  public int deptid;
  public String major;

  public Student () { super(); }

  public String getSQLTypeName() throws SQLException { return sql_type; }

  public void readSQL(SQLInput stream, String typeName) throws SQLException
  {
    super.readSQL (stream, typeName);    // read supertype attributes
    sql_type = typeName;
    deptid = stream.readInt();
    major = stream.readString();
  }

  public void writeSQL(SQLOutput stream) throws SQLException
  {
    super.writeSQL (stream);             // write supertype
                                         // attributes
    stream.writeInt (deptid);
    stream.writeString (major);
  }
}
```

Customized classes that implement the `SQLData` interface do not have to mirror the database object type hierarchy. For example, you could have declared the above class, `Student`, without a superclass. In this case, `Student` would contain fields to

hold the inherited attributes from PERSON_T as well as the attributes declared by STUDENT_T.

Student.java using SQLData Code for the `Student.java` class which does not extend the `Person.java` class, but implements the SQLData interface directly:

```
import java.sql.*;

public class Student implements SQLData
{
  private String sql_type;

  public int ssn;
  public String name;
  public String address;
  public int deptid;
  public String major;

  public Student () {}

  public String getSQLTypeName() throws SQLException { return sql_type; }

  public void readSQL(SQLInput stream, String typeName) throws SQLException
  {
    sql_type = typeName;
    ssn = stream.readInt();
    name = stream.readString();
    address = stream.readString();
    deptid = stream.readInt();
    major = stream.readString();
  }

  public void writeSQL(SQLOutput stream) throws SQLException
  {
    stream.writeInt (ssn);
    stream.writeString (name);
    stream.writeString (address);
    stream.writeInt (deptid);
    stream.writeString (major);
  }
}
```

JPublisher Utility

Even though you can manually create customized classes that implement the SQLData, ORAData, and ORADataFactory interfaces, it is recommended that you use Oracle9*i* JPublisher to automatically generate these classes. The customized classes generated by JPublisher that implement the SQLData, ORAData, and ORADataFactory interfaces, can mirror the inheritance hierarchy.

To learn more about JPublisher, see "Using JPublisher to Create Custom Object Classes" on page 9-45 and the *Oracle9i JPublisher User's Guide*.

Retrieving Subtype Objects

In a typical JDBC application, a subtype object is returned as one of the following:

- A query result
- A PL/SQL OUT parameter
- A type attribute

You can use either the default (oracle.sql.STRUCT), ORAData, or SQLData mapping to retrieve a subtype.

Using Default Mapping

By default, a database object is returned as an instance of the oracle.sql.STRUCT class. This instance may represent an object of either the declared type or subtype of the declared type. If the STRUCT class represents a subtype object in the database, then it contains the attributes of its supertype as well as those defined in the subtype.

The Oracle JDBC driver returns database objects in their most specific type. The JDBC application can use the getSQLTypeName() method of the STRUCT class to determine the SQL type of the STRUCT object. The following code shows this:

```
// tab1.person column can store PERSON_T, STUDENT_T and PARTIMESTUDENT_T objects
ResultSet rset = stmt.executeQuery ("select person from tab1");
while (rset.next())
{
  oracle.sql.STRUCT s = (oracle.sql.STRUCT) rset.getObject(1);
  if (s != null)
    System.out.println (s.getSQLTypeName());    // print out the type name which
                                                 // may be SCOTT.PERSON_T,
                                                 // SCOTT.STUDENT_T or
                                                 // SCOTT.PARTTIMESTUDENT_T
}
```

Using SQLData Mapping

With SQLData mapping, the JDBC driver returns the database object as an instance of the class implementing the SQLData interface.

To use SQLData mapping in retrieving database objects, do the following:

1. Implement the wrapper classes that implement the SQLData interface for the desired object types.
2. Populate the connection type map with entries that specify what custom Java type corresponds to each Oracle object type (SQL object type).
3. Use the getObject() method to access the SQL object values.

   The JDBC driver checks the type map for a entry match. If one exists, the driver returns the database object as an instance of the class implementing the SQLData interface.

The following code shows the whole SQLData customized mapping process:

```
// The JDBC application developer implements Person.java for PERSON_T,
// Student.java for STUDENT_T
// and ParttimeStudent.java for PARTTIMESTUDEN_T.

Connection conn = ...;  // make a JDBC connection

// obtains the connection typemap
java.util.Map map = conn.getTypeMap ();

// populate the type map
map.put ("SCOTT.PERSON_T", Class.forName ("Person"));
map.put ("SCOTT.STUDENT_T", Class.forName ("Student"));
map.put ("SCOTT.PARTTIMESTUDENT_T", Class.forName ("ParttimeStudent"));

// tab1.person column can store PERSON_T, STUDENT_T and PARTTIMESTUDENT_T
objects
ResultSet rset = stmt.executeQuery ("select person from tab1");
while (rset.next())
{
  // "s" is instance of Person, Student or ParttimeStudent
  Object s = rset.getObject(1);

  if (s != null)
  {
```

```
    if (s instanceof Person)
      System.out.println ("This is a Person");
    else if (s instanceof Student)
      System.out.println ("This is a Student");
    else if (s instanceof ParttimeStudent)
      System.out.pritnln ("This is a PartimeStudent");
    else
      System.out.println ("Unknown type");
  }
}
```

The JDBC drivers check the connection type map for each call to the following:

- `getObject()` method of the `java.sql.ResultSet` and `java.sql.CallableStatement` interfaces
- `getAttribute()` method of the `java.sql.Struct` interface
- `getArray()` method of the `java.sql.Array` interface
- `getValue()` method of the `oracle.sql.REF` interface

Using ORAData Mapping

With `ORAData` mapping, the JDBC driver returns the database object as an instance of the class implementing the `ORAData` interface.

The Oracle JDBC driver needs to be informed of what Java class is mapped to the Oracle object type. The following are the two ways to inform the Oracle JDBC drivers:

- The JDBC application uses the `getORAData(int idx, ORADataFactory f)` method to access database objects. The second parameter of the `getORAData()` method specifies an instance of the factory class that produces the customized class. The `getORAData()` method is available in the `OracleResultSet` and `OracleCallableStatement` classes.
- The JDBC application populates the connection type map with entries that specify what custom Java type corresponds to each Oracle object type. The `getObject()` method is used to access the Oracle object values.

The first approach avoids the type-map lookup and is therefore more efficient. However, the second approach involves the use of the standard `getObject()` method. The following code example demonstrates the first approach:

```
// tab1.person column can store both PERSON_T and STUDENT_T objects
```

```
ResultSet rset = stmt.executeQuery ("select person from tab1");
while (rset.next())
{
  Object s = rset.getORAData (1, PersonFactory.getORADataFactory());
  if (s != null)
  {
    if (s instanceof Person)
      System.out.println ("This is a Person");
    else if (s instanceof Student)
      System.out.println ("This is a Student");
    else if (s instanceof ParttimeStudent)
      System.out.pritnln ("This is a PartimeStudent");
    else
      System.out.println ("Unknown type");
  }
}
```

Creating Subtype Objects

There are cases where JDBC applications create database subtype objects with JDBC drivers. These objects are sent either to the database as bind variables or are used to exchange information within the JDBC application.

With customized mapping, the JDBC application creates either `SQLData`- or `ORAData`-based objects (depending on which approach you choose) to represent database subtype objects. With default mapping, the JDBC application creates `STRUCT` objects to represent database subtype objects. All the data fields inherited from the supertype as well as all the fields defined in the subtype must have values. The following code demonstrates this:

```
Connection conn = ...    // make a JDBC connection
StructDescriptor desc = StructDescriptor.createDescriptor
("SCOTT.PARTTIMESTUDENT", conn);
Object[] attrs = {
  new Integer(1234), "Scott", "500 Oracle Parkway", // data fields defined in
                                                    // PERSON_T
  new Integer(102), "CS",                           // data fields defined in
                                                    // STUDENT_T
  new Integer(4)                                    // data fields defined in
                                                    // PARTTIMESTUDENT_T
};
STRUCT s = new STRUCT (desc, conn, attrs);
```

s is initialized with data fields inherited from PERSON_T and STUDENT_T, and data fields defined in PARTTIMESTUDENT_T.

Sending Subtype Objects

In a typical JDBC application, a Java object that represents a database object is sent to the databases as one of the following:

- A Data Manipulation Language (DML) bind variable
- A PL/SQL IN parameter
- An object type attribute value

The Java object can be an instance of the STRUCT class or an instance of the class implementing either the SQLData or ORAData interface. The Oracle JDBC driver will convert the Java object into the linearized format acceptable to the database SQL engine. Binding a subtype object is the same as binding a normal object.

Accessing Subtype Data Fields

While the logic to access subtype data fields is part of the customized class, this logic for default mapping is defined in the JDBC application itself. The database objects are returned as instances of the oracle.sql.STRUCT class. The JDBC application needs to call one of the following access methods in the STRUCT class to access the data fields:

- `Object[] getAttribute()`
- `oracle.sql.Datum[] getOracleAttribute()`

Subtype Data Fields from the getAttribute() Method

The getAttribute() method of the java.sql.Struct interface is used in JDBC 2.0 to access object data fields. This method returns a java.lang.Object array, where each array element represents an object attribute. You can determine the individual element type by referencing the corresponding attribute type in the JDBC conversion matrix, as listed in Table 6–1, "Oracle Datatype Classes". For example, a SQL NUMBER attribute is converted to a java.math.BigDecimal object. The getAttribute() method returns all the data fields defined in the supertype of the object type as well as data fields defined in the subtype. The supertype data fields are listed first followed by the subtype data fields.

Subtype Data Fields from the getOracleAttribute() Method

The `getOracleAttribute()` method is an Oracle extension method and is more efficient than the `getAttribute()` method. The `getOracleAttribute()` method returns an `oracle.sql.Datum` array to hold the data fields. Each element in the `oracle.sql.Datum` array represents an attribute. You can determine the individual element type by referencing the corresponding attribute type in the Oracle conversion matrix, as listed in Table 6–1, "Oracle Datatype Classes". For example, a SQL `NUMBER` attribute is converted to an `oracle.sql.NUMBER` object. The `getOracleAttribute()` method returns all the attributes defined in the supertype of the object type, as well as attributes defined in the subtype. The supertype data fields are listed first followed by the subtype data fields.

The following code shows the use of the `getAttribute()` method:

```
// tab1.person column can store PERSON_T, STUDENT_T and PARTIMESTUDENT_T objects
ResultSet rset = stmt.executeQuery ("select person from tab1");
while (rset.next())
{
  oracle.sql.STRUCT s = (oracle.sql.STRUCT) rset.getObject(1);
  if (s != null)
  {
    String sqlname = s.getSQLTypeName();

    Object[] attrs = s.getAttribute();

    if (sqlname.equals ("SCOTT.PERSON")
    {
      System.out.println ("ssn="+((BigDecimal)attrs[0]).intValue());
      System.out.println ("name="+((String)attrs[1]));
      System.out.println ("address="+((String)attrs[2]));
    }
    else if (sqlname.equals ("SCOTT.STUDENT"))
    {
      System.out.println ("ssn="+((BigDecimal)attrs[0]).intValue());
      System.out.println ("name="+((String)attrs[1]));
      System.out.println ("address="+((String)attrs[2]));
      System.out.println ("deptid="+((BigDecimal)attrs[3]).intValue());
      System.out.println ("major="+((String)attrs[4]));
    }
    else if (sqlname.equals ("SCOTT.PARTTIMESTUDENT"))
    {
      System.out.println ("ssn="+((BigDecimal)attrs[0]).intValue());
      System.out.println ("name="+((String)attrs[1]));
      System.out.println ("address="+((String)attrs[2]));
```

```
      System.out.println ("deptid="+((BigDecimal)attrs[3]).intValue());
      System.out.println ("major="+((String)attrs[4]));
      System.out.println ("numHours="+((BigDecimal)attrs[5]).intValue());
    }
    else
      throw new Exception ("Invalid type name: "+sqlname);
  }
}
rset.close ();
stmt.close ();
conn.close ();
```

Inheritance Meta Data Methods

Oracle9*i* JDBC drivers provide a set of meta data methods to access inheritance properties. The inheritance meta data methods are defined in the `oracle.sql.StructDescriptor` and `oracle.jdbc.StructMetaData` classes.

The `oracle.sql.StructDescriptor` class provides the following inheritance meta data methods:

- `String[] getSubtypeNames()` : returns the SQL type names of the direct subtypes
- `boolean isFinalType()` : indicates whether the object type is a final type. An object type is `FINAL` if no subtypes can be created for this type; the default is `FINAL`, and a type declaration must have the `NOT FINAL` keyword to be "subtypable"
- `boolean isSubTyp()` : indicates whether the object type is a subtype.
- `boolean isInstantiable()` : indicates whether the object type is instantiable; an object type is `NOT INSTANTIABLE` if it is not possible to construct instances of this type
- `String getSupertypeName()` : returns the SQL type names of the direct supertype
- `int getLocalAttributeCount()` : returns the number of attributes defined in the subtype

The `StructMetaData` class provides inheritance meta data methods for subtype attributes; the `getMetaData()` method of the `StructDescriptor` class returns

an instance of `StructMetaData` of the type. The `StructMetaData` class contains the following inheritance meta data methods:

- `int getLocalColumnCount()` : returns the number of attributes defined in the subtype, which is similar to the `getLocalAttributeCount()` method of the `StructDescriptor` class
- `boolean isInherited(int column)` : indicates whether the attribute is inherited; the *column* begins with 1

Using JPublisher to Create Custom Object Classes

A convenient way to create custom object classes, as well as other kinds of custom Java classes, is to use the Oracle JPublisher utility. It generates a full definition for a custom Java class, which you can instantiate to hold the data from an Oracle object. JPublisher-generated classes include methods to convert data from SQL to Java and from Java to SQL, as well as getter and setter methods for the object attributes.

This section offers a brief overview. For more information, see the *Oracle9i JPublisher User's Guide.*

JPublisher Functionality

You can direct JPublisher to create custom object classes that implement either the `SQLData` interface or the `ORAData` interface, according to how you set the JPublisher type mappings.

If you use the `ORAData` interface, JPublisher will also create a custom reference class to map to object references for the Oracle object type. If you use the `SQLData` interface, JPublisher will not produce a custom reference class; you would use standard `java.sql.Ref` instances instead.

If you want additional functionality, you can subclass the custom object class and add features as desired. When you run JPublisher, there is a command-line option for specifying both a generated class name and the name of the subclass you will implement. For the SQL-Java mapping to work properly, JPublisher must know the subclass name, which is incorporated into some of the functionality of the generated class.

Note: Hand-editing the JPublisher-generated class, instead of subclassing it, is not recommended. If you hand-edit this class and later have to re-run JPublisher for some reason, you would have to re-implement your changes.

JPublisher Type Mappings

JPublisher offers various choices for how to map user-defined types and their attribute types between SQL and Java. The rest of this section lists categories of SQL types and the mapping options available for each category.

For general information about SQL-Java type mappings, see "Datatype Mappings" on page 3-16.

For more information about JPublisher features or options, see the *Oracle9i JPublisher User's Guide.*

Categories of SQL Types

JPublisher categorizes SQL types into the following groups, with corresponding JPublisher options as noted:

- user-defined types (UDT)—Oracle objects, references, and collections

  Use the JPublisher `-usertypes` option to specify the type-mapping implementation for UDTs—either a standard `SQLData` implementation or an Oracle-specific `ORAData` implementation.

- numeric types—anything stored in the database as SQL type `NUMBER`

  Use the JPublisher `-numbertypes` option to specify type-mapping for numeric types.

- LOB types—SQL types `BLOB` and `CLOB`

  Use the JPublisher `-lobtypes` option to specify type-mapping for LOB types.

- built-in types—anything stored in the database as a SQL type not covered by the preceding categories; for example: `CHAR`, `VARCHAR2`, `LONG`, and `RAW`

  Use the JPublisher `-builtintypes` option to specify type-mapping for built-in types.

Type-Mapping Modes

JPublisher defines the following type-mapping modes, two of which apply to numeric types only:

- JDBC mapping (setting `jdbc`)—Uses standard default mappings between SQL types and Java native types. For a custom object class, uses a `SQLData` implementation.
- Oracle mapping (setting `oracle`)—Uses corresponding `oracle.sql` types to map to SQL types. For a custom object, reference, or collection class, uses a `ORAData` implementation.
- object-JDBC mapping (for numeric types only) (setting `objectjdbc`)—This is an extension of JDBC mapping. Where relevant, object-JDBC mapping uses numeric object types from the standard `java.lang` package (such as `java.lang.Integer`, `Float`, and `Double`), instead of primitive Java types (such as `int`, `float`, and `double`). The `java.lang` types are nullable, while the primitive types are not.

- `BigDecimal` mapping (for numeric types only) (setting `bigdecimal`)—Uses `java.math.BigDecimal` to map to all numeric attributes; appropriate if you are dealing with large numbers but do not want to map to the `oracle.sql.NUMBER` class.

  Note: Using `BigDecimal` mapping can significantly degrade performance.

Mapping the Oracle object type to Java

Use the JPublisher `-usertypes` option to determine how JPublisher will implement the custom Java class that corresponds to a Oracle object type:

- A setting of `-usertypes=oracle` (the default setting) instructs JPublisher to create a `ORAData` implementation for the custom object class.

  This will also result in JPublisher producing a `ORAData` implementation for the corresponding custom reference class.

- A setting of `-usertypes=jdbc` instructs JPublisher to create a `SQLData` implementation for the custom object class. No custom reference class can be created—you must use `java.sql.Ref` or `oracle.sql.REF` for the reference type.

The next section discusses type mapping options that you can use for object attributes.

Note: You can also use JPublisher with a `-usertypes=oracle` setting in creating `ORAData` implementations to map SQL collection types.

The `-usertypes=jdbc` setting is not valid for mapping SQL collection types. (The `SQLData` interface is intended only for mapping Oracle object types.)

Mapping Attribute Types to Java

If you do not specify mappings for the attribute types of the Oracle object type, JPublisher uses the following defaults:

- For numeric attribute types, the default mapping is object-JDBC.
- For LOB attribute types, the default mapping is Oracle.

- For built-in type attribute types, the default mapping is JDBC.

If you want alternate mappings, use the `-numbertypes`, `-lobtypes`, and `-builtintypes` options as necessary, depending on the attribute types you have and the mappings you desire.

If an attribute type is itself an Oracle object type, it will be mapped according to the `-usertypes` setting.

Important: Be especially aware that if you specify a `SQLData` implementation for the custom object class and want the code to be portable, you must be sure to use portable mappings for the attribute types. The defaults for numeric types and built-in types are portable, but for LOB types you must specify `-lobtypes=jdbc`.

Summary of SQL Type Categories and Mapping Settings

Table 9–1 summarizes JPublisher categories for SQL types, the mapping settings relevant for each category, and the default settings.

Table 9–1 JPublisher SQL Type Categories, Supported Settings, and Defaults

SQL Type Category	JPublisher Mapping Option	Mapping Settings	Default
UDT types	-usertypes	oracle, jdbc	oracle
numeric types	-numbertypes	oracle, jdbc, objectjdbc, bigdecimal	objectjdbc
LOB types	-lobtypes	oracle, jdbc	oracle
built-in types	-builtintypes	oracle, jdbc	jdbc

Note: The JPublisher `-mapping` option used in previous releases will be deprecated but is currently still supported. For information about how JPublisher converts -mapping option settings to settings for the new mapping options, see the *Oracle9i JPublisher User's Guide.*

Describing an Object Type

Oracle JDBC includes functionality to retrieve information about a structured object type regarding its attribute names and types. This is similar conceptually to retrieving information from a result set about its column names and types, and in fact uses an almost identical method.

Functionality for Getting Object Meta Data

The `oracle.sql.StructDescriptor` class, discussed earlier in "STRUCT Descriptors" on page 9-4 and "Steps in Creating StructDescriptor and STRUCT Objects" on page 9-4, includes functionality to retrieve meta data about a structured object type.

The `StructDescriptor` class has a `getMetaData()` method with the same functionality as the standard `getMetaData()` method available in result set objects. It returns a set of attribute information such as attribute names and types. Call this method on a `StructDescriptor` object to get meta data about the Oracle object type that the `StructDescriptor` object describes. (Remember that each structured object type must have an associated `StructDescriptor` object.)

The signature of the `StructDescriptor` class `getMetaData()` method is the same as the signature specified for `getMetaData()` in the standard `ResultSet` interface:

- `ResultSetMetaData getMetaData() throws SQLException`

However, this method actually returns an instance of `oracle.jdbc.StructMetaData`, a class that supports structured object meta data in the same way that the standard `java.sql.ResultSetMetaData` interface specifies support for result set meta data.

The `StructMetaData` class includes the following standard methods that are also specified by `ResultSetMetaData`:

- `String getColumnName(int column) throws SQLException`

  This returns a `String` that specifies the name of the specified attribute, such as "salary".

- `int getColumnType(int column) throws SQLException`

  This returns an `int` that specifies the typecode of the specified attribute, according to the `java.sql.Types` and `oracle.jdbc.OracleTypes` classes.

- `String getColumnTypeName(int column) throws SQLException`

This returns a string that specifies the type of the specified attribute, such as "BigDecimal".

- `int getColumnCount() throws SQLException`

  This returns the number of attributes in the object type.

As well as the following method, supported only by `StructMetaData`:

- `String getOracleColumnClassName(int column)`
  `throws SQLException`

  This returns the fully-qualified name of the `oracle.sql.Datum` subclass whose instances are manufactured if the `OracleResultSet` class `getOracleObject()` method is called to retrieve the value of the specified attribute. For example, "`oracle.sql.NUMBER`".

  To use the `getOracleColumnClassName()` method, you must cast the `ResultSetMetaData` object (that was returned by the `getMetaData()` method) to a `StructMetaData` object.

Note: In all the preceding method signatures, "column" is something of a misnomer. Where you specify a "column" of 4, you really refer to the fourth attribute of the object.

Steps for Retrieving Object Meta Data

Use the following steps to obtain meta data about a structured object type:

1. Create or acquire a `StructDescriptor` instance that describes the relevant structured object type.
2. Call the `getMetaData()` method on the `StructDescriptor` instance.
3. Call the meta data getter methods as desired—`getColumnName()`, `getColumnType()`, and `getColumnTypeName()`.

Note: If one of the structured object attributes is itself a structured object, repeat steps 1 through 3.

Example The following method shows how to retrieve information about the attributes of a structured object type. This includes the initial step of creating a `StructDescriptor` instance.

```
//
// Print out the ADT's attribute names and types
//
void getAttributeInfo (Connection conn, String type_name) throws SQLException
{
  // get the type descriptor
  StructDescriptor desc = StructDescriptor.createDescriptor (type_name, conn);

  // get type meta data
  ResultSetMetaData md = desc.getMetaData ();

  // get # of attrs of this type
  int numAttrs = desc.length ();

  // temporary buffers
  String attr_name;
  int attr_type;
  String attr_typeName;

  System.out.println ("Attributes of "+type_name+" :");
  for (int i=0; i<numAttrs; i++)
  {
    attr_name = md.getColumnName (i+1);
    attr_type = md.getColumnType (i+1);
    System.out.println (" index"+(i+1)+" name="+attr_name+" type="+attr_type);

    // drill down nested object
    if (attrType == OracleTypes.STRUCT)
    {
      attr_typeName = md.getColumnTypeName (i+1);

      // recursive calls to print out nested object meta data
      getAttributeInfo (conn, attr_typeName);
    }
  }
}
```

SQLJ Object Types

This section describes how to use Oracle9*i* JDBC drivers to access SQLJ object types, SQL types for user-defined object types according to the *Information Technology - SQLJ - Part 2: SQL Types using the Java™ Programming Language* document (ANSI NCITS 331.2-2000).

> **Note:** SQLJ object types can either be in serialized or SQL representation. Because Oracle does not support SQLJ object types in serialized representation, this manual describes only SQLJ object types in SQL representation.

According to the *Information Technology - SQLJ - Part 2* document, a *SQLJ object type* is a database object type designed for Java. A SQLJ object type maps to a Java class. Once the mapping is "registered" through the extended SQL CREATE TYPE command (a DDL statement), the Java application can insert or select the Java objects directly into or from the database through an Oracle9*i* JDBC driver. The database SQL engine can access the data fields of these Java objects, stored as SQL attributes in the database, as well as invoke the methods defined in these Java objects.

The extended SQL CREATE TYPE command is further discussed in "Creating a Java Class Definition for a SQLJ Object Type" on page 9-53.

SQLJ object type functionality has the following features:

- Publishes pre-existing Java classes to SQL using the extended SQL CREATE TYPE command, creating a mapping between the SQL type and the Java type; no type map is necessary
- Provides a standard way to access Java objects in the database
- Provides a standard way to store Java objects persistently
- Accesses static fields in a Java class using SQL static functions and defines SQL member functions having side effects, which is useful in UPDATE statements

> **Note:** SQLJ object type functionality is similar to the use of custom Java classes to map to Oracle object types (SQL object types). The difference between SQLJ object type functionality and custom Java class functionality is that with SQLJ object types, you start with a Java class and then create a corresponding SQL type, instead of the other way around. See "Creating and Using Custom Object Classes for Oracle Objects" on page 9-10 and "SQLJ Object Types and Custom Object Types Compared" on page 9-62.

You can obtain additional information on SQLJ object types at the ANSI Web site:

`http://www.ansi.org/`

Creating a SQLJ Object Type in SQL Representation

There are three general steps involved in creating a SQLJ object type in a database:

1. Create the Java class whose instances will be accessed by the database.

   See "Creating a Java Class Definition for a SQLJ Object Type" below.

2. Load the class definition into the database.

   See "Loading the Java Class into the Database" on page 9-55.

3. Use the extended SQL `CREATE TYPE` command in Oracle9*i* to create a SQLJ object type that represents the Java type.

   See "Creating the SQLJ Object Type in the Database" on page 9-55.

Creating a Java Class Definition for a SQLJ Object Type

To use SQLJ object type functionality, the Java class must implement one of the following Java interfaces:

- `java.sql.SQLData`
- `oracle.sql.ORAData` (and `oracle.sql.ORADataFactory`)

> **Note:** The ORAData interface has replaced the CustomDatum interface. While the latter interface is deprecated for Oracle9*i*, it is still supported for backward compatibility. See "The Deprecated CustomDatum Interface" on page 9-27 for complete details.

The Java class corresponding to a SQLJ object type implements the SQLData interface or the ORAData and ORADataFactory interfaces, as is the case for custom Java classes that correspond to user-defined Oracle object types in previous Oracle JDBC implementations. The Java class provides methods for moving data between SQL and Java—either using the readSQL() and writeSQL() methods for classes implementing the SQLData interface, or the toDatum() method for classes implementing the ORAData interface.

The following code shows how the Person class for the SQLJ object type, PERSON_T, implements the SQLData interface:

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

public class Person implements SQLData
{
  private String sql_type = "SCOTT.PERSON_T";
  private int ssn;
  private String name;
  private Address address;
  public String getName() {return name;}
  public void setName(String nam) {name = nam;};
  public Address getAddress() {return address;}
  public void setAddress(Address addr) {address = addr;}

  public Person () {}

  public String getSQLTypeName() throws SQLException { return sql_type; }

  public void readSQL(SQLInput stream, String typeName) throws SQLException
  {
    sql_type = typeName;
    ssn = stream.readInt();
    name = stream.readString();
    address = stream.readObject();
  }

    public void writeSQL(SQLOutput stream) throws SQLException
```

```
  {
    stream.writeInt (ssn);
    stream.writeString (name);
    stream.writeObject (address);
  }

  // other methods
  public int length () { ... }
}
```

Loading the Java Class into the Database

Once you create the Java class, the next step is to make it available to the database. To do this, use the Oracle `loadjava` tool to load the Java class into the database. See the *Oracle9i Java Developer's Guide* for a complete description of the `loadjava` tool.

> **Note:** You can also invoke the `loadjava` tool by calling the `dbms_java.loadjava ('...')` procedure from SQL*Plus, specifying the `loadjava` command line as the input string.

The following command shows the `loadjava` tool loading the `Person` class into the database:

```
% loadjava -u SCOTT/TIGER -r -f -v Person.class
```

Creating the SQLJ Object Type in the Database

The final step in creating a SQLJ object type is to use the extended SQL `CREATE TYPE` command to create the type, specifying the corresponding Java class in the `EXTERNAL NAME` clause.

The follow code shows that `PERSON_T` is the SQLJ object type and `Person` is the corresponding Java class:

```
CREATE TYPE person_t AS OBJECT EXTERNAL NAME 'Person' LANGUAGE JAVA
USING SQLData
  (ss_no number (9) external name 'ssn',
  name VARCHAR2(200) external name 'name',
  address Address_t external name 'address',
  member function length return number external name 'length () return int');
/
```

The extended SQL CREATE TYPE command performs the following functions:

- It checks to see if a Java class exists that corresponds to the SQLJ object type and whether this class is public and implements the required interface as specified in the USING clause (see the catalog book Magdi told you about).
- It populates the database catalog with the external names for attributes, functions, and the Java class.
- If external attribute names are used, then the extended SQL CREATE TYPE command checks for the existence of the Java fields (as specified in the EXTERNAL NAME clause) and whether these fields are compatible with corresponding SQL attributes.
- If external attribute names are used, then the extended SQL CREATE TYPE command validates the SQL external function against the Java class methods.
- It generates internal classes to support constructors, external static variable names, and external functions that return `self` as a result. The classes are stored in the same schema as the SQLJ object type.

See the *Oracle9i SQL Reference* for a complete description of the extended SQL CREATE TYPE command.

Once a SQLJ object type is created, it can be used for the column type of a database table as well as for attributes of other object types. The database SQL engine can access the attributes of the SQLJ object type as well as invoke methods. For example, in SQL*Plus you can do the following:

```
SQL> select col2.ss_no from tab2;
...
SQL> select col2.length() from tab2;
...
```

External Attribute Names The extended SQL CREATE TYPE command validates the compatibility between SQLJ object type attributes and corresponding Java fields by comparing the external attribute names (`external name` variables) to the corresponding Java fields. An external attribute name specifies a field in the Java class. For example, in the following code, the `ssn` external name specifies the `ss_no` field in the `Person` Java class:

```
CREATE TYPE person_t AS OBJECT EXTERNAL NAME 'Person' LANGUAGE JAVA
USING SQLData
  (ss_no number (9) external name 'ssn',
  name VARCHAR2(200) external name 'name',
  address Address_t external name 'address',
```

```
  member function length return number external name 'length () return int');
/
```

Though optional, external attribute names are good to use when one-to-one correspondences exists between the attributes of a SQLJ object type and the fields of a corresponding Java class. If you choose to use this feature and a declared external attribute name does not exist in the Java class or the SQL attribute is not compatible with the external attribute type, then a SQL error occurs upon executing the extended SQL `CREATE TYPE` command. Or if the provided `SQLData` or `ORAData` interface implementation does not support compatible mapping between a SQL attribute and its corresponding Java field, then an exception may occur.

Note: A SQL attribute declared with an external attribute name may refer to a private Java field.

External SQL Functions The extended SQL `CREATE TYPE` command validates the compatibility between SQLJ object type functions and corresponding Java methods by comparing the external SQL function (`MEMBER FUNCTION` or `STATIC FUNCTION`) to the corresponding Java method. An external SQL function specifies a method in the Java class.

Note: Unlike an external attribute name, an external SQL function is mandatory.

When creating a SQLJ object type in the database, you can declare one or more external SQL functions along with the attributes. Table 9–2 describes the possible kinds of functions that you can use in the creation of a SQLJ object type:

Table 9–2 Kinds of External SQL Functions for a SQLJ Object Type

Function	Kind	Syntax
Static functions	Oracle-specific	`STATIC FUNCTION foo (...) RETURN NUMBER EXTERNAL NAME 'bar (...) return double'`
Member function	SQLJ Part2 Standard	`MEMBER FUNCTION foo (...) RETURN NUMBER EXTERNAL NAME 'todo (...) return double'`
Static function that returns the value of a static Java field, which can only be public	Oracle-specific	`STATIC FUNCTION foo RETURN NUMBER EXTERNAL VARIABLE NAME 'max_length'`
Static function that calls a constructor in Java	Oracle-specific	`STATIC FUNCTION foo (...) RETURN person_t EXTERNAL NAME 'Person (...) return Person'`
Member function that has a side effect (changes the state of an object)	SQLJ Part2 Standard	`MEMBER FUNCTION foo (...) RETURN SELF AS RESULT EXTERNAL NAME 'dump (...) return Person'`

Code Examples The following code shows some typical external SQL functions being declared for a SQLJ object type:

```
CREATE TYPE person_t AS OBJECT EXTERNAL NAME 'Person' LANGUAGE JAVA
USING SQLData
(
  num number external name 'foo',

  STATIC function construct (num number) return person_t
  external name   'Person.Person (int) return Person',
  STATIC function maxvalue return number external variable name 'max_length',
  MEMBER function selfish (num number) return self as result
    external name 'Person.dump (java.lang.Integer) return Person'
)
```

The following code shows how to create the SQLJ object type `PERSON_T` to represent the Java class `Person`:

```
CREATE TYPE person_t AS OBJECT EXTERNAL NAME 'Person' LANGUAGE JAVA
```

```
USING SQLData
(
  ss_no NUMBER(9) EXTERNAL NAME 'ssn',
  name VARCHAR2(100) EXTERNAL NAME 'name',
  address address_t EXTERNAL NAME 'address',
  MEMBER FUNCTION length RETURN integer EXTERNAL NAME 'length() return int'
);
```

Creating SQLJ Object Types Using JDBC As an alternative to creating a SQLJ object type directly in SQL, using a tool such as SQL*Plus, you can create a SQLJ object type using JDBC code. The following code shows this:

```
Connection conn = ....
Statement stmt = conn.createStatement();
String sql =
  "CREATE TYPE person_t as object external name 'Person' language java
  "  using SQLData "+
  "( "+
  "  ss_no number(9), "+
  "  name varchar2(100), "+
  "  address address_t "+
  ")";
stmt.execute(sql);
stmt.close();     // release the resource
conn.close();     // close the database connection

create table tab1 (col1 number, col2 person_t);
insert into tabl values (1, person_t(100, 'Scott', address_t('some street',
'some city', 'CA', '12345'));
insert into tabl ...
...
```

Inserting an Instance of a SQLJ Object Type

To create a SQLJ object type instance, the JDBC application creates a corresponding Java instance and then inserts it into the database using the `INSERT` statement. The Java instance can be inserted in one of the following ways:

- A bind variable
- A PL/SQL `IN` parameter
- An object attribute value

Before sending the Java object to the database, the Oracle JDBC driver converts it into a format acceptable to the database SQL engine.

To create a SQLJ object type of `person_t`, as described in previous sections, the JDBC application creates a `Person` object and then inserts it into the database. The following code binds the `person_t` SQLJ object type instance in a SQL insert statement:

```
Person person = new Person();
person.ssn = 1000;
person.name = "SCOTT";
person.address = new Address ("some street", "some city", "CA", 12345);

// insert a SQLJ Object "person_t"
PreparedStatement pstmt = conn.prepareStatement ("insert into tab1 (1, ?)");
pstmt.setObject (1, person);
pstmt.execute ();
```

Binding a Java instance of a SQLJ object type is equivalent to binding a Java instance of a regular Oracle object type.

Retrieving Instances of a SQLJ Object Type

In a typical JDBC application, Java instances of a SQLJ object type are returned from one of the following:

- Query results
- PL/SQL `OUT` parameters
- Object type attributes
- Collection elements

In each case, the Oracle JDBC driver materialize the database SQLJ object type instances as instances of the corresponding Java class.

See "Code Examples" on page 9-58, to learn how the SQLJ object type `person_t` and a database table are created.

Retrieving a SQLJ Object Type Instance Through Database Queries

When a JDBC application queries a column of SQLJ object types in a table, the column values are returned as instances of the Java class that corresponds to the SQLJ object type.

Assume that you have table `tab1` containing column `col1` of SQLJ object type `PERSON_T`. If `PERSON_T` was created to map to the Java class `Person`, then querying `col1` through the Oracle JDBC driver will return the data as instances of the `Person` class. The following code shows this:

```
ResultSet rset = stmt.executeQuery ("select col1 from tab1");
while (rset.next())
  Person value = (Person) rset.getObject(1);
```

Notes:

- If the Java class does not exist on the client when the SQLJ object type is returned, a run-time exception occurs.
- If the Java class exists on the client but has been modified, then the SQLJ object type will only be read or written properly if the `readSQL()` and `writeSQL()` methods for the `SQLData` interface, or the `create()` and `toDatum()` methods for the `ORAData` interface, remain compatible with the original set of SQL attributes.

Retrieving a SQLJ Object Type Instance as an Output Parameter

Use the `OracleTypes.JAVA_STRUCT` typecode as input to the `registerOutParameter()` method to register a SQLJ object type as a PL/SQL `OUT` parameter. The following code shows this:

```
CallableStatement cstmt = conn.prepareCall (...);
cstmt.registerOutParameter (1, OracleTypes.JAVA_STRUCT, "SCOTT.PERSON_T");
...
cstmt.execute();
Person value = (Person) cstmt.getObject (1);
```

Meta Data Methods for SQLJ Object Types

Meta data methods are used to query the properties of a datatype. The meta data methods for SQLJ object types are defined in the `oracle.sql.StructDescriptor` class and the `oracle.jdbc.StructMetaData` interface.

To obtain the type descriptor, use the static `createDescriptor()` factory method of the `oracle.sql.StructDescriptor` class as follows:

```
public static StructDescriptor createDescriptor(String name, Connection conn)
    throws SQLException
```

Where `name` is the SQLJ object type and `conn` is the connection to the database.

The `oracle.sql.StructDescriptor` class defines the following meta data (instance) methods:

- `boolean isJavaObject()` : indicates whether the type descriptor points to a SQLJ object type
- `String getJavaClassName()` : returns the name of the Java class corresponding to the SQLJ object type
- `String getLanguage()` : returns the string `JAVA` for a SQLJ object type and returns `null` for an Oracle object type (SQL object type)
- `ResultSetMetaData getMetaData()` : returns the meta data of the SQLJ object type as a result set meta data type (see "Functionality for Getting Object Meta Data" on page 9-49)
- `getLocalAttributeCount()` : returns the number of local attributes being used, which does not include those used through inheritance

The `oracle.jdbc.StructMetaData` interface provides the following method:

- `String getAttributeJavaName(int idx)`: returns the field name given the relative position of the SQL attribute; the relative position starts at zero and inherited attributes are included

SQLJ Object Types and Custom Object Types Compared

This section describes the differences between SQLJ object types and Oracle object types (custom object types).

Table 9–3 SQLJ Object Type and Custom Object Type Features Compared

Feature	SQLJ Object Type Behavior	Custom Object Type Behavior
Typecodes	Use the `OracleTypes.JAVA_STRUCT` typecode to register a SQLJ object type as a SQL `OUT` parameter. The `OracleTypes.JAVA_STRUCT` typecode is also used in the `_SQL_TYPECODE` field of a class implementing the `ORAData` or `SQLData` interface. This typecode is reported in a `ResultSetMetaData` instance and meta data or stored procedure.	Use the `OracleTypes.STRUCT` typecode to register a custom object type as a SQL `OUT` parameter. The `OracleTypes.STRUCT` typecode is also used in the `_SQL_TYPECODE` field of a class implementing the `ORAData` or `SQLData` interface.The `OracleTypes.STRUCT` typecode is reported in a `ResultSetMetaData` instance and meta data or stored procedure.
Creation	Create a Java class implementing the `SQLData` or `ORAData` and `ORADataFactory` interfaces first and then load the Java class into the database. Next, issue the extended SQL `CREATE TYPE` command to create the SQLJ object type.	Issue the extended SQL `CREATE TYPE` command for a custom object type and then create the `SQLData` or `ORAData` Java wrapper class using JPublisher, or do this manually. See "Using JPublisher to Create Custom Object Classes" on page 9-45 for complete details.
Method Support	Supports external names, constructor calls, and calls for member functions with side effects. See Table 9–2, "Kinds of External SQL Functions for a SQLJ Object Type" on page 9-58 for a complete description.	There is no default class for implementing type methods as Java methods. Some methods may also be implemented in SQL.
Type Mapping	Type mapping is automatically done by the extended SQL `CREATE TYPE` command. However, the SQLJ object type must have a defining Java class on the client.	Register the correspondence between SQL and Java in a type map. Otherwise, the type is materialized as `oracle.sql.STRUCT`.
Corresponding Java Class is Missing	If the corresponding Java class is missing when a SQLJ object type is returned to the client, you will receive an exception.	If the corresponding Java class is missing when a custom object type is returned to the client, then `oracle.sql.STRUCT` is used.
Inheritance	There are rules for mapping SQL hierarchy to a Java class hierarchy. See the *Oracle9i SQL Reference* for a complete description of these rules.	There are no mapping rules.

10

Working with Oracle Object References

This chapter describes Oracle extensions to standard JDBC that let you access and manipulate object references. The following topics are discussed:

- Oracle Extensions for Object References
- Overview of Object Reference Functionality
- Retrieving and Passing an Object Reference
- Accessing and Updating Object Values through an Object Reference
- Custom Reference Classes with JPublisher

Oracle Extensions for Object References

Oracle supports the use of references (pointers) to Oracle database objects. Oracle JDBC provides support for object references as:

- columns in a SELECT-list
- `IN` or `OUT` bind variables
- attributes in an Oracle object
- elements in a collection (array) type object

In SQL, an object reference (`REF`) is strongly typed. For example, a reference to an `EMPLOYEE` object would be defined as an `EMPLOYEE REF`, not just a `REF`.

When you select an object reference in Oracle JDBC, be aware that you are retrieving only a pointer to an object, not the object itself. You have the choice of materializing the reference as a weakly typed `oracle.sql.REF` instance (or a `java.sql.Ref` instance for portability), or materializing it as an instance of a custom Java class that you have created in advance, which is strongly typed. Custom Java classes used for object references are referred to as *custom reference classes* in this manual and must implement the `oracle.sql.ORAData` interface.

The `oracle.sql.REF` class implements the standard `java.sql.Ref` interface (`oracle.jdbc2.Ref` under JDK 1.1.x).

You can retrieve a `REF` instance through a result set or callable statement object, and pass an updated `REF` instance back to the database through a prepared statement or callable statement object. The `REF` class includes functionality to get and set underlying object attribute values, and get the SQL base type name of the underlying object (for example, `EMPLOYEE`).

Custom reference classes include this same functionality, as well as having the advantage of being strongly typed. This can help you find coding errors during compilation that might not otherwise be discovered until runtime.

For more information about custom reference classes, see "Custom Reference Classes with JPublisher" on page 10-10.

Notes:

- If you are using the `oracle.sql.ORAData` interface for custom object classes, you will presumably use `ORAData` for corresponding custom reference classes as well. If you are using the standard `java.sql.SQLData` interface for custom object classes, however, you can only use weak Java types for references (`java.sql.Ref` or `oracle.sql.REF`). The `SQLData` interface is for mapping SQL object types only.
- You cannot create `REF` objects in your JDBC application; you can only retrieve existing `REF` objects from the database.
- You cannot have a reference to an array, even though arrays, like objects, are structured types.

Overview of Object Reference Functionality

To access and update object data through an object reference, you must obtain the reference instance through a result set or callable statement and then pass it back as a bind variable in a prepared statement or callable statement. It is the reference instance that contains the functionality to access and update object attributes.

This section summarizes the following:

- statement and result set getter and setter methods for passing REF instances from and to the database
- REF class functionality to get and set object attributes

Remember that you can use custom reference classes instead of the ARRAY class. See "Custom Reference Classes with JPublisher" on page 10-10.

Object Reference Getter and Setter Methods

Use the following result set, callable statement, and prepared statement methods to retrieve and pass object references. Code examples are provided later in the chapter.

Result Set and Callable Statement Getter Methods The `OracleResultSet` and `OracleCallableStatement` classes support `getREF()` and `getRef()` methods to retrieve REF objects as output parameters—either as `oracle.sql.REF` instances or `java.sql.Ref` instances (`oracle.jdbc2.Ref` under JDK 1.1.x). You can also use the `getObject()` method. These methods take as input a `String` column name or `int` column index.

Prepared and Callable Statement Setter Methods The `OraclePreparedStatement` and `OracleCallableStatement` classes support `setREF()` and `setRef()` methods to take REF objects as bind variables and pass them to the database. You can also use the `setObject()` method. These methods take as input a `String` parameter name or `int` parameter index as well as, respectively, an `oracle.sql.REF` instance or a `java.sql.Ref` instance (`oracle.jdbc2.Ref` under JDK 1.1.x).

Key REF Class Methods

Use the following `oracle.sql.REF` class methods to retrieve the SQL object type name and retrieve and pass the underlying object data.

- `getBaseTypeName()`: Retrieves the fully-qualified SQL structured type name of the referenced object (for example, EMPLOYEE).

  This is a standard method specified by the `java.sql.Ref` interface.

- `getValue()`: Retrieves the referenced object from the database, allowing you to access its attribute values. It optionally takes a type map object, or else you can use the default type map of the database connection object.

  This method is an Oracle extension.

- `setValue()`: Sets the referenced object in the database, allowing you to update its attribute values. It takes an instance of the object type as input (either a `STRUCT` instance or an instance of a custom object class).

  This method is an Oracle extension.

Retrieving and Passing an Object Reference

This section discusses JDBC functionality for retrieving and passing object references.

Retrieving an Object Reference from a Result Set

To demonstrate how to retrieve object references, the following example first defines an Oracle object type ADDRESS, which is then referenced in the PEOPLE table:

```
create type ADDRESS as object
   (street_name     VARCHAR2(30),
    house_no        NUMBER);

create table PEOPLE
    (col1 VARCHAR2(30),
     col2 NUMBER,
     col3 REF ADDRESS);
```

The ADDRESS object type has two attributes: a street name and a house number. The PEOPLE table has three columns: a column for character data, a column for numeric data, and a column containing a reference to an ADDRESS object.

To retrieve an object reference, follow these general steps:

1. Use a standard SQL SELECT statement to retrieve the reference from a database table REF column.
2. Use `getREF()` to get the address reference from the result set into a REF object.
3. Let `Address` be the Java custom class corresponding to the SQL object type ADDRESS.
4. Add the correspondence between the Java class `Address` and the SQL type ADDRESS to your type map.
5. Use the `getValue()` method to retrieve the contents of the `Address` reference. Cast the output to a Java `Address` object.

Here is the code for these steps (other than adding `Address` to the type map), where `stmt` is a previously defined statement object. The PEOPLE database table is defined earlier in this section:

```
ResultSet rs = stmt.executeQuery("SELECT col3 FROM PEOPLE");
while (rs.next())
{
```

```
   REF ref = ((OracleResultSet)rs).getREF(1);
   Address a = (Address)ref.getValue();
}
```

As with other SQL types, you could retrieve the reference with the `getObject()` method of your result set. Note that this would require you to cast the output. For example:

```
REF ref = (REF)rs.getObject(1);
```

There are no performance advantages in using `getObject()` instead of `getREF()`; however, using `getREF()` allows you to avoid casting the output.

Retrieving an Object Reference from a Callable Statement

To retrieve an object reference as an `OUT` parameter in PL/SQL blocks, you must register the bind type for your `OUT` parameter.

1. Cast your callable statement to an `OracleCallableStatement`:

   ```
   OracleCallableStatement ocs =
      (OracleCallableStatement)conn.prepareCall("{? = call func()}");
   ```

2. Register the `OUT` parameter with this form of the `registerOutParameter()` method:

   ```
   ocs.registerOutParameter
               (int param_index, int sql_type, String sql_type_name);
   ```

   Where *`param_index`* is the parameter index and *`sql_type`* is the SQL typecode (in this case, `OracleTypes.REF`). The *`sql_type_name`* is the name of the structured object type that this reference is used for. For example, if the `OUT` parameter is a reference to an `ADDRESS` object (as in "Retrieving and Passing an Object Reference" on page 10-6), then `ADDRESS` is the *`sql_type_name`* that should be passed in.

3. Execute the call:

   ```
   ocs.execute();
   ```

Passing an Object Reference to a Prepared Statement

Pass an object reference to a prepared statement in the same way as you would pass any other SQL type. Use either the `setObject()` method or the `setREF()` method of a prepared statement object.

Continuing the example in "Retrieving and Passing an Object Reference" on page 10-6, use a prepared statement to update an address reference based on `ROWID`, as follows:

```
PreparedStatement pstmt =
   conn.prepareStatement ("update PEOPLE set ADDR_REF = ? where ROWID = ?");
((OraclePreparedStatement)pstmt).setREF (1, addr_ref);
((OraclePreparedStatement)pstmt).setROWID (2, rowid);
```

Accessing and Updating Object Values through an Object Reference

You can use the REF object `setValue()` method to update the value of an object in the database through an object reference. To do this, you must first retrieve the reference to the database object and create a Java object (if one does not already exist) that corresponds to the database object.

For example, you can use the code in the section "Retrieving and Passing an Object Reference" on page 10-6 to retrieve the reference to a database ADDRESS object:

```
ResultSet rs = stmt.executeQuery("SELECT col3 FROM PEOPLE");
if (rs.next())
{
   REF ref = rs.getREF(1);
   Address a = (Address)ref.getValue();
}
```

Then, you can create a Java `Address` object (this example omits the content for the constructor of the `Address` class) that corresponds to the database ADDRESS object. Use the `setValue()` method of the REF class to set the value of the database object:

```
Address addr = new Address(...);
ref.setValue(addr);
```

Here, the `setValue()` method updates the database ADDRESS object immediately.

Custom Reference Classes with JPublisher

This chapter primarily describes the functionality of the `oracle.sql.REF` class, but it is also possible to access Oracle object references through custom Java classes or, more specifically, *custom reference classes*.

Custom reference classes offer all the functionality described earlier in this chapter, as well as the advantage of being strongly typed. A custom reference class must satisfy three requirements:

- It must implement the `oracle.sql.ORAData` interface described under "Creating and Using Custom Object Classes for Oracle Objects" on page 9-10. Note that the standard JDBC `SQLData` interface, which is an alternative for custom object classes, is not intended for custom reference classes.
- It, or a companion class, must implement the `oracle.sql.ORADataFactory` interface, for creating instances of the custom reference class.
- It must provide a way to refer to the object data. JPublisher accomplishes this by using an `oracle.sql.REF` attribute.

You can create custom reference classes yourself, but the most convenient way to produce them is through the Oracle JPublisher utility. If you use JPublisher to generate a custom object class to map to an Oracle object, and you specify that JPublisher use a `ORAData` implementation, then JPublisher will also generate a custom reference class that implements `ORAData` and `ORADataFactory` and includes an `oracle.sql.REF` attribute. (The `ORAData` implementation will be used if JPublisher's `-usertypes` mapping option is set to `oracle`, which is the default.)

Custom reference classes are strongly typed. For example, if you define an Oracle object `EMPLOYEE`, then JPublisher can generate an `Employee` custom object class and an `EmployeeRef` custom reference class. Using `EmployeeRef` instances instead of generic `oracle.sql.REF` instances makes it easier to catch errors during compilation instead of at runtime—for example, if you accidentally assign some other kind of object reference into an `EmployeeRef` variable.

Be aware that the standard `SQLData` interface supports only SQL object mappings. For this reason, if you instruct JPublisher to implement the standard `SQLData` interface in creating a custom object class, then JPublisher will *not* generate a custom reference class. In this case your only option is to use standard `java.sql.Ref` instances (or `oracle.sql.REF` instances) to map to your object references. (Specifying the `SQLData` implementation is accomplished by setting JPublisher's UDT attributes mapping option to `jdbc`.)

For more information about JPublisher, see "Using JPublisher to Create Custom Object Classes" on page 9-45, or refer to the *Oracle9i JPublisher User's Guide.*

11

Working with Oracle Collections

This chapter describes Oracle extensions to standard JDBC that let you access and manipulate Oracle collections, which map to Java arrays, and their data. The following topics are discussed:

- Oracle Extensions for Collections (Arrays)
- Overview of Collection (Array) Functionality
- Creating and Using Arrays
- Using a Type Map to Map Array Elements
- Custom Collection Classes with JPublisher

Oracle Extensions for Collections (Arrays)

An Oracle *collection*—either a variable array (VARRAY) or a nested table in the database—maps to an array in Java. JDBC 2.0 arrays are used to materialize Oracle collections in Java. The terms "collection" and "array" are sometimes used interchangeably, although "collection" is more appropriate on the database side, and "array" is more appropriate on the JDBC application side.

Oracle supports only *named* collections, where you specify a SQL type name to describe a type of collection.

JDBC lets you use arrays as any of the following:

- columns in a SELECT-list
- `IN` or `OUT` bind variables
- attributes in an Oracle object
- as elements of other arrays (Oracle9*i* only)

The rest of this section discusses creating and materializing collections.

The remainder of the chapter describes how to access and update collection data through Java arrays.

Choices in Materializing Collections

In your application, you have the choice of materializing a collection as an instance of the `oracle.sql.ARRAY` class, which is weakly typed, or materializing it as an instance of a custom Java class that you have created in advance, which is strongly typed. Custom Java classes used for collections are referred to as *custom collection classes* in this manual. A custom collection class must implement the Oracle `oracle.sql.ORAData` interface. In addition, the custom class or a companion class must implement `oracle.sql.ORADataFactory`. (The standard `java.sql.SQLData` interface is for mapping SQL object types only.)

The `oracle.sql.ARRAY` class implements the standard `java.sql.Array` interface (`oracle.jdbc2.Array` under JDK 1.1.x).

The `ARRAY` class includes functionality to retrieve the array as a whole, retrieve a subset of the array elements, and retrieve the SQL base type name of the array elements. You cannot write to the array, however, as there are no setter methods.

Custom collection classes, as with the `ARRAY` class, allow you to retrieve all or part of the array and get the SQL base type name. They also have the advantage of being

strongly typed, which can help you find coding errors during compilation that might not otherwise be discovered until runtime.

Furthermore, custom collection classes produced by JPublisher offer the feature of being writable, with individually accessible elements. (This is also something you could implement in a custom collection class yourself.)

Note: There is no difference in your code between accessing VARRAYs and accessing nested tables. ARRAY class methods can determine if they are being applied to a VARRAY or nested table, and respond by taking the appropriate actions.

For more information about custom collection classes, see "Custom Collection Classes with JPublisher" on page 11-27.

Creating Collections

This section presents background information about creating Oracle collections.

Because Oracle supports only named collections, you must declare a particular VARRAY type name or nested table type name. "VARRAY" and "nested table" are not types themselves, but categories of types.

A SQL type name is assigned to a collection when you create it, as in the following SQL syntax:

```
CREATE TYPE <sql_type_name> AS <datatype>;
```

A VARRAY is an array of varying size. It has an ordered set of data elements, and all the elements are of the same datatype. Each element has an index, which is a number corresponding to the element's position in the VARRAY. The number of elements in a VARRAY is the "size" of the VARRAY. You must specify a maximum size when you declare the VARRAY type. For example:

```
CREATE TYPE myNumType AS VARRAY(10) OF NUMBER;
```

This statement defines myNumType as a SQL type name that describes a VARRAY of NUMBER values that can contain no more than 10-elements.

A nested table is an unordered set of data elements, all of the same datatype. The database stores a nested table in a separate table which has a single column, and the type of that column is a built-in type or an object type. If the table is an object type,

it can also be viewed as a multi-column table, with a column for each attribute of the object type. Create a nested table with this SQL syntax:

```
CREATE TYPE myNumList AS TABLE OF integer;
```

This statement identifies `myNumList` as a SQL type name that defines the table type used for the nested tables of the type `INTEGER`.

Creating Multi-Level Collection Types

The most common way to create a new multi-level collection type in JDBC is to pass the SQL `CREATE TYPE` statement to the `execute()` method of the `java.sql.Statement` class. The following code creates a one-level, nested table `first_level` and a two levels nested table `second_level` using the `execute()` method:

```
Connection conn = ....                                          // make a database
                                                                // connection
Statement stmt = conn.createStatement();                        // open a database
                                                                // cursor
stmt.execute("CREATE TYPE first_level AS TABLE OF NUMBER");  // create a nested
                                                                // table of number
stmt.execute("CREATE second_level AS TABLE OF first_level"); // create a two
                                                                // levels nested
                                                                // table
...                                                             // other operations
                                                                // here
stmt.close();                                                   // release the
                                                                // resource
conn.close();                                                   // close the
                                                                // database
                                                                // connection
```

Once the multi-level collection types have been created, they can be used as both columns of a base table as well as attributes of a object type.

See the *Oracle9i Application Developer's Guide - Object-Relational Features* for the SQL syntax to create multi-level collections types and how to specify the storage tables for inner collections.

Note: Multi-level collection types are available only for Oracle9*i*.

Overview of Collection (Array) Functionality

You can obtain collection data in an array instance through a result set or callable statement and pass it back as a bind variable in a prepared statement or callable statement.

The `oracle.sql.ARRAY` class, which implements the standard `java.sql.Array` interface (`oracle.jdbc2.Array` interface under JDK 1.1.x), provides the necessary functionality to access and update the data of an Oracle collection (either a VARRAY or nested table).

This section discusses the following:

- statement and result set getter and setter methods for passing collections to and from the database as Java arrays
- ARRAY descriptors and ARRAY class methods

Remember that you can use custom collection classes instead of the ARRAY class. See "Custom Collection Classes with JPublisher" on page 11-27.

Array Getter and Setter Methods

Use the following result set, callable statement, and prepared statement methods to retrieve and pass collections as Java arrays. Code examples are provided later in the chapter.

Result Set and Callable Statement Getter Methods The `OracleResultSet` and `OracleCallableStatement` classes support `getARRAY()` and `getArray()` methods to retrieve ARRAY objects as output parameters—either as `oracle.sql.ARRAY` instances or `java.sql.Array` instances (`oracle.jdbc2.Array` under JDK 1.1.x). You can also use the `getObject()` method. These methods take as input a `String` column name or `int` column index.

Prepared and Callable Statement Setter Methods The `OraclePreparedStatement` and `OracleCallableStatement` classes support `setARRAY()` and `setArray()` methods to take updated ARRAY objects as bind variables and pass them to the database. You can also use the `setObject()` method. These methods take as input a `String` parameter name or `int` parameter index as well as, respectively, an `oracle.sql.ARRAY` instance or a `java.sql.Array` instance (`oracle.jdbc2.Array` under JDK 1.1.x).

ARRAY Descriptors and ARRAY Class Functionality

The section introduces ARRAY descriptors and lists methods of the ARRAY class to provide an overview of its functionality.

ARRAY Descriptors

Creating and using an ARRAY object requires the existence of a descriptor—an instance of the `oracle.sql.ArrayDescriptor` class—to exist for the SQL type of the collection being materialized in the array. You need only one `ArrayDescriptor` object for any number of ARRAY objects that correspond to the same SQL type.

ARRAY descriptors are further discussed in "Creating ARRAY Objects and Descriptors" on page 11-11.

ARRAY Class Methods

The `oracle.sql.ARRAY` class includes the following methods:

- `getDescriptor()`: Returns the `ArrayDescriptor` object that describes the array type.
- `getArray()`: Retrieves the contents of the array in "default" JDBC types. If it retrieves an array of objects, then `getArray()` uses the default type map of the database connection object to determine the types.
- `getOracleArray()`: Identical to `getArray()`, but retrieves the elements in `oracle.sql.*` format.
- `getBaseType()`: Returns the SQL typecode for the array elements (see "Class oracle.jdbc.OracleTypes" on page 6-23 for information about typecodes).
- `getBaseTypeName()`: Returns the SQL type name of the elements of this array.
- `getSQLTypeName()` (Oracle extension): Returns the fully qualified SQL type name of the array as a whole.
- `getResultSet()`: Materializes the array elements as a result set.
- `getJavaSQLConnection()`: Returns the connection instance (`java.sql.Connection`) associated with this array.
- `length()`: Returns the number of elements in the array.

Note: As an example of the difference between `getBaseTypeName()` and `getSQLTypeName()`, if you define `ARRAY_OF_PERSON` as the array type for an array of `PERSON` objects in the `SCOTT` schema, then `getBaseTypeName()` would return "SCOTT.PERSON" and `getSQLTypeName()` would return "SCOTT.ARRAY_OF_PERSON".

ARRAY Performance Extension Methods

This section discusses the following topics:

- Accessing oracle.sql.ARRAY Elements as Arrays of Java Primitive Types
- ARRAY Automatic Element Buffering
- ARRAY Automatic Indexing

Accessing oracle.sql.ARRAY Elements as Arrays of Java Primitive Types

The `oracle.sql.ARRAY` class contains methods that return array elements as Java primitive types. These methods allow you to access collection elements more efficiently than accessing them as `Datum` instances and then converting each `Datum` instance to its Java primitive value.

Note: These specialized methods of the `oracle.sql.ARRAY` class are restricted to numeric collections.

Here are the methods:

- ```
  public int[] getIntArray()throws SQLException

  public int[] getIntArray(long index, int count)
     throws SQLException
  ```
- ```
  public long[] getLongArray()throws SQLException

  public long[] getLongArray(long index, int count)
     throws SQLException
  ```
- ```
  public float[] getFloatArray()throws SQLException

  public float[] getFloatArray(long index, int count)
     throws SQLException
  ```
- ```
  public double[] getDoubleArray()throws SQLException

  public double[] getDoubleArray(long index, int count)
     throws SQLException
  ```
- ```
  public short[] getShortArray()throws SQLException

  public short[] getShortArray(long index, int count)
     throws SQLException
  ```
  ```

Each method using the first signature returns collection elements as an *XXX*`[]`, where *XXX* is a Java primitive type. Each method using the second signature returns a slice of the collection containing the number of elements specified by `count`, starting at the `index` location.

ARRAY Automatic Element Buffering

The Oracle JDBC driver provides public methods to enable and disable buffering of ARRAY contents. (See "STRUCT Automatic Attribute Buffering" on page 9-9 for a discussion of how to buffer STRUCT attributes.)

The following methods are included with the `oracle.sql.`ARRAY class:

- `public void setAutoBuffering(boolean enable)`
- `public boolean getAutoBuffering()`

The `setAutoBuffering()` method enables or disables auto-buffering. The `getAutoBuffering()` method returns the current auto-buffering mode. By default, auto-buffering is disabled.

It is advisable to enable auto-buffering in a JDBC application when the ARRAY elements will be accessed more than once by the `getAttributes()` and `getArray()` methods (presuming the ARRAY data is able to fit into the JVM memory without overflow).

Important: Buffering the converted elements may cause the JDBC application to consume a significant amount of memory.

When you enable auto-buffering, the `oracle.sql.`ARRAY object keeps a local copy of all the converted elements. This data is retained so that a second access of this information does not require going through the data format conversion process.

ARRAY Automatic Indexing

If an array is in auto-indexing mode, the array object maintains an index table to hasten array element access.

The `oracle.sql.`ARRAY class contains the following methods to support automatic array-indexing:

- `public synchronized void setAutoIndexing (boolean enable, int direction) throws SQLException`
- `public synchronized void setAutoIndexing (boolean enable) throws SQLException`

The `setAutoIndexing()` method sets the auto-indexing mode for the `oracle.sql.ARRAY` object. The `direction` parameter gives the array object a hint: specify this parameter to help the JDBC driver determine the best indexing scheme. The following are the values you can specify for the `direction` parameter:

- `ARRAY.ACCESS_FORWARD`
- `ARRAY.ACCESS_REVERSE`
- `ARRAY.ACCESS_UNKNOWN`

The `setAutoIndexing(boolean)` method signature sets the access direction as `ARRAY.ACCESS_UNKNOWN` by default.

By default, auto-indexing is not enabled. For a JDBC application, enable auto-indexing for `ARRAY` objects if random access of array elements may occur through the `getArray()` and `getResultSet()` methods.

Creating and Using Arrays

This section discusses how to create array objects and how to retrieve and pass collections as array objects, including the following topics.

- Creating ARRAY Objects and Descriptors
- Retrieving an Array and Its Elements
- Passing Arrays to Statement Objects

Creating ARRAY Objects and Descriptors

This section describes how to create ARRAY objects and descriptors and lists useful methods of the `ArrayDescriptor` class.

Steps in Creating ArrayDescriptor and ARRAY Objects

This section describes how to construct an `oracle.sql.`ARRAY object. To do this, you must:

1. Create an `ArrayDescriptor` object (if one does not already exist) for the array.
2. Use the `ArrayDescriptor` object to construct the `oracle.sql.`ARRAY object for the array you want to pass.

An `ArrayDescriptor` is an object of the `oracle.sql.ArrayDescriptor` class and describes the SQL type of an array. Only one array descriptor is necessary for any one SQL type. The driver caches `ArrayDescriptor` objects to avoid recreating them if the SQL type has already been encountered. You can reuse the same descriptor object to create multiple instances of an `oracle.sql.`ARRAY object for the same array type.

Collections are strongly typed. Oracle supports only named collections, that is, a collection given a SQL type name. For example, when you create a collection with the CREATE TYPE statement:

```
CREATE TYPE num_varray AS varray(22) OF NUMBER(5,2);
```

Where NUM_VARRAY is the SQL type name for the collection type.

Note: The name of the collection type is not the same as the type name of the elements. For example:

```
CREATE TYPE person AS object
            (c1 NUMBER(5), c2 VARCHAR2(30));
CREATE TYPE array_of_persons AS varray(10)
             OF person;
```

In the preceding statements, the SQL name of the collection type is ARRAY_OF_PERSON. The SQL name of the collection elements is PERSON.

Before you can construct an `Array` object, an `ArrayDescriptor` must first exist for the given SQL type of the array. If an `ArrayDescriptor` does not exist, then you must construct one by passing the SQL type name of the collection type and your `Connection` object (which JDBC uses to go to the database to gather meta data) to the constructor.

```
ArrayDescriptor arraydesc = ArrayDescriptor.createDescriptor
                                          (sql_type_name, connection);
```

Where *`sql_type_name`* is the type name of the array and *`connection`* is your `Connection` object.

Once you have your `ArrayDescriptor` object for the SQL type of the array, you can construct the ARRAY object. To do this, pass in the array descriptor, your connection object, and a Java object containing the individual elements you want the array to contain.

```
ARRAY array = new ARRAY(arraydesc, connection, elements);
```

Where `arraydesc` is the array descriptor created previously, `connection` is your connection object, and `elements` is a Java array. The two possibilities for the contents of `elements` are:

- an array of Java primitives—for example, `int[]`
- an array of Java objects, such as *`xxx`*`[]` where *`xxx`* is the name of a Java class—for example, `Integer[]`

Note: The `setARRAY()`, `setArray()`, and `setObject()` methods of the `OraclePreparedStatement` class take an object of the type `oracle.sql.ARRAY` as an argument, not an array of objects.

Creating Multi-Level Collections

As with single-level collections, the JDBC application can create an `oracle.sql.ARRAY` instance to represent a multi-level collection, and then send the instance to the database. The `oracle.sql.ARRAY` constructor is defined as follows:

```
public ARRAY(ArrayDescriptor type, Connection conn, Object elements)
throws SQLException
```

The first argument is an `oracle.sql.ArrayDescriptor` object that describes the multi-level collection type. The second argument is the current database connection. And the third argument is a `java.lang.Object` that holds the multi-level collection elements. This is the same constructor used to create single-level collections, but in Oracle9*i*, this constructor is enhanced to create multi-level collections as well. The elements parameter can now be either a one dimension array or a nested Java array.

To create a single-level collection, the elements are a one dimensional Java array. To create a multi-level collection, the elements can be either an array of `oracle.sql.ARRAY[]` elements or a nested Java array or the combinations.

The following code shows how to create collection types with a nested Java array:

```
Connection conn = ...;          // make a JDBC connection

// create the collection types
Statement stmt = conn.createStatement ();
stmt.execute ("CREATE TYPE varray1 AS VARRAY(10) OF NUMBER(12, 2)"); // one
                                                                     // layer
stmt.execute ("CREATE TYPE varray2 AS VARRAY(10) OF varray1"); // two layers
stmt.execute ("CREATE TYPE varray3 AS VARRAY(10) OF varray2"); // three layers
stmt.execute ("CREATE TABLE tab2 (col1 index, col2 value)");
stmt.close ();

// obtain a type descriptor of "SCOTT.VARRAY3"
ArrayDescriptor desc = ArrayDescriptor.createDescriptor("SCOTT.VARRAY3", conn);

// prepare the multi level collection elements as a nested Java array
```

```
int[][][] elems = { {{1}, {1, 2}}, {{2}, {2, 3}}, {{3}, {3, 4}} };

// create the ARRAY by calling the constructor
ARRAY array3 = new ARRAY (desc, conn, elems);

// some operations
...

// close the database connection
conn.close();
```

In the above example, another implementation is to prepare the `elems` as a Java array of `oracle.sql.ARRAY[]` elements, and each `oracle.sql.ARRAY[]` element represents a `SCOTT.VARRAY3`.

Using ArrayDescriptor Methods

An ARRAY descriptor can be referred to as a *type object*. It has information about the SQL name of the underlying collection, the typecode of the array's elements, and, if it is an array of structured objects, the SQL name of the elements. The descriptor also contains the information on about to convert to and from the given type. You need only one descriptor object for any one type, then you can use that descriptor to create as many arrays of that type as you want.

The `ArrayDescriptor` class has the following methods for retrieving an element's typecode and type name:

- `createDescriptor()`: This is a factory for `ArrayDescriptor` instances; looks up the name in the database and determine the characteristics of the array.
- `getBaseType()`: Returns the integer typecode associated with this ARRAY descriptor (according to integer constants defined in the `OracleTypes` class, which "Package oracle.jdbc" on page 6-16 describes).
- `getBaseName()`: Returns a string with the type name associated with this array element if it is a STRUCT or REF.
- `getArrayType()`: Returns an integer indicating whether the array is a VARRAY or nested table. `ArrayDescriptor.TYPE_VARRAY` and `ArrayDescriptor.TYPE_NESTED_TABLE` are the possible return values.
- `getMaxLength()`: Returns the maximum number of elements for this array type.

- `getJavaSQLConnection()`: Returns the connection instance (`java.sql.Connection`) that was used in creating the ARRAY descriptor (a new descriptor must be created for each connection instance).

> **Note:** In releases prior to Oracle9*i*, you cannot use a collection within a collection. You can, however, use a structured object with a collection attribute, or a collection with structured object elements. In Oracle9*i*, you can use a collection within a collection.

Serializable ARRAY Descriptors

As "Steps in Creating ArrayDescriptor and ARRAY Objects" on page 11-11 discusses, when you create an ARRAY object, you first must create an `ArrayDescriptor` object. Create the `ArrayDescriptor` object by calling the `ArrayDescriptor.createDescriptor()` method. The `oracle.sql.ArrayDescriptor` class is serializable, meaning that you can write the state of an `ArrayDescriptor` object to an output stream for later use. Recreate the `ArrayDescriptor` object by reading its serialized state from an input stream. This is referred to as *deserializing*. With the `ArrayDescriptor` object serialized, you do not need to call the `createDescriptor()` method—simply deserialize the `ArrayDescriptor` object.

It is advisable to serialize an `ArrayDescriptor` object when the object type is complex but not changed often.

If you create an `ArrayDescriptor` object through deserialization, you must provide the appropriate database connection instance for the `ArrayDescriptor` object using the `setConnection()` method.

The following code furnishes the connection instance for an `ArrayDescriptor` object:

```
public void setConnection (Connection conn) throws SQLException
```

> **Note:** The JDBC driver does not verify that the connection object from the `setConnection()` method connects to the same database from which the type descriptor was initially derived.

Retrieving an Array and Its Elements

This section first discusses how to retrieve an ARRAY instance as a whole from a result set, and then how to retrieve the elements from the ARRAY instance.

Retrieving the Array

You can retrieve a SQL array from a result set by casting the result set to an `OracleResultSet` object and using the `getARRAY()` method, which returns an `oracle.sql.ARRAY` object. If you want to avoid casting the result set, then you can get the data with the standard `getObject()` method specified by the `java.sql.ResultSet` interface, and cast the output to an `oracle.sql.ARRAY` object.

Data Retrieval Methods

Once you have the array in an ARRAY object, you can retrieve the data using one of these three overloaded methods of the `oracle.sql.ARRAY` class:

- `getArray()`
- `getOracleArray()`
- `getResultSet()`

Oracle also provides methods that enable you to retrieve all the elements of an array, or a subset.

Note: In case you are working with an array of structured objects, Oracle provides versions of these three methods that enable you to specify a type map so that you can choose how to map the objects to Java.

---

getOracleArray() The `getOracleArray()` method is an Oracle-specific extension that is not specified in the standard `Array` interface (`java.sql.Array` under JDK 1.2.x or `oracle.jdbc2.Array` under JDK 1.1.x). The `getOracleArray()` method retrieves the element values of the array into a `Datum[]` array. The elements are of the `oracle.sql.*` datatype corresponding to the SQL type of the data in the original array.

For an array of structured objects, this method will use `oracle.sql.STRUCT` instances for the elements.

Oracle also provides a `getOracleArray(`*`index,count`*`)` method to get a subset of the array elements.

getResultSet() The `getResultSet()` method returns a result set that contains elements of the array designated by the ARRAY object. The result set contains one row for each array element, with two columns in each row. The first column stores

the index into the array for that element, and the second column stores the element value. In the case of VARRAYs, the index represents the position of the element in the array. In the case of nested tables, which are by definition unordered, the index reflects only the return order of the elements in the particular query.

Oracle recommends using `getResultSet()` when getting data from nested tables. Nested tables can have an unlimited number of elements. The `ResultSet` object returned by the method initially points at the first row of data. You get the contents of the nested table by using the `next()` method and the appropriate `getXXX()` method. In contrast, `getArray()` returns the entire contents of the nested table at one time.

The `getResultSet()` method uses the connection's default type map to determine the mapping between the SQL type of the Oracle object and its corresponding Java datatype. If you do not want to use the connection's default type map, another version of the method, `getResultSet(`*`map`*`)`, enables you to specify an alternate type map.

Oracle also provides the `getResultSet(`*`index`*`,`*`count`*`)` and `getResultSet(`*`index`*`,`*`count`*`,`*`map`*`)` methods to retrieve a subset of the array elements.

getArray() The `getArray()` method is a standard JDBC method that returns the array elements into a `java.lang.Object` instance that you can cast as appropriate (see "Comparing the Data Retrieval Methods" on page 11-17). The elements are converted to the Java types corresponding to the SQL type of the data in the original array.

Oracle also provides a `getArray(`*`index`*`,`*`count`*`)` method to retrieve a subset of the array elements.

Comparing the Data Retrieval Methods

If you use `getOracleArray()` to return the array elements, the use by that method of `oracle.sql.Datum` instances avoids the expense of data conversion from SQL to Java. The data inside a `Datum` (or subclass) instance remains in raw SQL format.

If you use `getResultSet()` to return an array of primitive datatypes, then the JDBC driver returns a `ResultSet` object that contains, for each element, the index into the array for the element and the element value. For example:

```
ResultSet rset = intArray.getResultSet();
```

In this case, the result set contains one row for each array element, with two columns in each row. The first column stores the index into the array; the second column stores the element value.

If you use `getArray()` to retrieve an array of primitive datatypes, then a `java.lang.Object` that contains the element values is returned. The elements of this array are of the Java type corresponding to the SQL type of the elements. For example:

```
BigDecimal[] values = (BigDecimal[]) intArray.getArray();
```

Where `intArray` is an `oracle.sql.ARRAY`, corresponding to a VARRAY of type `NUMBER`. The `values` array contains an array of elements of type `java.math.BigDecimal`, because the SQL `NUMBER` datatype maps to Java `BigDecimal` by default, according to the Oracle JDBC drivers.

Note: Using `BigDecimal` is a resource-intensive operation in Java. Because Oracle JDBC maps numeric SQL data to `BigDecimal` by default, using `getArray()` may impact performance, and is not recommended for numeric collections.

Retrieving Elements of a Structured Object Array According to a Type Map

By default, if you are working with an array whose elements are structured objects, and you use `getArray()` or `getResultSet()`, then the Oracle objects in the array will be mapped to their corresponding Java datatypes according to the default mapping. This is because these methods use the connection's default type map to determine the mapping.

However, if you do not want default behavior, then you can use the `getArray(`*`map`*`)` or `getResultSet(`*`map`*`)` method to specify a type map that contains alternate mappings. If there are entries in the type map corresponding to the Oracle objects in the array, then each object in the array is mapped to the corresponding Java type specified in the type map. For example:

```
Object[] object = (Object[])objArray.getArray(map);
```

Where `objArray` is an `oracle.sql.ARRAY` object and `map` is a `java.util.Map` object.

If the type map does not contain an entry for a particular Oracle object, then the element is returned as an `oracle.sql.STRUCT` object.

The `getResultSet(map)` method behaves similarly to the `getArray(map)` method.

For more information on using type maps with arrays, see "Using a Type Map to Map Array Elements" on page 11-25.

Retrieving a Subset of Array Elements

If you do not want to retrieve the entire contents of an array, then you can use signatures of `getArray()`, `getResultSet()`, and `getOracleArray()` that let you retrieve a subset. To retrieve a subset of the array, pass in an index and a count to indicate where in the array you want to start and how many elements you want to retrieve. As described above, you can specify a type map or use the default type map for your connection to convert to Java types. For example:

```
Object object = arr.getArray(index, count, map);
Object object = arr.getArray(index, count);
```

Similar examples using `getResultSet()` are:

```
ResultSet rset = arr.getResultSet(index, count, map);
ResultSet rset = arr.getResultSet(index, count);
```

A similar example using `getOracleArray()` is:

```
Datum arr = arr.getOracleArray(index, count);
```

Where *`arr`* is an `oracle.sql.ARRAY` object, *`index`* is type `long`, *`count`* is type `int`, and *`map`* is a `java.util.Map` object.

Note: There is no performance advantage in retrieving a subset of an array, as opposed to the entire array.

Retrieving Array Elements into an oracle.sql.Datum Array

Use `getOracleArray()` to return an `oracle.sql.Datum[]` array. The elements of the returned array will be of the `oracle.sql.*` type that correspond to the SQL datatype of the elements of the original array. For example:

```
Datum arraydata[] = arr.getOracleArray();
```

Where `arr` is an `oracle.sql.ARRAY` object.

The following example assumes that a connection object `conn` and a statement object `stmt` have already been created. In the example, an array with the SQL type

name NUM_ARRAY is created to store a VARRAY of NUMBER data. The NUM_ARRAY is in turn stored in a table VARRAY_TABLE.

A query selects the contents of the VARRAY_TABLE. The result set is cast to an `OracleResultSet` object; `getARRAY()` is applied to it to retrieve the array data into `my_array`, which is an `oracle.sql.ARRAY` object.

Because `my_array` is of type `oracle.sql.ARRAY`, you can apply the methods `getSQLTypeName()` and `getBaseType()` to it to return the name of the SQL type of each element in the array and its integer code.

The program then prints the contents of the array. Because the contents of `my_array` are of the SQL datatype NUMBER, it must first be cast to the `BigDecimal` datatype. In the `for` loop, the individual values of the array are cast to `BigDecimal` and printed to standard output.

```
stmt.execute ("CREATE TYPE num_varray AS VARRAY(10) OF NUMBER(12, 2)");
stmt.execute ("CREATE TABLE varray_table (col1 num_varray)");
stmt.execute ("INSERT INTO varray_table VALUES (num_varray(100, 200))");

ResultSet rs = stmt.executeQuery("SELECT * FROM varray_table");
ARRAY my_array = ((OracleResultSet)rs).getARRAY(1);

// return the SQL type names, integer codes,
// and lengths of the columns
System.out.println ("Array is of type " + array.getSQLTypeName());
System.out.println ("Array element is of typecode " + array.getBaseType());
System.out.println ("Array is of length " + array.length());

// get Array elements
BigDecimal[] values = (BigDecimal[]) my_array.getArray();

for (int i=0; i<values.length; i++)
{
   BigDecimal out_value = (BigDecimal) values[i];
   System.out.println(">> index " + i + " = " + out_value.intValue());
}
```

Note that if you use `getResultSet()` to obtain the array, you would first get the result set object, then use the `next()` method to iterate through it. Notice the use of the parameter indexes in the `getInt()` method to retrieve the element index and the element value.

```
ResultSet rset = my_array.getResultSet();
while (rset.next())
{
```

```
    // The first column contains the element index and the
    // second column contains the element value
    System.out.println(">> index " + rset.getInt(1)+" = " + rset.getInt(2));
}
```

Accessing Multi-Level Collection Elements

The `oracle.sql.ARRAY` class provides three methods (which can be overloaded) to access collection elements. For Oracle9*i* JDBC drivers, these methods are extended to support multi-level collections. The three methods are the following:

- `getArray()` method : JDBC standard
- `getOracleArray()` method : Oracle extension
- `getResultSet()` method : JDBC standard

The `getArray()` method returns a Java array that holds the collection elements. The array element type is determined by the collection element type and the JDBC default conversion matrix.

For example, the `getArray()` method returns a `java.math.BigDecimal` array for collection of SQL `NUMBER`. The `getOracleArray()` method returns a Datum array that holds the collection elements in Datum format. For multi-level collections, the `getArray()` and `getOracleArray()` methods both return a Java array of `oracle.sql.ARRAY` elements.

The `getResultSet()` method returns a `ResultSet` object that wraps the multi-level collection elements. For multi-level collections, the JDBC applications use the `getObject()`, `getARRAY()`, or `getArray()` method of the `ResultSet` class to access the collection elements as instances of `oracle.sql.ARRAY`.

The following code shows how to use the `getOracleArray()`, `getArray()`, and `getResultSet()` methods:

```
Connection conn = ...;          // make a JDBC connection
Statement stmt = conn.createStatement ();
ResultSet rset = stmt.executeQuery ("select col2 from tab2 where idx=1");

while (rset.next())
{
  ARRAY varray3 = (ARRAY) rset.getObject (1);
  Object varrayElems = varray3.getArray (1);  // access array elements of
    "varray3"
  Datum[] varray3Elems = (Datum[]) varrayElems;

  for (int i=0; i<varray3Elems.length; i++)
```

```
  {
    ARRAY varray2 = (ARRAY) varray3Elems[i];
    Datum[] varray2Elems = varray2.getOracleArray(); // access array elements of
      "varray2"

    for (int j=0; j<varray2Elems.length; j++)
    {
      ARRAY varray1 = (ARRAY) varray2Elems[j];
      ResultSet varray1Elems = varray1.getResultSet(); // access array elements
        of "varray1"

      while (varray1Elems.next())
        System.out.println ("idx="+varray1Elems.getInt(1)+"
          value="+varray1Elems.getInt(2));
    }
  }
}
rset.close ();
stmt.close ();
conn.close ();
```

Passing Arrays to Statement Objects

This section discusses how to pass arrays to prepared statement objects or callable statement objects.

Passing an Array to a Prepared Statement

Pass an array to a prepared statement as follows (use similar steps to pass an array to a callable statement). Note that you can use arrays as either `IN` or `OUT` bind variables.

1. Construct an `ArrayDescriptor` object for the SQL type that the array will contain (unless one has already been created for this SQL type). See "Steps in Creating ArrayDescriptor and ARRAY Objects" on page 11-11 for information about creating `ArrayDescriptor` objects.

   ```
   ArrayDescriptor descriptor = ArrayDescriptor.createDescriptor
                                       (sql_type_name, connection);
   ```

   Where *`sql_type_name`* is a Java string specifying the user-defined SQL type name of the array, and *`connection`* is your `Connection` object. See "Oracle Extensions for Collections (Arrays)" on page 11-2 for information about SQL typenames.

2. Define the array that you want to pass to the prepared statement as an `oracle.sql.ARRAY` object.

   ```
   ARRAY array = new ARRAY(descriptor, connection, elements);
   ```

   Where *`descriptor`* is the `ArrayDescriptor` object previously constructed and *`elements`* is a `java.lang.Object` containing a Java array of the elements.

3. Create a `java.sql.PreparedStatement` object containing the SQL statement to execute.

4. Cast your prepared statement to an `OraclePreparedStatement` and use the `setARRAY()` method of the `OraclePreparedStatement` object to pass the array to the prepared statement.

   ```
   (OraclePreparedStatement)stmt.setARRAY(parameterIndex, array);
   ```

   Where *`parameterIndex`* is the parameter index, and *`array`* is the `oracle.sql.ARRAY` object you constructed previously.

5. Execute the prepared statement.

Passing an Array to a Callable Statement

To retrieve a collection as an `OUT` parameter in PL/SQL blocks, execute the following to register the bind type for your `OUT` parameter.

1. Cast your callable statement to an `OracleCallableStatement`:

   ```
   OracleCallableStatement ocs =
      (OracleCallableStatement)conn.prepareCall("{? = call func()}");
   ```

2. Register the `OUT` parameter with this form of the `regsiterOutParameter()` method:

   ```
   ocs.registerOutParameter
           (int param_index, int sql_type, string sql_type_name);
   ```

   Where *`param_index`* is the parameter index, *`sql_type`* is the SQL typecode, and *`sql_type_name`* is the name of the array type. In this case, the *`sql_type`* is `OracleTypes.ARRAY`.

3. Execute the call:

   ```
   ocs.execute();
   ```

4. Get the value:

```
oracle.sql.ARRAY array = ocs.getARRAY(1);
```

Using a Type Map to Map Array Elements

If your array contains Oracle objects, then you can use a type map to associate the objects in the array with the corresponding Java class. If you do not specify a type map, or if the type map does not contain an entry for a particular Oracle object, then each element is returned as an `oracle.sql.STRUCT` object.

If you want the type map to determine the mapping between the Oracle objects in the array and their associated Java classes, then you must add an appropriate entry to the map. For instructions on how to add entries to an existing type map or how to create a new type map, see "Understanding Type Maps for SQLData Implementations" on page 9-11.

The following example illustrates how you can use a type map to map the elements of an array to a custom Java object class. In this case, the array is a nested table. The example begins by defining an `EMPLOYEE` object that has a name attribute and employee number attribute. `EMPLOYEE_LIST` is a nested table type of `EMPLOYEE` objects. Then an `EMPLOYEE_TABLE` is created to store the names of departments within a corporation and the employees associated with each department. In the `EMPLOYEE_TABLE`, the employees are stored in the form of `EMPLOYEE_LIST` tables.

```
stmt.execute("CREATE TYPE EMPLOYEE AS OBJECT
            (EmpName VARCHAR2(50),EmpNo INTEGER))");

stmt.execute("CREATE TYPE EMPLOYEE_LIST AS TABLE OF EMPLOYEE");

stmt.execute("CREATE TABLE EMPLOYEE_TABLE (DeptName VARCHAR2(20),
     Employees EMPLOYEE_LIST) NESTED TABLE Employees STORE AS ntable1");

stmt.execute("INSERT INTO EMPLOYEE_TABLE VALUES ("SALES", EMPLOYEE_LIST
            (EMPLOYEE('Susan Smith', 123), EMPLOYEE('Scott Tiger', 124)))");
```

If you want to retrieve all the employees belonging to the `SALES` department into an array of instances of the custom object class `EmployeeObj`, then you must add an entry to the type map to specify mapping between the `EMPLOYEE` SQL type and the `EmployeeObj` custom object class.

To do this, first create your statement and result set objects, then select the `EMPLOYEE_LIST` associated with the `SALES` department into the result set. Cast the result set to `OracleResultSet` so you can use the `getARRAY()` method to retrieve the `EMPLOYEE_LIST` into an `ARRAY` object (`employeeArray` in the example below).

The EmployeeObj custom object class in this example implements the SQLData interface.

```
Statement s = conn.createStatement();
OracleResultSet rs = (OracleResultSet)s.executeQuery
       ("SELECT Employees FROM employee_table WHERE DeptName = 'SALES'");

// get the array object
ARRAY employeeArray = ((OracleResultSet)rs).getARRAY(1);
```

Now that you have the EMPLOYEE_LIST object, get the existing type map and add an entry that maps the EMPLOYEE SQL type to the EmployeeObj Java type.

```
// add type map entry to map SQL type
// "EMPLOYEE" to Java type "EmployeeObj"
Map map = conn.getTypeMap();
map.put("EMPLOYEE", Class.forName("EmployeeObj"));
```

Next, retrieve the SQL EMPLOYEE objects from the EMPLOYEE_LIST. To do this, invoke the getArray() method of the employeeArray array object. This method returns an array of objects. The getArray() method returns the EMPLOYEE objects into the employees object array.

```
// Retrieve array elements
Object[] employees = (Object[]) employeeArray.getArray();
```

Finally, create a loop to assign each of the EMPLOYEE SQL objects to the EmployeeObj Java object emp.

```
// Each array element is mapped to EmployeeObj object.
for (int i=0; i<employees.length; i++)
{
   EmployeeObj emp = (EmployeeObj) employees[i];
   ...
}
```

Custom Collection Classes with JPublisher

This chapter primarily describes the functionality of the `oracle.sql.ARRAY` class, but it is also possible to access Oracle collections through custom Java classes or, more specifically, *custom collection classes*.

You can create custom collection classes yourself, but the most convenient way is to use the Oracle JPublisher utility. Custom collection classes generated by JPublisher offer all the functionality described earlier in this chapter, as well as the following advantages (it is also possible to implement such functionality yourself):

- They are strongly typed. This can help you find coding errors during compilation that might not otherwise be discovered until runtime.
- They can be changeable, or *mutable*. Custom collection classes produced by JPublisher, unlike the ARRAY class, allow you to get and set individual elements using the `getElement()` and `setElement()` methods. (This is also something you could implement in a custom collection class yourself.)

A custom collection class must satisfy three requirements:

- It must implement the `oracle.sql.ORAData` interface described under "Creating and Using Custom Object Classes for Oracle Objects" on page 9-10. Note that the standard JDBC `SQLData` interface, which is an alternative for custom object classes, is not intended for custom collection classes.
- It, or a companion class, must implement the `oracle.sql.ORADataFactory` interface, for creating instances of the custom collection class.
- It must have a means of storing the collection data. Typically it will directly or indirectly include an `oracle.sql.ARRAY` attribute for this purpose (this is the case with a JPublisher-produced custom collection class).

A JPublisher-generated custom collection class implements `ORAData` and `ORADataFactory` and indirectly includes an `oracle.sql.ARRAY` attribute. The custom collection class will have an `oracle.jpub.runtime.MutableArray` attribute. The `MutableArray` class has an `oracle.sql.ARRAY` attribute.

Note: When you use JPublisher to create a custom collection class, you must use the `ORAData` implementation. This will be true if JPublisher's `-usertypes` mapping option is set to `oracle`, which is the default.

You cannot use a `SQLData` implementation for a custom collection class (that implementation is for custom object classes only). Setting the `-usertypes` mapping option to `jdbc` is invalid.

As an example of custom collection classes being strongly typed, if you define an Oracle collection `MYVARRAY`, then JPublisher can generate a `MyVarray` custom collection class. Using `MyVarray` instances, instead of generic `oracle.sql.ARRAY` instances, makes it easier to catch errors during compilation instead of at runtime—for example, if you accidentally assign some other kind of array into a `MyVarray` variable.

If you do not use custom collection classes, then you would use standard `java.sql.Array` instances (or `oracle.sql.ARRAY` instances) to map to your collections.

For more information about JPublisher, see "Using JPublisher to Create Custom Object Classes" on page 9-45, or refer to the *Oracle9i JPublisher User's Guide.*

12

Performance Extensions

This chapter describes the Oracle performance extensions to the JDBC standard.

In the course of discussing update batching, it also includes a discussion of the standard update-batching model provided with JDBC 2.0.

This chapter covers the following topics:

- Update Batching
- Additional Oracle Performance Extensions

> **Note:** For a general overview of Oracle extensions and detailed discussion of Oracle packages and type extensions, see Chapter 6, "Overview of Oracle Extensions".

Update Batching

You can reduce the number of round trips to the database, thereby improving application performance, by grouping multiple `UPDATE`, `DELETE`, or `INSERT` statements into a single "batch" and having the whole batch sent to the database and processed in one trip. This is referred to in this manual as *update batching* and in the Sun Microsystems JDBC 2.0 specification as *batch updates*.

This is especially useful with prepared statements, when you are repeating the same statement with different bind variables.

With Oracle8*i* release 8.1.6 and higher, Oracle JDBC supports two distinct models for update batching:

- the standard model, supported since Oracle8*i* release 8.1.6 and implementing the Sun Microsystems JDBC 2.0 Specification, which is referred to as *standard update batching*
- the Oracle-specific model, supported since release 8.1.5 and independent of the Sun Microsystems JDBC 2.0 Specification, which is referred to as *Oracle update batching*

Note: It is important to be aware that you cannot mix theses models. In any single application, you can use the syntax of one model or the other, but not both. The Oracle JDBC driver will throw exceptions when you mix these syntaxes.

Overview of Update Batching Models

This section compares and contrasts the general models and types of statements supported for standard update batching and Oracle update batching.

Oracle Model versus Standard Model

Oracle update batching uses a *batch value* that typically results in implicit processing of a batch. The batch value is the number of operations you want to batch (accumulate) for each trip to the database. As soon as that many operations have been added to the batch, the batch is executed. Note the following:

- You can set a default batch for the connection object, which applies to any prepared statement executed in that connection.
- For any individual prepared statement object, you can set a statement batch value that overrides the connection batch value.

- You can choose to explicitly execute a batch at any time, overriding both the connection batch value and the statement batch value.

Standard update batching is a manual, explicit model. There is no batch value. You manually add operations to the batch and then explicitly choose when to execute the batch.

Oracle update batching is a more efficient model because the driver knows ahead of time how many operations will be batched. In this sense, the Oracle model is more static and predictable. With the standard model, the driver has no way of knowing in advance how many operations will be batched. In this sense, the standard model is more dynamic in nature.

If you want to use update batching, here is how to choose between the two models:

- Use Oracle update batching if portability is not critical. This will probably result in the greatest performance improvement.
- Use standard update batching if portability is a higher priority than performance.

Types of Statements Supported

As implemented by Oracle, update batching is intended for use with prepared statements, when you are repeating the same statement with different bind variables. Be aware of the following:

- Oracle update batching supports *only* Oracle prepared statement objects. In an Oracle callable statement, both the connection default batch value and the statement batch value are overridden with a value of 1. In an Oracle generic statement, there is no statement batch value, and the connection default batch value is overridden with a value of 1.

  Note that because Oracle update batching is vendor-specific, you must actually use (or cast to) `OraclePreparedStatement` objects, not general `PreparedStatement` objects.
- To adhere to the JDBC 2.0 standard, Oracle's implementation of standard update batching supports callable statements and generic statements, as well as prepared statements. You can migrate standard update batching syntax into an Oracle JDBC application without difficulty.
- You can batch only `UPDATE`, `INSERT`, or `DELETE` operations. Executing a batch that includes an operation that attempts to return a result set will cause an exception.

Note: The Oracle implementation of standard update batching does not implement true batching for generic statements and callable statements. Although Oracle JDBC supports the use of standard batching syntax for `Statement` and `CallableStatement` objects, you will see performance improvement for only `PreparedStatement` objects.

Note that with standard update batching, you can use either standard `PreparedStatement`, `CallableStatement`, and `Statement` objects, or Oracle-specific `OraclePreparedStatement`, `OracleCallableStatement`, and `OracleStatement` objects.

Oracle Update Batching

The Oracle update batching feature associates a batch value (limit) with each prepared statement object. With Oracle update batching, instead of the JDBC driver executing a prepared statement each time its `executeUpdate()` method is called, the driver adds the statement to a batch of accumulated execution requests. The driver will pass all the operations to the database for execution once the batch value is reached. For example, if the batch value is 10, then each batch of 10 operations will be sent to the database and processed in one trip.

A method in the `OracleConnection` class allows you to set a default batch value for the Oracle connection as a whole, and this batch value is relevant to any Oracle prepared statement in the connection. For any particular Oracle prepared statement, a method in the `OraclePreparedStatement` class allows you to set a statement batch value that overrides the connection batch value. You can also override both batch values by choosing to manually execute the pending batch.

Notes:

- Do not mix standard update batching syntax with Oracle update batching syntax in the same application. The JDBC driver will throw an exception when you mix these syntaxes.
- Disable auto-commit mode if you use either update batching model. In case an error occurs while you are executing a batch, this allows you the option of committing or rolling back the operations that executed successfully prior to the error.

Oracle Update Batching Characteristics and Limitations

Note the following limitations and implementation details regarding Oracle update batching:

- By default, there is no statement batch value, and the connection (default) batch value is 1.
- Batch values between 5 and 30 tend to be the most effective. Setting a very high value might even have a negative effect. It is worth trying different values to verify the effectiveness for your particular application.
- Regardless of the batch value in effect, if any of the bind variables of an Oracle prepared statement is (or becomes) a stream type, then the Oracle JDBC driver sets the batch value to 1 and sends any queued requests to the database for execution.
- The Oracle JDBC driver automatically executes the `sendBatch()` method of an Oracle prepared statement in any of the following circumstances: 1) the connection receives a `COMMIT` request, either as a result of invoking the `commit()` method or as a result of auto-commit mode; 2) the statement receives a `close()` request; or 3) the connection receives a `close()` request.

> **Note:** A connection `COMMIT` request, statement close, or connection close has no effect on a pending batch if you use standard update batching—only if you use Oracle update batching.

Setting the Connection Batch Value

You can specify a default batch value for any Oracle prepared statement in your Oracle connection. To do this, use the `setDefaultExecuteBatch()` method of the `OracleConnection` object. For example, the following code sets the default batch value to 20 for all prepared statement objects associated with the `conn` connection object:

```
((OracleConnection)conn).setDefaultExecuteBatch(20);
```

Even though this sets the default batch value for all the prepared statements of the connection, you can override it by calling `setDefaultBatch()` on individual Oracle prepared statements.

The connection batch value will apply to statement objects created after this batch value was set.

Note that instead of calling `setDefaultExecuteBatch()`, you can set the `defaultBatchValue` Java property if you use a Java `Properties` object in establishing the connection. See "Specifying a Database URL and Properties Object" on page 3-7.

Setting the Statement Batch Value

Use the following steps to set the statement batch value for a particular Oracle prepared statement. This will override any connection batch value set using the `setDefaultExecuteBatch()` method of the `OracleConnection` instance for the connection in which the statement executes.

1. Write your prepared statement and specify input values for the first row:

```
PreparedStatement ps = conn.prepareStatement
                              ("INSERT INTO dept VALUES (?,?,?)");
ps.setInt (1,12);
ps.setString (2,"Oracle");
ps.setString (3,"USA");
```

2. Cast your prepared statement to an `OraclePreparedStatement` object, and apply the `setExecuteBatch()` method. In this example, the batch size of the statement is set to 2.

```
((OraclePreparedStatement)ps).setExecuteBatch(2);
```

   If you wish, insert the `getExecuteBatch()` method at any point in the program to check the default batch value for the statement:

```
System.out.println (" Statement Execute Batch Value " +
                   ((OraclePreparedStatement)ps).getExecuteBatch());
```

3. If you send an execute-update call to the database at this point, then no data will be sent to the database, and the call will return 0.

```
// No data is sent to the database by this call to executeUpdate
System.out.println ("Number of rows updated so far: "
                                  + ps.executeUpdate ());
```

4. If you enter a set of input values for a second row and an execute-update, then the number of batch calls to `executeUpdate()` will be equal to the batch value of 2. The data will be sent to the database, and both rows will be inserted in a single round trip.

```
ps.setInt (1, 11);
ps.setString (2, "Applications");
```

```
ps.setString (3, "Indonesia");

int rows = ps.executeUpdate ();
System.out.println ("Number of rows updated now: " + rows);

ps.close ();
```

Checking the Batch Value

To check the overall connection batch value of an Oracle connection instance, use the `OracleConnection` class `getDefaultExecuteBatch()` method:

```
Integer batch_val = ((OracleConnection)conn).getDefaultExecuteBatch();
```

To check the particular statement batch value of an Oracle prepared statement, use the `OraclePreparedStatement` class `getExecuteBatch()` method:

```
Integer batch_val = ((OraclePreparedStatement)ps).getExecuteBatch();
```

> **Note:** If no statement batch value has been set, then `getExecuteBatch()` will return the connection batch value.

Overriding the Batch Value

If you want to execute accumulated operations before the batch value in effect is reached, then use the `sendBatch()` method of the `OraclePreparedStatement` object.

For this example, presume you set the connection batch value to 20. (This sets the default batch value for all prepared statement objects associated with the connection to 20.) You could accomplish this by casting your connection to an `OracleConnection` object and applying the `setDefaultExecuteBatch()` method for the connection, as follows:

```
((OracleConnection)conn).setDefaultExecuteBatch (20);
```

Override the batch value as follows:

1. Write your prepared statement and specify input values for the first row as usual, then execute the statement:

   ```
   PreparedStatement ps =
      conn.prepareStatement ("insert into dept values (?, ?, ?)");
   ```

```
ps.setInt (1, 32);
ps.setString (2, "Oracle");
ps.setString (3, "USA");

System.out.println (ps.executeUpdate ());
```

The batch is not executed at this point. The `ps.executeUpdate()` method returns "0".

2. If you enter a set of input values for a second operation and call `executeUpdate()` again, the data will still not be sent to the database, because the batch value in effect for the statement is the connection batch value: 20.

```
ps.setInt (1, 33);
ps.setString (2, "Applications");
ps.setString (3, "Indonesia");

// this batch is still not executed at this point
int rows = ps.executeUpdate ();

System.out.println ("Number of rows updated before calling sendBatch: "
                        + rows);
```

Note that the value of `rows` in the `println` statement is "0".

3. If you apply the `sendBatch()` method at this point, then the two previously batched operations will be sent to the database in a single round trip. The `sendBatch()` method also returns the total number of updated rows. This property of `sendBatch()` is used by `println` to print the number of updated rows.

```
// Execution of both previously batched executes will happen
// at this point. The number of rows updated will be
// returned by sendBatch.
rows = ((OraclePreparedStatement)ps).sendBatch ();

System.out.println ("Number of rows updated by calling sendBatch: "
                        + rows);
ps.close ();
```

Committing the Changes in Oracle Batching

After you execute the batch, you must still commit the changes, presuming auto-commit is disabled as recommended.

Calling `commit()` on the connection object in Oracle batching not only commits operations in batches that have been executed, but also issues an implicit `sendBatch()` call to execute all pending batches. So `commit()` effectively commits changes for all operations that have been added to a batch.

Update Counts in Oracle Batching

In a non-batching situation, the `executeUpdate()` method of an `OraclePreparedStatement` object will return the number of database rows affected by the operation.

In an Oracle batching situation, this method returns the number of rows affected at the time the method is invoked, as follows:

- If an `executeUpdate()` call results in the operation being added to the batch, then the method returns a value of 0, because nothing was written to the database yet.
- If an `executeUpdate()` call results in the batch value being reached and the batch being executed, then the method will return the total number of rows affected by all operations in the batch.

Similarly, the `sendBatch()` method of an `OraclePreparedStatement` object returns the total number of rows affected by all operations in the batch.

Example: Oracle Update Batching

The following example illustrates how you use the Oracle update batching feature. It assumes you have imported the `oracle.driver.*` interfaces.

```
...
Connection conn =
  DriverManager.getConnection("jdbc:oracle:oci:","scott","tiger");

conn.setAutoCommit(false);

PreparedStatement ps =
  conn.prepareStatement("insert into dept values (?, ?, ?)");

//Change batch size for this statement to 3
((OraclePreparedStatement)ps).setExecuteBatch (3);

ps.setInt(1, 23);
ps.setString(2, "Sales");
ps.setString(3, "USA");
ps.executeUpdate(); //JDBC queues this for later execution
```

```
ps.setInt(1, 24);
ps.setString(2, "Blue Sky");
ps.setString(3, "Montana");
ps.executeUpdate(); //JDBC queues this for later execution

ps.setInt(1, 25);
ps.setString(2, "Applications");
ps.setString(3, "India");
ps.executeUpdate(); //The queue size equals the batch value of 3
                    //JDBC sends the requests to the database

ps.setInt(1, 26);
ps.setString(2, "HR");
ps.setString(3, "Mongolia");
ps.executeUpdate(); //JDBC queues this for later execution

((OraclePreparedStatement)ps).sendBatch(); // JDBC sends the queued request
conn.commit();

ps.close();
...
```

Note: Updates deferred through batching can affect the results of other queries. In the following example, if the first query is deferred due to batching, then the second will return unexpected results:

```
UPDATE emp SET name = "Sue" WHERE name = "Bob";
SELECT name FROM emp WHERE name = "Sue";
```

Standard Update Batching

Oracle implements the standard update batching model according to the Sun Microsystems JDBC 2.0 Specification. Because it is a JDBC 2.0 feature, it is intended for use in a JDK 1.2.x environment. To use standard update batching in a JDK 1.1.x environment, you must cast to Oracle statement objects.

This model, unlike the Oracle update batching model, depends on explicitly adding statements to the batch using an `addBatch()` method and explicitly executing the batch using an `executeBatch()` method. (In the Oracle model, you invoke `executeUpdate()` as in a non-batching situation, but whether an operation is added to the batch or the whole batch is executed is typically determined implicitly, depending on whether a pre-determined batch value is reached.)

Notes:

- Do not mix standard update batching syntax with Oracle update batching syntax in the same application. The Oracle JDBC driver will throw exceptions when these syntaxes are mixed.
- Disable auto-commit mode if you use either update batching model. In case an error occurs while you are executing a batch, this allows you the option of committing or rolling back the operations that executed successfully prior to the error.

Limitations in the Oracle Implementation of Standard Batching

Note the following limitations and implementation details regarding Oracle's implementation of standard update batching:

- In Oracle JDBC applications, update batching is intended for use with prepared statements that are being executed repeatedly with different sets of bind values.

  The Oracle implementation of standard update batching does not implement true batching for generic statements and callable statements. Even though Oracle JDBC supports the use of standard batching syntax for `Statement` and `CallableStatement` objects, you are unlikely to see performance improvement.

- Oracle's implementation of standard update batching does not support stream types as bind values. (This is also true of Oracle update batching.) Any attempt to use stream types will result in an exception.

Adding Operations to the Batch

When any statement object is first created, its statement batch is empty. Use the standard `addBatch()` method to add an operation to the statement batch. This method is specified in the standard `java.sql.Statement`, `PreparedStatement`, and `CallableStatement` interfaces, which are implemented by interfaces `oracle.jdbc.OracleStatement`, `OraclePreparedStatement`, and `OracleCallableStatement`, respectively.

For a `Statement` object (or `OracleStatement`), the `addBatch()` method takes a Java string with a SQL operation as input. For example (assume a `Connection` instance `conn`):

```
...
```

```
Statement stmt = conn.createStatement();

stmt.addBatch("INSERT INTO emp VALUES(1000, 'Joe Jones')");
stmt.addBatch("INSERT INTO dept VALUES(260, 'Sales')");
stmt.addBatch("INSERT INTO emp_dept VALUES(1000, 260)");
...
```

At this point, three operations are in the batch.

(Remember, however, that in the Oracle implementation of standard update batching, you will probably see no performance improvement in batching generic statements.)

For prepared statements, update batching is used to batch multiple executions of the same statement with different sets of bind parameters. For a `PreparedStatement` or `OraclePreparedStatement` object, the `addBatch()` method takes no input—it simply adds the operation to the batch using the bind parameters last set by the appropriate `setXXX()` methods. (This is also true for `CallableStatement` or `OracleCallableStatement` objects, but remember that in the Oracle implementation of standard update batching, you will probably see no performance improvement in batching callable statements.)

For example (again assuming a `Connection` instance `conn`):

```
...
PreparedStatement pstmt =
          conn.prepareStatement("INSERT INTO employees VALUES(?, ?)");

pstmt.setInt(1, 2000);
pstmt.setString(2, "Milo Mumford");
pstmt.addBatch();

pstmt.setInt(1, 3000);
pstmt.setString(2, "Sulu Simpson");
pstmt.addBatch();
...
```

At this point, two operations are in the batch.

Because a batch is associated with a single prepared statement object, you can batch only repeated executions of a single prepared statement, as in this example.

Executing the Batch

To execute the current batch of operations, use the `executeBatch()` method of the statement object. This method is specified in the standard `Statement` interface,

which is extended by the standard `PreparedStatement` and `CallableStatement` interfaces.

Following is an example that repeats the prepared statement `addBatch()` calls shown previously and then executes the batch:

```
...
PreparedStatement pstmt =
         conn.prepareStatement("INSERT INTO employees VALUES(?, ?)");

pstmt.setInt(1, 2000);
pstmt.setString(2, "Milo Mumford");
pstmt.addBatch();

pstmt.setInt(1, 3000);
pstmt.setString(2, "Sulu Simpson");
pstmt.addBatch();

int[] updateCounts = pstmt.executeBatch();
...
```

The `executeBatch()` method returns an `int` array, typically one element per batched operation, indicating success or failure in executing the batch and sometimes containing information about the number of rows affected. This is discussed in "Update Counts in the Oracle Implementation of Standard Batching" on page 12-15.

Notes:

- After calling `addBatch()`, you must call either `executeBatch()` or `clearBatch()` before a call to `executeUpdate()`, otherwise there will be a SQL exception.
- When a batch is executed, operations are performed in the order in which they were batched.
- The statement batch is reset to empty once `executeBatch()` has returned.
- An `executeBatch()` call closes the statement object's current result set, if one exists.

Committing the Changes in the Oracle Implementation of Standard Batching

After you execute the batch, you must still commit the changes, presuming auto-commit is disabled as recommended.

Calling `commit()` commits non-batched operations and commits batched operations for statement batches that have been executed, but for the Oracle implementation of standard batching, has no effect on pending statement batches that have *not* been executed.

Clearing the Batch

To clear the current batch of operations instead of executing it, use the `clearBatch()` method of the statement object. This method is specified in the standard `Statement` interface, which is extended by the standard `PreparedStatement` and `CallableStatement` interfaces.

Following is an example that repeats the prepared statement `addBatch()` calls shown previously but then clears the batch under certain circumstances:

```
...
PreparedStatement pstmt =
          conn.prepareStatement("INSERT INTO employees VALUES(?, ?)");

pstmt.setInt(1, 2000);
pstmt.setString(2, "Milo Mumford");
pstmt.addBatch();

pstmt.setInt(1, 3000);
pstmt.setString(2, "Sulu Simpson");
pstmt.addBatch();

if (...condition...)
{
   int[] updateCounts = pstmt.executeBatch();
   ...
}
else
{
   pstmt.clearBatch();
   ...
}
```

Notes:

- After calling `addBatch()`, you must call either `executeBatch()` or `clearBatch()` before a call to `executeUpdate()`, otherwise there will be a SQL exception.
- A `clearBatch()` call resets the statement batch to empty.
- Nothing is returned by the `clearBatch()` method.

Update Counts in the Oracle Implementation of Standard Batching

If a statement batch is executed successfully (no batch exception is thrown), then the integer array—or *update counts* array—returned by the statement `executeBatch()` call will always have one element for each operation in the batch. In the Oracle implementation of standard update batching, the values of the array elements are as follows:

- For a prepared statement batch, it is not possible to know the number of rows affected in the database by each individual statement in the batch. Therefore, all array elements have a value of -2. According to the JDBC 2.0 specification, a value of -2 indicates that the operation was successful but the number of rows affected is unknown.
- For a generic statement batch or callable statement batch, the array contains the actual update counts indicating the number of rows affected by each operation. The actual update counts can be provided because Oracle JDBC cannot use true batching for generic and callable statements in the Oracle implementation of standard update batching.

In your code, upon successful execution of a batch, you should be prepared to handle either -2's or true update counts in the array elements. For a successful batch execution, the array contains either all -2's or all positive integers.

Note: For information about possible values in the update counts array for an *unsuccessful* batch execution, see "Error Handling in the Oracle Implementation of Standard Batching" on page 12-16.

Example: Standard Update Batching

This example combines the sample fragments in the previous sections, accomplishing the following steps:

- disabling auto-commit mode (which you should always do when using either update batching model)
- creating a prepared statement object
- adding operations to the batch associated with the prepared statement object
- executing the batch
- committing the operations from the batch

Assume a `Connection` instance `conn`:

```
conn.setAutoCommit(false);

PreparedStatement pstmt =
          conn.prepareStatement("INSERT INTO employees VALUES(?, ?)");

pstmt.setInt(1, 2000);
pstmt.setString(2, "Milo Mumford");
pstmt.addBatch();

pstmt.setInt(1, 3000);
pstmt.setString(2, "Sulu Simpson");
pstmt.addBatch();

int[] updateCounts = pstmt.executeBatch();

conn.commit();

pstmt.close();
...
```

You can process the update counts array to determine if the batch executed successfully. This is discussed in the next section ("Error Handling in the Oracle Implementation of Standard Batching").

Error Handling in the Oracle Implementation of Standard Batching

If any one of the batched operations fails to complete successfully (or attempts to return a result set) during an `executeBatch()` call, then execution stops and a `java.sql.BatchUpdateException` is generated (a subclass of `java.sql.SQLException`).

After a batch exception, the update counts array can be retrieved using the `getUpdateCounts()` method of the `BatchUpdateException` object. This returns an `int` array of update counts, just as the `executeBatch()` method does.

In the Oracle implementation of standard update batching, contents of the update counts array are as follows after a batch exception:

- For a prepared statement batch, it is not possible to know which operation failed. The array has one element for each operation in the batch, and each element has a value of -3. According to the JDBC 2.0 specification, a value of -3 indicates that an operation did not complete successfully. In this case, it was presumably just one operation that actually failed, but because the JDBC driver does not know which operation that was, it labels all the batched operations as failures.

  You should always perform a ROLLBACK operation in this situation.

- For a generic statement batch or callable statement batch, the update counts array is only a partial array containing the actual update counts up to the point of the error. The actual update counts can be provided because Oracle JDBC cannot use true batching for generic and callable statements in the Oracle implementation of standard update batching.

  For example, if there were 20 operations in the batch, the first 13 succeeded, and the 14th generated an exception, then the update counts array will have 13 elements, containing actual update counts of the successful operations.

  You can either commit or roll back the successful operations in this situation, as you prefer.

In your code, upon failed execution of a batch, you should be prepared to handle either -3's or true update counts in the array elements when an exception occurs. For a failed batch execution, you will have either a full array of -3's or a partial array of positive integers.

Intermixing Batched Statements and Non-Batched Statements

You cannot call `executeUpdate()` for regular, non-batched execution of an operation if the statement object has a pending batch of operations (essentially, if the batch associated with that statement object is non-empty).

You can, however, intermix batched operations and non-batched operations in a single statement object if you execute non-batched operations either prior to adding any operations to the statement batch or after executing the batch. Essentially, you can call `executeUpdate()` for a statement object only when its update batch is empty. If the batch is non-empty, then an exception will be generated.

For example, it is legal to have a sequence such as the following:

```
...
```

```
PreparedStatement pstmt =
          conn.prepareStatement("INSERT INTO employees VALUES(?, ?)");

pstmt.setInt(1, 2000);
pstmt.setString(2, "Milo Mumford");

int scount = pstmt.executeUpdate();   // OK; no operations in pstmt batch

pstmt.setInt(1, 3000);
pstmt.setString(2, "Sulu Simpson");
pstmt.addBatch();                     // Now start a batch

pstmt.setInt(1, 4000);
pstmt.setString(2, "Stan Leland");
pstmt.addBatch();

int[] bcounts = pstmt.executeBatch();

pstmt.setInt(1, 5000);
pstmt.setString(2, "Amy Feiner");

int scount = pstmt.executeUpdate();   // OK; pstmt batch was executed
...
```

Intermixing non-batched operations on one statement object and batched operations on another statement object within your code is permissible. Different statement objects are independent of each other with regards to update batching operations. A `COMMIT` request will affect all non-batched operations and all successful operations in executed batches, but will not affect any pending batches.

Premature Batch Flush

Premature batch flush happens due to a change in cached meta data. Cached meta data can be changed due to various reasons, such as the following:

- The initial bind was null and the following bind is not null
- A scalar type is initially bound as string and then bound as scalar type or the reverse

The premature batch flush count is summed to the return value of the next `executeUpdate()` or `sendBatch()` method.

The old functionality lost all these batch flush values which can be obtained now. To switch back to the old functionality, you can set the `AccumulateBatchResult` property to `false`, as shown below:

```
HashTable info = new HashTable ();
info.put ("user", "SCOTT");
info.put ("passwd", "TIGER");
// other properties
...

// property: batch flush type
info.put ("AccumulateBatchResult", "false");

Connection con = DriverManager.getConnection ("jdbc:oracle:oci:@", info);
```

Note: The `AccumulateBatchResult` property is set to `true` by default, in Oracle9*i*.

Example:

```
((OraclePreparedStatement)pstmt).setExecuteBatch (2);

pstmt.setNull (1, OracleTypes.NUMBER);
pstmt.setString (2, "test11");
int count = pstmt.executeUpdate (); // returns 0

/*
* Premature batch flush happens here.
*/
pstmt.setInt (1, 22);
pstmt.setString (2, "test22");
int count = pstmt.executeUpdate (); // returns 0

pstmt.setInt (1, 33);
pstmt.setString (2, "test33");
/*
*  returns 3 with the new batching scheme where as,
*  returns 2 with the old batching scheme.
*/
int count = pstmt.executeUpdate ();
```

Additional Oracle Performance Extensions

In addition to update batching, discussed previously, Oracle JDBC drivers support the following extensions that improve performance by reducing round trips to the database:

- prefetching rows

  This reduces round trips to the database by fetching multiple rows of data each time data is fetched—the extra data is stored in client-side buffers for later access by the client. The number of rows to prefetch can be set as desired.

- specifying column types

  This avoids an inefficiency in the normal JDBC protocol for performing and returning the results of queries.

- suppressing database metadata `TABLE_REMARKS` columns

  This avoids an expensive outer join operation.

Oracle provides several extensions to connection properties objects to support these performance extensions. These extensions enable you to set the `remarksReporting` flag and default values for row prefetching and update batching. For more information, see "Specifying a Database URL and Properties Object" on page 3-7.

Oracle Row Prefetching

Oracle JDBC drivers include extensions that allow you to set the number of rows to prefetch into the client while a result set is being populated during a query. This feature reduces the number of round trips to the server.

> **Note:** With JDBC 2.0, the ability to preset the fetch size has become standard functionality. For information about the standard implementation of this feature, see "Fetch Size" on page 13-24.

Setting the Oracle Prefetch Value

Standard JDBC receives the result set one row at a time, and each row requires a round trip to the database. The row-prefetching feature associates an integer row-prefetch setting with a given statement object. JDBC fetches that number of rows at a time from the database during the query. That is, JDBC will fetch N rows that match the query criteria and bring them all back to the client at once, where N

is the prefetch setting. Then, once your `next()` calls have run through those N rows, JDBC will go back to fetch the next N rows that match the criteria.

You can set the number of rows to prefetch for a particular Oracle statement (any type of statement). You can also reset the default number of rows that will be prefetched for all statements in your connection. The default number of rows to prefetch to the client is 10.

Set the number of rows to prefetch for a particular statement as follows:

1. Cast your statement object to an `OracleStatement`, `OraclePreparedStatement`, or `OracleCallableStatement` object, as applicable, if it is not already one of these.
2. Use the `setRowPrefetch()` method of the statement object to specify the number of rows to prefetch, passing in the number as an integer. If you want to check the current prefetch number, use the `getRowPrefetch()` method of the Statement object, which returns an integer.

Set the default number of rows to prefetch for all statements in a connection, as follows:

1. Cast your `Connection` object to an `OracleConnection` object.
2. Use the `setDefaultRowPrefetch()` method of your `OracleConnection` object to set the default number of rows to prefetch, passing in an integer that specifies the desired default. If you want to check the current setting of the default, then use the `getDefaultRowPrefetch()` method of the `OracleConnection` object. This method returns an integer.

   Equivalently, instead of calling `setDefaultRowPrefetch()`, you can set the `defaultRowPrefetch` Java property if you use a Java `Properties` object in establishing the connection. See "Specifying a Database URL and Properties Object" on page 3-7.

Notes:

- Do not mix the JDBC 2.0 fetch size API and the Oracle row-prefetching API in your application. You can use one or the other, but not both.
- Be aware that setting the Oracle row-prefetch value can affect not only queries, but also: 1) explicitly refetching rows in a result set through the result set `refreshRow()` method available with JDBC 2.0 (relevant for scroll-sensitive / read-only, scroll-sensitive / updatable, and scroll-insensitive / updatable result sets); and 2) the "window" size of a scroll-sensitive result set, affecting how often automatic refetches are performed. The Oracle row-prefetch value will be overridden, however, by any setting of the fetch size. See "Fetch Size" on page 13-24 for more information.

Example: Row Prefetching The following example illustrates the row-prefetching feature. It assumes you have imported the `oracle.jdbc.*` interfaces.

```
Connection conn =
       DriverManager.getConnection("jdbc:oracle:oci:","scott","tiger");

//Set the default row-prefetch setting for this connection
((OracleConnection)conn).setDefaultRowPrefetch(7);

/* The following statement gets the default row-prefetch value for
   the connection, that is, 7.
 */
Statement stmt = conn.createStatement();

/* Subsequent statements look the same, regardless of the row
   prefetch value. Only execution time changes.
 */
ResultSet rset = stmt.executeQuery("SELECT ename FROM emp");
System.out.println( rset.next () );

while( rset.next () )
    System.out.println( rset.getString (1) );

//Override the default row-prefetch setting for this statement
( (OracleStatement)stmt ).setRowPrefetch (2);
```

```
ResultSet rset = stmt.executeQuery("SELECT ename FROM emp");
System.out.println( rset.next () );

while( rset.next() )
   System.out.println( rset.getString (1) );

stmt.close();
```

Oracle Row-Prefetching Limitations

There is no maximum prefetch setting, but empirical evidence suggests that 10 is effective. Oracle does not recommend exceeding this value in most situations. If you do not set the default row-prefetch value for a connection, 10 is the default.

A statement object receives the default row-prefetch setting from the associated connection at the time the statement object is created. Subsequent changes to the connection's default row-prefetch setting have no effect on the statement's row-prefetch setting.

If a column of a result set is of datatype `LONG` or `LONG RAW` (that is, the streaming types), JDBC changes the statement's row-prefetch setting to 1, even if you never actually read a value of either of those types.

If you use the form of the `DriverManager` class `getConnection()` method that takes a `Properties` object as an argument, then you can set the connection's default row-prefetch value that way. See "Specifying a Database URL and Properties Object" on page 3-7.

Defining Column Types

Oracle JDBC drivers enable you to inform the driver of the types of the columns in an upcoming query, saving a round trip to the database that would otherwise be necessary to describe the table.

When standard JDBC performs a query, it first uses a round trip to the database to determine the types that it should use for the columns of the result set. Then, when JDBC receives data from the query, it converts the data, as necessary, as it populates the result set.

When you specify column types for a query, you avoid the first round trip to the database. The server, which is optimized to do so, performs any necessary type conversions.

Following these general steps to define column types for a query:

1. Cast your statement object to an `OracleStatement`, `OraclePreparedStatement`, or `OracleCallableStatement` object, as applicable, if it is not already one of these.
2. If necessary, use the `clearDefines()` method of your `Statement` object to clear any previous column definitions for this `Statement` object.
3. For each column of the expected result set, invoke the `defineColumnType()` method of your `Statement` object, passing it these parameters:
   - column index (integer)
   - typecode (integer)

     Use the static constants of the `java.sql.Types` class or `oracle.jdbc.OracleTypes` class (such as `Types.INTEGER`, `Types.FLOAT`, `Types.VARCHAR`, `OracleTypes.VARCHAR`, and `OracleTypes.ROWID`). Typecodes for standard types are identical in these two classes.
   - type name (string) (structured objects, object references, and arrays only)

     For structured objects, object references, and arrays, you must also specify the type name (for example, `Employee`, `EmployeeRef`, or `EmployeeArray`).
   - (optionally) maximum field size (integer)

     Optionally specify a maximum data length for this column.

     You cannot specify a maximum field size parameter if you are defining the column type for a structured object, object reference, or array. If you try to include this parameter, it will be ignored.

   For example, assuming `stmt` is an Oracle statement, use this syntax:

   ```
   stmt.defineColumnType(column_index, typeCode);
   ```

   or (recommended if the column is VARCHAR or equivalent and you know the length limit):

   ```
   stmt.defineColumnType(column_index, typeCode, max_size);
   ```

   or (for structured object, object reference, and array columns):

   ```
   stmt.defineColumnType(column_index, typeCode, typeName);
   ```

   Set a maximum field size if you do not want to receive the full default length of the data. Calling the `setMaxFieldSize()` method of the standard JDBC

`Statement` class sets a restriction on the amount of data returned. Specifically, the size of the data returned will be the minimum of:

- the maximum field size set in `defineColumnType()`

or:

- the maximum field size set in `setMaxFieldSize()`

or:

- the natural maximum size of the datatype

Once you complete these steps, use the statement's `executeQuery()` method to perform the query.

Note: You must define the datatype for *every* column of the expected result set. If the number of columns for which you specify types does not match the number of columns in the result set, the process fails with a SQL exception.

Example: Defining Column Types The following example illustrates the use of this feature. It assumes you have imported the `oracle.jdbc.*` interfaces.

```
Connection conn =
     DriverManager.getConnection("jdbc:oracle:oci:","scott","tiger");

Statement stmt = conn.createStatement();

/*Ask for the column as a string:
 *Avoid a round trip to get the column type.
 *Convert from number to string on the server.
 */
((OracleStatement)stmt).defineColumnType(1, Types.VARCHAR);

ResultSet rset = stmt.executeQuery("select empno from emp");

while (rset.next() )
    System.out.println(rset.getString(1));

stmt.close();
```

As this example shows, you must cast the statement (`stmt`) to type `OracleStatement` in the invocation of the `defineColumnType()` method. The connection's `createStatement()` method returns an object of type

`java.sql.Statement`, which does not have the `defineColumnType()` and `clearDefines()` methods. These methods are provided only in the `OracleStatement` implementation.

The define-extensions use JDBC types to specify the desired types. The allowed define types for columns depend on the internal Oracle type of the column.

All columns can be defined to their "natural" JDBC types; in most cases, they can be defined to the `Types.CHAR` or `Types.VARCHAR` typecode.

Table 12–1 lists the valid column definition arguments you can use in the `defineColumnType()` method.

Table 12–1 Valid Column Type Specifications

If the column has Oracle SQL type:	You can use defineColumnType() to define it as:
NUMBER, VARNUM	BIGINT, TINYINT, SMALLINT, INTEGER, FLOAT, REAL, DOUBLE, NUMERIC, DECIMAL, CHAR, VARCHAR
CHAR, VARCHAR2	CHAR, VARCHAR
LONG	CHAR, VARCHAR, LONGVARCHAR
LONGRAW	LONGVARBINARY, VARBINARY, BINARY
RAW	VARBINARY, BINARY
DATE	DATE, TIME, TIMESTAMP, CHAR, VARCHAR
ROWID	ROWID

DatabaseMetaData TABLE_REMARKS Reporting

The `getColumns()`, `getProcedureColumns()`, `getProcedures()`, and `getTables()` methods of the database metadata classes are slow if they must report `TABLE_REMARKS` columns, because this necessitates an expensive outer join. For this reason, the JDBC driver does *not* report `TABLE_REMARKS` columns by default.

You can enable `TABLE_REMARKS` reporting by passing a `true` argument to the `setRemarksReporting()` method of an `OracleConnection` object.

Equivalently, instead of calling `setRemarksReporting()`, you can set the `remarksReporting` Java property if you use a Java `Properties` object in establishing the connection. See "Specifying a Database URL and Properties Object" on page 3-7.

If you are using a standard `java.sql.Connection` object, you must cast it to `OracleConnection` to use `setRemarksReporting()`.

Example: TABLE_REMARKS Reporting

Assuming `conn` is the name of your standard `Connection` object, the following statement enables TABLE_REMARKS reporting.

```
( (oracle.jdbc.OracleConnection)conn ).setRemarksReporting(true);
```

Considerations for getProcedures() and getProcedureColumns() Methods

According to JDBC versions 1.1 and 1.2, the methods `getProcedures()` and `getProcedureColumns()` treat the `catalog`, `schemaPattern`, `columnNamePattern`, and `procedureNamePattern` parameters in the same way. In the Oracle definition of these methods, the parameters are treated differently:

- `catalog`: Oracle does not have multiple catalogs, but it does have packages. Consequently, the `catalog` parameter is treated as the package name. This applies both on input (the `catalog` parameter) and output (the `catalog` column in the returned `ResultSet`). On input, the construct `" "` (the empty string) retrieves procedures and arguments without a package, that is, standalone objects. A `null` value means to drop from the selection criteria, that is, return information about both stand-alone and packaged objects (same as passing in "%"). Otherwise the `catalog` parameter should be a package name pattern (with SQL wild cards, if desired).
- `schemaPattern`: All objects within Oracle must have a schema, so it does not make sense to return information for those objects without one. Thus, the construct `" "` (the empty string) is interpreted on input to mean the objects in the current schema (that is, the one to which you are currently connected). To be consistent with the behavior of the `catalog` parameter, `null` is interpreted to drop the schema from the selection criteria (same as passing in "%"). It can also be used as a pattern with SQL wild cards.
- `procedureNamePattern` and `columnNamePattern`: The empty string (" ") does not make sense for either parameter, because all procedures and arguments must have names. Thus, the construct `" "` will raise an exception. To be consistent with the behavior of other parameters, `null` has the same effect as passing in "%".

13

Result Set Enhancements

Standard JDBC 2.0 features in JDK 1.2.x include enhancements to result set functionality—processing forward or backward, positioning relatively or absolutely, seeing changes to the database made internally or externally, and updating result set data and then copying the changes to the database.

This chapter discusses these features, including the following topics:

- Overview
- Creating Scrollable or Updatable Result Sets
- Positioning and Processing in Scrollable Result Sets
- Updating Result Sets
- Fetch Size
- Refetching Rows
- Seeing Database Changes Made Internally and Externally
- Summary of New Methods for Result Set Enhancements

The Oracle JDBC drivers also include extensions to support these features in a JDK 1.1.x environment.

For more general and conceptual information about JDBC 2.0 result set enhancements, refer to the Sun Microsystems JDBC 2.0 API specification.

Overview

This section provides an overview of JDBC 2.0 result set functionality and categories, and some discussion of implementation requirements for the Oracle JDBC drivers.

Result Set Functionality and Result Set Categories Supported in JDBC 2.0

Result set functionality in JDBC 2.0 includes enhancements for scrollability and positioning, sensitivity to changes by others, and updatability.

- Scrollability, positioning, and sensitivity are determined by the *result set type*.
- Updatability is determined by the *concurrency type*.

Specify the desired result set type and concurrency type when you create the statement object that will produce the result set.

Together, the various result set types and concurrency types provide for six different categories of result set.

This section provides an overview of these enhancements, types, and categories.

Scrollability, Positioning, and Sensitivity

Scrollability refers to the ability to move backward as well as forward through a result set. Associated with scrollability is the ability to move to any particular position in the result set, through either *relative positioning* or *absolute positioning*.

Relative positioning allows you to move a specified number of rows forward or backward from the current row. Absolute positioning allows you to move to a specified row number, counting from either the beginning or the end of the result set.

Under JDBC 1.0 (in JDK 1.1.x) you can scroll only forward, using the `next()` method as described in "Processing the Result Set" on page 3-11, and there is no positioning functionality. You can start only at the beginning and iterate row-by-row until the end.

Under JDBC 2.0 (in JDK 1.2.x), scrollable / positionable result sets are also available.

When creating a scrollable / positionable result set, you must also specify *sensitivity*. This refers to the ability of a result set to detect and reveal changes made to the underlying database from outside the result set.

A *sensitive* result set can see changes made to the database while the result set is open, providing a dynamic view of the underlying data. Changes made to the underlying columns values of rows in the result set are visible.

An *insensitive* result set is *not* sensitive to changes made to the database while the result set is open, providing a static view of the underlying data. You would need to retrieve a new result set to see changes made to the database.

Sensitivity is not an option in a JDBC 1.0 / non-scrollable result set.

Result Set Types for Scrollability and Sensitivity

When you create a result set under JDBC 2.0 functionality, you must choose a particular result set type to specify whether the result set is scrollable / positional and sensitive to underlying database changes.

If the JDBC 1.0 functionality is all you desire, JDBC 2.0 continues to support this through the *forward-only* result set type. A forward-only result set cannot be sensitive.

If you want a scrollable result set, you must also specify sensitivity. Specify the *scroll-sensitive* type for the result set to be scrollable and sensitive to underlying changes. Specify the *scroll-insensitive* type for the result set to be scrollable but not sensitive to underlying changes.

To summarize, the following three result set types are available with JDBC 2.0:

- forward-only (JDBC 1.0 functionality—not scrollable, not positionable, and not sensitive)
- scroll-sensitive (scrollable and positionable; also sensitive to underlying database changes)
- scroll-insensitive (scrollable and positionable but not sensitive to underlying database changes)

> **Note:** The sensitivity of a scroll-sensitive result set (how often it is updated to see external changes) is affected by fetch size. See Fetch Size on page 13-24 and "Oracle Implementation of Scroll-Sensitive Result Sets" on page 13-30.

Updatability

Updatability refers to the ability to update data in a result set and then (presumably) copy the changes to the database. This includes inserting new rows into the result set or deleting existing rows.

Updatability might also require database write locks to mediate access to the underlying database. Because you cannot have multiple write locks concurrently, updatability in a result set is associated with *concurrency* in database access.

Result sets can optionally be updatable under JDBC 2.0, but not under JDBC 1.0.

Note: Updatability is independent of scrollability and sensitivity, although it is typical for an updatable result set to also be scrollable so that you can position it to particular rows that you want to update or delete.

Concurrency Types for Updatability

The concurrency type of a result set determines whether it is updatable. Under JDBC 2.0, the following concurrency types are available:

- updatable (updates, inserts, and deletes can be performed on the result set and copied to the database)
- read-only (the result set cannot be modified in any way)

Summary of Result Set Categories

Because scrollability and sensitivity are independent of updatability, the three result set types and two concurrency types combine for a total of six *result set categories*:

- forward-only / read-only
- forward-only / updatable
- scroll-sensitive / read-only
- scroll-sensitive / updatable
- scroll-insensitive / read-only
- scroll-insensitive / updatable

Note: A forward-only updatable result set has no positioning functionality. You can only update rows as you iterate through them with the `next()` method.

Oracle JDBC Implementation Overview for Result Set Enhancements

This section discusses key aspects of the Oracle JDBC implementation of result set enhancements for scrollability—through use of a client-side cache—and for updatability—through use of ROWIDs.

It is permissible for customers to implement their own client-side caching mechanism, and Oracle provides an interface to use in doing so.

Oracle JDBC Implementation for Result Set Scrollability

Because the underlying server does *not* support scrollable cursors, Oracle JDBC must implement scrollability in a separate layer.

It is important to be aware that this is accomplished by using a client-side memory cache to store rows of a scrollable result set.

Important: Because all rows of any scrollable result set are stored in the client-side cache, a situation where the result set contains many rows, many columns, or very large columns might cause the client-side Java virtual machine to fail. *Do not specify scrollability for a large result set*.

Scrollable cursors in the Oracle server, and therefore a server-side cache, will be supported in a future Oracle release.

Oracle JDBC Implementation for Result Set Updatability

To support updatability, Oracle JDBC uses ROWIDs to uniquely identify database rows that appear in a result set. For every query into an updatable result set, the Oracle JDBC driver automatically retrieves the ROWID along with the columns you select.

Note: Client-side caching is not required by updatability in and of itself. In particular, a forward-only updatable result set will not require a client-side cache.

Implementing a Custom Client-Side Cache for Scrollability

There is some flexibility in how to implement client-side caching in support of JDBC 2.0 scrollable result sets.

Although Oracle JDBC provides a complete implementation, it also supplies an interface, `OracleResultSetCache`, that you can implement as desired:

```
public interface OracleResultSetCache
{
  /**
   * Save the data in the i-th row and j-th column.
   */
  public void put (int i, int j, Object value) throws IOException;

  /**
   * Return the data stored in the i-th row and j-th column.
   */
  public Object get (int i, int j) throws IOException;

  /**
   * Remove the i-th row.
   */
  public void remove (int i) throws IOException;

  /**
   * Remove the data stored in i-th row and j-th column
   */
  public void remove (int i, int j) throws IOException;

  /**
   * Remove all data from the cache.
   */
  public void clear () throws IOException;

  /**
   * Close the cache.
   */
  public void close () throws IOException;
}
```

If you implement this interface with your own class, your application code must instantiate your class and then use the `setResultSetCache()` method of an `OracleStatement`, `OraclePreparedStatement`, or `OracleCallableStatement` object to set the caching mechanism to use your implementation. Following is the method signature:

- `void setResultSetCache(OracleResultSetCache cache)`
  `throws SQLException`

Call this method prior to executing a query. The result set produced by the query will then use your specified caching mechanism.

Creating Scrollable or Updatable Result Sets

Under JDBC 1.0, no special attention is required in creating and using a result set. A result set is produced automatically to store the results of a query, and no result set types or categories must be specified, because there is only one kind of result set available—forward-only / read-only. For example (given a connection object `conn`):

```
Statement stmt = conn.createStatement();
ResultSet rs = stmt.executeQuery("SELECT empno, sal FROM emp");
```

In using JDBC 2.0 result set enhancements, however, you may specify the result set type (for scrollability and sensitivity) and the concurrency type (for updatability) when you create a generic statement or prepare a prepared statement or callable statement that will execute a query.

(Note, however, that callable statements are intended to execute stored procedures and functions and rarely return a result set. Still, the callable statement class is a subclass of the prepared statement class and so inherits this functionality.)

This section discusses the creation of result sets to use JDBC 2.0 enhancements.

Specifying Result Set Scrollability and Updatability

Under JDBC 2.0, `Connection` classes have `createStatement()`, `prepareStatement()`, and `prepareCall()` method signatures that take a result set type and a concurrency type as input:

- `Statement createStatement (int resultSetType, int resultSetConcurrency)`
- `PreparedStatement prepareStatement (String sql, int resultSetType, int resultSetConcurrency)`
- `CallableStatement prepareCall (String sql, int resultSetType, int resultSetConcurrency)`

The statement objects created will have the intelligence to produce the appropriate kind of result sets.

You can specify one of the following static constant values for result set type:

- `ResultSet.TYPE_FORWARD_ONLY`
- `ResultSet.TYPE_SCROLL_INSENSITIVE`
- `ResultSet.TYPE_SCROLL_SENSITIVE`

> **Note:** See "Oracle Implementation of Scroll-Sensitive Result Sets" on page 13-30 for information about possible performance impact.

And you can specify one of the following static constant values for concurrency type:

- `ResultSet.CONCUR_READ_ONLY`
- `ResultSet.CONCUR_UPDATABLE`

> **Note:** If you are using the Oracle JDBC drivers in a JDK 1.1.x environment , the static constants discussed here are part of the Oracle extensions, belonging only to the `OracleResultSet` class, which you must specify. For example:
>
> ```
> OracleResultSet.TYPE_SCROLL_SENSITIVE
> ```
>
> instead of:
>
> ```
> ResultSet.TYPE_SCROLL_SENSITIVE
> ```

After creating a `Statement`, `PreparedStatement`, or `CallableStatement` object, you can verify its result set type and concurrency type by calling the following methods on the statement object:

- `int getResultSetType() throws SQLException`
- `int getResultSetConcurrency() throws SQLException`

Example Following is an example of a prepared statement object that specifies a scroll-sensitive and updatable result set for queries executed through that statement (where `conn` is a connection object):

```
...
PreparedStatement pstmt = conn.prepareStatement
         ("SELECT empno, sal FROM emp WHERE empno = ?",
         ResultSet.TYPE_SCROLL_SENSITIVE, ResultSet.CONCUR_UPDATABLE);

pstmt.setString(1, "28959");
ResultSet rs = pstmt.executeQuery();
...
```

Result Set Limitations and Downgrade Rules

Some types of result sets are not feasible for certain kinds of queries. If you specify an unfeasible result set type or concurrency type for the query you execute, the JDBC driver follows a set of rules to determine the best feasible types to use instead.

The actual result set type and concurrency type are determined when the statement is executed, with the driver issuing a `SQLWarning` on the statement object if the desired result set type or concurrency type is not feasible. The `SQLWarning` object will contain the reason why the requested type was not feasible. Check for warnings to verify whether you received the type of result set that you requested, or call the methods described in "Verifying Result Set Type and Concurrency Type" on page 13-11.

FOR UPDATE Clause Limitation in an Updatable Result Set

A query cannot have the `FOR UPDATE` clause in the `SELECT` statement if you are using an updatable result set. If you use the `FOR UPDATE` clause and try to update a result set, an SQLException will be thrown.

Result Set Limitations

The following limitations are placed on queries for enhanced result sets. Failure to follow these guidelines will result in the JDBC driver choosing an alternative result set type or concurrency type.

To produce an updatable result set:

- A query can select from only a single table and cannot contain any join operations.

  In addition, for inserts to be feasible, the query must select all non-nullable columns and all columns that do not have a default value.
- A query cannot use "`SELECT * `". (But see the workaround below.)
- A query must select table columns only. It cannot select derived columns or aggregates such as the `SUM` or `MAX` of a set of columns.

To produce a scroll-sensitive result set:

- A query cannot use "`SELECT * `". (But see the workaround below.)
- A query can select from only a single table.

(See "Summary of New Methods for Result Set Enhancements" on page 13-32 for general information about refetching.)

Workaround As a workaround for the "`SELECT *`" limitation, you can use table aliases as in the following example:

```
SELECT t.* FROM TABLE t ...
```

Hint: There is a simple way to determine if your query will probably produce a scroll-sensitive or updatable result set: If you can legally add a ROWID column to the query list, then the query is probably suitable for either a scroll-sensitive or an updatable result set. (You can try this out using SQL*Plus, for example.)

Result Set Downgrade Rules

If the specified result set type or concurrency type is not feasible, the Oracle JDBC driver uses the following rules in choosing alternate types:

- If the specified result set type is `TYPE_SCROLL_SENSITIVE`, but the JDBC driver cannot fulfill that request, then the driver attempts a downgrade to `TYPE_SCROLL_INSENSITIVE`.
- If the specified (or downgraded) result set type is `TYPE_SCROLL_INSENSITIVE`, but the JDBC driver cannot fulfill that request, then the driver attempts a downgrade to `TYPE_FORWARD_ONLY`.

Furthermore:

- If the specified concurrency type is `CONCUR_UPDATABLE`, but the JDBC driver cannot fulfill that request, then the JDBC driver attempts a downgrade to `CONCUR_READ_ONLY`.

Notes:

- Criteria that would prevent the JDBC driver from fulfilling the result set type specifications are listed in "Result Set Limitations" on page 13-10.
- Any manipulations of the result set type and concurrency type by the JDBC driver are independent of each other.

Verifying Result Set Type and Concurrency Type

After a query has been executed, you can verify the result set type and concurrency type that the JDBC driver actually used, by calling methods on the result set object.

- `int getType() throws SQLException`

  This method returns an `int` value for the result set type used for the query. `ResultSet.TYPE_FORWARD_ONLY`, `ResultSet.TYPE_SCROLL_SENSITIVE`, or `ResultSet.TYPE_SCROLL_INSENSITIVE` are the possible values.

- `int getConcurrency() throws SQLException`

  This method returns an `int` value for the concurrency type used for the query. `ResultSet.CONCUR_READ_ONLY` or `ResultSet.CONCUR_UPDATABLE` are the possible values.

Positioning and Processing in Scrollable Result Sets

Scrollable result sets (result set type `TYPE_SCROLL_SENSITIVE` or `TYPE_SCROLL_INSENSITIVE`) allow you to iterate through, them either forward or backward, and to position the result set to any desired row.

This section discusses positioning within a scrollable result set and how to process a scrollable result set backward, instead of forward.

Positioning in a Scrollable Result Set

In a scrollable result set, you can use several result set methods to move to a desired position and to check the current position.

Methods for Moving to a New Position

The following result set methods are available for moving to a new position in a scrollable result set:

- `void beforeFirst() throws SQLException`
- `void afterLast() throws SQLException`
- `boolean first() throws SQLException`
- `boolean last() throws SQLException`
- `boolean absolute(int row) throws SQLException`
- `boolean relative(int row) throws SQLException`

Note: You cannot position a forward-only result set. Any attempt to position it or to determine the current position will result in a SQL exception.

---

beforeFirst() Method Positions to before the first row of the result set, or has no effect if there are no rows in the result set.

This is where you would typically start iterating through a result set to process it going forward, and is the default initial position for any kind of result set.

You are outside the result set bounds after a `beforeFirst()` call. There is no valid current row, and you cannot position relatively from this point.

afterLast() Method Positions to after the last row of the result set, or has no effect if there are no rows in the result set.

This is where you would typically start iterating through a result set to process it going backward.

You are outside the result set bounds after an `afterLast()` call. There is no valid current row, and you cannot position relatively from this point.

first() Method Positions to the first row of the result set, or returns `false` if there are no rows in the result set.

last() Method Positions to the last row of the result set, or returns `false` if there are no rows in the result set.

absolute() Method Positions to an absolute row from either the beginning or end of the result set. If you input a positive number, it positions from the beginning; if you input a negative number, it positions from the end. This method returns `false` if there are no rows in the result set.

Attempting to move forward beyond the last row, such as an `absolute(11)` call if there are 10 rows, will position to after the last row, having the same effect as an `afterLast()` call.

Attempting to move backward beyond the first row, such as an `absolute(-11)` call if there are 10 rows, will position to before the first row, having the same effect as a `beforeFirst()` call.

Note: Calling `absolute(1)` is equivalent to calling `first()`; calling `absolute(-1)` is equivalent to calling `last()`.

---

relative() Method Moves to a position relative to the current row, either forward if you input a positive number or backward if you input a negative number, or returns `false` if there are no rows in the result set.

The result set must be at a valid current row for use of the `relative()` method.

Attempting to move forward beyond the last row will position to after the last row, having the same effect as an `afterLast()` call.

Attempting to move backward beyond the first row will position to before the first row, having the same effect as a `beforeFirst()` call.

A `relative(0)` call is valid but has no effect.

Important: You cannot position relatively from before the first row (which is the default initial position) or after the last row. Attempting relative positioning from either of these positions would result in a SQL exception.

Methods for Checking the Current Position

The following result set methods are available for checking the current position in a scrollable result set:

- `boolean isBeforeFirst() throws SQLException`

  Returns `true` if the position is before the first row.

- `boolean isAfterLast() throws SQLException`

  Returns `true` if the position is after the last row.

- `boolean isFirst() throws SQLException`

  Returns `true` if the position is at the first row.

- `boolean isLast() throws SQLException`

  Returns `true` if the position is at the last row.

- `int getRow() throws SQLException`

  Returns the row number of the current row, or returns 0 if there is no valid current row.

Note: The boolean methods—`isFirst()`, `isLast()`, `isAfterFirst()`, and `isAfterLast()`—all return `false` (and do *not* throw an exception) if there are no rows in the result set.

Processing a Scrollable Result Set

In a scrollable result set you can iterate backward instead of forward as you process the result set. The following methods are available:

- `boolean next() throws SQLException`
- `boolean previous() throws SQLException`

The `previous()` method works similarly to the `next()` method, in that it returns `true` as long as the new current row is valid, and `false` as soon as it runs out of rows (has passed the first row).

Backward versus Forward Processing

You can process the entire result set going forward, using the `next()` method as in JDBC 1.0. This is documented in "Processing the Result Set" on page 3-11. The default initial position in the result set is before the first row, appropriately, but you can call the `beforeFirst()` method if you have moved elsewhere since the result set was created.

To process the entire result set going backward, call `afterLast()`, then use the `previous()` method. For example (where `conn` is a connection object):

```
...
/* NOTE: The specified concurrency type, CONCUR_UPDATABLE, is not relevant to
this example. */

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

ResultSet rs = stmt.executeQuery("SELECT empno, sal FROM emp");

rs.afterLast();
while (rs.previous())
{
   System.out.println(rs.getString("empno") + " " + rs.getFloat("sal"));
}
...
```

Unlike relative positioning, you can (and typically do) use `next()` from before the first row and `previous()` from after the last row. You do not have to be at a valid current row to use these methods.

Note: In a non-scrollable result set, you can process only with the `next()` method. Attempting to use the `previous()` method will cause a SQL exception.

Presetting the Fetch Direction

The JDBC 2.0 standard allows the ability to pre-specify the direction, known as the *fetch direction*, for use in processing a result set. This allows the JDBC driver to optimize its processing. The following result set methods are specified:

- `void setFetchDirection(int direction) throws SQLException`
- `int getFetchDirection() throws SQLException`

The Oracle JDBC drivers support only the forward preset value, which you can specify by inputting the `ResultSet.FETCH_FORWARD` static constant value.

The values `ResultSet.FETCH_REVERSE` and `ResultSet.FETCH_UNKNOWN` are not supported—attempting to specify them causes a SQL warning, and the settings are ignored.

Updating Result Sets

A concurrency type of CONCUR_UPDATABLE allows you to update rows in the result set, delete rows from the result set, or insert rows into the result set.

After you perform an UPDATE or INSERT operation in a result set, you propagate the changes to the database in a separate step that you can skip if you want to cancel the changes.

A DELETE operation in a result set, however, is immediately executed (but not necessarily committed) in the database as well.

Note: When using an updatable result set, it is typical to also make it scrollable. This allows you to position to any row that you want to change. With a forward-only updatable result set, you can change rows only as you iterate through them with the `next()` method.

Performing a DELETE Operation in a Result Set

The result set `deleteRow()` method will delete the current row. Following is the method signature:

- `void deleteRow() throws SQLException`

Important: Unlike UPDATE and INSERT operations in a result set, which require a separate step to propagate the changes to the database, a DELETE operation in a result set is immediately executed in the corresponding row in the database as well.

Once you call `deleteRow()`, the changes will be made permanent with the next transaction COMMIT operation. Remember also that by default, the auto-commit flag is set to `true`. Therefore, unless you override this default, any `deleteRow()` operation will be executed and committed immediately.

Presuming the result set is also scrollable, you can position to a row using any of the available positioning methods (except `beforeFirst()` and `afterLast()`, which do not go to a valid current row), and then delete that row, as in the following example (presuming a result set `rs`):

```
...
```

```
rs.absolute(5);
rs.deleteRow();
...
```

See "Positioning in a Scrollable Result Set" on page 13-13 for information about the positioning methods.

Important: The deleted row remains in the result set object even after it has been deleted from the database.

In a scrollable result set, by contrast, a `DELETE` operation is evident in the local result set object—the row would no longer be in the result set after the `DELETE`. The row preceding the deleted row becomes the current row, and row numbers of subsequent rows are changed accordingly.

Refer to "Seeing Internal Changes" on page 13-27 for more information.

Performing an UPDATE Operation in a Result Set

Performing a result set `UPDATE` operation requires two separate steps to first update the data in the result set and then copy the changes to the database.

Presuming the result set is also scrollable, you can position to a row using any of the available positioning methods (except `beforeFirst()` and `afterLast()`, which do not go to a valid current row), and then update that row as desired.

See "Positioning in a Scrollable Result Set" on page 13-13 for information about the positioning methods.

Here are the steps for updating a row in the result set and database:

1. Call the appropriate `updateXXX()` methods to update the data in the columns you want to change.

   With JDBC 2.0, a result set object has an `updateXXX()` method for each datatype, as with the `setXXX()` methods previously available for updating the database directly.

   Each of these methods takes an `int` for the column number or a string for the column name and then an item of the appropriate datatype to set the new value. Following are a couple of examples for a result set `rs`:

   ```
   rs.updateString(1, "mystring");
   ```

```
rs.updateFloat(2, 10000.0f);
```

2. Call the `updateRow()` method to copy the changes to the database (or the `cancelRowUpdates()` method to cancel the changes).

   Once you call `updateRow()`, the changes are executed and will be made permanent with the next transaction `COMMIT` operation. Be aware that by default, the auto-commit flag is set to `true` so that any executed operation is committed immediately.

   If you choose to cancel the changes before copying them to the database, call the `cancelRowUpdates()` method instead. This will also revert to the original values for that row in the local result set object. Note that once you call the `updateRow()` method, the changes are written to the transaction and cannot be canceled unless you roll back the transaction (auto-commit must be disabled to allow a `ROLLBACK` operation).

   Positioning to a different row before calling `updateRow()` also cancels the changes and reverts to the original values in the result set.

   Before calling `updateRow()`, you can call the usual `getXXX()` methods to verify that the values have been updated correctly. These methods take an `int` column index or string column name as input. For example:

```
float myfloat = rs.getFloat(2);
...process myfloat to see if it's appropriate...
```

Note: Result set `UPDATE` operations are visible in the local result set object for all result set types (forward-only, scroll-sensitive, and scroll-insensitive).

Refer to "Seeing Internal Changes" on page 13-27 for more information.

Example Following is an example of a result set `UPDATE` operation that is also copied to the database. The tenth row is updated. (The column number is used to specify column 1, and the column name—`sal`— is used to specify column 2.)

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

ResultSet rs = stmt.executeQuery("SELECT empno, sal FROM emp");
```

```
if (rs.absolute(10))        // (returns false if row does not exist)
{
   rs.updateString(1, "28959");
   rs.updateFloat("sal", 100000.0f);
   rs.updateRow();
}
// Changes will be made permanent with the next COMMIT operation.
...
```

Performing an INSERT Operation in a Result Set

Result set INSERT operations use what is called the result set *insert-row*, which is a staging area that holds the data for the inserted row until it is copied to the database. You must explicitly move to this row to write the data that will be inserted.

As with UPDATE operations, result set INSERT operations require separate steps to first write the data to the insert-row and then copy it to the database .

Following are the steps in executing a result set INSERT operation.

1. Move to the insert-row by calling the result set `moveToInsertRow()` method.

   Note: The result set will remember the current position prior to the `moveToInsertRow()` call. Afterward, you can go back to it with a `moveToCurrentRow()` call.

2. As with UPDATE operations, use the appropriate `updateXXX()` methods to write data to the columns. For example:

   ```
   rs.updateString(1, "mystring");
   rs.updateFloat(2, 10000.0f);
   ```

   (Note that you can specify a string for column name, instead of an integer for column number.)

Important: Each column value in the insert-row is undefined until you call the `updateXXX()` method for that column. You must call this method and specify a non-null value for all non-nullable columns, or else attempting to copy the row into the database will result in a SQL exception.

It is permissible, however, to *not* call `updateXXX()` for a nullable column. This will result in a value of `null`.

---

3. Copy the changes to the database by calling the result set `insertRow()` method.

   Once you call `insertRow()`, the insert is executed and will be made permanent with the next transaction `COMMIT` operation.

   Positioning to a different row before calling `insertRow()` cancels the insert and clears the insert-row.

   Before calling `insertRow()` you can call the usual `getXXX()` methods to verify that the values have been set correctly in the insert-row. These methods take an `int` column index or string column name as input. For example:

```
float myfloat = rs.getFloat(2);
...process myfloat to see if it's appropriate...
```

Note: No result set type (neither scroll-sensitive, scroll-insensitive, nor forward-only) can see a row inserted by a result set `INSERT` operation.

Refer to "Seeing Internal Changes" on page 13-27 for more information.

Example The following example performs a result set `INSERT` operation, moving to the insert-row, writing the data, copying the data into the database, and then returning to what was the current row prior to going to the insert-row. (The column number is used to specify column 1, and the column name—`sal`— is used to specify column 2.)

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

```
ResultSet rs = stmt.executeQuery("SELECT empno, sal FROM emp");

rs.moveToInsertRow();
rs.updateString(1, "28959");
rs.updateFloat("sal", 100000.0f);
rs.insertRow();
// Changes will be made permanent with the next COMMIT operation.
rs.moveToCurrentRow();  // Go back to where we came from...
...
```

Update Conflicts

It is important to be aware of the following facts regarding updatable result sets with the JDBC drivers:

- The drivers do not enforce write locks for an updatable result set.
- The drivers do not check for conflicts with a result set DELETE or UPDATE operation.

A conflict will occur if you try to perform a DELETE or UPDATE operation on a row updated by another committed transaction.

The Oracle JDBC drivers use the ROWID to uniquely identify a row in a database table. As long as the ROWID is still valid when a driver tries to send an UPDATE or DELETE operation to the database, the operation will be executed.

The driver will not report any changes made by another committed transaction. Any conflicts are silently ignored and your changes will overwrite the previous changes.

To avoid such conflicts, use the Oracle FOR UPDATE feature when executing the query that produces the result set. This will avoid conflicts, but will also prevent simultaneous access to the data. Only a single write lock can be held concurrently on a data item.

Fetch Size

By default, when Oracle JDBC executes a query, it receives the result set 10 rows at a time from the database cursor. This is the default Oracle *row-prefetch value*. You can change the number of rows retrieved with each trip to the database cursor by changing the row-prefetch value (see "Oracle Row Prefetching" on page 12-20 for more information).

JDBC 2.0 also allows you to specify the number of rows fetched with each database round trip for a query, and this number is referred to as the *fetch size*. In Oracle JDBC, the row-prefetch value is used as the default fetch size in a statement object. Setting the fetch size overrides the row-prefetch setting and affects subsequent queries executed through that statement object.

Fetch size is also used in a result set. When the statement object executes a query, the fetch size of the statement object is passed to the result set object produced by the query. However, you can also set the fetch size in the result set object to override the statement fetch size that was passed to it. (Also note that changes made to a statement object's fetch size after a result set is produced will have no affect on that result set.)

The result set fetch size, either set explicitly, or by default equal to the statement fetch size that was passed to it, determines the number of rows that are retrieved in any subsequent trips to the database for that result set. This includes any trips that are still required to complete the original query, as well as any *refetching* of data into the result set. (Data can be refetched, either explicitly or implicitly, to update a scroll-sensitive or scroll-insensitive / updatable result set. See "Refetching Rows" on page 13-26.)

Setting the Fetch Size

The following methods are available in all `Statement`, `PreparedStatement`, `CallableStatement`, and `ResultSet` objects for setting and getting the fetch size:

- `void setFetchSize(int rows) throws SQLException`
- `int getFetchSize() throws SQLException`

To set the fetch size for a query, call `setFetchSize()` on the statement object prior to executing the query. If you set the fetch size to N, then N rows are fetched with each trip to the database.

After you have executed the query, you can call `setFetchSize()` on the result set object to override the statement object fetch size that was passed to it. This will

affect any subsequent trips to the database to get more rows for the original query, as well as affecting any later refetching of rows. (See "Refetching Rows" on page 13-26.)

Use of Standard Fetch Size versus Oracle Row-Prefetch Setting

Using the JDBC 2.0 fetch size is fundamentally similar to using the Oracle row-prefetch value, except that with the row-prefetch value you do not have the flexibility of distinct values in the statement object and result set object. The row prefetch value would be used everywhere.

Furthermore, JDBC 2.0 fetch size usage is portable and can be used with other JDBC drivers. Oracle row-prefetch usage is vendor-specific.

See "Oracle Row Prefetching" on page 12-20 for a general discussion of this Oracle feature.

Note: Do not mix the JDBC 2.0 fetch size API and the Oracle row prefetching API in your application. You can use one or the other, but not both.

Refetching Rows

The result set `refreshRow()` method is supported for some types of result sets for *refetching* data. This consists of going back to the database to re-obtain the database rows that correspond to N rows in the result set, starting with the current row, where N is the fetch size (described above in "Fetch Size" on page 13-24). This lets you see the latest updates to the database that were made outside of your result set, subject to the isolation level of the enclosing transaction.

Because refetching re-obtains only rows that correspond to rows already in your result set, it does nothing about rows that have been inserted or deleted in the database since the original query. It ignores rows that have been inserted, and rows will remain in your result set even after the corresponding rows have been deleted from the database. When there is an attempt to refetch a row that has been deleted in the database, the corresponding row in the result set will maintain its original values.

Following is the `refreshRow()` method signature:

- `void refreshRow() throws SQLException`

You must be at a valid current row when you call this method, not outside the row bounds and not at the insert-row.

With the 8.1.6 release, the `refreshRow()` method is supported for the following result set categories:

- scroll-sensitive / read-only
- scroll-sensitive / updatable
- scroll-insensitive / updatable

Oracle JDBC might support additional result set categories in future releases.

Note: Scroll-sensitive result set functionality is implemented through implicit calls to `refreshRow()`. See "Oracle Implementation of Scroll-Sensitive Result Sets" on page 13-30 for details.

Seeing Database Changes Made Internally and Externally

This section discusses the ability of a result set to see the following:

- its own changes (DELETE, UPDATE, or INSERT operations within the result set), referred to as *internal changes*
- changes made from elsewhere (either from your own transaction outside the result set, or from other committed transactions), referred to as *external changes*

Near the end of the section is a summary table.

Note: External changes are referred to as "other's changes" in the Sun Microsystems JDBC 2.0 specification.

Seeing Internal Changes

The ability of an updatable result set to see its own changes depends on both the result set type and the kind of change (UPDATE, DELETE, or INSERT). This is discussed at various points throughout the "Updating Result Sets" section beginning on on page 13-18, and is summarized as follows:

- Internal DELETE operations are visible for scrollable result sets (scroll-sensitive or scroll-insensitive), but are not visible for forward-only result sets.

  After you delete a row in a scrollable result set, the preceding row becomes the new current row, and subsequent row numbers are updated accordingly.
- Internal UPDATE operations are always visible, regardless of the result set type (forward-only, scroll-sensitive, or scroll-insensitive).
- Internal INSERT operations are never visible, regardless of the result set type (neither forward-only, scroll-sensitive, nor scroll-insensitive).

An internal change being "visible" essentially means that a subsequent `getXXX()` call will see the data changed by a preceding `updateXXX()` call on the same data item.

JDBC 2.0 `DatabaseMetaData` objects include the following methods to verify this. Each takes a result set type as input (`ResultSet.TYPE_FORWARD_ONLY`, `ResultSet.TYPE_SCROLL_SENSITIVE`, or `ResultSet.TYPE_SCROLL_INSENSITIVE`).

- `boolean ownDeletesAreVisible(int) throws SQLException`
- `boolean ownUpdatesAreVisible(int) throws SQLException`

- `boolean ownInsertsAreVisible(int) throws SQLException`

> **Note:** When you make an internal change that causes a trigger to execute, the trigger changes are effectively external changes. However, if the trigger affects data in the row you are updating, you *will* see those changes for any scrollable/updatable result set, because an implicit row refetch occurs after the update.

Seeing External Changes

Only a scroll-sensitive result set can see external changes to the underlying database, and it can only see the changes from external `UPDATE` operations. Changes from external `DELETE or INSERT` operations are never visible.

> **Note:** Any discussion of seeing changes from outside the enclosing transaction presumes the transaction itself has an isolation level setting that allows the changes to be visible.

For implementation details of scroll-sensitive result sets, including exactly how and how soon external updates become visible, see "Oracle Implementation of Scroll-Sensitive Result Sets" on page 13-30.

JDBC 2.0 `DatabaseMetaData` objects include the following methods to verify this. Each takes a result set type as input (`ResultSet.TYPE_FORWARD_ONLY`, `ResultSet.TYPE_SCROLL_SENSITIVE`, or `ResultSet.TYPE_SCROLL_INSENSITIVE`).

- `boolean othersDeletesAreVisible(int) throws SQLException`
- `boolean othersUpdatesAreVisible(int) throws SQLException`
- `boolean othersInsertsAreVisible(int) throws SQLException`

Note: Explicit use of the `refreshRow()` method, described in "Refetching Rows" on page 13-26, is distinct from this discussion of visibility. For example, even though external updates are "invisible" to a scroll-insensitive result set, you can explicitly refetch rows in a scroll-insensitive / updatable result set and retrieve external changes that have been made. "Visibility" refers only to the fact that the scroll-insensitive / updatable result set would not see such changes automatically and implicitly.

Visibility versus Detection of External Changes

Regarding changes made to the underlying database by external sources, there are two similar but distinct concepts with respect to visibility of the changes from your local result set:

- visibility of changes
- detection of changes

A change being "visible" means that when you look at a row in the result set, you can see new data values from changes made by external sources to the corresponding row in the database.

A change being "detected", however, means that the result set is *aware* that this is a new value since the result set was first populated.

Even when an Oracle result set sees new data (as with an external `UPDATE` in a scroll-sensitive result set), it has no awareness that this data has changed since the result set was populated. Such changes are not "detected".

JDBC 2.0 `DatabaseMetaData` objects include the following methods to verify this. Each takes a result set type as input (`ResultSet.TYPE_FORWARD_ONLY`, `ResultSet.TYPE_SCROLL_SENSITIVE`, or `ResultSet.TYPE_SCROLL_INSENSITIVE`).

- `boolean deletesAreDetected(int) throws SQLException`
- `boolean updatesAreDetected(int) throws SQLException`
- `boolean insertsAreDetected(int) throws SQLException`

It follows, then, that result set methods specified by JDBC 2.0 to detect changes—`rowDeleted()`, `rowUpdated()`, and `rowInserted()`—will always return false with the 8.1.6 Oracle JDBC drivers. There is no use in calling them.

Summary of Visibility of Internal and External Changes

Table 13–1 summarizes the discussion in the preceding sections regarding whether a result set object in the Oracle JDBC implementation can see changes made internally through the result set itself, and changes made externally to the underlying database from elsewhere in your transaction or from other committed transactions.

Table 13–1 Visibility of Internal and External Changes for Oracle JDBC

Result Set Type	Can See Internal DELETE?	Can See Internal UPDATE?	Can See Internal INSERT?	Can See External DELETE?	Can See External UPDATE?	Can See External INSERT?
forward-only	no	yes	no	no	no	no
scroll-sensitive	yes	yes	no	no	yes	no
scroll-insensitive	yes	yes	no	no	no	no

For implementation details of scroll-sensitive result sets, including exactly how and how soon external updates become visible, see "Oracle Implementation of Scroll-Sensitive Result Sets" on page 13-30.

Notes:

- Remember that explicit use of the `refreshRow()` method, described in "Refetching Rows" on page 13-26, is distinct from the concept of "visibility" of external changes. This is discussed in "Seeing External Changes" on page 13-28.
- Remember that even when external changes are "visible", as with `UPDATE` operations underlying a scroll-sensitive result set, they are not "detected". The result set `rowDeleted()`, `rowUpdated()`, and `rowInserted()` methods always return `false`. This is further discussed in "Visibility versus Detection of External Changes" on page 13-29.

Oracle Implementation of Scroll-Sensitive Result Sets

The Oracle implementation of scroll-sensitive result sets involves the concept of a *window*, with a window size that is based on the fetch size. The window size affects how often rows are updated in the result set.

Once you establish a current row by moving to a specified row (as described in "Positioning in a Scrollable Result Set" on page 13-13), the window consists of the N

rows in the result set starting with that row, where N is the fetch size being used by the result set (see "Fetch Size" on page 13-24). Note that there is no current row, and therefore no window, when a result set is first created. The default position is before the first row, which is not a valid current row.

As you move from row to row, the window remains unchanged as long as the current row stays within that window. However, once you move to a new current row outside the window, you redefine the window to be the N rows starting with the new current row.

Whenever the window is redefined, the N rows in the database corresponding to the rows in the new window are automatically refetched through an implicit call to the `refreshRow()` method (described in "Refetching Rows" on page 13-26), thereby updating the data throughout the new window.

So external updates are not instantaneously visible in a scroll-sensitive result set; they are only visible after the automatic refetches just described.

Note: Because this kind of refetching is not a highly efficient or optimized methodology, there are significant performance concerns. Consider carefully before using scroll-sensitive result sets as currently implemented. There is also a significant tradeoff between sensitivity and performance. The most sensitive result set is one with a fetch size of 1, which would result in the new current row being refetched every time you move between rows. However, this would have a significant impact on the performance of your application.

Summary of New Methods for Result Set Enhancements

This section summarizes all the new connection, result set, statement, and database meta data methods added for JDBC 2.0 result set enhancements. These methods are more fully discussed throughout this chapter.

Modified Connection Methods

Following is an alphabetical summary of modified connection methods that allow you to specify result set and concurrency types when you create statement objects.

- `Statement createStatement (int resultSetType, int resultSetConcurrency)`

  This method now allows you to specify result set type and concurrency type when you create a generic `Statement` object.

- `CallableStatement prepareCall (String sql, int resultSetType, int resultSetConcurrency)`

  This method now allows you to specify result set type and concurrency type when you create a `PreparedStatement` object.

- `PreparedStatement prepareStatement (String sql, int resultSetType, int resultSetConcurrency)`

  This method now allows you to specify result set type and concurrency type when you create a `CallableStatement` object.

New Result Set Methods

Following is an alphabetical summary of new result set methods for JDBC 2.0 result set enhancements.

- `boolean absolute(int row) throws SQLException`

  Move to an absolute row position in the result set.

- `void afterLast() throws SQLException`

  Move to after the last row in the result set (you will not be at a valid current row after this call).

- `void beforeFirst() throws SQLException`

  Move to before the first row in the result set (you will not be at a valid current row after this call).

- `void cancelRowUpdates() throws SQLException`

  Cancel an `UPDATE` operation on the current row. (Call this after the `updateXXX()` calls but before the `updateRow()` call.)

- `void deleteRow() throws SQLException`

  Delete the current row.

- `boolean first() throws SQLException`

  Move to the first row in the result set.

- `int getConcurrency() throws SQLException`

  Returns an `int` value for the concurrency type used for the query (either `ResultSet.CONCUR_READ_ONLY` or `ResultSet.CONCUR_UPDATABLE`).

- `int getFetchSize() throws SQLException`

  Check the fetch size to determine how many rows are fetched in each database round trip (also available in statement objects).

- `int getRow() throws SQLException`

  Returns the row number of the current row. Returns 0 if there is no valid current row.

- `int getType() throws SQLException`

  Returns an `int` value for the result set type used for the query (either `ResultSet.TYPE_FORWARD_ONLY`, `ResultSet.TYPE_SCROLL_SENSITIVE`, or `ResultSet.TYPE_SCROLL_INSENSITIVE`).

- `void insertRow() throws SQLException`

  Write a result set `INSERT` operation to the database. Call this after calling `updateXXX()` methods to set the data values.

- `boolean isAfterLast() throws SQLException`

  Returns `true` if the position is after the last row.

- `boolean isBeforeFirst() throws SQLException`

  Returns `true` if the position is before the first row.

- `boolean isFirst() throws SQLException`

  Returns `true` if the position is at the first row.

- `boolean isLast() throws SQLException`

Returns `true` if the position is at the last row.

- `boolean last() throws SQLException`

  Move to the last row in the result set.

- `void moveToCurrentRow() throws SQLException`

  Move from the insert-row staging area back to what had been the current row prior to the `moveToInsertRow()` call.

- `void moveToInsertRow() throws SQLException`

  Move to the insert-row staging area to set up a row to be inserted.

- `boolean next() throws SQLException`

  Iterate forward through the result set.

- `boolean previous() throws SQLException`

  Iterate backward through the result set.

- `void refreshRow() throws SQLException`

  Refetch the database rows corresponding to the current window in the result set, to update the data. This method is called implicitly for scroll-sensitive result sets.

- `boolean relative(int row) throws SQLException`

  Move to a relative row position, either forward or backward from the current row.

- `void setFetchSize(int rows) throws SQLException`

  Set the fetch size to determine how many rows are fetched in each database round trip when refetching (also available in statement objects).

- `void updateRow() throws SQLException`

  Write an `UPDATE` operation to the database after using `updateXXX()` methods to update the data values.

- `void updateXXX() throws SQLException`

  Set or update data values in a row to be updated or inserted. There is an `updateXXX()` method for each datatype. After calling all the appropriate `updateXXX()` methods for the columns to be updated or inserted, call `updateRow()` for an `UPDATE` operation or `insertRow()` for an `INSERT` operation.

Statement Methods

Following is an alphabetical summary of statement methods for JDBC 2.0 result set enhancements. These methods are available in generic statement, prepared statement, and callable statement objects.

- `int getFetchSize() throws SQLException`

  Check the fetch size to determine how many rows are fetched in each database round trip when executing a query (also available in result set objects).

- `void setFetchSize(int rows) throws SQLException`

  Set the fetch size to determine how many rows are fetched in each database round trip when executing a query (also available in result set objects).

- `void setResultSetCache(OracleResultSetCache cache) throws SQLException`

  Use your own client-side cache implementation for scrollable result sets. Create your own class that implements the `OracleResultSetCache` interface, then use the `setResultSetCache()` method to input an instance of this class to the statement object that will create the result set.

- `int getResultSetType() throws SQLException`

  Check the result set type of result sets produced by this statement object (which was specified when the statement object was created).

- `int getResultSetConcurrency() throws SQLException`

  Check the concurrency type of result sets produced by this statement object (which was specified when the statement object was created).

Database Meta Data Methods

Following is an alphabetical summary of database meta data methods for JDBC 2.0 result set enhancements.

- `boolean ownDeletesAreVisible(int) throws SQLException`

  Returns `true` if, in this JDBC implementation, the specified result set type can see the effect of its own internal `DELETE` operations.

- `boolean ownUpdatesAreVisible(int) throws SQLException`

  Returns `true` if, in this JDBC implementation, the specified result set type can see the effect of its own internal `UPDATE` operations.

- `boolean ownInsertsAreVisible(int) throws SQLException`

  Returns `true` if, in this JDBC implementation, the specified result set type can see the effect of its own internal `INSERT` operations.

- `boolean othersDeletesAreVisible(int) throws SQLException`

  Returns `true` if, in this JDBC implementation, the specified result set type can see the effect of an external `DELETE` operation in the database.

- `boolean othersUpdatesAreVisible(int) throws SQLException`

  Returns `true` if, in this JDBC implementation, the specified result set type can see the effect of an external `UPDATE` operation in the database.

- `boolean othersInsertsAreVisible(int) throws SQLException`

  Returns `true` if, in this JDBC implementation, the specified result set type can see the effect of an external `INSERT` operation in the database.

- `boolean deletesAreDetected(int) throws SQLException`

  Returns `true` if, in this JDBC implementation, the specified result set type can detect when an external `DELETE` operation occurs in the database. This method always returns `false` in Oracle8*i* release 8.1.6 and higher.

- `boolean updatesAreDetected(int) throws SQLException`

  Returns `true` if, in this JDBC implementation, the specified result set type can detect when an external `UPDATE` operation occurs in the database. This method always returns `false` in Oracle8*i* release 8.1.6 and higher.

- `boolean insertsAreDetected(int) throws SQLException`

  Returns `true` if, in this JDBC implementation, the specified result set type can detect when an external `INSERT` operation occurs in the database. This method always returns `false` in Oracle8*i* release 8.1.6 and higher.

14

Distributed Transactions

This chapter discusses the Oracle JDBC implementation of distributed transactions. These are multi-phased transactions, often using multiple databases, that must be committed in a coordinated way. There is also related discussion of XA, which is a general standard (not specific to Java) for distributed transactions.

The following topics are discussed:

- Overview
- XA Components
- Error Handling and Optimizations
- Implementing a Distributed Transaction

> **Note:** This chapter discusses features of the JDBC 2.0 Optional Package, formerly known as the JDBC 2.0 Standard Extension API, which is available through the `javax` packages from Sun Microsystems. The Optional Package is not part of the standard JDK, but relevant packages are included with the Oracle JDBC `classes111.zip` and `classes12.zip` files.

For further introductory and general information about distributed transactions, refer to the Sun Microsystems specifications for the JDBC 2.0 Optional Package and the Java Transaction API (JTA).

For information on the OCI-specific HeteroRM XA feature, see "OCI HeteroRM XA" on page 16-19.

Overview

A *distributed transaction*, sometimes referred to as a *global transaction*, is a set of two or more related transactions that must be managed in a coordinated way. The transactions that constitute a distributed transaction might be in the same database, but more typically are in different databases and often in different locations. Each individual transaction of a distributed transaction is referred to as a *transaction branch*.

For example, a distributed transaction might consist of money being transferred from an account in one bank to an account in another bank. You would not want either transaction committed without assurance that both will complete successfully.

In the JDBC 2.0 extension API, distributed transaction functionality is built on top of connection pooling functionality, described under "Connection Pooling" on page 15-11. This distributed transaction functionality is also built upon the open XA standard for distributed transactions. (XA is part of the X/Open standard and is not specific to Java.)

JDBC is used to connect to database resources. However, to include all changes to multiple databases within a transaction, you must use the JDBC connections within a JTA global transaction. The process of including database SQL updates within a transaction is referred to as enlisting a database resource.

The remainder of this overview covers the following topics:

- Distributed Transaction Components and Scenarios
- Distributed Transaction Concepts
- Switching Between Global and Local Transactions
- Oracle XA Packages

For further introductory and general information about distributed transactions and XA, refer to the Sun Microsystems specifications for the JDBC 2.0 Optional Package and the Java Transaction API.

Note: Distributed transaction (XA) features require Oracle8*i* 8.1.6 or later.

Distributed Transaction Components and Scenarios

In reading the remainder of the distributed transactions section, it will be helpful to keep the following points in mind:

- A distributed transaction system typically relies on an external *transaction manager*—such as a software component that implements standard Java Transaction API functionality—to coordinate the individual transactions.

  Many vendors will offer XA-compliant JTA modules. This includes Oracle, which is developing a JTA module based on the Oracle implementation of XA discussed below.

- XA functionality is usually isolated from a client application, being implemented instead in a middle-tier environment such as an application server.

  In many scenarios, the application server and transaction manager will be together on the middle tier, possibly together with some of the application code as well.

- Discussion throughout this section is intended mostly for middle-tier developers.

- The term *resource manager* is often used in discussing distributed transactions. A resource manager is simply an entity that manages data or some other kind of resource. Wherever the term is used in this chapter, it refers to a database.

Note: Using JTA functionality requires file `jta.jar` to be in the `CLASSPATH`. (This file is located at `$ORACLE_HOME/jlib`.) Oracle includes this file with the JDBC product. (You can also obtain it from the Sun Microsystems Web site, but it is advisable to use the version from Oracle, because that has been tested with the Oracle drivers.)

Distributed Transaction Concepts

When you use XA functionality, the transaction manager uses *XA resource* instances to prepare and coordinate each transaction branch and then to commit or roll back all transaction branches appropriately.

XA functionality includes the following key components:

- XA data sources—These are extensions of connection pool data sources and other data sources, and similar in concept and functionality.

There will be one XA data source instance for each resource manager (database) that will be used in the distributed transaction. You will typically create XA data source instances (using the class constructor) in your middle-tier software.

XA data sources produce XA connections.

- XA connections—These are extensions of pooled connections, and similar in concept and functionality. An XA connection encapsulates a physical database connection; individual connection instances are temporary handles to these physical connections.

  An XA connection instance corresponds to a single Oracle session, although the session can be used in sequence by multiple logical connection instances (one at a time), as with pooled connection instances.

  You will typically get an XA connection instance from an XA data source instance (using a `get` method) in your middle-tier software. You can get multiple XA connection instances from a single XA data source instance if the distributed transaction will involve multiple sessions (multiple physical connections) in the same database.

  XA connections produce XA resource instances and JDBC connection instances.

- XA resources—These are used by a transaction manager in coordinating the transaction branches of a distributed transaction.

  You will get one XA resource instance from each XA connection instance (using a `get` method), typically in your middle-tier software. There is a one-to-one correlation between XA resource instances and XA connection instances; equivalently, there is a one-to-one correlation between XA resource instances and Oracle sessions (physical connections).

  In a typical scenario, the middle-tier component will hand off XA resource instances to the transaction manager, for use in coordinating distributed transactions.

  Because each XA resource instance corresponds to a single Oracle session, there can be only a single active transaction branch associated with an XA resource instance at any given time. There can be additional suspended transaction branches, however—see "XA Resource Method Functionality and Input Parameters" on page 14-11.

  Each XA resource instance has the functionality to start, end, prepare, commit, or roll back the operations of the transaction branch running in the session with which the XA resource instance is associated.

The "prepare" step is the first step of a two-phase `COMMIT` operation. The transaction manager will issue a `prepare` to each XA resource instance. Once the transaction manager sees that the operations of each transaction branch have prepared successfully (essentially, that the databases can be accessed without error), it will issue a `COMMIT` to each XA resource instance to commit all the changes.

- Transaction IDs—These are used to identify transaction branches. Each ID includes a transaction branch ID component and a distributed transaction ID component—this is how a branch is associated with a distributed transaction. All XA resource instances associated with a given distributed transaction would have a transaction ID that includes the same distributed transaction ID component.

Switching Between Global and Local Transactions

As of JDBC 3.0, applications can switch connections between local transactions and global transactions.

A connection is always in one of three modes: `NO_TXN`, `LOCAL_TXN`, or `GLOBAL_TXN`.

- **`NO_TXN`** —no transaction is actively using this connection.
- **`LOCAL_TXN`**—a local transaction with auto-commit turned off or disabled is actively using this connection.
- **`GLOBAL_TXN`**—a global transaction is actively using this connection.

Each connection switches automatically between these modes depending on the operations executed on the connection. A connection is always in `NO_TXN` mode when it is instantiated.

Table 14–1 Connection Mode Transitions

Current Mode	Switches To NO_TXN When	Switches to LOCAL_TXN When	Switches To GLOBAL_TXN When
NO_TXN		Auto-commit mode is false and an Oracle DML (SELECT, INSERT, UPDATE) statement is executed	`start()` is invoked on an `XAResource` obtained from the `XAconnection` that provided this connection
LOCAL_TXN	Any of the following happens: An Oracle DDL statement (CREATE, DROP, RENAME, ALTER) is executed. `commit()` is invoked. `rollback()` is invoked (parameterless version only).		**NEVER**
GLOBAL_TXN	Within a global transaction open on this connection, `end()` is invoked on an `XAResource` obtained from the `XAconnection` that provided this connection.	**NEVER**	

If none of the rules above is applicable, the mode does not change.

Mode Restrictions On Operations

The current connection mode restricts which operations are valid within a transaction.

- In LOCAL_TXN mode, applications must not invoke `prepare()`, `commit()`, `rollback()`, `forget()`, or `end()` on an `XAResource`. Doing so causes an `XAException` to be thrown.
- In GLOBAL_TXN mode, applications must not invoke `commit()`, `rollback()` (both versions), `setAutoCommit()`, or `setSavepoint() on a java.sql.Connection`, and must not invoke `OracleSetSavepoint()` or

`oracleRollback()` on an `oracle.jdbc.OracleConnection`. Doing so causes an `SQLException` to be thrown.

Note: This mode-restriction error checking is in addition to the standard error checking on the transaction and savepoint APIs, documented in this chapter and in "Transaction Savepoints" on page 5-5.

Oracle XA Packages

Oracle supplies the following three packages that have classes to implement distributed transaction functionality according to the XA standard:

- `oracle.jdbc.xa` (`OracleXid` and `OracleXAException` classes)
- `oracle.jdbc.xa.client`
- `oracle.jdbc.xa.server`

Classes for XA data sources, XA connections, and XA resources are in both the `client` package and the `server` package. (An abstract class for each is in the top-level package.) The `OracleXid` and `OracleXAException` classes are in the top-level `oracle.jdbc.xa` package, because their functionality does not depend on where the code is running.

In middle-tier scenarios, you will import `OracleXid`, `OracleXAException`, and the `oracle.jdbc.xa.client` package.

If you intend your XA code to run in the target Oracle database, however, you will import the `oracle.jdbc.xa.server` package instead of the `client` package.

If code that will run inside a target database must also access remote databases, then do not import either package—instead, you must fully qualify the names of any classes that you use from the `client` package (to access a remote database) or from the `server` package (to access the local database). Class names are duplicated between these packages.

XA Components

This section discusses the XA components—standard XA interfaces specified in the JDBC 2.0 Optional Package, and the Oracle classes that implement them. The following topics are covered:

- XA Data Source Interface and Oracle Implementation
- XA Connection Interface and Oracle Implementation
- XA Resource Interface and Oracle Implementation
- XA Resource Method Functionality and Input Parameters
- XA ID Interface and Oracle Implementation

XA Data Source Interface and Oracle Implementation

The `javax.sql.XADataSource` interface outlines standard functionality of XA data sources, which are factories for XA connections. The overloaded `getXAConnection()` method returns an XA connection instance and optionally takes a user name and password as input:

```
public interface XADataSource
{
   XAConnection getXAConnection() throws SQLException;
   XAConnection getXAConnection(String user, String password)
      throws SQLException;
   ...
}
```

Oracle JDBC implements the `XADataSource` interface with the `OracleXADataSource` class, located both in the `oracle.jdbc.xa.client` package and the `oracle.jdbc.xa.server` package.

The `OracleXADataSource` classes also extend the `OracleConnectionPoolDataSource` class (which extends the `OracleDataSource` class), so include all the connection properties described in "Data Source Properties" on page 15-4.

The `OracleXADataSource` class `getXAConnection()` methods return the Oracle implementation of XA connection instances, which are `OracleXAConnection` instances (as the next section discusses).

Note: You can register XA data sources in JNDI using the same naming conventions as discussed previously for non-pooling data sources in "Register the Data Source" on page 15-9.

XA Connection Interface and Oracle Implementation

An XA connection instance, as with a pooled connection instance, encapsulates a physical connection to a database. This would be the database specified in the connection properties of the XA data source instance that produced the XA connection instance.

Each XA connection instance also has the facility to produce the XA resource instance that will correspond to it for use in coordinating the distributed transaction.

An XA connection instance is an instance of a class that implements the standard `javax.sql.XAConnection` interface:

```
public interface XAConnection extends PooledConnection
{
   javax.jta.xa.XAResource getXAResource() throws SQLException;
}
```

As you see, the `XAConnection` interface extends the `javax.sql.PooledConnection` interface, so it also includes the `getConnection()`, `close()`, `addConnectionEventListener()`, and `removeConnectionEventListener()` methods listed in "Pooled Connection Interface and Oracle Implementation" on page 15-13.

Oracle JDBC implements the `XAConnection` interface with the `OracleXAConnection` class, located both in the `oracle.jdbc.xa.client package` and the `oracle.jdbc.xa.server` package.

The `OracleXAConnection` classes also extend the `OraclePooledConnection` class.

The `OracleXAConnection` class `getXAResource()` method returns the Oracle implementation of an XA resource instance, which is an `OracleXAResource` instance (as the next section discusses). The `getConnection()` method returns an `OracleConnection` instance.

A JDBC connection instance returned by an XA connection instance acts as a temporary handle to the physical connection, as opposed to encapsulating the

physical connection. The physical connection is encapsulated by the XA connection instance.

Each time an XA connection instance `getConnection()` method is called, it returns a new connection instance that exhibits the default behavior, and closes any previous connection instance that still exists and had been returned by the same XA connection instance. It is advisable to explicitly close any previous connection instance before opening a new one, however.

Calling the `close()` method of an XA connection instance closes the physical connection to the database. This is typically performed in the middle tier.

XA Resource Interface and Oracle Implementation

The transaction manager uses XA resource instances to coordinate all the transaction branches that constitute a distributed transaction.

Each XA resource instance provides the following key functionality, typically invoked by the transaction manager:

- It associates and disassociates distributed transactions with the transaction branch operating in the XA connection instance that produced this XA resource instance. (Essentially, associates distributed transactions with the physical connection or session encapsulated by the XA connection instance.) This is done through use of transaction IDs.
- It performs the two-phase `COMMIT` functionality of a distributed transaction to ensure that changes are not committed in one transaction branch before there is assurance that the changes will succeed in all transaction branches.

  "XA Resource Method Functionality and Input Parameters" on page 14-11 further discusses this.

Notes:

- Because there must always be a one-to-one correlation between XA connection instances and XA resource instances, an XA resource instance is implicitly closed when the associated XA connection instance is closed.
- If a transaction is opened by a given XA resource instance, it must also be closed by the same XA resource instance.

An XA resource instance is an instance of a class that implements the standard `javax.transaction.xa.XAResource` interface:

```
public interface XAResource
{
   void commit(Xid xid, boolean onePhase) throws XAException;
   void end(Xid xid, int flags) throws XAException;
   void forget(Xid xid) throws XAException;
   int prepare(Xid xid) throws XAException;
   Xid[] recover(int flag) throws XAException;
   void rollback(Xid xid) throws XAException;
   void start(Xid xid, int flags) throws XAException;
   boolean isSameRM(XAResource xares) throws XAException;
}
```

Oracle JDBC implements the `XAResource` interface with the `OracleXAResource` class, located both in the `oracle.jdbc.xa.client package` and the `oracle.jdbc.xa.server` package.

The Oracle JDBC driver creates and returns an `OracleXAResource` instance whenever the `OracleXAConnection` class `getXAResource()` method is called, and it is the Oracle JDBC driver that associates an XA resource instance with a connection instance and the transaction branch being executed through that connection.

This method is how an `OracleXAResource` instance is associated with a particular connection and with the transaction branch being executed in that connection.

XA Resource Method Functionality and Input Parameters

The `OracleXAResource` class has several methods to coordinate a transaction branch with the distributed transaction with which it is associated. This functionality usually involves two-phase `COMMIT` operations.

A transaction manager, receiving `OracleXAResource` instances from a middle-tier component such as an application server, typically invokes this functionality.

Each of these methods takes a transaction ID as input, in the form of an `Xid` instance, which includes a transaction branch ID component and a distributed transaction ID component. Every transaction branch has a unique transaction ID, but transaction branches belonging to the same global transaction have the same global transaction component as part of their transaction IDs.

"XA ID Interface and Oracle Implementation" on page 14-16 discusses the `OracleXid` class and the standard interface upon which it is based.

Following is a description of key XA resource functionality, the methods used, and additional input parameters. Each of these methods throws an XA exception if an error is encountered. See "XA Exception Classes and Methods" on page 14-18.

Start Start work on behalf of a transaction branch, associating the transaction branch with a distributed transaction.

```
void start(Xid xid, int flags)
```

The `flags` parameter must be one of the following values:

- `XAResource.TMNOFLAGS` (no special flag)—Flag the start of a new transaction branch for subsequent operations in the session associated with this XA resource instance. This branch will have the transaction ID `xid`, which is an `OracleXid` instance created by the transaction manager. This will map the transaction branch to the appropriate distributed transaction.
- `XAResource.TMJOIN`—Join subsequent operations in the session associated with this XA resource instance to the existing transaction branch specified by `xid`.
- `XAResource.TMRESUME`—Resume the transaction branch specified by `xid`. (It must first have been suspended.)
- `XAResource.ORATMSERIALIZABLE`—Start a serializable transaction with transaction ID `xid.`
- `XAResource.ORATMREADONLY`—Start a read-only transaction with transaction ID `xid.`
- `XAResource.ORATMREADWRITE`—Start a read / write transaction with transaction ID `xid.`

`TMNOFLAGS`, `TMJOIN`, `TMRESUME`, `ORATMSERIALIZABLE`, `ORATMREADONLY`, and `ORATMREADWRITE` are defined as static members of the `XAResource` interface and `OracleXAResource` class. `ORATMSERIALIZABLE`, `ORATMREADONLY`, and `ORATMREADWRITE` are the isolation-mode flags. The default isolation behavior is `READ COMMITTED`.

Notes:

- Instead of using the `start()` method with `TMRESUME`, the transaction manager can cast to an `OracleXAResource` instance and use the `resume(Xid xid)` method, an Oracle extension.
- If you use `TMRESUME`, you must also use `TMNOMIGRATE`, as in `end(xid, XAResource.TMRESUME | OracleXAResource.TMNOMIGRATE);`. This prevents the application's receiving the error `ORA 1002: fetch out of sequence.`
- If you use the isolation-mode flags incorrectly, an exception with code XAER_INVAL is raised. Furthermore, you cannot use isolation-mode flags when resuming a global transaction, because you cannot set the isolation level of an existing transaction. If you try to use the isolation-mode flags when resuming a transaction, an external Oracle exception with code ORA-24790 is raised.

Note that to create an appropriate transaction ID in starting a transaction branch, the transaction manager must know which distributed transaction the transaction branch should belong to. The mechanics of this are handled between the middle tier and transaction manager and are beyond the scope of this document. Refer to the Sun Microsystems specifications for the JDBC 2.0 Optional Package and the Java Transaction API.

End End work on behalf of the transaction branch specified by `xid`, disassociating the transaction branch from its distributed transaction.

```
void end(Xid xid, int flags)
```

The `flags` parameter can have one of the following values:

- `XAResource.TMSUCCESS`—This is to indicate that this transaction branch is known to have succeeded.
- `XAResource.TMFAIL`—This is to indicate that this transaction branch is known to have failed.
- `XAResource.TM`—This is to suspend the transaction branch specified by `xid`. (By suspending transaction branches, you can have multiple transaction branches in a single session. Only one can be active at any given time, however. Also, this tends to be more expensive in terms of resources than having two sessions.)

TMSUCCESS, TMFAIL, and TMSUSPEND are defined as static members of the XAResource interface and OracleXAResource class.

Notes:

- Instead of using the end() method with TMSUSPEND, the transaction manager can cast to an OracleXAResource instance and use the suspend(Xid xid) method, an Oracle extension.
- This XA functionality to suspend a transaction provides a way to switch between various transactions within a single JDBC connection. You can use the XA classes to accomplish this, even if you are not in a distributed transaction environment and would otherwise have no need for the XA classes.
- If you use TMSUSPEND, you must also use TMNOMIGRATE, as in end(xid, XAResource.TMSUSPEND | OracleXAResource.TMNOMIGRATE);. This prevents the application's receiving the error ORA 1002: fetch out of sequence.

Prepare Prepare the changes performed in the transaction branch specified by xid. This is the first phase of a two-phase COMMIT operation, to ensure that the database is accessible and that the changes can be committed successfully.

```
int prepare(Xid xid)
```

This method returns an integer value as follows:

- XAResource.XA_RDONLY—This is returned if the transaction branch executes only read-only operations such as SELECT statements.
- XAResource.XA_OK—This is returned if the transaction branch executes updates that are all prepared without error.
- n/a (no value returned)—No value is returned if the transaction branch executes updates and any of them encounter errors during preparation. In this case, an XA exception is thrown.

XA_RDONLY and XA_OK are defined as static members of the XAResource interface and OracleXAResource class.

Notes:

- Always call the `end()` method on a branch before calling the `prepare()` method.
- If there is only one transaction branch in a distributed transaction, then there is no need to call the `prepare()` method. You can call the XA resource `commit()` method without preparing first.

Commit Commit prepared changes in the transaction branch specified by `xid`. This is the second phase of a two-phase `COMMIT` and is performed only after all transaction branches have been successfully prepared.

```
void commit(Xid xid, boolean onePhase)
```

Set the `onePhase` parameter as follows:

- `true`—This is to use one-phase instead of two-phase protocol in committing the transaction branch. This is appropriate if there is only one transaction branch in the distributed transaction; the `prepare` step would be skipped.
- `false`—This is to use two-phase protocol in committing the transaction branch (typical).

Roll back Rolls back prepared changes in the transaction branch specified by `xid`.

```
void rollback(Xid xid)
```

Forget Tells the resource manager to forget about a heuristically completed transaction branch.

```
public void forget(Xid xid)
```

Recover The transaction manager calls this method during recovery to obtain the list of transaction branches that are currently in prepared or heuristically completed states.

```
public Xid[] recover(int flag)
```

Note: The `flag` parameter is ignored and therefore not implemented for Oracle8*i* 8.1.7 since the `scan` option (flag parameter) is not meaningful without a `count` parameter. See the Sun Microsystems *Java Transaction API (JTA)* Specification for more detail.

The resource manager returns zero or more `Xid`s for the transaction branches that are currently in a prepared or heuristically completed state. If an error occurs during the operation, the resource manager throws the appropriate `XAException`.

Check for same RM To determine if two XA resource instances correspond to the same resource manager (database), call the `isSameRM()` method from one XA resource instance, specifying the other XA resource instance as input. In the following example, presume `xares1` and `xares2` are `OracleXAResource` instances:

```
boolean sameRM = xares1.isSameRM(xares2);
```

A transaction manager can use this method regarding certain Oracle optimizations, as "Oracle XA Optimizations" on page 14-20 explains.

XA ID Interface and Oracle Implementation

The transaction manager creates transaction ID instances and uses them in coordinating the branches of a distributed transaction. Each transaction branch is assigned a unique transaction ID, which includes the following information:

- format identifier (4 bytes)

  A format identifier specifies a Java transaction manager—for example, there could be a format identifier `ORCL`. This field *cannot* be null.

- global transaction identifier (64 bytes) (or "distributed transaction ID component", as discussed earlier)
- branch qualifier (64 bytes) (or "transaction branch ID component", as discussed earlier)

The 64-byte global transaction identifier value will be identical in the transaction IDs of all transaction branches belonging to the same distributed transaction. The overall transaction ID, however, is unique for every transaction branch.

An XA transaction ID instance is an instance of a class that implements the standard `javax.transaction.xa.Xid` interface, which is a Java mapping of the X/Open transaction identifier XID structure.

Oracle implements this interface with the `OracleXid` class in the `oracle.jdbc.xa` package. `OracleXid` instances are employed only in a transaction manager, transparent to application programs or an application server.

Note: Oracle8*i* 8.1.7 does not require the use of `OracleXid` for Oracle XA resource calls. Instead, use any class that implements `javax.transaction.xa.Xid` interface.

A transaction manager may use the following in creating an `OracleXid` instance:

```
public OracleXid(int fId, byte gId[], byte bId[]) throws XAException
```

Where `fId` is an integer value for the format identifier, `gId[]` is a byte array for the global transaction identifier, and `bId[]` is a byte array for the branch qualifier.

The `Xid` interface specifies the following getter methods:

- `public int getFormatId()`
- `public byte[] getGlobalTransactionId()`
- `public type[] getBranchQualifier()`

Error Handling and Optimizations

This section has two focuses: 1) the functionality of XA exceptions and error handling; and 2) Oracle optimizations in its XA implementation. The following topics are covered:

- XA Exception Classes and Methods
- Mapping between Oracle Errors and XA Errors
- XA Error Handling
- Oracle XA Optimizations

The exception and error-handling discussion includes the standard XA exception class and the Oracle-specific XA exception class, as well as particular XA error codes and error-handling techniques.

XA Exception Classes and Methods

XA methods throw XA exceptions, as opposed to general exceptions or SQL exceptions. An XA exception is an instance of the standard class `javax.transaction.xa.XAException` or a subclass. Oracle subclasses `XAException` with the `oracle.jdbc.xa.OracleXAException` class.

An `OracleXAException` instance consists of an Oracle error portion and an XA error portion and is constructed as follows by the Oracle JDBC driver:

```
public OracleXAException()
```

or:

```
public OracleXAException(int error)
```

The error value is an error code that combines an Oracle SQL error value and an XA error value. (The JDBC driver determines exactly how to combine the Oracle and XA error values.)

The `OracleXAException` class has the following methods:

- `public int getOracleError()`

  This method returns the Oracle SQL error code pertaining to the exception—a standard ORA error number (or 0 if there is no Oracle SQL error).

- `public int getXAError()`

This method returns the XA error code pertaining to the exception. XA error values are defined in the `javax.transaction.xa.XAException` class; refer to its Javadoc at the Sun Microsystems Web site for more information.

Mapping between Oracle Errors and XA Errors

Oracle errors correspond to XA errors in `OracleXAException` instances as documented in Table 14–2.

Table 14–2 Oracle-XA Error Mapping

Oracle Error Code	XA Error Code
ORA 3113	XAException.XAER_RMFAIL
ORA 3114	XAException.XAER_RMFAIL
ORA 24756	XAException.XAER_NOTA
ORA 24764	XAException.XA_HEURCOM
ORA 24765	XAException.XA_HEURRB
ORA 24766	XAException.XA_HEURMIX
ORA 24767	XAException.XA_RDONLY
ORA 25351	XAException.XA_RETRY
all other ORA errors	XAException.XAER_RMERR

XA Error Handling

The following example uses the `OracleXAException` class to process an XA exception:

```
try {
   ...
   ...Perform XA operations...
   ...
} catch(OracleXAException oxae) {
  int oraerr = oxae.getOracleError();
  System.out.println("Error " + oraerr);
}
  catch(XAException xae)
{...Process generic XA exception...}
```

In case the XA operations did not throw an Oracle-specific XA exception, the code drops through to process a generic XA exception.

Oracle XA Optimizations

Oracle JDBC has functionality to improve performance if two or more branches of a distributed transaction use the same database instance—meaning that the XA resource instances associated with these branches are associated with the same resource manager.

In such a circumstance, the `prepare()` method of only one of these XA resource instances will return `XA_OK` (or failure); the rest will return `XA_RDONLY`, even if updates are made. This allows the transaction manager to implicitly join all the transaction branches and commit (or roll back, if failure) the joined transaction through the XA resource instance that returned `XA_OK` (or failure).

The transaction manager can use the `OracleXAResource` class `isSameRM()` method to determine if two XA resource instances are using the same resource manager. This way it can interpret the meaning of `XA_RDONLY` return values.

Implementing a Distributed Transaction

This section provides an example of how to implement a distributed transaction using Oracle XA functionality.

Summary of Imports for Oracle XA

You must import the following for Oracle XA functionality:

```
import oracle.jdbc.xa.OracleXid;
import oracle.jdbc.xa.OracleXAException;
import oracle.jdbc.pool.*;
import oracle.jdbc.xa.client.*;
import javax.transaction.xa.*;
```

The `oracle.jdbc.pool` package has classes for connection pooling functionality, some of which are subclassed by XA-related classes.

In addition, if the code will run inside an Oracle database and access that database for SQL operations, you must import the following:

```
import oracle.jdbc.xa.server.*;
```

(And if you intend to access *only* the database in which the code runs, you would not need the `oracle.jdbc.xa.client` classes.)

The `client` and `server` packages each have versions of the `OracleXADataSource`, `OracleXAConnection`, and `OracleXAResource` classes. Abstract versions of these three classes are in the top-level `oracle.jdbc.xa` package.

Oracle XA Code Sample

This example uses a two-phase distributed transaction with two transaction branches, each to a separate database.

Note that for simplicity, this example combines code that would typically be in a middle tier with code that would typically be in a transaction manager (such as the XA resource method invocations and the creation of transaction IDs).

For brevity, the specifics of creating transaction IDs (in the `createID()` method) and performing SQL operations (in the `doSomeWork1()` and `doSomeWork2()` methods) are not shown here. The complete example is shipped with the product.

This example executes the following sequence:

1. Start transaction branch #1.
2. Start transaction branch #2.
3. Execute DML operations on branch #1.
4. Execute DML operations on branch #2.
5. End transaction branch #1.
6. End transaction branch #2.
7. Prepare branch #1.
8. Prepare branch #2.
9. Commit branch #1.
10. Commit branch #2.

```
// You need to import the java.sql package to use JDBC
import java.sql.*;
import javax.sql.*;
import oracle.jdbc.*;
import oracle.jdbc.pool.*;
import oracle.jdbc.xa.OracleXid;
import oracle.jdbc.xa.OracleXAException;
import oracle.jdbc.xa.client.*;
import javax.transaction.xa.*;

class XA4
{
  public static void main (String args [])
       throws SQLException
  {

    try
    {
        String URL1 = "jdbc:oracle:oci:@";
        String URL2 ="jdbc:oracle:thin:@(description=(address=(host=dlsun991)
                     (protocol=tcp)(port=5521))(connect_data=(sid=rdbms2)))";

        DriverManager.registerDriver(new OracleDriver());

        // You can put a database name after the @ sign in the connection URL.
        Connection conna =
          DriverManager.getConnection (URL1, "scott", "tiger");

        // Prepare a statement to create the table
```

```
Statement stmta = conna.createStatement ();

Connection connb =
  DriverManager.getConnection (URL2, "scott", "tiger");

// Prepare a statement to create the table
Statement stmtb = connb.createStatement ();

try
{
  // Drop the test table
  stmta.execute ("drop table my_table");
}
catch (SQLException e)
{
  // Ignore an error here
}

try
{
  // Create a test table
  stmta.execute ("create table my_table (col1 int)");
}
catch (SQLException e)
{
  // Ignore an error here too
}

try
{
  // Drop the test table
  stmtb.execute ("drop table my_tab");
}
catch (SQLException e)
{
  // Ignore an error here
}

try
{
  // Create a test table
  stmtb.execute ("create table my_tab (col1 char(30))");
}
catch (SQLException e)
{
```

```
  // Ignore an error here too
}

// Create XADataSource instances and set properties.
OracleXADataSource oxds1 = new OracleXADataSource();
oxds1.setURL("jdbc:oracle:oci:@");
oxds1.setUser("scott");
oxds1.setPassword("tiger");

OracleXADataSource oxds2 = new OracleXADataSource();

oxds2.setURL("jdbc:oracle:thin:@(description=(address=(host=dlsun991)
           (protocol=tcp)(port=5521))(connect_data=(sid=rdbms2)))");
oxds2.setUser("scott");
oxds2.setPassword("tiger");

// Get XA connections to the underlying data sources
XAConnection pc1  = oxds1.getXAConnection();
XAConnection pc2  = oxds2.getXAConnection();

// Get the physical connections
Connection conn1 = pc1.getConnection();
Connection conn2 = pc2.getConnection();

// Get the XA resources
XAResource oxar1 = pc1.getXAResource();
XAResource oxar2 = pc2.getXAResource();

// Create the Xids With the Same Global Ids
Xid xid1 = createXid(1);
Xid xid2 = createXid(2);

// Start the Resources
oxar1.start (xid1, XAResource.TMNOFLAGS);
oxar2.start (xid2, XAResource.TMNOFLAGS);

// Execute SQL operations with conn1 and conn2
doSomeWork1 (conn1);
doSomeWork2 (conn2);

// END both the branches -- IMPORTANT
oxar1.end(xid1, XAResource.TMSUCCESS);
oxar2.end(xid2, XAResource.TMSUCCESS);

// Prepare the RMs
```

```
int prp1 =  oxar1.prepare (xid1);
int prp2 =  oxar2.prepare (xid2);

System.out.println("Return value of prepare 1 is " + prp1);
System.out.println("Return value of prepare 2 is " + prp2);

boolean do_commit = true;

if (!((prp1 == XAResource.XA_OK) || (prp1 == XAResource.XA_RDONLY)))
   do_commit = false;

if (!((prp2 == XAResource.XA_OK) || (prp2 == XAResource.XA_RDONLY)))
   do_commit = false;

System.out.println("do_commit is " + do_commit);
System.out.println("Is oxar1 same as oxar2 ? " + oxar1.isSameRM(oxar2));

if (prp1 == XAResource.XA_OK)
  if (do_commit)
     oxar1.commit (xid1, false);
  else
     oxar1.rollback (xid1);

if (prp2 == XAResource.XA_OK)
  if (do_commit)
     oxar2.commit (xid2, false);
  else
     oxar2.rollback (xid2);

 // Close connections
conn1.close();
conn1 = null;
conn2.close();
conn2 = null;

pc1.close();
pc1 = null;
pc2.close();
pc2 = null;

ResultSet rset = stmta.executeQuery ("select col1 from my_table");
while (rset.next())
  System.out.println("Col1 is " + rset.getInt(1));

rset.close();
```

```
            rset = null;

            rset = stmtb.executeQuery ("select col1 from my_tab");
            while (rset.next())
              System.out.println("Col1 is " + rset.getString(1));

            rset.close();
            rset = null;

            stmta.close();
            stmta = null;
            stmtb.close();
            stmtb = null;

            conna.close();
            conna = null;
            connb.close();
            connb = null;

        } catch (SQLException sqe)
        {
          sqe.printStackTrace();
        } catch (XAException xae)
        {
          if (xae instanceof OracleXAException) {
            System.out.println("XA Error is " +
                        ((OracleXAException)xae).getXAError());
            System.out.println("SQL Error is " +
                        ((OracleXAException)xae).getOracleError());
          }
        }
      }

      static Xid createXid(int bids)
        throws XAException
      {...Create transaction IDs...}

      private static void doSomeWork1 (Connection conn)
       throws SQLException
      {...Execute SQL operations...}

      private static void doSomeWork2 (Connection conn)
       throws SQLException
      {...Execute SQL operations...}
    }
```

15

Connection Pooling and Caching

This chapter covers the Oracle JDBC implementations of (1) data sources, a standard facility for specifying resources to use, including databases; (2) connection pooling, which is a framework for caches of database connections; and (3) connection caching, including documentation of a sample Oracle implementation. You will also find related discussion of Oracle JDBC support for the standard Java Naming and Directory Interface (JNDI).

The following topics, which apply to all Oracle JDBC drivers, are described in this chapter:

- Data Sources
- Connection Pooling
- Connection Caching

> **Notes:** This chapter describes features of the Sun Microsystems JDBC 2.0 Standard Extension API, which are available through the `javax` packages from Sun Microsystems. These packages are not part of the standard JDK, but relevant packages are included with the `classes111.zip` and `classes12.zip` files.

For further information on listed topics, refer to the Sun Microsystems specification for the JDBC 2.0 Standard Extension API. For information about additional connection pooling functionality specific to the OCI driver, see "OCI Driver Connection Pooling" on page 16-2.

Data Sources

The JDBC 2.0 extension API introduced the concept of *data sources*, which are standard, general-use objects for specifying databases or other resources to use. Data sources can optionally be bound to Java Naming and Directory Interface (JNDI) entities so that you can access databases by logical names, for convenience and portability.

This functionality is a more standard and versatile alternative to the connection functionality described under "Opening a Connection to a Database" on page 3-3. The data source facility provides a complete replacement for the previous JDBC `DriverManager` facility.

You can use both facilities in the same application, but ultimately developers will be encouraged to use data sources for their connections, regardless of whether connection pooling or distributed transactions are required. Eventually, Sun Microsystems will probably deprecate `DriverManager` and related classes and functionality.

For further introductory and general information about data sources and JNDI, refer to the Sun Microsystems specification for the JDBC 2.0 Optional Package.

A Brief Overview of Oracle Data Source Support for JNDI

The standard Java Naming and Directory Interface, or JNDI, provides a way for applications to find and access remote services and resources. These services can be any enterprise services, but for a JDBC application would include database connections and services.

JNDI allows an application to use logical names in accessing these services, removing vendor-specific syntax from application code. JNDI has the functionality to associate a logical name with a particular source for a desired service.

All Oracle JDBC data sources are JNDI-referenceable. The developer is not required to use this functionality, but accessing databases through JNDI logical names makes the code more portable.

Note: Using JNDI functionality requires the file `jndi.jar` to be in the `CLASSPATH`. This file is included with the Java products on the Oracle9*i* CD, but is not included in the `classes12.zip` and `classes111.zip` files. You must add it to the `CLASSPATH` separately. (You can also obtain it from the Sun Microsystems Web site, but it is advisable to use the version from Oracle, because that has been tested with the Oracle drivers.)

Data Source Features and Properties

"First Steps in JDBC" on page 3-2 includes sections on how to use the JDBC `DriverManager` class to register driver classes and open database connections. The problem with this model is that it requires your code to include vendor-specific class names, database URLs, and possibly other properties, such as machine names and port numbers.

With data source functionality, using JNDI, you do not need to register the vendor-specific JDBC driver class name, and you can use logical names for URLs and other properties. This allows your application code for opening database connections to be portable to other environments.

Data Source Interface and Oracle Implementation

A JDBC data source is an instance of a class that implements the standard `javax.sql.DataSource` interface:

```
public interface DataSource
{
   Connection getConnection() throws SQLException;
   Connection getConnection(String username, String password)
      throws SQLException;
   ...
}
```

Oracle implements this interface with the `OracleDataSource` class in the `oracle.jdbc.pool` package. The overloaded `getConnection()` method returns an `OracleConnection` instance, optionally taking a user name and password as input.

To use other values, you can set properties using appropriate setter methods discussed in the next section. For alternative user names and passwords, you can also use the `getConnection()` signature that takes these as input—this would take priority over the property settings.

Note: The `OracleDataSource` class and all subclasses implement the `java.io.Serializable` and `javax.naming.Referenceable` interfaces.

Data Source Properties

The `OracleDataSource` class, as with any class that implements the `DataSource` interface, provides a set of properties that can be used to specify a database to connect to. These properties follow the JavaBeans design pattern.

Table 15–1 and Table 15–2 document `OracleDataSource` properties. The properties in Table 15–1 are standard properties according to the Sun Microsystems specification. (Be aware, however, that Oracle does not implement the standard `roleName` property.) The properties in Table 15–2 are Oracle extensions.

Table 15–1 Standard Data Source Properties

Name	Type	Description
`databaseName`	`String`	name of the particular database on the server; also known as the "SID" in Oracle terminology
`dataSourceName`	`String`	name of the underlying data source class (for connection pooling, this is an underlying pooled connection data source class; for distributed transactions, this is an underlying XA data source class)
`description`	`String`	description of the data source
`networkProtocol`	`String`	network protocol for communicating with the server; for Oracle, this applies only to the OCI drivers and defaults to `tcp` (Other possible settings include `ipc`. See the *Oracle Net Services Administrator's Guide* for more information.)
`password`	`String`	login password for the user name
`portNumber`	`int`	number of the port where the server listens for requests
`serverName`	`String`	name of the database server
`user`	`String`	name for the login account

The `OracleDataSource` class implements the following setter and getter methods for the standard properties:

- `public synchronized void setDatabaseName(String dbname)`
- `public synchronized String getDatabaseName()`
- `public synchronized void setDataSourceName(String dsname)`
- `public synchronized String getDataSourceName()`
- `public synchronized void setDescription(String desc)`
- `public synchronized String getDescription()`
- `public synchronized void setNetworkProtocol(String np)`
- `public synchronized String getNetworkProtocol()`
- `public synchronized void setPassword(String pwd)`
- `public synchronized void setPortNumber(int pn)`
- `public synchronized int getPortNumber()`
- `public synchronized void setServerName(String sn)`
- `public synchronized String getServerName()`
- `public synchronized void setUser(String user)`
- `public synchronized String getUser()`

Note that there is no `getPassword()` method, for security reasons.

Table 15–2 Oracle Extended Data Source Properties

Name	Type	Description
driverType	String	This designates the Oracle JDBC driver type as either `oci`, `thin`, or `kprb` (server-side internal).
tnsEntry	String	This is the TNS entry name, relevant only for the OCI driver. It assumes an Oracle client installation with a `TNS_ADMIN` environment variable that is set appropriately. Enable this `OracleXADataSource` property when using the HeteroRM feature with the OCI driver, to access Oracle pre-8.1.6 databases and higher. The HeteroRM XA feature is described in "OCI HeteroRM XA" on page 16-19. If the tnsEntry property is not set when using the HeteroRM XA feature, an SQLException with error code ORA-17207 is thrown.
url	String	This is the URL of the database connect string. Provided as a convenience, it can help you migrate from an older Oracle database. You can use this property in place of the Oracle `tnsEntry` and `driverType` properties and the standard `portNumber`, `networkProtocol`, `serverName`, and `databaseName` properties.
nativeXA	boolean	Enable this `OracleXADataSource` property when using the HeteroRM feature with the OCI driver, to access Oracle pre-8.1.6 databases and higher. The HeteroRM XA feature is described in "OCI HeteroRM XA" on page 16-19. If the nativeXA property is enabled, be sure to set the tnsEntry property as well. This `DataSource` property defaults to `false`.

Note: Since nativeXA performs better than JavaXA, use nativeXA whenever possible.

The `OracleDataSource` class implements the following `setXXX()` and `getXXX()` methods for the Oracle extended properties:

- `public synchronized void setDriverType(String dt)`
- `public synchronized String getDriverType()`
- `public synchronized void setURL(String url)`
- `public synchronized String getURL()`

- `public synchronized void setTNSEntryName(String tns)`
- `public synchronized String getTNSEntryName()`
- `public synchronized void setNativeXA(boolean nativeXA)`
- `public synchronized boolean getNativeXA()`

If you are using the server-side internal driver—`driverType` property is set to `kprb`—then any other property settings are ignored.

If you are using a Thin or OCI driver, note the following:

- A URL setting can include settings for `user` and `password`, as in the following example, in which case this takes precedence over individual `user` and `password` property settings:

  ```
  jdbc:oracle:thin:scott/tiger@localhost:1521:orcl
  ```

- Settings for `user` and `password` are required, either directly, through the URL setting, or through the `getConnection()` call. The `user` and `password` settings in a `getConnection()` call take precedence over any property settings.
- If the `url` property is set, then any `tnsEntry`, `driverType`, `portNumber`, `networkProtocol`, `serverName`, and `databaseName` property settings are ignored.
- If the `tnsEntry` property is set (which presumes the `url` property is not set), then any `databaseName`, `serverName`, `portNumber`, and `networkProtocol` settings are ignored.
- If you are using an OCI driver (which presumes the `driverType` property is set to `oci`) and the `networkProtocol` is set to `ipc`, then any other property settings are ignored.

Creating a Data Source Instance and Connecting (without JNDI)

This section shows an example of the most basic use of a data source to connect to a database, without using JNDI functionality. Note that this requires vendor-specific, hard-coded property settings.

Create an `OracleDataSource` instance, initialize its connection properties as appropriate, and get a connection instance as in the following example:

```
...
OracleDataSource ods = new OracleDataSource();
```

```
ods.setDriverType("oci");
ods.setServerName("dlsun999");
ods.setNetworkProtocol("tcp");
ods.setDatabaseName("816");
ods.setPortNumber(1521);
ods.setUser("scott");
ods.setPassword("tiger");

Connection conn = ods.getConnection();
...
```

Or optionally override the user name and password:

```
...
Connection conn = ods.getConnection("bill", "lion");
...
```

Creating a Data Source Instance, Registering with JNDI, and Connecting

This section exhibits JNDI functionality in using data sources to connect to a database. Vendor-specific, hard-coded property settings are required only in the portion of code that binds a data source instance to a JNDI logical name. From that point onward, you can create portable code by using the logical name in creating data sources from which you will get your connection instances.

> **Note:** Creating and registering data sources is typically handled by a JNDI administrator, not in a JDBC application.

Initialize Connection Properties

Create an `OracleDataSource` instance, and then initialize its connection properties as appropriate, as in the following example:

```
...
OracleDataSource ods = new OracleDataSource();

ods.setDriverType("oci");
ods.setServerName("dlsun999");
ods.setNetworkProtocol("tcp");
ods.setDatabaseName("816");
ods.setPortNumber(1521);
```

```
ods.setUser("scott");
ods.setPassword("tiger");
...
```

Register the Data Source

Once you have initialized the connection properties of the `OracleDataSource` instance `ods`, as shown in the preceding example, you can register this data source instance with JNDI, as in the following example:

```
...
Context ctx = new InitialContext();
ctx.bind("jdbc/sampledb", ods);
...
```

Calling the JNDI `InitialContext()` constructor creates a Java object that references the initial JNDI naming context. System properties that are not shown instruct JNDI which service provider to use.

The `ctx.bind()` call binds the `OracleDataSource` instance to a logical JNDI name. This means that anytime after the `ctx.bind()` call, you can use the logical name `jdbc/sampledb` in opening a connection to the database described by the properties of the `OracleDataSource` instance `ods`. The logical name `jdbc/sampledb` is logically bound to this database.

The JNDI name space has a hierarchy similar to that of a file system. In this example, the JNDI name specifies the subcontext `jdbc` under the root naming context and specifies the logical name `sampledb` within the `jdbc` subcontext.

The `Context` interface and `InitialContext` class are in the standard `javax.naming` package.

Notes: The JDBC 2.0 Specification requires that all JDBC data sources be registered in the `jdbc` naming subcontext of a JNDI namespace or in a child subcontext of the `jdbc` subcontext.

Open a Connection

To perform a lookup and open a connection to the database logically bound to the JNDI name, use the logical JNDI name. Doing this requires casting the lookup result (which is otherwise simply a Java `Object`) to a new `OracleDataSource` instance and then using its `getConnection()` method to open the connection.

Here is an example:

```
...
OracleDataSource odsconn = (OracleDataSource)ctx.lookup("jdbc/sampledb");
Connection conn = odsconn.getConnection();
...
```

Logging and Tracing

The data source facility offers a way to register a character stream for JDBC to use as output for error logging and tracing information. This facility allows tracing specific to a particular data source instance. If you want all data source instances to use the same character stream, then you must register the stream with each data source instance individually.

The `OracleDataSource` class implements the following standard data source methods for logging and tracing:

- `public synchronized void setLogWriter(PrintWriter pw)`
- `public synchronized PrintWriter getLogWriter()`

The `PrintWriter` class is in the standard `java.io` package.

Notes:

- When a data source instance is created, logging is disabled by default (the log stream name is initially null).
- Messages written to a log stream registered to a data source instance are not written to the log stream normally maintained by `DriverManager`.
- An `OracleDataSource` instance obtained from a JNDI name lookup will not have its `PrinterWriter` set, even if the `PrintWriter` was set when a data source instance was first bound to this JNDI name.

Connection Pooling

Connection pooling in the JDBC 2.0 extension API is a framework for caching database connections. This allows reuse of physical connections and reduced overhead for your application. Connection pooling functionality minimizes expensive operations in the creation and closing of sessions.

The following are central concepts:

- *Connection pool data sources*—similar in concept and functionality to the data sources described previously, but with methods to return *pooled connection* instances, instead of normal connection instances.
- *Pooled connections*—a pooled connection instance represents a single physical connection to a database, remaining open during use by a series of *logical connection instances.*

  A logical connection instance is a simple connection instance (such as a standard `Connection` instance or an `OracleConnection` instance) returned by a pooled connection instance. Each logical connection instance acts as a temporary handle to the physical connection represented by the pooled connection instance.

For connection pooling information specific to OCI drivers, see "OCI Driver Connection Pooling" on page 16-2. For further introductory and general information about connection pooling, refer to the Sun Microsystems specification for the JDBC 2.0 Optional Package.

Note: The concept of connection pooling is not relevant to the server-side internal driver, where you are simply using the default connection, and is only relevant to the server-side Thin driver within a single session.

Connection Pooling Concepts

If you do not use connection pooling, each connection instance (`java.sql.Connection` or `oracle.jdbc.OracleConnection` instance) encapsulates its own physical database connection. When you call the `close()` method of the connection instance, the physical connection itself is closed. This is true whether you obtain the connection instance through the JDBC 2.0 data source facility described under "Data Sources" on page 15-2, or through the `DriverManager` facility described under "Opening a Connection to a Database" on page 3-3.

With connection pooling, an additional step allows physical database connections to be reused by multiple logical connection instances, which are temporary handles to the physical connection. Use a connection pool data source to return a pooled connection, which is what encapsulates the physical database connection. Then use the pooled connection to return JDBC connection instances (one at a time) that each act as a temporary handle.

Closing a connection instance that was obtained from a pooled connection does *not* close the physical database connection. It does, however, free the resources of the connection instance, clear the state, close statement objects created from the connection instance, and restore the defaults for the next connection instance that will be created.

To actually close the physical connection, you must invoke the `close()` method of the pooled connection. This would typically be performed in the middle tier.

Connection Pool Data Source Interface and Oracle Implementation

The `javax.sql.ConnectionPoolDataSource` interface outlines standard functionality of connection pool data sources, which are factories for pooled connections. The overloaded `getPooledConnection()` method returns a pooled connection instance and optionally takes a user name and password as input:

```
public interface ConnectionPoolDataSource
{
   PooledConnection getPooledConnection() throws SQLException;
   PooledConnection getPooledConnection(String user, String password)
      throws SQLException;
   ...
}
```

Oracle JDBC implements the `ConnectionPoolDataSource` interface with the `oracle.jdbc.pool.OracleConnectionPoolDataSource` class. This class also extends the `OracleDataSource` class, so it includes all the connection properties and getter and setter methods described in "Data Source Properties" on page 15-4.

The `OracleConnectionPoolDataSource` class `getPooledConnection()` methods return the Oracle implementation of pooled connection instances, which are `OraclePooledConnection` instances (as discussed in the next section).

Note: You can register connection pool data sources in JNDI using the same naming conventions as discussed for non-pooling data sources in "Register the Data Source" on page 15-9.

Pooled Connection Interface and Oracle Implementation

A pooled connection instance encapsulates a physical connection to a database. This database would be the one specified in the connection properties of the connection pool data source instance used to produce the pooled connection instance.

A pooled connection instance is an instance of a class that implements the standard `javax.sql.PooledConnection` interface. The `getConnection()` method specified by this interface returns a logical connection instance that acts as a temporary handle to the physical connection, as opposed to encapsulating the physical connection, as does a non-pooling connection instance:

```
public interface PooledConnection
{
   Connection getConnection() throws SQLException;
   void close() throws SQLException;
   void addConnectionEventListener(ConnectionEventListener listener) ... ;
   void removeConnectionEventListener(ConnectionEventListener listener);
   void setStmtCacheSize(int size);
   void setStmtCacheSize(int size, boolean clearMetaData);
   int getStmtCacheSize();
}
```

(Event listeners are used in connection caching and are discussed in "Typical Steps in Using a Connection Cache" on page 15-20.)

Oracle JDBC implements the `PooledConnection` interface with the `oracle.jdbc.pool.OraclePooledConnection` class. The `getConnection()` method returns an `OracleConnection` instance.

A pooled connection instance will typically be asked to produce a series of connection instances during its existence, but only one of these connection instances can be open at any particular time.

Each time a pooled connection instance `getConnection()` method is called, it returns a new connection instance that exhibits the default behavior, and it closes any previous connection instance that still exists and has been returned by the same pooled connection instance. You should explicitly close any previous connection instance before opening a new one, however.

Calling the `close()` method of a pooled connection instance closes the physical connection to the database. The middle-tier layer typically performs this.

The `OraclePooledConnection` class includes methods to enable statement caching for a pooled connection. The cache for statements is maintained for the pooled connection as a whole, and all logical connections obtained from the pooled connection share it. Therefore, when statement caching is enabled, a statement you create on one logical connection can be re-used on another logical connection. For the same reason, you cannot enable or disable statement caching on individual logical connections. This function applies to both implicit and explicit statement caching.

The following are `OraclePooledConnection` method definitions for statement caching:

```
public void setStmtCacheSize (int size)
   throws SQLException

public void setStmtCacheSize (int size, boolean clearMetaData)
   throws SQLException

public int getStmtCacheSize()
```

See Chapter 18, "Statement Caching", for more details on **statement caching.**

Creating a Connection Pool Data Source and Connecting

This section contains an example of the most basic use of a connection pool data source to connect to a database without using JNDI functionality. You could optionally use JNDI, binding the connection pool data source instance to a JNDI logical name, in the same way that you would for a generic data source instance (as "Register the Data Source" on page 15-9 illustrates).

Summary of Imports for Oracle Connection Pooling

You must import the following for Oracle connection pooling functionality:

```
import oracle.jdbc.pool.*;
```

This package contains the `OracleDataSource`, `OracleConnectionPoolDataSource`, and `OraclePooledConnection` classes, in addition to classes for connection caching and event-handling, which "Connection Caching" on page 15-16 discusses.

Oracle Connection Pooling Code Sample

This example first creates an `OracleConnectionPoolDataSource` instance, next initializes its connection properties, then gets a pooled connection instance from the connection pool data source instance, and finally gets a connection instance from the pooled connection instance. (The `getPooledConnection()` method actually returns an `OraclePooledConnection` instance, but in this case only generic `PooledConnection` functionality is required.)

```
...
OracleConnectionPoolDataSource ocpds = new OracleConnectionPoolDataSource();

ocpds.setDriverType("oci");
ocpds.setServerName("dlsun999");
ocpds.setNetworkProtocol("tcp");
ocpds.setDatabaseName("816");
ocpds.setPortNumber(1521);
ocpds.setUser("scott");
ocpds.setPassword("tiger");

PooledConnection pc = ocpds.getPooledConnection();

Connection conn = pc.getConnection();
...
```

Connection Caching

Connection caching, generally implemented in a middle tier, is a means of keeping and using caches of physical database connections.

Connection caching uses the connection pooling framework—such as connection pool data sources and pooled connections—in much of its operations. "Connection Pooling", starting on page 15-11, describes this framework.

The JDBC 2.0 specification does not mandate a connection caching implementation, but Oracle provides a simple implementation to serve at least as an example.

This section is divided into the following topics:

- Overview of Connection Caching
- Typical Steps in Using a Connection Cache
- Oracle Connection Cache Specification: OracleConnectionCache Interface
- Oracle Connection Cache Implementation: OracleConnectionCacheImpl Class
- Oracle Connection Event Listener: OracleConnectionEventListener Class

---

Note: The concept of connection caching is not relevant to the server-side internal driver, where you are simply using the default connection, and is only relevant to the server-side Thin driver within a single session.

Overview of Connection Caching

Each connection cache is represented by an instance of a *connection cache class* and has an associated group of pooled connection instances. For a single connection cache instance, the associated pooled connection instances must all represent physical connections to the same database and schema. Pooled connection instances are created as needed, which is whenever a connection is requested and the connection cache does not have any free pooled connection instances. A "free" pooled connection instance is one that currently has no logical connection instance associated with it; in other words, a pooled connection instance whose physical connection is not being used.

Basics of Setting Up a Connection Cache

The middle tier, in setting up a connection cache, will create an instance of a connection cache class and set its data source connection properties as

appropriate—for example, `serverName`, `databaseName`, or `URL`. Recall that a connection cache class extends a data source class. For information about data source properties, see "Data Source Properties" on page 15-4.

An example of a connection cache class is `OracleConnectionCacheImpl`. How to instantiate this class and set its connection properties is described in "Instantiating OracleConnectionCacheImpl and Setting Properties" on page 15-24. This class extends the `OracleDataSource` class and so includes the setter methods to set connection properties to specify the database to connect to. All the pooled connection instances in the cache would represent physical connections to this same database, and in fact to the same schema.

Once the middle tier has created a connection cache instance, it can optionally bind this instance to JNDI as with any data source instance, which is described in "Register the Data Source" on page 15-9.

Basics of Accessing the Connection Cache

A JDBC application must retrieve a connection cache instance to use the cache. This is typically accomplished through the middle tier, often using a JNDI lookup. In a connection caching scenario, a JNDI lookup would return a connection cache instance instead of a generic data source instance. Because a connection cache class extends a data source class, connection cache instances include data source functionality.

Executing a JNDI lookup is described in "Open a Connection" on page 15-9.

If JNDI is not used, the middle tier will typically have some vendor-specific API through which a connection cache instance is retrieved for the application.

Basics of Opening Connections

A connection cache class, as with a pooled connection class, has a `getConnection()` method. The `getConnection()` method of a connection cache instance returns a logical connection to the database and schema associated with the cache. This association is through the connection properties of the connection cache instance, as typically set by the middle tier.

Whenever a JDBC application wants a connection to a database in a connection caching scenario, it will call the `getConnection()` method of the connection cache instance associated with the database.

This `getConnection()` method checks if there are any free pooled connection instances in the cache. If not, one is created. Then a logical connection instance will

be retrieved from a previously existing or newly created pooled connection instance, and this logical connection instance will be supplied to the application.

Basics of Closing Connections: Use of Connection Events

JDBC uses JavaBeans-style events to keep track of when a physical connection (pooled connection instance) can be returned to the cache or when it should be closed due to a fatal error. When a JDBC application calls the `close()` method of a logical connection instance, an event is triggered and communicated to the event listener or listeners associated with the pooled connection instance that produced the logical connection instance. This triggers a connection-closed event and informs the pooled connection instance that its physical connection can be reused. Essentially, this puts the pooled connection instance and its physical connection back into the cache.

The point at which a connection event listener is created and registered with a pooled connection instance is implementation-specific. This could happen, for example, when the pooled connection instance is first created or each time the logical connection associated with it is closed.

It is also possible for the cache class to implement the connection event listener class. In this case, the connection event listener is part of the connection cache instance. (This is not the case in the Oracle sample implementation.) Even in this case, however, an explicit association must be made between the connection event listener and each pooled connection instance.

Basics of Connection Timeout

By default, all connections last until they are explicitly closed by the application. Some application developers prefer to have connections released automatically after a certain timespan. This prevents slow resource leaks when an application fails to close connections. `OracleConnectionCacheImpl` provides properties that set connection time-outs; each property has public get and set methods.

- `CacheInactivityTimeout` **(physical connections only)** —the maximum period a physical connection can be unused. When the period expires, the connection is closed and its resources are freed.
- `CacheTimeToLiveTimeout` **(logical connections only)**—the maximum period a logical connection can be active. After this time expires, whether or not the connection is still in use, the connection is closed, its resources are freed, and the connection is returned to the cache.
- `ThreadWakeUpInterval` **(applies to both CacheInactivityTimeout and CacheTimeToLiveTimeout)**— controls how often the cache thread checks

whether a physical connection has become available. `ThreadWakeUpInterval` defaults to 15 minutes.

In addition to the above connection time-outs, the fixed-wait scheme provides a connection-request time-out. By default, connection requests wait forever for an available connection. Using the `CacheFixedWaitTimeout` property, applications can specify how long a connection request waits before terminating.

- `CacheFixedWaitTimeout`—the maximum period that any connection request will wait before expiring. A connection request waits only when all `MAX_LIMIT` physical connections are already in use. When the time-out expires, a time-out exception, `EOJ_FIXED_WAIT_TIMEOUT`, is thrown.

Note: An additional property, `CacheFixedWaitIdleTime`, controls how long the cache waits before polling for an available connection. Defaults to 30 seconds.

Implementation Scenarios

Middle-tier developers have the option of implementing their own connection cache class and connection event listener class.

For convenience, however, Oracle provides the following, all in the `oracle.jdbc.pool` package:

- a connection cache interface: `OracleConnectionCache`
- a connection cache class: `OracleConnectionCacheImpl`
- a connection event listener class: `OracleConnectionEventListener`

The `OracleConnectionCacheImpl` class is a simple connection cache class implementation that Oracle supplies as an example, providing sufficient but minimal functionality. It implements the `OracleConnectionCache` interface and uses instances of the `OracleConnectionEventListener` class for connection events.

If you want more functionality than `OracleConnectionCacheImpl` has to offer but still want to use `OracleConnectionEventListener` for connection events, then you can create your own class that implements `OracleConnectionCache`.

Or you can create your own connection cache class and connection event listener class from scratch.

Typical Steps in Using a Connection Cache

This section lists the general steps in how a JDBC application and middle-tier will use a connection cache in opening and closing a logical connection.

Preliminary Steps in Connection Caching

Presume the following has already been accomplished:

1. The middle tier has created a connection cache instance, as described in "Basics of Setting Up a Connection Cache" on page 15-16.
2. The middle tier has provided connection information to the connection cache instance for the database and schema that will be used. This can be accomplished when constructing the connection cache instance.
3. The application has retrieved the connection cache instance, as described in "Basics of Accessing the Connection Cache" on page 15-17.

General Steps in Opening a Connection

Once the JDBC application has access to the connection cache instance, the application and middle tier perform the following steps to produce a logical connection instance for use by the application:

1. The application requests a connection through the `getConnection()` method of the connection cache instance. No input is necessary, because a connection cache instance is already associated with a particular database and schema.
2. The connection cache instance examines its cache as follows: a) to see if there are any pooled connection instances in the cache yet; and b) if so, if any are free—that is, to see if there is at least one pooled connection instance that currently has no logical connection instance associated with it.
3. The connection cache instance chooses an available pooled connection instance or, if none is available, might create a new one (this is implementation-specific). In creating a pooled connection instance, the connection cache instance can specify connection properties according to its own connection properties, because the pooled connection instance will be associated with the same database and schema.

Note: Exactly what happens in a situation where no pooled connection instances are available depends on the implementation schemes and whether the cache is limited to a maximum number of pooled connections. For the Oracle sample implementation, this is discussed in "Schemes for Creating New Pooled Connections in the Oracle Implementation" on page 15-26.

4. Depending on the situation and implementation, the connection cache instance creates a connection event listener (a process that associates the listener with the connection cache instance) and associates the listener with the chosen or newly created pooled connection instance. The association with the pooled connection instance is accomplished by calling the standard `addConnectionEventListener()` method specified by the `PooledConnection` interface. This method takes the connection event listener instance as input. If the connection cache class implements the connection event listener class, then the argument to the `addConnectionEventListener()` method would be the `this` object.

   In some implementations, the creation and association of the connection event listener can occur only when the pooled connection instance is first created. In the Oracle sample implementation, this also occurs each time a pooled connection instance is reused.

   Note that in being associated with both the connection cache instance and a pooled connection instance, the connection event listener becomes the bridge between the two.

5. The connection cache instance gets a logical connection instance from the chosen or newly created pooled connection instance, using the pooled connection `getConnection()` method.

   No input is necessary to `getConnection()`, because a pooled connection instance is already associated with a particular database and schema.

6. The connection cache instance passes the logical connection instance to the application.

The JDBC application uses this logical connection instance as it would any other connection instance.

General Steps in Closing a Connection

Once the JDBC application has finished using the logical connection instance, its associated pooled connection instance can be returned to the connection cache (or closed, as appropriate, if a fatal error occurred). The application and middle tier perform the following steps to accomplish this:

1. The application calls the `close()` method on the logical connection instance (as it would with any connection instance).
2. The pooled connection instance that produced the logical connection instance triggers an event to the connection event listener or listeners associated with it (associated with it through previous calls by the connection cache instance to the pooled connection instance `addConnectionEventListener()` method).
3. The connection event listener performs one of the following:

   - It puts the pooled connection instance back into the cache and flags it as available (typical).

   or:

   - It closes the pooled connection instance (if a fatal error occurred during use of its physical connection).

   The connection event listener will typically perform these steps by calling methods of the connection cache instance, which is implementation-specific. For the Oracle sample implementation, these functions are performed by methods specified in the `OracleConnectionCache` interface, as discussed in"Oracle Connection Cache Specification: OracleConnectionCache Interface" on page 15-23.
4. Depending on the situation and implementation, the connection cache instance disassociates the connection event listener from the pooled connection instance. This is accomplished by calling the standard `removeConnectionEventListener()` method specified by the `PooledConnection` interface.

   In some implementations, this step can be performed only when a pooled connection instance is closed, either because of a fatal error or because the application is finished with the physical connection. In the Oracle sample implementation, however, the connection event listener is disassociated with the pooled connection instance each time the pooled connection is returned to the available cache (because in the Oracle implementation, a connection event listener is associated with the pooled connection instance whenever it is reused).

Oracle Connection Cache Specification: OracleConnectionCache Interface

Middle-tier developers are free to implement their own connection caching scheme as desired, but Oracle offers the `OracleConnectionCache` interface, which you can implement in a connection cache class and which uses instances of the `OracleConnectionEventListener` class for its listener functionality.

In addition, Oracle offers a class that implements this interface, `OracleConnectionCacheImpl`, which can be used as is. This class also extends the `OracleDataSource` class and, therefore, includes a `getConnection()` method. For more information about this class, see "Oracle Connection Cache Implementation: OracleConnectionCacheImpl Class" on page 15-24.

These Oracle classes and interfaces are all in the `oracle.jdbc.pool` package.

The `OracleConnectionCache` interface specifies the following methods (in addition to data source methods that it inherits), to be implemented in a connection cache class:

- `reusePooledConnection()`: Takes a pooled connection instance as input and returns it to the cache of available pooled connections (essentially, the available physical connections).

  This method would be invoked by a connection event listener after a JDBC application has finished using the logical connection instance provided by the pooled connection instance (through previous use of the pooled connection `getConnection()` method).

- `closePooledConnection()`: Takes a pooled connection instance as input and closes it.

  A connection event listener would invoke this method after a fatal error has occurred through the logical connection instance provided by the pooled connection instance. The listener would call `closePooledConnection()`, for example, if it notices a server crash.

- `close()`: Closes the connection cache instance, after the application has finished using connection caching with the associated database.

The functionality of the `reusePooledConnection()` and `closePooledConnection()` methods is an implementation of some of the steps described generally in "General Steps in Closing a Connection" on page 15-22.

Oracle Connection Cache Implementation: OracleConnectionCacheImpl Class

Oracle offers a sample implementation of connection caching and connection event listeners, providing the `OracleConnectionCacheImpl` class. This class implements the `OracleConnectionCache` interface (which you can optionally implement yourself in some other connection cache class) and uses instances of the `OracleConnectionEventListener` class for listener functionality.

These Oracle classes and interfaces are all in the `oracle.jdbc.pool` package.

If you use the `OracleConnectionCacheImpl` class for your connection caching functionality, you should be familiar with the following topics, discussed immediately below:

- Instantiating OracleConnectionCacheImpl and Setting Properties
- Setting a Maximum Number of Pooled Connections
- Setting a Minimum Number of Pooled Connections
- Schemes for Creating New Pooled Connections in the Oracle Implementation
- Additional OracleConnectionCacheImpl Methods

Instantiating OracleConnectionCacheImpl and Setting Properties

A middle tier that uses the Oracle implementation of connection caching can construct an `OracleConnectionCacheImpl` instance and set its connection properties in one of three ways:

- It can use the `OracleConnectionCacheImpl` constructor that takes an existing connection pool data source as input. This is convenient if the middle tier has already created a connection pool data source instance and set its connection properties. For example, where `cpds` is a connection pool data source instance:

  ```
  OracleConnectionCacheImpl ocacheimpl = new OracleConnectionCacheImpl(cpds);
  ```

or:

- It can use the default `OracleConnectionCacheImpl` constructor (which takes no input) and then the `setConnectionPoolDataSource()` method, which takes an existing connection pool data source instance as input. Again, this is convenient if the middle tier already has a connection pool data source instance with its connection properties set. For example, where `cpds` is a connection pool data source instance:

  ```
  OracleConnectionCacheImpl ocacheimpl = new OracleConnectionCacheImpl();
  ```

```
ocacheimpl.setConnectionPoolDataSource(cpds);
```

Notes:

- You can also use the `setConnectionPoolDataSource()` method to override a previously set pooled connection data source or previously set connection properties.
- If you call `setConnectionPoolDataSource()` when there is already a connection pool data source with associated logical connections in use, then an exception will be thrown if the new connection pool data source specifies a different database schema than the old connection pool data source.

or:

- It can use the default `OracleConnectionCacheImpl` constructor and then set the properties individually, using setter methods. For example:

```
OracleConnectionCacheImpl ocacheimpl = new OracleConnectionCacheImpl();

ocacheimpl.setDriverType("oci");
ocacheimpl.setServerName("dlsun999");
ocacheimpl.setNetworkProtocol("tcp");
ocacheimpl.setDatabaseName("816");
ocacheimpl.setPortNumber(1521);
ocacheimpl.setUser("scott");
ocacheimpl.setPassword("tiger");
```

  This is equivalent to setting properties in any generic data source or connection pool data source, as discussed in "Initialize Connection Properties" on page 15-8.

Setting a Maximum Number of Pooled Connections

In any connection caching implementation, the middle-tier developer must decide whether there should be a maximum number of pooled connections in the cache, and how to handle situations where no pooled connections are available and the maximum number has been reached.

The `OracleConnectionCacheImpl` class includes a maximum cache size that you can set using the `setMaxLimit()` method (taking an `int` as input). The default value is 1.

The following is an example that presumes `ocacheimpl` is an `OracleConnectionCacheImpl` instance:

```
ocacheimpl.setMaxLimit(10);
```

This example limits the cache to a maximum size of ten pooled-connection instances.

Setting a Minimum Number of Pooled Connections

Just as the middle-tier developer can set the maximum number of pooled connections, you can also determine if there should be a minimum number of pre-spawned pooled connections in the cache. The minimum number is passed as an argument to the `setMinLimit()`method. If the cache doesn't have the specified number of pooled connections instances, the cache will create the new spooled-connection instances, not exceeding the specified minimum limit. The cache always keeps the minimum number of pooled connections open whether the connections are active or idle.

The following is an example that presumes `ocacheimpl` is an `OracleConnectionCacheImpl` instance:

```
ocacheimpl.setMinLimit(3);
```

The cache, in this example, always has a minimum of three pooled-connection instances.

Schemes for Creating New Pooled Connections in the Oracle Implementation

The `OracleConnectionCacheImpl` class supports three *connection cache schemes*. Use these schemes in situations where (1) the application has requested a connection, (2) all existing pooled connections are in use, and (3) the maximum number of pooled connections in the cache have been reached.

- dynamic

  In this default scheme, you can create new pooled connections above and beyond the maximum limit, but each one is automatically closed and freed as soon as the logical connection instance that it provided is no longer in use. (As opposed to the normal scenario when a pooled connection instance is finished being used, where it is returned to the available cache.)

- fixed with no wait

  In this scheme, the maximum limit cannot be exceeded. Requests for connections when the maximum has already been reached will return `null`.

- fixed wait

  Same as the "fixed with no wait" scheme except that a request for a new connection will wait if the limit for the number of connections has been reached. In this case, the connection request waits until another client releases a connection.

Set the cache scheme by invoking the `setCacheScheme()` method of the `OracleConnectionCacheImpl` instance.

There are two versions of `setCacheScheme()`, one that takes a string and one that takes an integer.

- The string version is case-insensitive and accepts "`dynamic_scheme`", "`fixed_return_null_scheme`", or "`fixed_wait_scheme`" .
- The integer version accepts the class static constants `DYNAMIC_SCHEME`, `FIXED_RETURN_NULL_SCHEME`, or `FIXED_WAIT_SCHEME.`

For example, if `ocacheimpl` is an `OracleConnectionCacheImpl` instance, you could set the cached scheme to fixed with no wait using either the integer version of `setCacheScheme()`:

```
ocacheimpl.setCacheScheme(OracleConnectionCacheImpl.FIXED_RETURN_NULL_SCHEME);
```

or the string version:

```
setCacheScheme("fixed_return_null_scheme")
```

Additional OracleConnectionCacheImpl Methods

In addition to the key methods already discussed in "Oracle Connection Cache Specification: OracleConnectionCache Interface" on page 15-23, the following `OracleConnectionCacheImpl` methods may be useful:

- `getActiveSize()`: Returns the number of currently active pooled connections in the cache (pooled connection instances with an associated logical connection instance being used by the JDBC application).
- `getCacheSize()`: Returns the total number of pooled connections in the cache, both active and inactive.

Oracle Connection Event Listener: OracleConnectionEventListener Class

This section discusses `OracleConnectionEventListener` functionality by summarizing its constructors and methods.

Instantiating an Oracle Connection Event Listener

In the Oracle implementation of connection caching, an `OracleConnectionCacheImpl` instance constructs an Oracle connection event listener, specifying the connection cache instance itself (its `this` instance) as the constructor argument. This instance associates the connection event listener with the connection cache instance.

In general, however, the `OracleConnectionEventListener` constructor can take any data source instance as input. For example, where `ds` is a generic data source:

```
OracleConnectionEventListener ocel = new OracleConnectionEventListener(ds);
```

There is also a default constructor that takes no input and can be used in conjunction with the `OracleConnectionEventListener` class `setDataSource()` method:

```
OracleConnectionEventListener ocel = new OracleConnectionEventListener();
...
ocel.setDataSource(ds);
```

The input can be any kind of data source, including an `OracleConnectionCacheImpl` instance (because that class extends `OracleDataSource`).

Oracle Connection Event Listener Methods

This section summarizes the methods of the `OracleConnectionEventListener` class:

- `setDataSource()` (previously discussed): Used to input a data source to the connection event listener, in case one was not provided when constructing the listener. This can take any type of data source as input.
- `connectionClosed()`: Invoked when the JDBC application calls `close()` on its representation of the connection.
- `connectionErrorOccurred()`: Invoked when a fatal connection error occurs, just before a `SQLException` is issued to the application.

16

JDBC OCI Extensions

This chapter describes the following OCI driver-specific features:

- OCI Driver Connection Pooling
- Middle-Tier Authentication Through Proxy Connections
- OCI Driver Transparent Application Failover
- OCI HeteroRM XA
- Accessing PL/SQL Index-by Tables

OCI Driver Connection Pooling

OCI driver connection pooling functionality, provided by the `OracleOCIConnectionPool` class, is part of the JDBC client. Enhanced connection pooling provides the following benefits:

- **Improved scalability** - The pooling granularity is superior to that provided by the `OraclePooledConnection` class, since fewer physical connections are needed to support a large number of non-current, logical connections. This is valuable since physical connections are expensive. The physical connection of the `OraclePooledConnection` object is available for reuse after the application is done using it. Also, since the user session is not closed on the server-side once the `OraclePooledConnection` object is returned to the pool of available connection objects, every new call to the `getConnection()` method of the `OracleConnectionCacheImpl` class requires that the user remain the same. For a dedicated server instance, this results in the number of backend Oracle processes being reduced as the number of in-coming connections are also reduced. To boost performance, a physical connection is locked only for the duration of a call.
- **Uniform interface** - A single, uniform interface of connection pooling reduces overall code maintenance.
- **Flexible schemas** - Each `OracleOCIConnection` object can have a different user ID and therefore point to different schemas.
- **Dynamic configuration** - Ability to dynamically configure the connection pool.

> **Note:** The existing connection support of mapping one JDBC user session to one physical connection, and the reuse of physical connection objects using the `OraclePooledConnection` class, is still supported. (See "Connection Pooling" on page 15-11 for details.) However, it is recommended that you use the improved functionality of the `OracleOCIConnectionPool` class instead.

A JDBC application can have multiple pools at the same time. Multiple pools can correspond to multiple application servers, or pools to different data sources. The connection pooling provided by OCI in Oracle9*i* allows applications to have many logical connections, all using a small set of physical connections. Each call on this logical connection will be routed on the physical connection that is available at that time. Call-duration based pooling of connections is a more scalable connection pooling solution.

For information about Oracle JDBC connection pooling and caching features that apply to all Oracle JDBC drivers, see Chapter 15, "Connection Pooling and Caching".

OCI Driver Connection Pooling: Background

With the Oracle9*i* JDBC OCI driver, there are several transaction monitor capabilities such as the fine-grained management of Oracle sessions and connections. It is possible for a high-end application server or transaction monitor to multiplex several sessions over fewer physical connections on a call-level basis, thereby achieving a high degree of scalability by pooling of connections and backend Oracle server processes.

The connection pooling provided by the `OracleOCIConnectionPool` interface simplifies the Session/Connection separation interface hiding the management of the physical connection pool. The Oracle sessions are the `OracleOCIConnection` connection objects obtained from the `OracleOCIConnectionPool`. The connection pool itself is normally configured with a much smaller shared pool of physical connections, translating to a backend server pool containing an identical number of dedicated server processes. Note that many more Oracle sessions can be multiplexed over this pool of fewer shared connections and backend Oracle processes.

OCI Driver Connection Pooling and Shared Servers Compared

In some ways, what OCI driver connection pooling offers on the middle tier is similar to what shared server processes offeron the backend. OCI driver connection pooling makes a dedicated server instance behave as an shared instance by managing the session multiplexing logic on the middle tier. Therefore, the pooling of dedicated server processes and incoming connections into the dedicated server processes is controlled by the OCI connection pool on the middle tier.

The main difference between OCI connection pooling and shared servers is that in case of shared servers, the connection from the client is normally to a dispatcher in the database instance. The dispatcher is responsible for directing the client request to an appropriate shared server. On the other hand, the physical connection from the OCI connection pool is established directly from the middle tier to the Oracle dedicated server process in the backend server pool.

Note that OCI connection pool is mainly beneficial only if the middle tier is multi-threaded. Each thread could maintain a session to the database. The actual connections to the database are maintained by the `OracleOCIConnectionPool`

and these connections (including the pool of dedicated database server processes) are shared among all the threads in the middle tier.

Stateless Sessions Compared to Stateful Sessions

OCI connection pooling offers stateless physical connections and stateful sessions. If you need to work with a stateless session behavior, you can use the `OracleConnectionCacheImpl` interface.

Defining an OCI Connection Pool

An OCI connection pool is created at the beginning of the application. Creating connections from a pool is quite similar to creating connections using the `OracleDataSource` class.

The `oracle.jdbc.pool.OracleOCIConnectionPool` class, which extends the `OracleDataSource` class, is used to create OCI connection pools. From an `OracleOCIConnectionPool` class instance, you can obtain logical connection objects. These connection objects are of the `OracleOCIConnection` class type. This class implements the `OracleConnection` interface. The `Statement` objects you create from the `OracleOCIConnection` class have the same fields and methods as `OracleStatement` objects you create from `OracleConnection` instances.

The following code shows header information for the `OracleOCIConnectionPool` class:

```
/*
   * @param us  ConnectionPool user-id.
   * @param p   ConnectionPool password
   * @param name  logical name of the pool. This needs to be one in the
   *                   tnsnames.ora configuration file.
     @param config (optional)  Properties of the pool, if the default does not
                suffice. Default connection configuration is min =1, max=1,
                incr=0
                  Please refer setPoolConfig for property names.

                 Since this is optional, pass null if the default configuration
                 suffices.

   * @return
   *
   * Notes: Choose a userid and password that can act as proxy for the users
   *        in the getProxyConnection() method.
```

```
            If config is null, then the following default values will take
            effect
            CONNPOOL_MIN_LIMIT = 1
            CONNPOOL_MAX_LIMIT = 1
            CONNPOOL_INCREMENT = 0

*/

public synchronized OracleOCIConnectionPool
  (String       user,    String   password,  String name, Properties config)
  throws SQLException

/*
 * This will use the user-id, password and connection pool name values set
   LATER using the methods setUser, setPassword, setConnectionPoolName.

 * @return
 *
 * Notes:

     No OracleOCIConnection objects can be created on
     this class unless the methods setUser, setPassword, setPoolConfig
     are invoked.
     When invoking the setUser, setPassword later, choose a userid and
     password that can act as proxy for the users
 *   in the getProxyConnection() method.
 */
  public synchronized OracleOCIConnectionPool ()
    throws SQLException
```

Importing the oracle.jdbc.pool and oracle.jdbc.oci Packages

Before you create an OCI connection pool, import the following to have Oracle OCI connection pooling functionality:

```
import oracle.jdbc.pool.*;
import oracle.jdbc.oci.*;
```

The `oracle.jdbc.pool.*` package contains the `OracleDataSource`, `OracleConnectionPoolDataSource`, and `OracleOCIConnectionPool` classes, in addition to classes for connection caching and event-handling. The `oracle.jdbc.oci.*` package contains the `OracleOCIConnection` class and the `OracleOCIFailover` interface.

Creating an OCI Connection Pool

The following code show how you create an instance of the `OracleOCIConnectionPool` class called `cpool`:

```
OracleOCIConnectionPool cpool = new OracleOCIConnectionPool
    ("SCOTT", "TIGER", "jdbc:oracle:oci:@(description=(address=(host=
    myhost)(protocol=tcp)(port=1521))(connect_data=(INSTANCE_NAME=orcl)))",
    poolConfig);
```

`poolConfig` is a set of properties which specify the connection pool. If `poolConfig` is null, then the default values are used. For example, consider the following:

- `poolConfig.put (OracleOCIConnectionPool.CONNPOOL_MIN_LIMIT, "4");`
- `poolConfig.put (OracleOCIConnectionPool.CONNPOOL_MAX_LIMIT, "10");`
- `poolConfig.put (OracleOCIConnectionPool.CONNPOOL_INCREMENT, "2");`

As an alternative to the above constructor call, you can create an instance of the `OracleOCIConnectionPool` class using individual methods to specify the user, password, and connection string.

```
OracleOCIConnectionPool cpool = new OracleOCIConnectionPool ( );
cpool.setUser("SCOTT");
cpool.setPassword("TIGER");
cpool.setURL("jdbc:oracle:oci:@(description=(address=(host=
    myhost)(protocol=tcp)(port=1521))(connect_data=(INSTANCE_NAME=orcl)))");
cpool.setPoolConfig(poolConfig);  // In case you want to specify a different
                                  // configuration other than the default
                                  // values.
```

Setting the OCI Connection Pool Parameters

The connection pool configuration is determined by the following `OracleOCIConnectionPool` class attributes:

- `CONNPOOL_MIN_LIMIT` : Specifies the minimum number of physical connections that can be maintained by the pool.
- `CONNPOOL_MAX_LIMIT` : Specifies the maximum number of physical connections that can be maintained by the pool.

- CONNPOOL_INCREMENT : Specifies the incremental number of physical connections to be opened when all the existing ones are busy and a call needs one more connection; the increment is done only when the total number of open physical connections is less than the maximum number that can be opened in that pool.
- CONNPOOL_TIMEOUT : Specifies how much time must pass before an idle physical connection is disconnected; this does not affect a logical connection.
- CONNPOOL_NOWAIT : When enabled, this attributes specifies that an error is returned if a call needs a physical connection while the maximum number of connections in the pool are busy; if disabled, a call waits until a connection is available. Once this attribute is set to "true", it cannot be reset to "false".

You can configure all of these attributes dynamically. Therefore, an application has the flexibility of reading the current load (number of open connections and number of busy connections) and adjusting these attributes appropriately, using the setPoolConfig() method.

Note: The default values for the CONNPOOL_MIN_LIMIT, CONNPOOL_MAX_LIMIT, and CONNPOOL_INCREMENT parameters are 1, 1, and 0, respectively.

The setPoolConfig() method is used to configure OCI connection pool properties. The following is a typical example of how the OracleOCIConnectionPool class attributes can be set:

```
...
java.util.Properties p  = new java.util.Properties( );
p.put (OracleOCIConnectionPool.CONNPOOL_MIN_LIMIT, "1");
p.put (OracleOCIConnectionPool.CONNPOOL_MAX_LIMIT, "5");
p.put (OracleOCIConnectionPool.CONNPOOL_INCREMENT, "2");
p.put (OracleOCIConnectionPool.CONNPOOL_TIMEOUT, "10");
p.put (OracleOCIConnectionPool.CONNPOOL_NOWAIT, "true");
cpool.setPoolConfig(p);
...
```

Observe the following rules when setting the above attributes:

- CONNPOOL_MIN_LIMIT, CONNPOOL_MAX_LIMIT, and CONNPOOL_INCREMENT are mandatory.
- CONNPOOL_MIN_LIMIT must be a value greater than zero.

- CONNPOOL_MAX_LIMIT must be a value greater than or equal to CONNPOOL_MIN_LIMIT plus CONNPOOL_INCREMENT.
- CONNPOOL_INCREMENT must be a value greater than or equal to zero
- CONNPOOL_TIMEOUT must be a value greater than zero.
- CONNPOOL_NOWAIT must be "true" or "false" (case insensitive).

Checking the OCI Connection Pool Status

To check the status of the connection pool, use the following methods from the OracleOCIConnectionPool class:

- int getMinLimit() : Retrieves the minimum number of physical connections that can be maintained by the pool.
- int getMaxLimit() : Retrieves the maximum number of physical connections that can be maintained by the pool.
- int getConnectionIncrement() : Retrieves the incremental number of physical connections to be opened when all the existing ones are busy and a call needs a connection.
- int getTimeout() : Retrieves the specified time (in seconds) that a physical connection in a pool can remain idle before it is disconnected; the age of a connection is based on the Least Recently Used (LRU) scheme.
- String getNoWait() : Retrieves whether the NOWAIT property is enabled. It returns a string of "true" or "false".
- int getPoolSize() : Retrieves the number of physical connections that are open. This should be used only as estimate and for statistical analysis.
- int getActiveSize() : Retrieves the number of physical connections that are open and busy. This should be used only as estimate and for statistical analysis.
- boolean isPoolCreated() : Retrieves whether the pool has been created. The pool is actually created when OracleOCIConnection (user, password, url, poolConfig) is called or when setUser, setPassword, and setURL has been done after calling OracleOCIConnection().

Connecting to an OCI Connection Pool

The OracleOCIConnectionPool class, through a getConnection() method call, creates an instance of the OracleOCIConnection class. This instance

represents a connection. See "Data Sources" on page 15-2 for database connection descriptions that apply to all JDBC drivers.

Since the `OracleOCIConnection` class extends `OracleConnection` class, it has the funtionality of this class too. Close the `OracleOCIConnection` objects once the user session is over, otherwise, they are closed when the pool instance is closed.

There are two ways of calling `getConnection()`:

- `OracleConnection getConnection(String user, String password)` : Get a logical connection identified with the specified user and password, which can be different from that used for pool creation.
- `OracleConnection getConnection()` : If you do not supply the user name and password, then the default user name and password used for the creation of the connection pool are used while creating the connection objects.

As an enhancement to `OracleConnection`, the following new method is added into `OracleOCIConnection` as a way to change password for the user:

```
void passwordChange (String user, String oldPassword, String newPassword)
```

The following code shows how an application uses connection pool with re-configuration:

```
import oracle.jdbc.oci.*;
import oracle.jdbc.pool.*;

public class cpoolTest
{
  public static void main (String args [])
    throws SQLException
  {
    /* pass the URL and "inst1" as the database link name from tnsnames.ora */
    OracleOCIConnectionPool cpool = new OracleOCIConnectionPool
      ("scott", "tiger", "jdbc:oracle:oci@inst1", null);

    /* create virtual connection objects from the connection pool "cpool." The
       poolConfig can be null when using default values of min = 1, max = 1, and
       increment = 0, otherwise needs to set the properties mentioned earlier */
    OracleOCIConnection conn1 = (OracleOCIConnection) cpool.getConnection
      ("user1", password1");

    /* create few Statement objects and work on this connection, conn1 */
    Statement stmt = conn1.createStatement();
    ...
    OracleOCIConnection conn90 = (OracleOCIConnection) cpool.getConnection
```

```
      ("user90", "password90")   /* work on statement object from virtual
                                    connection "conn90" */
    ...
    /* if the throughput is less, increase the pool size */
    string newmin = String.valueOf (cpool.getMinLimit);
    string newmax = String.valueOf (2*cpool.getMaxLimit());
    string newincr = String.valueOf (1 + cpool.getConnectionIncrement());
    Properties newproperties = newProperties();
    newproperties.put (OracleOCIConnectionPool.CONNPOOL_MIN_LIMIT, newmin);
    newproperties.put (OracleOCIConnectionPool.CONNPOOL_MAX_LIMIT, newmax);
    newproperties.put (OracleOCIConnectionPool.CONNPOOL_INCREMENT, newincr);
    cpool.setPoolConfig (newproperties);
    }  /* end of main */
}  /* end of cpoolTest */
```

Statement Handling and Caching

Statement caching is supported with `OracleOCIConnectionPool`. The caching improves performance by not having to open, parse and close cursors. When `OracleOCIConnection.prepareStatement` ("SQL query") is done, the statement cache is searched for a statement that matches the SQL query. If a match is found, we can reuse the `Statement` object instead of incurring the cost of creating another `Statement` object. The cache size can be dynamically increased or decreased. The default cache size is zero.

Note: The `OracleStatement` object created from `OracleOCIConnection` has the same behavior as one that is created from `OracleConnection`.

Statement caching in `OracleOCIConnectionPool` is a little different from the standard functionality in `OracleConnectionCacheImpl`. The `setStmtCacheSize()` method sets the statement cache sizes of all the `OracleOCIConnection` objects retrieved from this pool. But unlike logical (`OracleConnection`) connection objects obtained from `OracleConnectionCacheImpl`, the individual cache sizes of the logical (`OracleOCIConnection`) connection objects can also be changed if desired. (The default cache size is zero.)

The following code shows the signatures of the `getConnection()` method:

```
public synchronized OracleConnection getConnection( )
```

```
                    throws SQLException

/*
 * For getting a connection to the database.
 *
 * @param us  Connection user-id
 * @param p   Connection password
 * @return     connection object
 */
public synchronized OracleConnection getConnection(String us, String p)
throws SQLException
```

Types of Statement Caching used with the OCI Connection Pool

There are two forms of statement caching: implicit and explicit. (See Chapter 18, "Statement Caching" for a complete description of implicit and explicit statement caching.) Both forms of statement caching use the `setStmtCacheSize()` method. Explicit statement caching requires the JDBC application to provide a key while opening and closing `Statement` objects. Implicit statement caching does not require the JDBC application to provide the key; the caching is transparent to the application. Also in explicit statement caching, the fetch state of the result set is not cleared. So after doing a `Statement.close(key="abc")`, `Connection.preparedStatement(key="abc")` will return the `Statement` object and fetches will continue with the fetch state when the previous `Statement.close(key="abc")` is done.

For implicit statement caching, the fetch state is cleared and the cursor is re-executed, but the cursor meta data is cached to improve performance. In some cases, the client may also need to clear the meta data (through the `clearMetaData` parameter).

The following header information documents method signatures:

```
synchronized public void setStmtCacheSize (int size)

  /**
   *
   * @param size Size of the Cache
   * @param clearMetaData Whether the state has to be cleared or not
   * @exception     SQLException
   */
  public synchronized void setStmtCacheSize (int size, boolean clearMetaData)

 /**
```

```
   * Return the size of Statement Cache.
   * @return int Size of Statement Cache.

                If not set ie if statement caching is not enabled ,
   *             the default 0 is returned.
   */
  public synchronized int getStmtCacheSize()

   /*
   * Check whether Statement
   * Caching is enabled for this pool or Not.
   */
 public synchronized boolean isStmtCacheEnabled ()
```

JNDI and the OCI Connection Pool

The Java Naming and Directory Interface (JNDI) feature makes persistent the properties of Java object so these properties can be used to construct a new instance of the object (such as cloning the object). The benefit is that the old object can be freed, and at a later time a new object with exactly the same properties can be created. The `InitialContext.bind()` method makes persistent the properties, either on file or in a database, while the `InitialContext.lookup()` method retrieves the properties from the persistent store and creates a new object with these properties.

`OracleOCIConnectionPool` objects can be bound and looked up using the JNDI feature. No new interface calls in `OracleOCIConnectionPool` are necessary.

Middle-Tier Authentication Through Proxy Connections

Middle-tier authentication allows one JDBC connection (session) to act as proxy for other JDBC connections. A proxy session could be required for one of the following:

- If the middle tier does not know the password of the proxy user. This is done by first authenticating using:

  ```
  alter user jeff grant connect through scott with roles role1, role2;
  ```

  Then the method allows you to connect as "jeff" using the already authenticated credentials of "scott". It is sometimes a security concern for the middle tier to know the passwords of all the database users. Though the created session will behave much like "jeff" was connected normally (using "jeff"/"jeff-password"), "jeff" will not have to divulge its password to the middle tier. The schema which this proxy session has access to is schema of "jeff" plus what is indicated in the list of roles. Therefore, if "scott" wants "jeff" to access its table EMP, the following code can be used:

  ```
  create role role1;
  grant select on EMP to role1;
  ```

  The role clause can also be thought as limiting "jeff's" access to only those database objects of "scott" mentioned in the list of the roles. The list of roles can be empty.

- For accounting purposes. The transactions made via proxy sessions can be better accounted by proxying the user ("jeff"), under different users such as "scott", "scott2" assuming "scott"and "scott2" are authenticated. Transactions made under these different proxy sessions by "jeff" can be logged separately.

There are three ways to create proxy sessions in the OCI driver. Roles can be associated with any of the following options:

- USER NAME : This is done by supplying the user name and/or the password. The reason why the "password" option exists is so that database operations made by the user ("jeff"), can be accounted. The SQL clause is:

  ```
  alter user jeff grant connect through scott authenticated using password;
  ```

  Having no authenticated clause implies the default—authenticated using the user-name without the password requirement.

- DISTINGUISHED NAME : This is a global name in lieu of the password of the user being proxied for. So you could say "create user jeff identified globally as:

```
'CN=jeff,OU=americas,O=oracle,L=redwoodshores,ST=ca,C=us';
```

The string after the "globally as" clause is the distinguished name. It is then necessary to authenticate as:

```
alter user jeff grant connect through scott authenticated using
distinguished name;
```

- CERTIFICATE : This is a more encrypted way of passing the credentials of the user (to be proxied) to the database. The certificate contains the distinguished encoded name. One way of generating it is by creating a wallet (using "`runutl mkwallet`"), then decoding the wallet to get the certificate. It is then necessary to authenticate as:

```
alter user jeff grant connect through scott authenticated using certificate;
```

The following code shows signatures of the `getProxyConnection()` method with information about the proxy type process:

```
/*
   * For creating a proxy connection. All macros are defined
   * in OracleOCIConnectionPool.java
   *
   * @param proxyType  Can be one of following types
              PROXYTYPE_USER_NAME
                        - This will be the normal mode of specifying the user
                          name in proxyUser as in Oracle8i

              PROXYTYPE_DISTINGUISHED_NAME
                        - This will specify the distinguished name of the user
                          in proxyUser

             PROXYTYPE_CERTIFICATE
                        - This will specify the proxy certificate

    The Properties (ie prop) should be set as follows.

    If PROXYTYPE_USER_NAME
       PROXY_USER_NAME and/or PROXY_USER_PASSWORD depending
          on how the connection-pool owner was authenticated
          to act as proxy for this proxy user
          PROXY_USER_NAME (String) = user to be proxied for
          PROXY_PASSWORD (String) = password of the user to be proxied for

   else if PROXYTYPE_DISTINGUISHED_NAME
        PROXY_DISTINGUISHED_NAME (String) = (global) distinguished name of the
```

```
user to be proxied for
    else if PROXYTYPE_CERTIFICATE (byte[])
         PROXY_CERTIFICATE = certficate containing the encoded
                                distinguished name



    PROXY_ROLES (String[])  Set of roles which this proxy connection can use.
Roles can be null, and can be associated
with any of the above proxy methods.

   *
   * @return   connection object
   *
   * Notes: The user and password used to create OracleOCIConnectionPool()
   *        must be allowed to act as proxy for user 'us'.
   */
   public synchronized OracleConnection getProxyConnection(String proxyType,
     Properties prop)
     throws SQLException
```

OCI Driver Transparent Application Failover

Transparent Application Failover (TAF) or simply *Application Failover* is a feature of the OCI driver. It enables you to automatically reconnect to a database if the database instance to which the connection is made goes down. In this case, the active transactions roll back. (A transaction rollback restores the last committed transaction.) The new database connection, though created by a different node, is identical to the original. This is true regardless of how the connection was lost.

TAF is always active and does not have to be set.

For additional details regarding OCI and TAF, see the *Programmer's Guide to the Oracle Call Interface*.

Failover Type Events

The following are possible failover events in the `OracleOCIFailover` interface:

- `FO_SESSION` : Is equivalent to `FAILOVER_MODE=SESSION` in the `tnsnames.ora` file `CONNECT_DATA` flags. This means that only the user session is re-authenticated on the server-side while open cursors in the OCI application need to be re-executed.
- `FO_SELECT` : Is equivalent to `FAILOVER_MODE=SELECT` in `tnsnames.ora` file `CONNECT_DATA` flags. This means that not only the user session is re-authenticated on the server-side, but open cursors in the OCI can continue fetching. This implies that the client-side logic maintains fetch-state of each open cursor.
- `FO_NONE` : Is equivalent to `FAILOVER_MODE=NONE` in the `tnsnames.ora` file `CONNECT_DATA` flags. This is the default, in which no failover functionality is used. This can also be explicitly specified to prevent failover from happening. Additionally, `FO_TYPE_UNKNOWN` implies that a bad failover type was returned from the OCI driver.
- `FO_BEGIN` : Indicates that failover has detected a lost connection and failover is starting.
- `FO_END` : Indicates successful completion of failover.
- `FO_ABORT` : Indicates that failover was unsuccessful and there is no option of retrying.
- `FO_REAUTH` : indicates that a user handle has been re-authenticated.

- FO_ERROR : indicates that failover was temporarily un-successful, but it gives the application the opportunity to handle the error and retry failover. The usual method of error handling is to issue the `sleep()` method and retry by returning the value FO_RETRY.
- FO_RETRY : See above.
- FO_EVENT_UNKNOWN : A bad failover event.

TAF Callbacks

TAF callbacks are used in the event of the failure of one database connection, and failover to another database connection. *TAF callbacks* are callbacks that are registered in case of failover. The callback is called during the failover to notify the JDBC application of events generated. The application also has some control of failover.

Note: The callback setting is optional.

Java TAF Callback Interface

The `OracleOCIFailover` interface includes the callbackFn() method, supporting the following types and events:

```
public interface OracleOCIFailover{

// Possible Failover Types
public static final int FO_SESSION = 1;
public static final int FO_SELECT  = 2;
public static final int FO_NONE  = 3;
public static final int;

// Possible Failover events registered with callback
public static final int FO_BEGIN   = 1;
public static final int FO_END     = 2;
public static final int FO_ABORT   = 3;
public static final int FO_REAUTH  = 4;
public static final int FO_ERROR  = 5;
public static final int FO_RETRY  = 6;
public static final int FO_EVENT_UNKNOWN = 7;

public int callbackFn (Connection conn,
                       Object ctxt, // ANy thing the user wants to save
```

```
                                int type, // One of the above possible Failover Types
                                int event ); // One of the above possible Failover Events
```

Handling the FO_ERROR Event

In case of an error while failing-over to a new connection, the JDBC application is able to retry failover. Typically, the application sleeps for a while and then it retries, either indefinitely or for a limited amount of time, by having the callback return FO_RETRY.

Handling the FO_ABORT Event

Callback registered should return the FO_ABORT event if the FO_ERROR event is passed to it.

OCI HeteroRM XA

Unlike the regular JDBC XA feature which works only with Oracle8*i* 8.1.6 and later databases, JDBC HeteroRM XA also allows you to do XA operations in Oracle8*i* releases prior to 8.1.6. In general, the HeteroRM XA is recommended for use whenever possible.

HeteroRM XA is enabled through the use of the `tnsEntry` and `nativeXA` properties of the `OracleXADataSource` class. Table 15–2, "Oracle Extended Data Source Properties" on page 15-6 explains these properties in detail.

For a complete discussion of XA, see Chapter 14, "Distributed Transactions".

Configuration and Installation

The Solaris shared libraries, `libheteroxa9.so` and `libheteroxa9_g.so`, enable the HeteroRM XA feature to support access to Oracle8*i* releases prior to release 8.1.6. The NT version of these libraries are `heteroxa9.dll` and `heteroxa9_g.dll`. In order for the HeteroRM XA feature to work properly, these libraries need to be installed and available in either the Solaris search path or the NT DLL path, depending on your system.

Note: Libraries with the `_g` suffix are debug libraries.

Exception Handling

When using the HeteroRM XA feature in distributed transactions, it is recommended that the application simply check for `XAException` or `SQLException`, rather than `OracleXAException` or `OracleSQLException`.

See "HeteroRM XA Messages" on page B-15 for a listing of HeteroRM XA messages.

Note: The mapping from SQL error codes to standard XA error codes does not apply to the HeteroRM XA feature.

HeteroRM XA Code Example

The following portion of code shows how to enable the HeteroRM XA feature.

```
// Create a XADataSource instance
OracleXADataSource oxds = new OracleXADataSource();
oxds.setURL(url);
```

```
// Set the nativeXA property to use HeteroRM XA feature
oxds.setNativeXA(true);

// Set the tnsEntry property to an older DB as required
oxds.setTNSEntryName("ora805");
```

Accessing PL/SQL Index-by Tables

The Oracle JDBC OCI driver enables JDBC applications to make PL/SQL calls with index-by table parameters.

Important: Index-by tables of PL/SQL records are not supported.

Overview

The Oracle JDBC OCI driver supports PL/SQL index-by tables of scalar datatypes. Table 16–1 displays the supported scalar types and the corresponding JDBC typecodes.

Table 16–1 PL/SQL Types and Corresponding JDBC Types

PL/SQL Types	JDBC Types
BINARY_INTEGER	NUMERIC
NATURAL	NUMERIC
NATURALN	NUMERIC
PLS_INTEGER	NUMERIC
POSITIVE	NUMERIC
POSITIVEN	NUMERIC
SIGNTYPE	NUMERIC
STRING	VARCHAR

Note: Oracle JDBC does not support RAW, DATE, and PL/SQL RECORD as element types.

Typical Oracle JDBC input binding, output registration, and data-access methods do not support PL/SQL index-by tables. This chapter introduces additional methods to support these types.

The `OraclePreparedStatement` and `OracleCallableStatement` classes define the additional methods. These methods include the following:

- `setPlsqlIndexTable()`

- `registerIndexTableOutParameter()`
- `getOraclePlsqlIndexTable()`
- `getPlsqlIndexTable()`

These methods handle PL/SQL index-by tables as `IN`, `OUT` (including function return values), or `IN OUT` parameters. For general information about PL/SQL syntax, see the *PL/SQL User's Guide and Reference*.

The following sections describe the methods used to bind and register PL/SQL index-by tables.

Binding IN Parameters

To bind a PL/SQL index-by table parameter in the `IN` parameter mode, use the `setPlsqlIndexTable()` method defined in the `OraclePreparedStatement` and `OracleCallableStatement` classes.

```
synchronized public void setPlsqlIndexTable
   (int paramIndex, Object arrayData, int maxLen, int curLen, int elemSqlType,
   int elemMaxLen) throws SQLException
```

Table 16–2 describes the arguments of the `setPlsqlIndexTable()` method.

Table 16–2 Arguments of the setPlsqlIndexTable () Method

Argument	Description
`int paramIndex`	This argument indicates the parameter position within the statement.
`Object arrayData`	This argument is an array of values to be bound to the PL/SQL index-by table parameter. The value is of type `java.lang.Object`, and the value can be a Java primitive type array such as `int[]` or a Java object array such as `BigDecimal[]`.
`int maxLen`	This argument specifies the maximum table length of the index-by table bind value which defines the maximum possible `curLen` for batch updates. For standalone binds, `maxLen` should use the same value as `curLen`. This argument is required.

Table 16–2 Arguments of the setPlsqlIndexTable () Method (Cont.)

Argument	Description
`int curLen`	This argument specifies the actual size of the index-by table bind value in `arrayData`. If the `curLen` value is smaller than the size of `arrayData`, only the `curLen` number of table elements is passed to the database. If the `curLen` value is larger than the size of `arrayData`, the entire `arrayData` is sent to the database.
`int elemSqlType`	This argument specifies the index-by table element type based on the values defined in the `OracleTypes` class.
`int elemMaxLen`	This argument specifies the index-table element maximum length in case the element type is CHAR, VARCHAR, or RAW. This value is ignored for other types.

The following code example uses the `setPlsqlIndexTable()` method to bind an index-by table as an `IN` parameter:

```
// Prepare the statement
OracleCallableStatement procin = (OracleCallableStatement)
   conn.prepareCall ("begin procin (?); end;");

// index-by table bind value
int[] values = { 1, 2, 3 };

// maximum length of the index-by table bind value. This
// value defines the maximum possible "currentLen" for batch
// updates. For standalone binds, "maxLen" should be the
// same as "currentLen".
int maxLen = values.length;

// actual size of the index-by table bind value
int currentLen = values.length;

// index-by table element type
int elemSqlType = OracleTypes.NUMBER;

// index-by table element length in case the element type
// is CHAR, VARCHAR or RAW. This value is ignored for other
// types.
int elemMaxLen = 0;

// set the value
```

```
procin.setPlsqlIndexTable (1, values,
                           maxLen, currentLen,
                           elemSqlType, elemMaxLen);

// execute the call
procin.execute ();
```

Receiving OUT Parameters

This section describes how to register a PL/SQL index-by table as an OUT parameter. In addition, it describes how to access the OUT bind values in various mapping styles.

> **Note:** The methods this section describes apply to function return values and the IN OUT parameter mode as well.

Registering the OUT Parameters

To register a PL/SQL index-by table as an OUT parameter, use the `registerIndexTableOutParameter()` method defined in the `OracleCallableStatement` class.

```
synchronized registerIndexTableOutParameter
   (int paramIndex, int maxLen, int elemSqlType, int elemMaxLen)
   throws SQLException
```

Table 16–3 describes the arguments of the `registerIndexTableOutParameter()` method.

Table 16–3 Arguments of the registerIndexTableOutParameter () Method

Argument	Description
`int paramIndex`	This argument indicates the parameter position within the statement.
`int maxLen`	This argument specifies the maximum table length of the index-by table bind value to be returned.
`int elemSqlType`	This argument specifies the index-by table element type based on the values defined in the `OracleTypes` class.
`int elemMaxLen`	This argument specifies the index-by table element maximum length in case the element type is CHAR, VARCHAR, or RAW. This value is ignored for other types.

The following code example uses the `registerIndexTableOutParameter()` method to register an index-by table as an `OUT` parameter:

```
// maximum length of the index-by table value. This
// value defines the maximum table size to be returned.
int maxLen = 10;

// index-by table element type
int elemSqlType = OracleTypes.NUMBER;

// index-by table element length in case the element type
// is CHAR, VARCHAR or RAW. This value is ignored for other
// types
int elemMaxLen = 0;

// register the return value
funcnone.registerIndexTableOutParameter
   (1, maxLen, elemSqlType, elemMaxLen);
```

Accessing the OUT Parameter Values

To access the `OUT` bind value, the `OracleCallableStatement` class defines multiple methods that return the index-by table values in different mapping styles. There are three mapping choices available in JDBC drivers:

Mappings	Methods to Use
JDBC default mappings	`getPlsqlIndexTable(int)`
Oracle mappings	`getOraclePlsqlIndexTable(int)`
Java primitive type mappings	`getPlsqlIndexTable(int, Class)`

JDBC Default Mappings The `getPlsqlIndexTable()` method with the `(int)` signature returns index-by table elements using JDBC default mappings.

```
public Object getPlsqlIndexTable (int paramIndex)
   throws SQLException
```

Table 16–4 describes the argument of the `getPlsqlIndexTable()` method.

Table 16–4 Argument of the getPlsqlIndexTable () Method

Argument	Description
`int paramIndex`	This argument indicates the parameter position within the statement.

The return value is a Java array. The elements of this array are of the default Java type corresponding to the SQL type of the elements. For example, for an index-by table with elements of `NUMERIC` typecode, the element values are mapped to `BigDecimal` by the Oracle JDBC driver, and the `getPlsqlIndexTable()` method returns a `BigDecimal[]` array. For a JDBC application, you must cast the return value to a `BigDecimal[]` array to access the table element values. (See "Datatype Mappings" on page 3-16 for a list of default mappings.)

The following code example uses the `getPlsqlIndexTable()` method to return index-by table elements with JDBC default mapping:

```
// access the value using JDBC default mapping
BigDecimal[] values =
   (BigDecimal[]) procout.getPlsqlIndexTable (1);

// print the elements
for (int i=0; i<values.length; i++)
   System.out.println (values[i].intValue());
```

Oracle Mappings The `getOraclePlsqlIndexTable()` method returns index-by table elements using Oracle mapping.

```
public Datum[] getOraclePlsqlIndexTable (int paramIndex)
      throws SQLException
```

Table 16–5 describes the argument of the `getOraclePlsqlIndexTable()` method.

Table 16–5 Argument of the getOraclePlsqlIndexTable () Method

Argument	Description
`int paramIndex`	This argument indicates the parameter position within the statement.

The return value is an `oracle.sql.Datum` array and the elements in the `Datum` array will be the default `Datum` type corresponding to the SQL type of the element.

For example, the element values of an index-by table of numeric elements are mapped to the `oracle.sql.NUMBER` type in Oracle mapping, and the `getOraclePlsqlIndexTable()` method returns an `oracle.sql.Datum` array that contains `oracle.sql.NUMBER` elements.

The following code example uses the `getOraclePlsqlIndexTable()` method to access the elements of a PL/SQL index-by table `OUT` parameter, using Oracle mapping. (The code for registration is omitted.)

```
// Prepare the statement
OracleCallableStatement procout = (OracleCallableStatement)
                                  conn.prepareCall ("begin procout (?); end;");

...

// execute the call
procout.execute ();

// access the value using Oracle JDBC mapping
Datum[] outvalues = procout.getOraclePlsqlIndexTable (1);

// print the elements
for (int i=0; i<outvalues.length; i++)
   System.out.println (outvalues[i].intValue());
```

Java Primitive Type Mappings The `getPlsqlIndexTable()` method with the `(int, Class)` signature returns index-by table elements in Java primitive types. The return value is a Java array.

```
synchronized public Object getPlsqlIndexTable
   (int paramIndex, Class primitiveType) throws SQLException
```

Table 16–6 describes the arguments of the `getPlsqlIndexTable()` method.

Table 16–6 Arguments of the getPlsqlIndexTable () Method

Argument	Description
`int paramIndex`	This argument indicates the parameter position within the statement.

`Class primitiveType`	This argument specifies a Java primitive type to which the index-by table elements are to be converted. For example, if you specify `java.lang.Integer.TYPE`, the return value is an `int` array.
	The following are the possible values of this parameter:
	`java.lang.Integer.TYPE`
	`java.lang.Long.TYPE`
	`java.lang.Float.TYPE`
	`java.lang.Double.TYPE`
	`java.lang.Short.TYPE`

The following code example uses the `getPlsqlIndexTable()` method to access the elements of a PL/SQL index-by table of numbers. In the example, the second parameter specifies `java.lang.Integer.TYPE`, so the return value of the `getPlsqlIndexTable()` method is an `int` array.

```
OracleCallableStatement funcnone = (OracleCallableStatement)
   conn.prepareCall ("begin ? := funcnone; end;");

// maximum length of the index-by table value. This
// value defines the maximum table size to be returned.
int maxLen = 10;

// index-by table element type
int elemSqlType = OracleTypes.NUMBER;

// index-by table element length in case the element type
// is CHAR, VARCHAR or RAW. This value is ignored for other
// types
int elemMaxLen = 0;

// register the return value
funcnone.registerIndexTableOutParameter (1, maxLen,
                                         elemSqlType, elemMaxLen);
// execute the call
```

```
funcnone.execute ();

// access the value as a Java primitive array.
int[] values = (int[])
   funcnone.getPlsqlIndexTable (1, java.lang.Integer.TYPE);

// print the elements
for (int i=0; i<values.length; i++)
   System.out.println (values[i]);
```

17

Advanced Topics

This chapter describes the following advanced JDBC topics:

- JDBC and Globalization Support
- JDBC Client-Side Security Features
- JDBC in Applets
- JDBC in the Server: the Server-Side Internal Driver

JDBC and Globalization Support

After a brief overview, this section covers the following topics:

- How JDBC Drivers Perform Globalization Support Conversions
- Globalization Support and Object Types
- SQL CHAR Data Size Restrictions with the Thin Driver

Oracle's JDBC drivers support Globalization Support (formerly NLS). Globalization Support allows you retrieve data or insert data into a database in any character set that Oracle supports. If the clients and the server use different character sets, then the driver provides the support to perform the conversions between the database character set and the client character set.

For more information on Globalization Support, Globalization Support environment variables, and the character sets that Oracle supports, see "Oracle Character Datatypes Support" on page 6-28 and the *Oracle9i Database Globalization Support Guide*. See the *Oracle9i Reference* for more information on the database character set and how it is created.

Here are a few examples of commonly used Java methods for JDBC that rely heavily on character set conversion:

- The `java.sql.ResultSet` methods `getString()` and `getUnicodeStream()` return values from the database as Java strings and as a stream of Unicode characters, respectively.
- The `oracle.sql.CLOB` method `getCharacterStream()` returns the contents of a `CLOB` as a Unicode stream.
- The `oracle.sql.CHAR` methods `getString()`, `toString()`, and `getStringWithReplacement()` convert the following data to strings:
  - `getString()`: This converts the sequence of characters represented by the `CHAR` object to a string and returns a Java `String` object.
  - `toString()`: This is identical to `getString()`, but if the character set is not recognized, then `toString()` returns a hexadecimal representation of the `CHAR` data.
  - `getStringWithReplacement()`: This is identical to `getString()`, except characters that have no Unicode representation in the character set of this `CHAR` object are replaced by a default replacement character.

How JDBC Drivers Perform Globalization Support Conversions

The techniques that the Oracle JDBC drivers use to perform character set conversion for Java applications depend on the character set the database uses. The simplest case is where the database uses the US7ASCII or WE8ISO8859P1 character set. In this case, the driver converts the data directly from the database character set to UTF-16, which is used in Java applications, and vice versa.

If you are working with databases that employ a non-US7ASCII or non-WE8ISO8859P1 character set (for example, JA16SJIS or KO16KSC5601), then the driver converts the data first to UTF-8 (this step does not apply to the server-side internal driver), then to UTF-16. For example, the driver always converts CHAR and VARCHAR2 data in a non-US7ASCII, non-WE8ISO8859P1 character set. It does not convert RAW data.

Note: The JDBC drivers perform all character set conversions transparently. No user intervention is necessary for the conversions to occur.

JDBC OCI Driver and Globalization Support

For the JDBC OCI driver, the client character set is in the NLS_LANG environment variable, which is set at client-installation time. The language and territory settings, by default, are set to the Java VM locale settings.

Note that there are also server-side settings for these parameters, determined during database creation. So, when performing character set conversion, the JDBC OCI driver considers the following:

- database character set and language
- client character set and language
- Java application's character set

The JDBC OCI driver transfers the data from the server to the client in the character set of the database. Depending on the value of the NLS_LANG environment variable, the driver handles character set conversions in one of two ways:

- If NLS_LANG is not specified, or specifies the US7ASCII or WE8ISO8859P1 character set, then the JDBC OCI driver uses Java to convert the character set from US7ASCII or WE8ISO8859P1 directly to UTF-16, or the reverse.

or:

- If NLS_LANG specifies a character set other than US7ASCII or WE8ISO8859P1, the driver uses UTF-8 as the client character set. This happens automatically and does not require any user intervention. OCI converts the data from the database character set to UTF-8. The JDBC OCI driver then passes the UTF-8 data to the JDBC Class Library, where the UTF-8 data is converted to UTF-16.

  Notes:

  - The driver uses UTF-8 as the character set to minimize the number of conversions it performs in Java.
  - The change to UTF-8 is for the JDBC application process only.

JDBC Thin Driver and Globalization Support

If you are using the JDBC Thin driver, then there will presumably be no Oracle client installation. Globalization Support conversions must be handled differently.

Language and Territory The Thin driver obtains language and territory settings (NLS_LANGUAGE and NLS_TERRITORY) from the Java locale in the JVM user.language property. The date format (NLS_DATE_FORMAT) is set according to the territory setting.

Character Set If the database character set is US7ASCII or WE8ISO8859P1, then the data is transferred to the client without any conversion. The driver then converts the character set to UTF-16 in Java.

If the database character set is something other than US7ASCII or WE8ISO8859P1, then the server first translates the data to UTF-8 before transferring it to the client. On the client, the JDBC Thin driver converts the data to UTF-16 in Java.

Server-Side Internal Driver and Globalization Support

If your JDBC code running in the server accesses the database, then the JDBC server-side internal driver performs a character set conversion based on the database character set. The target character set of all Java programs is UTF-16.

Globalization Support and Object Types

The Oracle JDBC class files, classes12.zip and classes111.zip, provide Globalization Support for the Thin and OCI drivers. The files contain all the necessary classes to provide complete Globalization Support for all Oracle character sets for CHAR and NCHAR datatypes not retrieved or inserted as part of an Oracle

object or collection type. See "Oracle Character Datatypes Support" on page 6-28 for a description of CHAR and NCHAR datatypes.

However, in the case of the CHAR and VARCHAR data portion of Oracle objects and collections, the JDBC class files provide support for only the following commonly used character sets:

- US7ASCII
- WE8DEC
- ISO-LATIN-1
- UTF-8

To provide support for all character sets, the Oracle JDBC driver installation includes two additional files: `nls_charset12.zip` for JDK 1.2.x and `nls_charset11.zip` for JDK 1.1.*x*. The OCI and Thin drivers require these files to support all Oracle characters sets for CHAR and VARCHAR data in Oracle object types and collections. To obtain this support, you must add the appropriate `nls_charset*.zip` file to your CLASSPATH.

It is important to note that the `nls_charset*.zip` files are very large, because they must support a large number of character sets. To save space, you might want to keep only the classes you need from the `nls_charset*.zip` file. If you want to do this, follow these steps:

1. Unzip the appropriate `nls_charset*.zip` file.
2. Add only the needed character set classes to the CLASSPATH.
3. Remove the unneeded character set files from your system.

The character set extension class files are named in the following format:

`CharacterConverter<`*`OracleCharacterSetId`*`>.class`

where <*OracleCharacterSetId*> is the hexadecimal representation of the Oracle character set ID that corresponds to a character set name.

Note: The preceding discussion is not relevant in using the server-side internal driver, which provides complete Globalization Support and does not require the character set classes.

SQL CHAR Data Size Restrictions with the Thin Driver

If the database character set is neither ASCII (US7ASCII) nor ISO-LATIN-1 (WE8ISO8859P1), then the Thin driver must impose size restrictions for CHAR and VARCHAR2 bind parameters that are more restrictive than normal database size limitations. This is necessary to allow for data expansion during conversion.

The Thin driver checks CHAR bind sizes when the setXXX() method is called. If the data size exceeds the size restriction, then the driver throws a SQL exception ("Data size bigger than max size for this type") from the setXXX() call. This limitation is necessary to avoid the chance of data corruption whenever a conversion occurs and increases the length of the data. This limitation is enforced when you are doing all the following:

- using the Thin driver
- using binds (not defines)
- using CHAR, VARCHAR2, or LONG datatypes
- connecting to a database whose character set is neither ASCII (US7ASCII) nor ISO-Latin-1 (WE8ISO8859P1)

Role of the Expansion Factor

As previously discussed, when the database character set is neither US7ASCII nor WE8ISO8859P1, the Thin driver converts Java UTF-16 characters to UTF-8 encoding bytes for CHAR or VARCHAR2 binds. The UTF-8 encoding bytes are then transferred to the database, and the database converts the UTF-8 encoding bytes to the database character set encoding.

This conversion to the character set encoding can result in an increase in the number of bytes required to store the data. The *expansion factor* for a database character set indicates the maximum possible expansion in converting a character from UTF-8 to the character set: If the database character set is either UTF-8 or AL32UTF8, the expansion factor (exp_factor) is 1. Otherwise, the expansion factor is equal to the maximum character size in the database character set.

Size Restriction Formulas

Table 17–1 shows the database size limitations for CHAR data and the Thin driver size restriction formulas for CHAR binds. Database limits are in bytes. Formulas determine the maximum size of the UTF-8 encoding in bytes.

Table 17–1 Maximum CHAR and NCHAR Bind Sizes, Thin Driver

Oracle Version	Datatype	Max Size Allowed by Database (bytes)	Formula for Thin Driver Max Bind Size (UTF-8 bytes)
Oracle8 and later	CHAR	2000	4000 / `exp_factor`
Oracle8 and later	VARCHAR2	4000	4000 / `exp_factor`
Oracle8 and later	LONG	$2^{31} - 1$	$(2^{31} - 1)$ / `exp_factor`
Oracle7	CHAR	255	255
Oracle7	VARCHAR2	2000	2000 / `exp_factor`

The formulas guarantee that after the data is converted from `UTF-8` to the database character set, the size will not exceed the database maximum size.

The number of `UTF-16` characters that can be supported is determined by the number of bytes per character in the data. All `ASCII` characters are one byte long in `UTF-8` encoding. Other character types can be two or three bytes long.

Expansion Factors and Calculated Size Restrictions for Common Character Sets

Table 17–2 lists the expansion factors of some common server character sets, then shows the Thin driver maximum bind sizes for `SQL CHAR` data for each character set, as determined by using the expansion factor in the appropriate formula.

Again, maximum bind sizes are for `UTF-8` encoding, in bytes.

Table 17–2 Expansion Factors and Size Limits, Oracle8, Common Character Sets

Server Character Set	Expansion Factor	Thin Driver Max SQL CHAR Bind Size (UTF-8 bytes)
`WE8DEC`	1	4000
`JA16SJIS`	2	2000
`WE8ISO8859P1`	3	1333
`AL32UTF8`	1	4000

JDBC Client-Side Security Features

This section discusses support in the Oracle JDBC OCI and Thin drivers for login authentication, data encryption, and data integrity—particularly with respect to features of the Oracle Advanced Security option.

Oracle Advanced Security, previously known as the "Advanced Networking Option" (ANO) or "Advanced Security Option" (ASO), includes features to support data encryption, data integrity, third-party authentication, and authorizations. Oracle JDBC supports most of these features; however, the JDBC Thin driver must be considered separately from the JDBC OCI driver.

Note: This discussion is not relevant to the server-side internal driver, given that all communication through that driver is completely internal to the server.

JDBC Support for Oracle Advanced Security

Both the JDBC OCI drivers and the JDBC Thin driver support at least some of the features of Oracle Advanced Security. If you are using one of the OCI drivers, you can set relevant parameters in the same way that you would in any thick-client setting. The Thin driver supports Advanced Security features through a set of Java classes included with the JDBC classes ZIP file, and supports security parameter settings through Java properties objects.

Included in your Oracle JDBC `classes111.zip` or `classes12.zip` file are a JAR file containing classes that incorporate features of Oracle Advance Security, and a JAR file containing classes whose function is to interface between the JDBC classes and the Advanced Security classes for use with the JDBC Thin driver.

OCI Driver Support for Oracle Advanced Security

If you are using one of the JDBC OCI drivers, which presumes you are running from a thick-client machine with an Oracle client installation, then support for Oracle Advanced Security and incorporated third-party features is, for the most part, no different from any Oracle thick-client situation. Your use of Advanced Security features is determined by related settings in the `SQLNET.ORA` file on the client machine, as discussed in the *Oracle Advanced Security Administrator's Guide*. Refer to that manual for information.

Important: The one key exception to the preceding, with respect to Java, is that SSL—Sun Microsystem's standard Secure Socket Layer protocol—is supported by the Oracle JDBC OCI drivers only if you use native threads in your application. This requires special attention, because green threads are generally the default.

Thin Driver Support for Oracle Advanced Security

Because the Thin driver was designed to be downloadable with applets, one obviously cannot assume that there is an Oracle client installation and a `SQLNET.ORA` file where the Thin driver is used. This necessitated the design of a new, 100% Java approach to Oracle Advanced Security support.

Java classes that implement Oracle Advanced Security are included in your JDBC `classes12.zip` or `classes111.zip` file. Security parameters for encryption and integrity, normally set in `SQLNET.ORA`, are set in a Java properties file instead.

For information about parameter settings, see "Thin Driver Support for Encryption and Integrity" on page 17-12.

JDBC Support for Login Authentication

Basic login authentication through JDBC consists of user names and passwords, as with any other means of logging in to an Oracle server. Specify the user name and password through a Java properties object or directly through the `getConnection()` method call, as discussed in "Opening a Connection to a Database" on page 3-3.

This applies regardless of which client-side Oracle JDBC driver you are using, but is irrelevant if you are using the server-side internal driver, which uses a special direct connection and does not require a user name or password.

The Oracle JDBC Thin driver implements Oracle O3LOGON challenge-response protocol to authenticate the user.

Note: Third-party authentication features supported by Oracle Advanced Security—such as those provided by RADIUS, Kerberos, or SecurID—are not supported by the Oracle JDBC Thin driver. For the Oracle JDBC OCI driver, support is the same as in any thick-client situation—refer to the *Oracle Advanced Security Administrator's Guide*.

JDBC Support for Data Encryption and Integrity

You can use Oracle Advanced Security data encryption and integrity features in your Java database applications, depending on related settings in the server.

When using an OCI driver in a thick-client setting, set parameters as you would in any Oracle client situation. When using the Thin driver, set parameters through a Java properties file.

Encryption is enabled or disabled based on a combination of the client-side encryption-level setting and the server-side encryption-level setting.

Similarly, integrity is enabled or disabled based on a combination of the client-side integrity-level setting and the server-side integrity-level setting.

Encryption and integrity support the same setting levels—`REJECTED`, `ACCEPTED`, `REQUESTED`, and `REQUIRED`. Table 17–3 shows how these possible settings on the client-side and server-side combine to either enable or disable the feature.

Table 17–3 Client/Server Negotiations for Encryption or Integrity

	Client Rejected	**Client Accepted (default)**	**Client Requested**	**Client Required**
Server Rejected	OFF	OFF	OFF	connection fails
Server Accepted (default)	OFF	OFF	ON	ON
Server Requested	OFF	ON	ON	ON
Server Required	connection fails	ON	ON	ON

This table shows, for example, that if encryption is requested by the client, but rejected by the server, it is disabled. The same is true for integrity. As another example, if encryption is accepted by the client and requested by the server, it is enabled. And, again, the same is true for integrity.

The general settings are further discussed in the *Oracle Advanced Security Administrator's Guide*. How to set them for a JDBC application is described in the following subsections.

Note: The term "checksum" still appears in integrity parameter names, as you will see in the following subsections, but is no longer used otherwise. For all intents and purposes, "checksum" and "integrity" are synonymous.

OCI Driver Support for Encryption and Integrity

If you are using one of the Oracle JDBC OCI drivers, which presumes a thick-client setting with an Oracle client installation, you can enable or disable data encryption or integrity and set related parameters as you would in any Oracle client situation, through settings in the `SQLNET.ORA` file on the client machine.

To summarize, the client parameters are shown in Table 17–4:

Table 17–4 OCI Driver Client Parameters for Encryption and Integrity

Parameter Description	Parameter Name	Possible Settings

Client encryption level	`SQLNET.ENCRYPTION_CLIENT`	`REJECTED`
		`ACCEPTED`
		`REQUESTED`
		`REQUIRED`

Client encryption selected list	`SQLNET.ENCRYPTION_TYPES_CLIENT`	`RC4_40`
		`RC4_56`
		`DES`
		`DES40`
		(see note below)

Client integrity level	`SQLNET.CRYPTO_CHECKSUM_CLIENT`	`REJECTED`
		`ACCEPTED`
		`REQUESTED`
		`REQUIRED`

Client integrity selected list	`SQLNET.CRYPTO_CHECKSUM_TYPES_CLIENT`	`MD5`

Note: For the Oracle Advanced Security domestic edition only, a setting of `RC4_128` is also possible.

These settings, and corresponding settings in the server, are further discussed in Appendix A of the *Oracle Advanced Security Administrator's Guide*.

Thin Driver Support for Encryption and Integrity

Thin driver support for data encryption and integrity parameter settings parallels the thick-client support discussed in the preceding section. Corresponding parameters exist under the `oracle.net` package and can be set through a Java properties object that you would then use in opening your database connection.

If you replace "SQLNET" in the parameter names in Table 17–4 with "oracle.net", you will get the parameter names supported by the Thin driver (but note that in Java, the parameter names are all-lowercase).

Table 17–5 lists the parameter information for the Thin driver. See the next section for examples of how to set these parameters in Java.

Table 17–5 Thin Driver Client Parameters for Encryption and Integrity

Parameter Name	Parameter Type	Parameter Class	Possible Settings

`oracle.net.encryption_client`	string	static	`REJECTED`
			`ACCEPTED`
			`REQUESTED`
			`REQUIRED`

`oracle.net.encryption_types_client`	string	static	`RC4_40`
			`RC4_56`
			`DES40C`
			`DES56C`

`oracle.net.crypto_checksum_client`	string	static	`REJECTED`
			`ACCEPTED`
			`REQUESTED`
			`REQUIRED`

`oracle.net.crypto_checksum_types_client`	string	static	`MD5`

Notes:

- Because Oracle Advanced Security support for the Thin driver is incorporated directly into the JDBC classes ZIP file, there is only one version, not separate domestic and export editions. Only parameter settings that would be suitable for an export edition are possible.
- The "C" in `DES40C` and `DES56C` refers to CBC (cipher block chaining) mode.

Setting Encryption and Integrity Parameters in Java

Use a Java properties object (`java.util.Properties`) to set the data encryption and integrity parameters supported by the Oracle JDBC Thin driver.

The following example instantiates a Java properties object, uses it to set each of the parameters in Table 17–5, and then uses the properties object in opening a connection to the database:

```
...
Properties prop = new Properties();
prop.put("oracle.net.encryption_client", "REQUIRED");
prop.put("oracle.net.encryption_types_client", "( DES40 )");
prop.put("oracle.net.crypto_checksum_client", "REQUESTED");
prop.put("oracle.net.crypto_checksum_types_client", "( MD5 )");
Connection conn = DriverManager.getConnection
   ("jdbc:oracle:thin:@localhost:1521:main", prop);
...
```

The parentheses around the parameter values in the `encryption_types_client` and `crypto_checksum_types_client` settings allow for lists of values. Currently, the Thin driver supports only one possible value in each case; however, in the future, when multiple values are supported, specifying a list will result in a negotiation between the server and the client that determines which value is actually used.

Complete example Following is a complete example of a class that sets data encryption and integrity parameters before connecting to a database to perform a query.

Note that in this example, the string "REQUIRED" is retrieved dynamically through functionality of the `AnoServices` and `Service` classes. You have the option of retrieving the strings in this manner or hardcoding them as in the previous examples.

```
import java.sql.*;
import java.sql.*;
import java.io.*;
import java.util.*;
import oracle.net.ns.*;
import oracle.net.ano.*;

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

```
    throws Exception
  {

    // Register the Oracle JDBC driver
    System.out.println("Registring the driver...");
    DriverManager.registerDriver(new oracle.jdbc.OracleDriver());

    Properties props = new Properties();

    try {
      FileInputStream defaultStream = new FileInputStream(args[0]);
      props.load(defaultStream);


      int level = AnoServices.REQUIRED;
      props.put("oracle.net.encryption_client", Service.getLevelString(level));
      props.put("oracle.net.encryption_types_client", "( DES40 )");
      props.put("oracle.net.crypto_checksum_client",
                 Service.getLevelString(level));
      props.put("oracle.net.crypto_checksum_types_client", "( MD5 )");
    } catch (Exception e) { e.printStackTrace(); }


    // You can put a database name after the @ sign in the connection URL.
    Connection conn = DriverManager.getConnection
               ("jdbc:oracle:thin:@dlsun608.us.oracle.com:1521:main", props);

    // Create a Statement
    Statement stmt = conn.createStatement ();

    // Select the ENAME column from the EMP table
    ResultSet rset = stmt.executeQuery ("select ENAME from EMP");

    // Iterate through the result and print the employee names
    while (rset.next ())
       System.out.println (rset.getString (1));

    conn.close();
  }

}
```

JDBC in Applets

This section describes some of the basics of working with Oracle JDBC applets, which must use the JDBC Thin driver so that an Oracle installation is not required on the client. The Thin driver connects to the database with TCP/IP protocol.

Aside from having to use the Thin driver, and being mindful of applet connection and security issues, there is essentially no difference between coding a JDBC applet and a JDBC application. There is also no difference between coding for a JDK 1.2.x browser or a JDK 1.1.x browser, other than general JDK 1.1.x to 1.2.x migration issues discussed in "Migration from JDK 1.1.x to JDK 1.2.x" on page 4-5.

This section describes what you must do for the applet to connect to a database, including how to use the Oracle Connection Manager or signed applets if you are connecting to a database not running on the same host as the Web server. It also describes how your applet can connect to a database through a firewall. The section concludes with how to package and deploy the applet.

The following topics are covered:

- Connecting to the Database through the Applet
- Connecting to a Database on a Different Host Than the Web Server
- Using Applets with Firewalls
- Packaging Applets
- Specifying an Applet in an HTML Page

For general information about connecting to the database, see "Opening a Connection to a Database" on page 3-3.

> **Note:** Beginning with release 8.1.6, Oracle JDBC no longer supports JDK 1.0.x versions. This also applies to applets running in browsers that incorporate JDK 1.0.x versions. The user must upgrade to a browser with an environment of JDK 1.1.x or higher.

Connecting to the Database through the Applet

The most common task of an applet using the JDBC driver is to connect to and query a database. Because of applet security restrictions, unless particular steps are taken an applet can open TCP/IP sockets only to the host from which it was downloaded (this is the host on which the Web server is running). This means that

without these steps, your applet can connect only to a database that is running on the same host as the Web server.

If your database and Web server are running on the same host, then there is no issue and no special steps are required. You can connect to the database as you would from an application.

As with connecting from an application, there are two ways in which you can specify the connection information to the driver. You can provide it in the form of `host:port:sid` or in the form of a TNS keyword-value syntax.

For example, if the database to which you want to connect resides on host `prodHost`, at port `1521`, and SID `ORCL`, and you want to connect with user name `scott` with password `tiger`, then use either of the two following connect strings:

using `host:port:sid` syntax:

```
String connString="jdbc:oracle:thin:@prodHost:1521:ORCL";
conn = DriverManager.getConnection(connString, "scott", "tiger");
```

using TNS keyword-value syntax:

```
String connString = "jdbc:oracle:thin:@(description=(address_list=
   (address=(protocol=tcp)(port=1521)(host=prodHost)))
   (connect_data=(INSTANCE_NAME=ORCL)))";
conn = DriverManager.getConnection(connString, "scott", "tiger");
```

If you use the TNS keyword-value pair to specify the connection information to the JDBC Thin driver, then you must declare the protocol as TCP.

However, a Web server and an Oracle database server both require many resources; you seldom find both servers running on the same machine. Usually, your applet connects to a database on a host other than the one on which the Web server runs. There are two possible ways in which you can work around the security restriction:

- You can connect to the database by using the Oracle Connection Manager.

or:

- You can use a signed applet to connect to the database directly.

These options are discussed in the next section, "Connecting to a Database on a Different Host Than the Web Server".

Connecting to a Database on a Different Host Than the Web Server

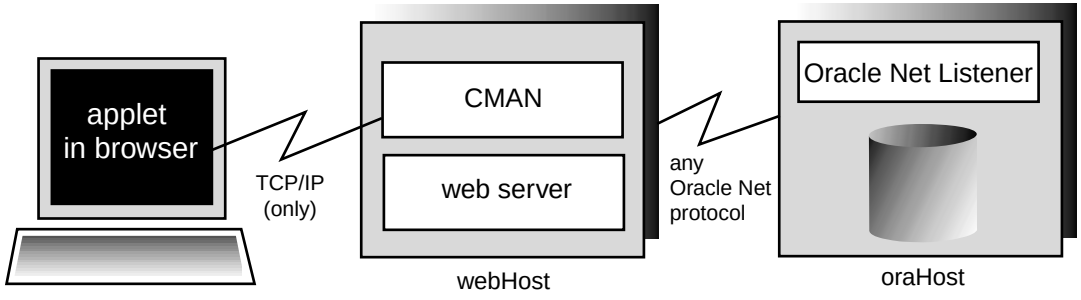
If you are connecting to a database on a host other than the one on which the Web server is running, then you must overcome applet security restrictions. You can do this by using either the Oracle Connection Manager or signed applets.

Using the Oracle Connection Manager

The Oracle Connection Manager is a lightweight, highly-scalable program that can receive Oracle Net packets and re-transmit them to a different server. To a client running Oracle Net, the Connection Manager looks exactly like a database server. An applet that uses the JDBC Thin driver can connect to a Connection Manager running on the Web server host and have the Connection Manager redirect the Oracle Net packets to an Oracle server running on a different host.

Figure 17–1 illustrates the relationship between the applet, the Oracle Connection Manager, and the database.

Figure 17–1 Applet, Connection Manager, and Database Relationship



Using the Oracle Connection Manager requires two steps:

- Install and run the Connection Manager.
- Write the connection string that targets the Connection Manager.

There is also discussion of how to connect using multiple connection managers.

Installing and Running the Oracle Connection Manager You must install the Connection Manager, available on the Oracle9*i* distribution media, onto the Web server host. You can find the installation instructions in the *Oracle Net Services Administrator's Guide*.

On the Web server host, create a CMAN.ORA file in the [ORACLE_HOME]/NET8/ADMIN directory. The options you can declare in a CMAN.ORA file include firewall and connection pooling support.

Here is an example of a very simple CMAN.ORA file. Replace <*web-server-host*> with the name of your Web server host. The fourth line in the file indicates that the Connection Manager is listening on port 1610. You must use this port number in your connect string for JDBC.

```
cman = (ADDRESS_LIST =
       (ADDRESS = (PROTOCOL=TCP)
       (HOST=<web-server-host>)
       (PORT=1610)))

cman_profile = (parameter_list =
       (MAXIMUM_RELAYS=512)
       (LOG_LEVEL=1)
   (TRACING=YES)
       (RELAY_STATISTICS=YES)
       (SHOW_TNS_INFO=YES)
       (USE_ASYNC_CALL=YES)
       (AUTHENTICATION_LEVEL=0)
       )
```

Note that the Java Oracle Net version inside the JDBC Thin driver does not have authentication service support. This means that the AUTHENTICATION_LEVEL configuration parameter in the CMAN.ORA file must be set to 0.

After you create the file, start the Connection Manager at the operating system prompt with this command:

```
cmctl start
```

To use your applet, you must now write the connect string for it.

Writing the Connect String that Targets the Connection Manager This section describes how to write the connect string in your applet so that the applet connects to the Connection Manager, and the Connection Manager connects with the database. In the connect string, you specify an address list that lists the protocol, port, and name of the Web server host on which the Connection Manager is running, followed by the protocol, port, and name of the host on which the database is running.

The following example describes the configuration illustrated in Figure 17–1. The Web server on which the Connection Manager is running is on host webHost and is listening on port 1610. The database to which you want to connect is running on

host `oraHost`, listening on port `1521`, and SID `ORCL`. You write the connect string in TNS keyword-value format:

```
Connection conn =
   DriverManager.getConnection ("jdbc:oracle:thin:" +
   "@(description=(address_list=" +
   "(address=(protocol=tcp)(host=webHost)(port=1610))" +
   "(address=(protocol=tcp)(host=oraHost)(port=1521)))" +
   "(source_route=yes)" +
   "(connect_data=(INSTANCE_NAME=orcl)))", "scott", "tiger");
```

The first element in the `address_list` entry represents the connection to the Connection Manager. The second element represents the database to which you want to connect. The order in which you list the addresses is important.

Notice that you can also write the same connect string in this format:

```
String connString =
   "jdbc:oracle:thin:@(description=(address_list=
   (address=(protocol=tcp)(port=1610)(host=webHost))
   (address=(protocol=tcp)(port=1521)(host=oraHost)))
   (connect_data=(INSTANCE_NAME=orcl))
   (source_route=yes))";
Connection conn = DriverManager.getConnection(connString, "scott", "tiger");
```

When your applet uses a connect string such as the one above, it will behave exactly as if it were connected directly to the database on the host `oraHost`.

For more information on the parameters that you specify in the connect string, see the *Oracle Net Services Administrator's Guide*.

Connecting through Multiple Connection Managers Your applet can reach its target database even if it first has to go through multiple Connection Managers (for example, if the Connection Managers form a "proxy chain"). To do this, add the addresses of the Connection Managers to the address list, in the order that you plan to access them. The database listener should be the last address on this list. See the *Oracle Net Services Administrator's Guide* for more information about `source_route` addressing.

Using Signed Applets

In either a JDK 1.2.x-based browser or a JDK 1.1.x-based browser, an applet can request socket connection privileges and connect to a database running on a different host than the Web server host. In Netscape 4.0, you perform this by signing your applet (that is, writing a signed applet). You must follow these steps:

1. Sign the applet. For information on the steps you must follow to sign an applet, see Sun Microsystem's *Signed Applet Example* at:

   ```
   http://java.sun.com/security/signExample/index.html
   ```

2. Include applet code that asks for appropriate permission before opening a socket.

   If you are using Netscape, then your code would include a statement like this:

   ```
   netscape.security.PrivilegeManager.enablePrivilege("UniversalConnect");
   connection = DriverManager.getConnection
                ("jdbc:oracle:thin:scott/tiger@dlsun511:1721:orcl");
   ```

3. You must obtain an object-signing certificate. See Netscape's *Object-Signing Resources* page at:

   ```
   http://developer.netscape.com/software/signedobj/index.html
   ```

   This site provides information on obtaining and installing a certificate.

For more information on writing applet code that asks for permissions, see Netscape's *Introduction to Capabilities Classes* at:

```
http://developer.netscape.com/docs/manuals/signedobj/capabilities/contents.htm
```

For information about the Java Security API, including signed applet examples under JDK 1.2.x and 1.1.x, see the following Sun Microsystems site:

```
http://java.sun.com/security
```

Using Applets with Firewalls

Under normal circumstances, an applet that uses the JDBC Thin driver cannot access the database through a firewall. In general, the purpose of a firewall is to prevent unauthorized clients from reaching the server. In the case of applets trying to connect to the database, the firewall prevents the opening of a TCP/IP socket to the database.

Firewalls are rule-based. They have a list of rules that define which clients can connect, and which cannot. Firewalls compare the client's hostname with the rules, and based on this comparison, either grant the client access, or not. If the hostname lookup fails, the firewall tries again. This time, the firewall extracts the IP address of the client and compares it to the rules. The firewall is designed to do this so that users can specify rules that include hostnames as well as IP addresses.

You can solve the firewall issue by using an Oracle Net-compliant firewall and connection strings that comply with the firewall configuration. Oracle Net-compliant firewalls are available from many leading vendors; a more detailed discussion of these firewalls is beyond the scope of this manual.

An unsigned applet can access only the same host from which it was downloaded. In this case, the Oracle Net-compliant firewall must be installed on that host. In contrast, a signed applet can connect to any host. In this case, the firewall on the target host controls the access.

Connecting through a firewall requires two steps, described in the following sections:

- Configuring a Firewall for Applets that use the JDBC Thin Driver
- Writing a Connect String to Connect through a Firewall

Configuring a Firewall for Applets that use the JDBC Thin Driver

The instructions in this section assume that you are running an Oracle Net-compliant firewall.

Java applets do not have access to the local system—that is, they cannot get the hostname or environment variables locally—because of security limitations. As a result, the JDBC Thin driver cannot access the hostname on which it is running. The firewall cannot be provided with the hostname. To allow requests from JDBC Thin clients to go through the firewall, you must do the following two things to the firewall's list of rules:

- Add the IP address (not the hostname) of the host on which the JDBC applet is running.
- Ensure that the hostname "`__jdbc__`" never appears in the firewall's rules. This hostname has been hard-coded as a false hostname inside the driver to force an IP address lookup. If you do enter this hostname in the list of rules, then every applet using Oracle's JDBC Thin driver will be able to go through your firewall.

By not including the Thin driver's hostname, the firewall is forced to do an IP address lookup and base its access decision on the IP address, instead of the hostname.

Writing a Connect String to Connect through a Firewall

To write a connect string that allows you to connect through a firewall, you must specify the name of the firewall host and the name of the database host to which you want to connect.

For example, if you want to connect to a database on host `oraHost`, listening on port `1521`, with SID `ORCL`, and you are going though a firewall on host `fireWallHost`, listening on port `1610`, then use the following connect string:

```
Connection conn =
      DriverManager.getConnection ("jdbc:oracle:thin:" +
      "@(description=(address_list=" +
      (address=(protocol=tcp)(host=<firewall-host>)(port=1610))" +
      "(address=(protocol=tcp)(host=oraHost)(port=1521)))" +
      "(source_route=yes)" +
      "(connect_data=(INSTANCE_NAME=orcl)))", "scott", "tiger");
```

Note: To connect through a firewall, you cannot specify the connection string in `host:port:sid` syntax. For example, a connection string specified as follows will *not* work:

```
String connString =
      "jdbc:oracle:thin:@ixta.us.oracle.com:1521:orcl";
conn = DriverManager.getConnection (connString, "scott",
      "tiger");
```

The first element in the `address_list` represents the connection to the firewall. The second element represents the database to which you want to connect. Note that the order in which you specify the addresses is important.

Notice that you can also write the preceding connect string in this format:

```
String connString =
      "jdbc:oracle:thin:@(description=(address_list=
      (address=(protocol=tcp)(port=1600)(host=fireWallHost))
      (address=(protocol=tcp)(port=1521)(host=oraHost)))
      (connect_data=(INSTANCE_NAME=orcl))
      (source_route=yes))";
Connection conn = DriverManager.getConnection(connString, "scott", "tiger");
```

When your applet uses a connect string similar to the one above, it will behave as if it were connected to the database on host `oraHost`.

Note: All the parameters shown in the preceding example are required. In the `address_list`, the firewall address must precede the database server address.

For more information on the parameters used in the above example, see the *Oracle Net Services Administrator's Guide*. For more information on how to configure a firewall, please see your firewall's documentation or contact your firewall vendor.

Packaging Applets

After you have coded your applet, you must package it and make it available to users. To package an applet, you will need your applet class files and the JDBC driver class files (these will be contained in either `classes12.zip`, if you are targeting a browser that incorporates a JDK 1.2.x version, or `classes111.zip`, for a browser incorporating a JDK 1.1.x version).

Follow these steps:

1. Move the JDBC driver classes file `classes12.zip` (or `classes111.zip`) to an empty directory.

   If your applet will connect to a database with a non-`US7ASCII` and non-`WE8ISO8859P1` character set, then also move the `nls_charset12.zip` or `nls_charset11.zip` file to the same directory.

2. Unzip the JDBC driver classes ZIP file (and character set ZIP file, if applicable).

3. Add your applet classes files to the directory, and any other files the applet might require.

4. Zip the applet classes and driver classes together into a single ZIP or JAR file. The single zip file should contain the following:

   - class files from `classes12.zip` or `classes111.zip` (and required class files from `nls_charset12.zip` or `nls_charset11.zip` if the applet requires Globalization Support)
   - your applet classes

   Additionally, if you are using `DatabaseMetaData` entry points in your applet, include the `oracle/jdbc/driver/OracleDatabaseMetaData.class` file. Note that this file is very large and might have a negative impact on performance. If you do not use `DatabaseMetaData` methods, omit this file.

5. Ensure that the ZIP or JAR file is *not* compressed.

You can now make the applet available to users. One way to do this is to add the APPLET tag to the HTML page from which the applet will be run. For example:

```
<APPLET WIDTH=500 HEIGHT=200 CODE=JdbcApplet ARCHIVE=JdbcApplet.zip
      CODEBASE=Applet_Samples
</APPLET>
```

You can find a description of the APPLET, CODE, ARCHIVE, CODEBASE, WIDTH, and HEIGHT parameters in the next section.

Specifying an Applet in an HTML Page

The APPLET tag specifies an applet that runs in the context of an HTML page. The APPLET tag can have these parameters: CODE, ARCHIVE, CODEBASE, WIDTH, and HEIGHT to specify the name of the applet and its location, and the height and width of the applet display area. These parameters are described in the following sections.

CODE, HEIGHT, and WIDTH

The HTML page that runs the applet must have an APPLET tag with an initial width and height to specify the size of the applet display area. You use the HEIGHT and WIDTH parameters to specify the size, measured in pixels. This size should not count any windows or dialogs that the applet opens.

The APPLET tag must also specify the name of the file that contains the applet's compiled Applet subclass—specify the file name with the CODE parameter. Any path must be relative to the base URL of the applet—the path cannot be absolute.

In the following example, `JdbcApplet.class` is the name of the Applet's compiled applet subclass:

```
<APPLET CODE="JdbcApplet" WIDTH=500 HEIGHT=200>
</APPLET>
```

If you use this form of the CODE tag, then the classes for the applet and the classes for the JDBC Thin driver must be in the same directory as the HTML page.

Notice that in the CODE specification, you do not include the file name extension "`.class`".

CODEBASE

The CODEBASE parameter is optional and specifies the base URL of the applet; that is, the name of the directory that contains the applet's code. If it is not specified, then the document's URL is used. This means that the classes for the applet and the

JDBC Thin driver must be in the same directory as the HTML page. For example, if the current directory is `my_Dir`:

```
<APPLET WIDTH=500 HEIGHT=200 CODE=JdbcApplet CODEBASE="."
</APPLET>
```

The entry `CODEBASE="."` indicates that the applet resides in the current directory (`my_Dir`). If the value of `codebase` was set to `Applet_Samples`, for example:

```
CODEBASE="Applet_Samples"
```

This would indicate that the applet resides in the `my_Dir/Applet_Samples` directory.

ARCHIVE

The `ARCHIVE` parameter is optional and specifies the name of the archive file (either a `.zip` or `.jar` file), if applicable, that contains the applet classes and resources the applet needs. Oracle recommends using a `.zip` file or `.jar` file, which saves many extra roundtrips to the server.

The `.zip` (or `.jar`) file will be preloaded. If you have more than one archive in the list, separate them with commas. In the following example, the class files are stored in the archive file `JdbcApplet.zip`:

```
<APPLET CODE="JdbcApplet" ARCHIVE="JdbcApplet.zip" WIDTH=500 HEIGHT=200>
</APPLET>
```

Note: Version 3.0 browsers do not support the `ARCHIVE` parameter.

JDBC in the Server: the Server-Side Internal Driver

This section covers the following topics:

- Connecting to the Database with the Server-Side Internal Driver
- Exception-Handling Extensions for the Server-Side Internal Driver
- Session and Transaction Context for the Server-Side Internal Driver
- Testing JDBC on the Server
- Server-Side Character Set Conversion of oracle.sql.CHAR Data

This driver is intrinsically tied to the Oracle database and to the Java virtual machine (JVM). The driver runs as part of the same process as the database. It also runs within the default session—the same session in which the JVM was invoked.

The server-side internal driver is optimized to run within the database server and provide direct access to SQL data and PL/SQL subprograms on the local database. The entire JVM operates in the same address space as the database and the SQL engine. Access to the SQL engine is a function call; there is no network. This enhances the performance of your JDBC programs and is much faster than executing a remote Oracle Net call to access the SQL engine.

The server-side internal driver supports the same features, APIs, and Oracle extensions as the client-side drivers. This makes application partitioning very straightforward. For example, if you have a Java application that is data-intensive, you can easily move it into the database server for better performance, without having to modify the application-specific calls.

For general information about the Oracle Java platform server-side configuration or functionality, see the *Oracle9i Java Developer's Guide*.

Connecting to the Database with the Server-Side Internal Driver

As described in the preceding section, the server-side internal driver runs within a default session. You are already "connected". There are two methods you can use to access the default connection:

- Use the static `DriverManager.getConnection()` method, with either `jdbc:oracle:kprb` or `jdbc:default:connection` as the URL string.
- Use the Oracle-specific `defaultConnection()` method of the `OracleDriver` class.

Using `defaultConnection()` is generally recommended.

Note: You are no longer required to register the `OracleDriver` class for connecting with the server-side internal driver, although there is no harm in doing so. This is true whether you are using `getConnection()` or `defaultConnection()` to make the connection.

Connecting with the OracleDriver Class defaultConnection() Method

The `oracle.jdbc.OracleDriver` class `defaultConnection()` method is an Oracle extension and always returns the same connection object. Even if you invoke this method multiple times, assigning the resulting connection object to different variable names, just a single connection object is reused.

You do not need to include a connect string in the `defaultConnection()` call. For example:

```
import java.sql.*;
import oracle.jdbc.*;

class JDBCConnection
{
  public static Connection connect() throws SQLException
  {
    Connection conn = null;
    try {
      // connect with the server-side internal driver
         OracleDriver ora = new OracleDriver();
         conn = ora.defaultConnection();
      }

    } catch (SQLException e) {...}
    return conn;
  }
}
```

Note that there is no `conn.close()` call in the example. When JDBC code is running inside the target server, the connection is an implicit data channel, not an explicit connection instance as from a client. It should typically not be closed.

If you do call the `close()` method, be aware of the following:

- All connection instances obtained through the `defaultConnection()` method, which actually all reference the same connection object, will be closed and unavailable for further use, with state and resource cleanup as appropriate.

Executing `defaultConnection()` afterward would result in a new connection object.

- Even though the connection object is closed, the implicit connection to the database will not be closed.

Connecting with the DriverManager.getConnection() Method

To connect to the internal server connection from code that is running within the target server, you can use the static `DriverManager.getConnection()` method with either of the following connect strings:

```
DriverManager.getConnection("jdbc:oracle:kprb:");
```

or:

```
DriverManager.getConnection("jdbc:default:connection:");
```

Any user name or password you include in the URL string is ignored in connecting to the server default connection.

The `DriverManager.getConnection()` method returns a new Java `Connection` object every time you call it. Note that although the method is not creating a new physical connection (only a single implicit connection is used), it is returning a new object.

The fact that `DriverManager.getConnection()` returns a new connection object every time you call it is significant if you are working with object maps (or "type maps"). A type map is associated with a specific `Connection` object and with any state that is part of the object. If you want to use multiple type maps as part of your program, then you can call `getConnection()` to create a new `Connection` object for each type map.

Exception-Handling Extensions for the Server-Side Internal Driver

The server-side internal driver, in addition to having standard exception-handling capabilities such as `getMessage()`, `getErrorCode()`, and `getSQLState()` (as described in "Processing SQL Exceptions" on page 3-34), offers extended features through the `oracle.jdbc.driver.OracleSQLException` class. This class is a subclass of the standard `java.sql.SQLException` class and is not available to the client-side JDBC drivers or the server-side Thin driver.

When an error condition occurs in the server, it often results in a series of related errors being placed in an internal error stack. The JDBC server-side internal driver

retrieves errors from the stack and places them in a chain of `OracleSQLException` objects.

You can use the following methods in processing these exceptions:

- `SQLException getNextException()` (standard method)

  This method returns the next exception in the chain (or `null` if no further exceptions). You can start with the first exception you receive and work through the chain.

- `int getNumParameters()` (Oracle extension)

  Errors from the server usually include parameters, or variables, that are part of the error message. These may indicate what type of error occurred, what kind of operation was being attempted, or the invalid or affected values.

  This method returns the number of parameters included with this error.

- `Object[] getParameters()` (Oracle extension)

  This method returns a Java `Object[]` array containing the parameters included with this error.

Example Following is an example of server-side error processing:

```
try
{
   // should get "ORA-942: table or view does not exist"
   stmt.execute("drop table no_such_table");
}
catch (OracleSQLException e)
{
   System.out.println(e.getMessage());
   // prints "ORA-942: table or view does not exist"

   System.out.println(e.getNumParameters());
   // prints "1"

   Object[] params = e.getParameters();
   System.out.println(params[0]);
   // prints "NO_SUCH_TABLE"
}
```

Session and Transaction Context for the Server-Side Internal Driver

The server-side driver operates within a default session and default transaction context. The default session is the session in which the JVM was invoked. In effect, you are already connected to the database on the server. This is different from the client side where there is no default session: you must explicitly connect to the database.

Auto-commit mode is disabled in the server. You must manage transaction `COMMIT` and `ROLLBACK` operations explicitly by using the appropriate methods on the connection object:

```
conn.commit();
```

or:

```
conn.rollback();
```

Testing JDBC on the Server

Almost any JDBC program that can run on a client can also run on the server. All the programs in the `samples` directory can be run on the server with only minor modifications. Usually, these modifications concern only the connection statement.

For example, consider the test program `JdbcCheckup.java` described in "Testing JDBC and the Database Connection: JdbcCheckup" on page 2-9. If you want to run this program on the server and connect with the `DriverManager.getConnection()` method, then open the file in your favorite text editor and change the driver name in the connection string from "`oci`" to "`kprb`". For example:

```
Connection conn = DriverManager.getConnection
                  ("jdbc:oracle:kprb:@" + database, user, password);
```

The advantage of using this method is that you must change only a short string in your original program. The disadvantage is that you still must provide the user, password, and database information, even though the driver will discard it. In addition, if you issue the `getConnection()` method again, the driver will create another new (and unnecessary) connection object.

However, if you connect with `defaultConnection()`, the preferred method of connecting to the database from the server-side internal driver, you do not have to enter any user, password, or database information. You can delete these statements from your program.

For the connection statement, use:

```
Connection conn =  new oracle.jdbc.OracleDriver().defaultConnection();
```

The following example is a rewrite of the `JdbcCheckup.java` program which uses the `defaultConnection()` connection statement. The connection statement is printed in bold. The unnecessary user, password, and database information statements, along with the utility function to read from standard input, have been deleted.

```
/*
 * This sample can be used to check the JDBC installation.
 * Just run it and provide the connect information.  It will select
 * "Hello World" from the database.
 */
// You need to import the java.sql package to use JDBC
import java.sql.*;
// We import java.io to be able to read from the command line
import java.io.*;

class JdbcCheckup
{
   public static void main (String args []) throws SQLException, IOException
   {
      // Load the Oracle JDBC driver
      DriverManager.registerDriver(new oracle.jdbc.OracleDriver());

      Connection conn =
           new oracle.jdbc.OracleDriver ().defaultConnection ();

       // Create a statement
       Statement stmt = conn.createStatement ();

       // Do the SQL "Hello World" thing
       ResultSet rset = stmt.executeQuery ("SELECT 'Hello World' FROM dual");

       while (rset.next ())
          System.out.println (rset.getString (1));
       System.out.println ("Your JDBC installation is correct.");
   }
}
```

Loading an Application into the Server

When loading an application into the server, you can load `.class` files that you have already compiled on the client, or you can load `.java` source files and have them compiled automatically in the server.

In either case, use the Oracle `loadjava` client-side utility to load your files. You can either specify source file names on the command line (note that the command line understands wildcards), or put the files into a JAR file and specify the JAR file name on the command line. The `loadjava` utility is discussed in detail in the *Oracle9i Java Developer's Guide*.

The `loadjava` script, which runs the actual utility, is in the `bin` subdirectory under your `[Oracle Home]` directory. This directory should already be in your path once Oracle has been installed.

Note: As of release 8.1.6, the `loadjava` utility does support compressed files.

Loading Class Files into the Server

Consider a case where you have three class files in your application: `Foo1.class`, `Foo2.class`, and `Foo3.class`. The following three examples demonstrate: 1) specifying the individual class file names; 2) specifying the class file names using a wildcard; and 3) specifying a JAR file that contains the class files.

Each class is written into its own class schema object in the server.

These three examples use the default OCI driver in loading the files:

```
loadjava -user scott/tiger Foo1.class Foo2.class Foo3.class
```

or:

```
loadjava -user scott/tiger Foo*.class
```

or:

```
loadjava -user scott/tiger Foo.jar
```

Or use the following command to load with the Thin driver (specifying the `-thin` option and an appropriate URL):

```
loadjava -thin -user scott/tiger@localhost:1521:ORCL Foo.jar
```

(Whether to use an OCI driver or the Thin driver to load classes depends on your particular environment and which performs better for you.)

> **Note:** Because the server-side embedded JVM uses JDK 1.2.x, it is advisable to compile classes under JDK 1.2.x if they will be loaded into the server. This will catch incompatibilities during compilation, instead of at runtime (for example, JDK 1.1.x artifacts such as leftover use of the `oracle.jdbc2` package).

Loading Source Files into the Server

If you enable the `loadjava -resolve` option in loading a `.java` source file, then the server-side compiler will compile your application as it is loaded, resulting in both a source schema object for the original source code, and one or more class schema objects for the compiled output.

If you do not specify `-resolve`, then the source is loaded into a source schema object without any compilation. In this case, however, the source *is* implicitly compiled the first time an attempt is made to use a class defined in the source.

For example, run `loadjava` as follows to load and compile `Foo.java`, using the default OCI driver:

```
loadjava -user scott/tiger -resolve Foo.java
```

Or use the following command to load with the Thin driver (specifying the `-thin` option and an appropriate URL):

```
loadjava -thin -user scott/tiger@localhost:1521:ORCL -resolve Foo.java
```

Either of these will result in appropriate class schema objects being created in addition to the source schema object.

> **Note:** Oracle generally recommends compiling source on the client whenever possible, and loading the `.class` files instead of the source files into the server.

Server-Side Character Set Conversion of oracle.sql.CHAR Data

The server-side internal driver performs character set conversions for `oracle.sql.CHAR` in C. This is a different implementation than for the client-side drivers, which perform character set conversions for `oracle.sql.CHAR` in Java,

and offers better performance. For more information on the `oracle.sql.CHAR` class, see "Class oracle.sql.CHAR" on page 6-29.

18

Statement Caching

This chapter describes the benefits and use of statement caching, an Oracle JDBC extension.

This following topics are discussed:

- About Statement Caching
- Using Statement Caching

> **Note:** Release 2 (9.2) of JDBC provides a new statement cache interface and implementation, replacing the API supported at Release 9.1 0. The previous API is now deprecated.

About Statement Caching

Statement caching improves performance by caching executable statements that are used repeatedly, such as in a loop or in a method that is called repeatedly. JDBC 3.0 defines a statement-caching interface.

Statement caching can:

- Prevent the overhead of repeated cursor creation
- Prevent repeated statement parsing and creation

Basics of Statement Caching

Use a statement cache to cache statements associated with a particular physical connection. For a simple connection, the cache is associated with an `OracleConnection` object. For a pooled connection, the cache is associated with an `OraclePooledConnection` or `PooledConnection` object. The `OracleConnection` and `OraclePooledConnection` objects include methods to enable statement caching. When you enable statement caching, a statement object is cached when you call the "close" methods.

Because each physical connection has its own cache, multiple caches can exist if you enable statement caching for multiple physical connections. When you enable statement caching on a pooled connection, all the logical connections will use the *same* cache. If you try to enable statement caching on a logical connection of a pooled connection, this will throw an exception.

There are two types of statement caching: implicit and explicit. Each type of statement cache can be enabled or disabled independent of the other: you can have either, neither, or both in effect. Both types of statement caching share a cache.

Implicit Statement Caching

When you enable *implicit statement caching*, JDBC automatically caches the prepared or callable statement when you call the `close()` method of this statement object. The prepared and callable statements are cached and retrieved using standard connection object and statement object methods.

Plain statements are not implicitly cached, because implicit statement caching uses a SQL string as a key, and plain statements are created without a SQL string. Therefore, implicit statement caching applies only to the `OraclePreparedStatement` and `OracleCallableStatement` objects, which are created with a SQL string. When one of these statements is created, the JDBC

driver automatically searches the cache for a matching statement. The match criteria are the following:

- The SQL string in the statement must be identical (case-sensitive) to one in the cache.
- The statement type must be the same (prepared or callable).
- The scrollable type of result sets produced by the statement must be the same (forward-only or scrollable). You can determine the scrollability when you create the statement. (See "Specifying Result Set Scrollability and Updatability" on page 13-8 for complete details.)

If a match is found during the cache search, the cached statement is returned. If a match is not found, then a new statement is created and returned. The new statement, along with its cursor and state, are cached when you call the `close()` method of the statement object.

When a cached `OraclePreparedStatement` or `OracleCallableStatement` object is retrieved, the state and data information are automatically re-initialized and reset to default values, while metadata is saved. The Least Recently Used (LRU) scheme performs the statement cache operation.

Note: The JDBC driver does not clear metadata. However, although metadata is saved for performance reasons, it has no semantic impact. A statement that comes from the implicit cache appears as if it were newly created.

You can prevent a particular statement from being implicitly cached; see "Disabling Implicit Statement Caching for a Particular Statement" on page 18-8.

Explicit Statement Caching

Explicit statement caching enables you to cache and retrieve selected prepared, callable, and plain statements. Explicit statement caching relies on a *key*, an arbitrary Java string that you provide.

Because explicit statement caching retains statement data and state as well as metadata, it has a performance edge over implicit statement caching, which retains only metadata. However, because explicit statement caching saves all three types of information for re-use, you must be cautious when using this type of caching—you may not be aware of what was retained for data and state in the previous statement.

With implicit statement caching, you take no special action to retrieve statements from a cache. Instead, whenever you call `prepareStatement()` or `prepareCall()`, JDBC automatically checks the cache for a matching statement and returns it if found.

With explicit statement caching, you use specialized Oracle "WithKey" methods to cache and retrieve statement objects.

Implicit statement caching uses the SQL string of a prepared or callable statement as the key, requiring no action on your part. Explicit statement caching requires you to provide a Java string, which it uses as the key.

During implicit statement caching, if the JDBC driver cannot find a statement in cache, it will automatically create one. During explicit statement caching, if the JDBC driver cannot find a matching statement in cache, it will return a `null` value.

Table 18–1 compares the different methods employed in implicit and explicit statement caching.

Table 18–1 Comparing Methods Used in Statement Caching

	Allocate	Insert Into Cache	Retrieve From Cache
Implicit	`prepareStatement()` `prepareCall()`	`close()`	`prepareStatement()` `prepareCall()`

Explicit	`createStatement()`
	`prepareStatement()`
	`prepareCall()`
		`closeWithKey()`	`getStatementWithKey()`
			`getCallWithKey()`

Using Statement Caching

This section discusses the following topics:

- Enabling and Disabling Statement Caching
- Checking for Statement Creation Status
- Physically Closing a Cached Statement
- Using Implicit Statement Caching
- Using Explicit Statement Caching

Enabling and Disabling Statement Caching

Implicit and explicit statement caching can be enabled or disabled independent of one other: you can have either, neither, or both in effect.

Enabling and Disabling Implicit Statement Caching

Enable implicit statement caching in one of two ways:

- Invoking `setImplicitStatementCaching(true)` on the connection
- Invoking `OracleDataSource.getConnection ()` with the `ImplicitStatementCachingEnabled` property set to **`true`**; you set `ImplicitStatementCachingEnabled` by calling `OracleDataSource.setImplicitStatementCachingEnabled(true)`

Disable implicit statement caching by invoking `setImplicitStatementCaching(false)` on the connection or by setting the `ImplicitStatementCachingEnabled` property to `false`.

To determine whether implicit caching is enabled, call `getImplicitStatementCachingEnabled()`, which returns `true` if implicit caching is enabled, `false` otherwise.

Enabling and Disabling Explicit Statement Caching

To enable explicit statement caching you must first set the application cache size. You set the cache size in one of two ways:

- invoking `OracleConnection.setStatementCacheSize()` on the physical connection
- invoking `OracleDatasource.setMaxStatements()`

In either case, the argument you supply is the maximum number of statements in the cache; an argument of 0 specifies no caching. To check the cache size, use the `getStatementCacheSize()` method.

```
System.out.println("Stmt Cache size is " +
   ((OracleConnection)conn).getStatementCacheSize());
```

Enable explicit statement caching by invoking `setExplicitStatementCaching(true)` on the connection.

To determine whether explicit caching is enabled, call `getExplicitStatementCachingEnabled()`, which returns `true` if implicit caching is enabled, `false` otherwise.

Notes:

- You enable implicit and explicit caching for a particular physical connection independently. Therefore, it is possible to do statement caching both implicitly and explicitly during the same session.
- Implicit and explicit statement caching share the *same* cache. Remember this when you set the statement cache size.

The following code specifies a cache size of ten statements:

```
((OracleConnection)conn).setStatementCacheSize(10);
```

Disable explicit statement caching by calling `setExplicitStatementCaching(false)`. Disabling caching or closing the cache purges the cache.

The following code disables explicit statement caching.

```
((OracleConnection)conn).setExplicitStatementCaching(false);
```

Checking for Statement Creation Status

By calling the `creationState()` method of a statement object, you can determine if a statement was newly created or if it was retrieved from cache on an implicit or explicit lookup. The `creationState()` method returns the following integer values for plain, prepared, and callable statements:

- `NEW` - The statement was newly created.

- `IMPLICIT` - The statement was retrieved on an implicit statement lookup.
- `EXPLICIT` - The statement was retrieved on an explicit statement lookup.

For example, the JDBC driver returns `OracleStatement.EXPLICIT` for an explicitly cached statement. The following code checks the statement creation status for `stmt`:

```
int state = ((OracleStatement)stmt).creationState()
   ...(process state)
```

Physically Closing a Cached Statement

With implicit statement caching enabled, you cannot truly physically close statements manually. The `close()` method of a statement object caches the statement instead of closing it. The statement is physically closed automatically under one of three conditions: (1) when the associated connection is closed, (2) when the cache reaches its size limit and the least recently used statement object is preempted from cache by the LRU scheme, or (3) if you call the `close()` method on a statement for which statement caching is disabled. (See "Disabling Implicit Statement Caching for a Particular Statement" on page 18-8 for more details.)

Using Implicit Statement Caching

Once you enable implicit statement caching, by default all prepared and callable statements are automatically cached. Implicit statement caching includes the following steps:

1. Enable implicit statement caching as described in "Enabling and Disabling Implicit Statement Caching" on page 18-5.
2. Allocate a statement using one of the standard methods.
3. (Optional) Disable implicit statement caching for any particular statement you do not want to cache.
4. Cache the statement using the `close()` method.
5. Retrieve the implicitly cached statement by calling the appropriate standard "prepare" method.

The following sections explain the implicit statement caching steps in more detail.

Allocating a Statement for Implicit Caching

To allocate a statement for implicit statement caching, use either the `prepareStatement()` or `prepareCall()` method as you would normally. (These are methods of the connection object.)

The following code allocates a new statement object called `pstmt`:

```
PreparedStatement pstmt = conn.prepareStatement
   ("UPDATE emp SET ename = ? WHERE rowid = ?");
```

Disabling Implicit Statement Caching for a Particular Statement

With implicit statement caching enabled for a connection, by default all callable and prepared statements of that connection are automatically cached. To prevent a particular callable or prepared statement from being implicitly cached, use the `setDisableStatementCaching()` method of the statement object. To help you manage cache space, you can call the `setDisableStatementCaching()` method on any infrequently used statement.

The following code disables implicit statement caching for `pstmt`:

```
PreparedStatement pstmt = conn.prepareStatement ("SELECT 1 from DUAL");
((OraclePreparedStatement)pstmt).setDisableStatementCaching (true);
pstmt.close ();
```

Implicitly Caching a Statement

To cache an allocated statement, call the `close()` method of the statement object. When you call the `close()` method on an `OraclePreparedStatement` or `OracleCallableStatement` object, the JDBC driver automatically puts this statement in cache, unless you have disabled caching for this statement.

The following code caches the `pstmt` statement:

```
((OraclePreparedStatement)pstmt).close ();
```

Retrieving an Implicitly Cached Statement

To retrieve an implicitly cached statement, call either the `prepareStatement()` or `prepareCall()` method, depending on the statement type.

The following code retrieves `pstmt` from cache using the `prepareStatement()` method:

```
pstmt = conn.prepareStatement ("UPDATE emp SET ename = ? WHERE rowid = ?");
```

If you call the `creationState()` method on the `pstmt` statement object, the method returns `IMPLICIT`. If the `pstmt` statement object was not in cache, then the `creationState()` method returns `NEW` to indicate a new statement was recently created by the JDBC driver.

Table 18–2 describes the methods used to allocate statements and retrieve implicitly cached statements.

Table 18–2 Methods Used in Statement Allocation and Implicit Statement Caching

Method	Functionality for Implicit Statement Caching
`prepareStatement()`	Triggers a cache search that either finds and returns the desired cached `OraclePreparedStatement` object or allocates a new `OraclePreparedStatement` object if a match is not found
`prepareCall()`	Triggers a cache search that either finds and returns the desired cached `OracleCallableStatement` object or allocates a new `OracleCallableStatement` object if a match is not found

Using Explicit Statement Caching

A plain, prepared, or callable statement can be explicitly cached when you enable explicit statement caching. Explicit statement caching includes the following steps:

1. Enable explicit statement caching as described in "Enabling and Disabling Explicit Statement Caching" on page 18-5.
2. Allocate a statement using one of the standard methods.
3. Explicitly cache the statement by closing it with a key, using the `closeWithKey()` method.
4. Retrieve the explicitly cached statement by calling the appropriate Oracle "WithKey" method, specifying the appropriate key.
5. Re-cache an open, explicitly cached statement by closing it again with the `closeWithKey()` method. Each time a cached statement is closed, it is re-cached with its key.

The following sections explain the explicit statement caching steps in more detail.

Allocating a Statement for Explicit Caching

To allocate a statement for explicit statement caching, use either the `createStatement()`, `prepareStatement()`, or `prepareCall()` method as you would normally. (These are methods of the connection object.)

The following code allocates a new statement object called `pstmt`:

```
PreparedStatement pstmt =
   conn.prepareStatement ("UPDATE emp SET ename = ? WHERE rowid = ?");
```

Explicitly Caching a Statement

To explicitly cache an allocated statement, call the `closeWithKey()` method of the statement object, specifying a key. The key is an arbitrary Java string that you provide. The `closeWithKey()` method caches a statement as is. This means the data, state, and metadata are retained and not cleared.

The following code caches the `pstmt` statement with the key `"mykey"`:

```
((OraclePreparedStatement)pstmt).closeWithKey ("mykey");
```

Retrieving an Explicitly Cached Statement

To recall an explicitly cached statement, call either the `getStatementWithKey()` or `getCallWithKey()` methods depending on the statement type.

If you retrieve a statement with a specified key, the JDBC driver searches the cache for the statement, based on the specified key. If a match is found, the matching statement is returned, along with its state, data, and metadata. This information is returned as it was when last closed. If a match is not found, the JDBC driver returns `null`.

The following code recalls `pstmt` from cache using the `"mykey"` key with the `gettatementWithKey()` method. Recall that the `pstmt` statement object was cached with the `"mykey"` key.

```
pstmt = ((OracleConnection)conn).getStatementWithKey ("mykey");
```

If you call the `creationState()` method on the `pstmt` statement object, the method returns `EXPLICIT`.

Important: When you retrieve an explicitly cached statement, be sure to use the method that is appropriate for your statement type when specifying the key. For example, if you used the `prepareStatement()` method to allocate a statement, then use the `getStatementWithKey()` method to retrieve that statement from cache. The JDBC driver cannot verify the type of statement it is returning.

Table 18–3 describes the methods used to retrieve explicitly cached statements.

Table 18–3 Methods Used to Retrieve Explicitly Cached Statements

Method	Functionality for Explicit Statement Caching
`createStatementWithKey()`	specifies the key needed to retrieve a plain statement from cache
`getStatementWithKey()`	specifies the key needed to retrieve a prepared statement from cache
`getCallWithKey()`	specifies the key needed to retrieve a callable statement from cache

19

Reference Information

This chapter contains detailed JDBC reference information, including the following topics:

- Valid SQL-JDBC Datatype Mappings
- Supported SQL and PL/SQL Datatypes
- Embedded SQL92 Syntax
- Oracle JDBC Notes and Limitations
- Related Information

Valid SQL-JDBC Datatype Mappings

Table 3–2 in Chapter 3 describes the default mappings between Java classes and SQL datatypes supported by the Oracle JDBC drivers. Compare the contents of the **JDBC Datatypes, Standard Java Types** and **SQL Datatypes** columns in Table 3–2 with the contents of Table 19–1 below.

Table 19–1 lists all the possible Java types to which a given SQL datatype can be validly mapped. The Oracle JDBC drivers will support these "non-default" mappings. For example, to materialize SQL `CHAR` data in an `oracle.sql.CHAR` object use the `getCHAR()` method. To materialize it as a `java.math.BigDecimal` object, use the `getBigDecimal()` method.

Notes:

- For the following SQL datatypes, `oracle.sql.ORAData` or `oracle.sql.Datum` can be materialized as java types.
- For classes where `oracle.sql.ORAData` appears in italic, these can be generated by JPublisher.

Table 19–1 Valid SQL Datatype-Java Class Mappings

These SQL datatypes:	Can be materialized as these Java types:
CHAR, VARCHAR2, LONG	oracle.sql.CHAR
	java.lang.String
	java.sql.Date
	java.sql.Time
	java.sql.Timestamp
	java.lang.Byte
	java.lang.Short
	java.lang.Integer
	java.lang.Long
	java.lang.Float
	java.lang.Double
	java.math.BigDecimal
	byte, short, int, long, float, double

Table 19–1 Valid SQL Datatype-Java Class Mappings (Cont.)

These SQL datatypes:	Can be materialized as these Java types:
DATE	oracle.sql.DATE
	java.sql.Date
	java.sql.Time
	java.sql.Timestamp
	java.lang.String
NUMBER	oracle.sql.NUMBER
	java.lang.Byte
	java.lang.Short
	java.lang.Integer
	java.lang.Long
	java.lang.Float
	java.lang.Double
	java.math.BigDecimal
	byte, short, int, long, float, double
OPAQUE	oracle.sql.OPAQUE
RAW, LONG RAW	oracle.sql.RAW
	byte[]
ROWID	oracle.sql.CHAR
	oracle.sql.ROWID
	java.lang.String
BFILE	oracle.sql.BFILE
BLOB	oracle.sql.BLOB
	java.sql.Blob (oracle.jdbc2.Blob under JDK 1.1.x)
CLOB	oracle.sql.CLOB
	java.sql.Clob (oracle.jdbc2.Clob under JDK 1.1.x)
Object types and SQLJ types	oracle.sql.STRUCT
TS	oracle.sql.TIMESTAMP

Table 19–1 Valid SQL Datatype-Java Class Mappings (Cont.)

These SQL datatypes:	Can be materialized as these Java types:
TSTZ	oracle.sql.TIMESTAMPTZ
TSLTZ	oracle.sql.TIMESTAMPLTZ
	java.sql.Struct (oracle.jdbc2.Struct under JDK 1.1.x)
	java.sql.SqlData
	oracle.sql.ORAData
Reference types	oracle.sql.REF
	java.sql.Ref (oracle.jdbc2.Ref under JDK 1.1.x)
	oracle.sql.ORAData
Nested table types and VARRAY types	oracle.sql.ARRAY
	java.sql.Array (oracle.jdbc2.Array under JDK 1.1.x)
	oracle.sql.ORAData

Notes:

- The type `UROWID` is not supported.
- The `oracle.sql.Datum` class is abstract. The value passed to a parameter of type `oracle.sql.Datum` must be of the Java type corresponding to the underlying SQL type. Likewise, the value returned by a method with return type `oracle.sql.Datum` must be of the Java type corresponding to the underlying SQL type.
- The mappings to `oracle.sql` classes are optimal if no conversion from SQL format to Java format is necessary.

Supported SQL and PL/SQL Datatypes

The tables in this section list SQL and PL/SQL datatypes, and whether the Oracle JDBC drivers and SQLJ support them. Table 19–2 describes Oracle JDBC driver and SQLJ support for SQL datatypes.

Table 19–2 Support for SQL Datatypes

SQL Datatype	Supported by JDBC Drivers?	Supported by SQLJ?
BFILE	yes	yes
BLOB	yes	yes
CHAR	yes	yes
CLOB	yes	yes
DATE	yes	yes
NCHAR	no	no
NCHAR VARYING	no	no
NUMBER	yes	yes
NVARCHAR2	no	no
RAW	yes	yes
REF	yes	yes
ROWID	yes	yes
UROWID	no	no
VARCHAR2	yes	yes

Table 19–3 describes Oracle JDBC driver and SQLJ support for the ANSI-supported SQL datatypes.

Table 19–3 Support for ANSI-92 SQL Datatypes

ANSI-Supported SQL Datatype	Supported by JDBC Drivers?	Supported by SQLJ?
CHARACTER	yes	yes
DEC	yes	yes
DECIMAL	yes	yes
DOUBLE PRECISION	yes	yes

Table 19–3 Support for ANSI-92 SQL Datatypes (Cont.)

ANSI-Supported SQL Datatype	Supported by JDBC Drivers?	Supported by SQLJ?
FLOAT	yes	yes
INT	yes	yes
INTEGER	yes	yes
NATIONAL CHARACTER	no	no
NATIONAL CHARACTER VARYING	no	no
NATIONAL CHAR	yes	yes
NATIONAL CHAR VARYING	no	no
NCHAR	yes	yes
NCHAR VARYING	no	no
NUMERIC	yes	yes
REAL	yes	yes
SMALLINT	yes	yes
VARCHAR	yes	yes

Table 19–4 describes Oracle JDBC driver and SQLJ support for SQL User-Defined types.

Table 19–4 Support for SQL User-Defined Types

SQL User-Defined type	Supported by JDBC Drivers?	Supported by SQLJ?
OPAQUE	yes	no
Reference types	yes	yes
SQLJ types (JAVA_STRUCT)	yes	no
Object types (JAVA_OBJECT)	yes	yes
Nested table types and VARRAY types	yes	yes

Note: SQLJ types are described in the *Information Technology - SQLJ - Part 2: SQL Types using the JAVATM Programming Language* document (ANSI NCITS 331.2-2000).

Table 19–5 describes Oracle JDBC driver and SQLJ support for PL/SQL datatypes. Note that PL/SQL datatypes include these categories:

- scalar types
- scalar character types (includes boolean and date datatypes)
- composite types
- reference types
- LOB types

Table 19–5 Support for PL/SQL Datatypes

PL/SQL Datatype	Supported by JDBC Drivers?	Supported by SQLJ?
Scalar Types:		
BINARY INTEGER	yes	yes
DEC	yes	yes
DECIMAL	yes	yes
DOUBLE PRECISION	yes	yes
FLOAT	yes	yes
INT	yes	yes
INTEGER	yes	yes
NATURAL	yes	yes
NATURAL*n*	no	no
NUMBER	yes	yes
NUMERIC	yes	yes
PLS_INTEGER	yes	yes
POSITIVE	yes	yes
POSITIVE*n*	no	no

Table 19–5 Support for PL/SQL Datatypes (Cont.)

PL/SQL Datatype	Supported by JDBC Drivers?	Supported by SQLJ?
REAL	yes	yes
SIGNTYPE	yes	yes
SMALLINT	yes	yes
Scalar Character Types:		
CHAR	yes	yes
CHARACTER	yes	yes
LONG	yes	yes
LONG RAW	yes	yes
NCHAR	no	no
NVARCHAR2	no	no
RAW	yes	yes
ROWID	yes	yes
STRING	yes	yes
UROWID	no	no
VARCHAR	yes	yes
VARCHAR2	yes	yes
BOOLEAN	yes	yes
DATE	yes	yes
Composite Types:		
RECORD	no	no
TABLE	no	no
VARRAY	yes	yes
Reference Types:		
REF CURSOR types	yes	yes
object reference types	yes	yes
LOB Types:		
BFILE	yes	yes

Table 19–5 Support for PL/SQL Datatypes (Cont.)

PL/SQL Datatype	Supported by JDBC Drivers?	Supported by SQLJ?
BLOB	yes	yes
CLOB	yes	yes
NCLOB	yes	yes

Notes:

- The types NATURAL, NATURAL*n*, POSITIVE, POSITIVE*n*, and SIGNTYPE are subtypes of BINARY INTEGER.
- The types DEC, DECIMAL, DOUBLE PRECISION, FLOAT, INT, INTEGER, NUMERIC, REAL, and SMALLINT are subtypes of NUMBER.

Embedded SQL92 Syntax

Oracle's JDBC drivers support some embedded SQL92 syntax. This is the syntax that you specify between curly braces. The current support is basic. This section describes the support offered by the drivers for the following SQL92 constructs:

- Time and Date Literals
- Scalar Functions
- LIKE Escape Characters
- Outer Joins
- Function Call Syntax

Where driver support is limited, these sections also describe possible workarounds.

Disabling Escape Processing Escape processing for SQL92 syntax is enabled by default, which results in the JDBC driver performing escape substitution before sending the SQL code to the database. If you want the driver to use regular Oracle SQL syntax, which is more efficient than SQL92 syntax and escape processing, then use this statement:

```
stmt.setEscapeProcessing(false);
```

> **Note:** Because prepared statements have usually been parsed prior to a call to `setEscapeProcessing()`, disabling escape processing for prepared statements will probably have no affect.

Time and Date Literals

Databases differ in the syntax they use for date, time, and timestamp literals. JDBC supports dates and times written only in a specific format. This section describes the formats you must use for date, time, and timestamp literals in SQL statements.

Date Literals

The JDBC drivers support date literals in SQL statements written in the format:

```
{d 'yyyy-mm-dd'}
```

Where `yyyy-mm-dd` represents the year, month, and day—for example:

```
{d '1995-10-22'}
```

The JDBC drivers will replace this escape clause with the equivalent Oracle representation: "22 OCT 1995".

This code snippet contains an example of using a date literal in a SQL statement.

```
// Connect to the database
// You can put a database name after the @ sign in the connection URL.
Connection conn = DriverManager.getConnection
                  ("jdbc:oracle:oci:@", "scott", "tiger");

// Create a Statement
Statement stmt = conn.createStatement ();

// Select the ename column from the emp table where the hiredate is Jan-23-1982
ResultSet rset = stmt.executeQuery
                 ("SELECT ename FROM emp WHERE hiredate = {d '1982-01-23'}");

// Iterate through the result and print the employee names
while (rset.next ())
   System.out.println (rset.getString (1));
```

Time Literals

The JDBC drivers support time literals in SQL statements written in the format:

```
{t 'hh:mm:ss'}
```

where `hh:mm:ss` represents the hours, minutes, and seconds—for example:

```
{t '05:10:45'}
```

The JDBC drivers will replace this escape clause with the equivalent Oracle representation: "05:10:45".

If the time is specified as:

```
{t '14:20:50'}
```

Then the equivalent Oracle representation would be "14:20:50", assuming the server is using a 24-hour clock.

This code snippet contains an example of using a time literal in a SQL statement.

```
ResultSet rset = stmt.executeQuery
                 ("SELECT ename FROM emp WHERE hiredate = {t '12:00:00'}");
```

Timestamp Literals

The JDBC drivers support timestamp literals in SQL statements written in the format:

```
{ts 'yyyy-mm-dd hh:mm:ss.f...'}
```

where `yyyy-mm-dd hh:mm:ss.f...` represents the year, month, day, hours, minutes, and seconds. The fractional seconds portion (`.f...`) is optional and can be omitted. For example: `{ts '1997-11-01 13:22:45'}` represents, in Oracle format, NOV 01 1997 13:22:45.

This code snippet contains an example of using a timestamp literal in a SQL statement.

```
ResultSet rset = stmt.executeQuery
    ("SELECT ename FROM emp WHERE hiredate = {ts '1982-01-23 12:00:00'}");
```

Scalar Functions

The Oracle JDBC drivers do not support all scalar functions. To find out which functions the drivers support, use the following methods supported by the Oracle-specific `oracle.jdbc.OracleDatabaseMetaData` class and the standard Java `java.sql.DatabaseMetadata` interface:

- `getNumericFunctions()`: Returns a comma-separated list of math functions supported by the driver. For example, ABS(*number*), COS(*float*), SQRT(*float*).
- `getStringFunctions()`: Returns a comma-separated list of string functions supported by the driver. For example, ASCII(*string*), LOCATE(*string1*, *string2*, *start*).
- `getSystemFunctions()`: Returns a comma-separated list of system functions supported by the driver. For example, DATABASE(), IFNULL(*expression*, *value*), USER().
- `getTimeDateFunctions()`: Returns a comma-separated list of time and date functions supported by the driver. For example, CURDATE(), DAYOFYEAR(*date*), HOUR(*time*).

Note: As of release 9.2.0, Oracle's JDBC drivers support `fn`, the function keyword.

LIKE Escape Characters

The characters "%" and "_" have special meaning in SQL LIKE clauses (you use "%" to match zero or more characters, "_" to match exactly one character). If you want to interpret these characters literally in strings, you precede them with a special escape character. For example, if you want to use the ampersand "&" as the escape character, you identify it in the SQL statement as {escape '&'}:

```
Statement stmt = conn.createStatement ();

// Select the empno column from the emp table where the ename starts with '_'
ResultSet rset = stmt.executeQuery
          ("SELECT empno FROM emp WHERE ename LIKE '&_%' {ESCAPE '&'}");

// Iterate through the result and print the employee numbers
while (rset.next ())
   System.out.println (rset.getString (1));
```

Note: If you want to use the backslash character (\) as an escape character, you must enter it twice (that is, \ \). For example:

```
ResultSet rset = stmt.executeQuery("SELECT empno FROM emp
                 WHERE ename LIKE '\\_%' {escape '\\'}");
```

Outer Joins

Oracle's JDBC drivers do not support outer join syntax: {*oj outer-join*}. The workaround is to use Oracle outer join syntax:

Instead of:

```
Statement stmt = conn.createStatement ();
ResultSet rset = stmt.executeQuery
     ("SELECT ename, dname
       FROM {OJ dept LEFT OUTER JOIN emp ON dept.deptno = emp.deptno}
       ORDER BY ename");
```

Use Oracle SQL syntax:

```
Statement stmt = conn.createStatement ();
ResultSet rset = stmt.executeQuery
     ("SELECT ename, dname
       FROM emp a, dept b WHERE a.deptno = b.deptno(+)
       ORDER BY ename");
```

Function Call Syntax

Oracle's JDBC drivers support the following procedure and function call syntax:

Procedure calls (without a return value):

```
{ call procedure_name (argument1, argument2,...) }
```

Function calls (with a return value):

```
{ ? = call procedure_name (argument1, argument2,...) }
```

SQL92 to SQL Syntax Example

You can write a simple program to translate SQL92 syntax to standard SQL syntax. The following program prints the comparable SQL syntax for SQL92 statements for function calls, date literals, time literals, and timestamp literals. In the program, the `oracle.jdbc.OracleSql` class `parse()` method performs the conversions.

```
import oracle.jdbc.OracleSql;

public class Foo
{
   public static void main (String args[]) throws Exception
   {
      show ("{call foo(?, ?)}");
      show ("{? = call bar (?, ?)}");
      show ("{d '1998-10-22'}");
      show ("{t '16:22:34'}");
      show ("{ts '1998-10-22 16:22:34'}");
   }

   public static void show (String s) throws Exception
   {
      System.out.println (s + " => " + new OracleSql().parse (s));
   }
}
```

The following code is the output that prints the comparable SQL syntax.

```
{call foo(?, ?)} => BEGIN foo(:1, :2); END;
{? = call bar (?, ?)} => BEGIN :1 := bar (:2, :3); END;
{d '1998-10-22'} => TO_DATE ('1998-10-22', 'YYYY-MM-DD')
{t '16:22:34'} => TO_DATE ('16:22:34', 'HH24:MI:SS')
{ts '1998-10-22 16:22:34'} => TO_DATE ('1998-10-22 16:22:34', 'YYYY-MM-DD
HH24:MI:SS')
```

Oracle JDBC Notes and Limitations

The following limitations exist in the Oracle JDBC implementation, but all of them are either insignificant or have easy workarounds.

CursorName

Oracle JDBC drivers do not support the `get getCursorName()` and `setCursorName()` methods, because there is no convenient way to map them to Oracle constructs. Oracle recommends using `ROWID` instead. For more information on how to use and manipulate ROWIDs, see "Oracle ROWID Type" on page 6-33.

SQL92 Outer Join Escapes

Oracle JDBC drivers do not support SQL92 outer join escapes. Use Oracle SQL syntax with "(+)" instead. For more information on SQL92 syntax, see "Embedded SQL92 Syntax" on page 19-10.

PL/SQL TABLE, BOOLEAN, and RECORD Types

It is not feasible for Oracle JDBC drivers to support calling arguments or return values of the PL/SQL `RECORD`, `BOOLEAN`, or table with non-scalar element types. However, Oracle JDBC drivers support PL/SQL index-by table of scalar element types. For a complete description of this, see "Accessing PL/SQL Index-by Tables" on page 16-21.

As a workaround to PL/SQL `RECORD`, `BOOLEAN`, or non-scalar table types, create wrapper procedures that handle the data as types supported by JDBC. For example, to wrap a stored procedure that uses PL/SQL booleans, create a stored procedure that takes a character or number from JDBC and passes it to the original procedure as `BOOLEAN` or, for an output parameter, accepts a `BOOLEAN` argument from the original procedure and passes it as a `CHAR` or `NUMBER` to JDBC. Similarly, to wrap a stored procedure that uses PL/SQL records, create a stored procedure that handles a record in its individual components (such as `CHAR` and `NUMBER`) or in a structured object type. To wrap a stored procedure that uses PL/SQL tables, break the data into components or perhaps use Oracle collection types.

For an example of a workaround for `BOOLEAN`, see "Boolean Parameters in PL/SQL Stored Procedures" on page 20-9.

IEEE 754 Floating Point Compliance

The arithmetic for the Oracle `NUMBER` type does not comply with the IEEE 754 standard for floating-point arithmetic. Therefore, there can be small disagreements between the results of computations performed by Oracle and the same computations performed by Java.

Oracle stores numbers in a format compatible with decimal arithmetic and guarantees 38 decimal digits of precision. It represents zero, minus infinity, and plus infinity exactly. For each positive number it represents, it represents a negative number of the same absolute value.

It represents every positive number between 10^{-30} and $(1 - 10^{-38}) * 10^{126}$ to full 38-digit precision.

Catalog Arguments to DatabaseMetaData Calls

Certain `DatabaseMetaData` methods define a `catalog` parameter. This parameter is one of the selection criteria for the method. Oracle does not have multiple catalogs, but it does have packages. For more information on how the Oracle JDBC drivers treat the `catalog` argument, see "DatabaseMetaData TABLE_REMARKS Reporting" on page 12-26.

SQLWarning Class

The `java.sql.SQLWarning` class provides information on a database access warning. Warnings typically contain a description of the warning and a code that identifies the warning. Warnings are silently chained to the object whose method caused it to be reported. The Oracle JDBC drivers generally do not support `SQLWarning`. (As an exception to this, scrollable result set operations do generate SQL warnings, but the `SQLWarning` instance is created on the client, not in the database.)

For information on how the Oracle JDBC drivers handle errors, see "Processing SQL Exceptions" on page 3-34.

Bind by Name

Binding by name is not supported. Under certain circumstances, previous versions of the Oracle JDBC drivers have allowed binding statement variables by name. In the following statement, the named variable `EmpId` would be bound to the integer `314159`.

```
PreparedStatement p = conn.prepareStatement
```

```
                          ("SELECT name FROM emp WHERE id = :EmpId");
p.setInt(1, 314159);
```

This capability to bind by name is not part of the JDBC specification, either 1.0 or 2.0, and Oracle does not support it. The JDBC drivers can throw a `SQLException` or produce unexpected results.

Prior releases of the Oracle JDBC drivers did not retain bound values from one call of execute to the next as specified in JDBC 1.0. Bound values are now retained. For example:

```
PreparedStatement p = conn.prepareStatement
                      ("SELECT name FROM emp WHERE id = :? AND dept = :?");
p.setInt(1, 314159);
p.setString(2, "SALES");
ResultSet r1 = p.execute();
p.setInt(1, 425260);
ResultSet r2 = p.execute();
```

Previously, a `SQLException` would be thrown by the second `execute()` call because no value was bound to the second argument. In this release, the second execute will return the correct value, retaining the binding of the second argument to the string "SALES".

If the retained bound value is a stream, then the Oracle JDBC drivers will not reset the stream. Unless the application code resets, repositions, or otherwise modifies the stream, the subsequent execute calls will send `NULL` as the value of the argument.

Related Information

This section lists Web sites that contain useful information for JDBC programmers. Many of the sites are referenced in other sections of this manual. In this list you can find references to the Oracle JDBC drivers, Oracle SQLJ, Java technology, the Java Developer's Kit APIs (for versions 1.2.x and 1.1.x), the Java Security API, and resources to help you write signed applets.

Oracle JDBC Drivers and SQLJ

Oracle JDBC Driver Home Page (Oracle Corporation)

`http://www.oracle.com/java/jdbc`

Oracle SQLJ Home Page (Oracle Corporation)

`http://www.oracle.com/java/sqlj`

Java Technology

Java Technology Home Page (Sun Microsystems, Inc.):

`http://www.javasoft.com`

Java Development Kit (JDK1.2.x and 1.1.x) (Sun Microsystems, Inc.):

`http://java.sun.com/products/jdk`

20

Coding Tips and Troubleshooting

This chapter describes how to optimize and troubleshoot a JDBC application or applet, including the following topics:

- JDBC and Multithreading
- Performance Optimization
- Common Problems
- Basic Debugging Procedures
- Transaction Isolation Levels and Access Modes

JDBC and Multithreading

The Oracle JDBC drivers provide full support for programs that use Java multithreading. The following example creates a specified number of threads and lets you determine whether or not the threads will share a connection. If you choose to share the connection, then the same JDBC connection object will be used by all threads (each thread will have its own statement object, however).

Because all Oracle JDBC API methods are synchronized, if two threads try to use the connection object simultaneously, then one will be forced to wait until the other one finishes its use.

The program displays each thread ID and the employee name and employee ID associated with that thread.

Execute the program by entering:

```
java JdbcMTSample [number_of_threads] [share]
```

Where *number_of_threads* is the number of threads that you want to create, and `share` specifies that you want the threads to share the connection. If you do not specify the number of threads, then the program creates 10 by default.

```
/*
 * This sample is a  multi-threaded JDBC program.
 */

import java.sql.*;
import oracle.jdbc.OracleStatement;

public class JdbcMTSample extends Thread
{
  // Default no of threads to 10
  private static int NUM_OF_THREADS = 10;

  int m_myId;

  static  int c_nextId = 1;
  static  Connection s_conn = null;
  static  boolean   share_connection = false;

  synchronized static int getNextId()
  {
      return c_nextId++;
  }
```

```
public static void main (String args [])
{
  try
  {
    /* Load the JDBC driver */
    DriverManager.registerDriver(new oracle.jdbc.OracleDriver());

    // If NoOfThreads is specified, then read it
    if ((args.length > 2)  ||
         ((args.length > 1) && !(args[1].equals("share"))))
    {
       System.out.println("Error: Invalid Syntax. ");
       System.out.println("java JdbcMTSample [NoOfThreads] [share]");
       System.exit(0);
    }

    if (args.length > 1)
    {
       share_connection = true;
       System.out.println
              ("All threads will be sharing the same connection");
    }

    // get the no of threads if given
    if (args.length > 0)
       NUM_OF_THREADS = Integer.parseInt (args[0]);

    // get a shared connection
    if (share_connection)
        s_conn = DriverManager.getConnection
                               ("jdbc:oracle:" +args[1], "scott","tiger");

    // Create the threads
    Thread[] threadList = new Thread[NUM_OF_THREADS];

    // spawn threads
    for (int i = 0; i < NUM_OF_THREADS; i++)
    {
        threadList[i] = new JdbcMTSample();
        threadList[i].start();
    }

    // Start everyone at the same time
    setGreenLight ();
```

```
    // wait for all threads to end
    for (int i = 0; i < NUM_OF_THREADS; i++)
    {
        threadList[i].join();
    }

    if (share_connection)
    {
        s_conn.close();
        s_conn = null;
    }

  }
  catch (Exception e)
  {
     e.printStackTrace();
  }

}

public JdbcMTSample()
{
   super();
   // Assign an Id to the thread
   m_myId = getNextId();
}

public void run()
{
  Connection conn = null;
  ResultSet     rs   = null;
  Statement  stmt = null;

  try
  {
    // Get the connection

    if (share_connection)
      stmt = s_conn.createStatement (); // Create a Statement
    else
    {
      conn = DriverManager.getConnection("jdbc:oracle:oci:@",
                                         "scott","tiger");
      stmt = conn.createStatement (); // Create a Statement
    }
```

```
      while (!getGreenLight())
        yield();

      // Execute the Query
      rs = stmt.executeQuery ("select * from EMP");

      // Loop through the results
      while (rs.next())
      {
        System.out.println("Thread " + m_myId +
                           " Employee Id : " + rs.getInt(1) +
                           " Name : " + rs.getString(2));
        yield();  // Yield To other threads
      }

      // Close all the resources
      rs.close();
      rs = null;

      // Close the statement
      stmt.close();
      stmt = null;

      // Close the local connection
      if ((!share_connection) && (conn != null))
      {
         conn.close();
         conn = null;
      }
      System.out.println("Thread " + m_myId +  " is finished. ");
    }
    catch (Exception e)
    {
      System.out.println("Thread " + m_myId + " got Exception: " + e);
      e.printStackTrace();
      return;
    }
  }

  static boolean greenLight = false;
  static synchronized void setGreenLight () { greenLight = true; }
  synchronized boolean getGreenLight () { return greenLight; }

}
```

Performance Optimization

You can significantly enhance the performance of your JDBC programs by using any of these features:

- Disabling Auto-Commit Mode
- Standard Fetch Size and Oracle Row Prefetching
- Standard and Oracle Update Batching

Disabling Auto-Commit Mode

Auto-commit mode indicates to the database whether to issue an automatic `COMMIT` operation after every SQL operation. Being in auto-commit mode can be expensive in terms of time and processing effort if, for example, you are repeating the same statement with different bind variables.

By default, new connection objects are in auto-commit mode. However, you can disable auto-commit mode with the `setAutoCommit()` method of the connection object (either `java.sql.Conection` or `oracle.jdbc.OracleConnection`).

In auto-commit mode, the `COMMIT` operation occurs either when the statement completes or the next execute occurs, whichever comes first. In the case of statements returning a `ResultSet`, the statement completes when the last row of the `ResultSet` has been retrieved or when the `ResultSet` has been closed. In more complex cases, a single statement can return multiple results as well as output parameter values. Here, the `COMMIT` occurs when all results and output parameter values have been retrieved.

If you disable auto-commit mode with a `setAutoCommit(false)` call, then you must manually commit or roll back groups of operations using the `commit()` or `rollback()` method of the connection object.

Example: Disabling AutoCommit The following example illustrates loading the driver and connecting to the database. Because new connections are in auto-commit mode by default, this example shows how to disable auto-commit. In the example, `conn` represents the `Connection` object, and `stmt` represents the `Statement` object.

```
// Load the Oracle JDBC driver
DriverManager.registerDriver(new oracle.jdbc.OracleDriver());

// Connect to the database
// You can put a database hostname after the @ sign in the connection URL.
Connection conn =
      DriverManager.getConnection ("jdbc:oracle:oci:@", "scott", "tiger");
```

```
// It's faster when auto commit is off
conn.setAutoCommit (false);

// Create a Statement
Statement stmt = conn.createStatement ();
...
```

Standard Fetch Size and Oracle Row Prefetching

Oracle JDBC connection and statement objects allow you to specify the number of rows to prefetch into the client with each trip to the database while a result set is being populated during a query. You can set a value in a connection object that affects each statement produced through that connection, and you can override that value in any particular statement object. The default value in a connection object is 10. Prefetching data into the client reduces the number of round trips to the server.

Similarly, and with more flexibility, JDBC 2.0 allows you to specify the number of rows to fetch with each trip, both for statement objects (affecting subsequent queries) and for result set objects (affecting row refetches). By default, a result set uses the value for the statement object that produced it. If you do not set the JDBC 2.0 fetch size, then the Oracle connection row-prefetch value is used by default.

For more information, see "Oracle Row Prefetching" on page 12-20 and "Fetch Size" on page 13-24.

Standard and Oracle Update Batching

The Oracle JDBC drivers allow you to accumulate `INSERT`, `DELETE`, and `UPDATE` operations of prepared statements at the client and send them to the server in batches. This feature reduces round trips to the server. You can either use Oracle update batching, which typically executes a batch implicitly once a pre-set batch value is reached, or standard update batching, where the batch is executed explicitly.

For a description of the update batching models and how to use them, see "Update Batching" on page 12-2.

Common Problems

This section describes some common problems that you might encounter while using the Oracle JDBC drivers. These problems include:

- Space Padding for CHAR Columns Defined as OUT or IN / OUT Variables
- Memory Leaks and Running Out of Cursors
- Boolean Parameters in PL / SQL Stored Procedures
- Opening More Than 16 OCI Connections for a Process

Space Padding for CHAR Columns Defined as OUT or IN/OUT Variables

In PL / SQL, `CHAR` columns defined as `OUT` or `IN / OUT` variables are returned to a length of 32767 bytes, padded with spaces as needed. Note that `VARCHAR2` columns do not exhibit this behavior.

To avoid this problem, use the `setMaxFieldSize()` method on the `Statement` object to set a maximum limit on the length of the data that can be returned for any column. The length of the data will be the value you specify for `setMaxFieldSize()`, padded with spaces as needed. You must select the value for `setMaxFieldSize()` carefully, because this method is statement-specific and affects the length of all `CHAR`, `RAW`, `LONG`, `LONG RAW`, and `VARCHAR2` columns.

To be effective, you must invoke the `setMaxFieldSize()` method before you register your `OUT` variables.

Memory Leaks and Running Out of Cursors

If you receive messages that you are running out of cursors or that you are running out of memory, make sure that all your `Statement` and `ResultSet` objects are explicitly closed. The Oracle JDBC drivers do not have finalizer methods. They perform cleanup routines by using the `close()` method of the `ResultSet` and `Statement` classes. If you do not explicitly close your result set and statement objects, significant memory leaks can occur. You could also run out of cursors in the database. Closing a result set or statement releases the corresponding cursor in the database.

Similarly, you must explicitly close `Connection` objects to avoid leaking and running out of cursors on the server side. When you close the connection, the JDBC driver closes any open statement objects associated with it, thus releasing the cursor objects on the server side.

Boolean Parameters in PL/SQL Stored Procedures

Due to a restriction in the OCI layer, the JDBC drivers do not support the passing of BOOLEAN parameters to PL/SQL stored procedures. If a PL/SQL procedure contains BOOLEAN values, you can work around the restriction by wrapping the PL/SQL procedure with a second PL/SQL procedure that accepts the argument as an INT and passes it to the first stored procedure. When the second procedure is called, the server performs the conversion from INT to BOOLEAN.

The following is an example of a stored procedure, BOOLPROC, that attempts to pass a BOOLEAN parameter, and a second procedure, BOOLWRAP, that performs the substitution of an INT value for the BOOLEAN.

```
CREATE OR REPLACE PROCEDURE boolproc(x boolean)
AS
BEGIN
[...]
END;

CREATE OR REPLACE PROCEDURE boolwrap(x int)
AS
BEGIN
IF (x=1) THEN
  boolproc(TRUE);
ELSE
  boolproc(FALSE);
END IF;
END;

// Create the database connection
Connection conn = DriverManager.getConnection
                  ("jdbc:oracle:oci:@<...hoststring...>", "scott", "tiger");
CallableStatement cs = conn.prepareCall ("begin boolwrap(?); end;");
cs.setInt(1, 1);
cs.execute ();
```

Opening More Than 16 OCI Connections for a Process

You might find that you are not able to open more than approximately 16 JDBC-OCI connections for a process at any given time. The most likely reasons for this would be either that the number of processes on the server exceeded the limit specified in the initialization file, or that the per-process file descriptors limit was exceeded. It is

important to note that one JDBC-OCI connection can use more than one file descriptor (it might use anywhere between 3 and 4 file descriptors).

If the server allows more than 16 processes, then the problem could be with the per-process file descriptor limit. The possible solution would be to increase this limit.

Basic Debugging Procedures

This section describes strategies for debugging a JDBC program:

- Oracle Net Tracing to Trap Network Events
- Third Party Debugging Tools

For information about processing SQL exceptions, including printing stack traces to aid in debugging, see "Processing SQL Exceptions" on page 3-34.

Oracle Net Tracing to Trap Network Events

You can enable client and server Oracle-Net trace to trap the packets sent over Oracle Net. You can use client-side tracing only for the JDBC OCI driver; it is not supported for the JDBC Thin driver. You can find more information on tracing and reading trace files in the *Oracle Net Services Administrator's Guide*.

The trace facility produces a detailed sequence of statements that describe network events as they execute. "Tracing" an operation lets you obtain more information on the internal operations of the event. This information is output to a readable file that identifies the events that led to the error. Several Oracle Net parameters in the `SQLNET.ORA` file control the gathering of trace information. After setting the parameters in `SQLNET.ORA`, you must make a new connection for tracing to be performed.

The higher the trace level, the more detail is captured in the trace file. Because the trace file can be hard to understand, start with a trace level of 4 when enabling tracing. The first part of the trace file contains connection handshake information, so look beyond this for the SQL statements and error messages related to your JDBC program.

Note: The trace facility uses a large amount of disk space and might have significant impact upon system performance. Therefore, enable tracing only when necessary.

Client-Side Tracing

Set the following parameters in the SQLNET.ORA file on the client system.

TRACE_LEVEL_CLIENT

Purpose: Turns tracing on / off to a certain specified level.

Default Value: 0 or OFF

Available Values:
- 0 or OFF - No trace output
- 4 or USER - User trace information
- 10 or ADMIN - Administration trace information
- 16 or SUPPORT - WorldWide Customer Support trace information

Example: TRACE_LEVEL_CLIENT=10

TRACE_DIRECTORY_CLIENT

Purpose: Specifies the destination directory of the trace file.

Default Value: $ORACLE_HOME / network / trace

Example: on UNIX: TRACE_DIRECTORY_CLIENT= / oracle / traces

on Windows NT: TRACE_DIRECTORY_CLIENT=C:\ORACLE\TRACES

TRACE_FILE_CLIENT

Purpose: Specifies the name of the client trace file.

Default Value: SQLNET.TRC

Example: TRACE_FILE_CLIENT=cli_Connection1.trc

Note: Ensure that the name you choose for the TRACE_FILE_CLIENT file is different from the name you choose for the TRACE_FILE_SERVER file.

TRACE_UNIQUE_CLIENT

Purpose: Gives each client-side trace a unique name to prevent each trace file from being overwritten with the next occurrence of a client trace. The PID is attached to the end of the file name.

Default Value: OFF

Purpose: Gives each client-side trace a unique name to prevent each trace file from being overwritten with the next occurrence of a client trace. The PID is attached to the end of the file name.

Example: TRACE_UNIQUE_CLIENT = ON

Server-Side Tracing

Set the following parameters in the SQLNET.ORA file on the server system. Each connection will generate a separate file with a unique file name.

TRACE_LEVEL_SERVER

Purpose: Turns tracing on/off to a certain specified level.

Default Value: 0 or OFF

Available Values:

- 0 or OFF - No trace output
- 4 or USER - User trace information
- 10 or ADMIN - Administration trace information
- 16 or SUPPORT - WorldWide Customer Support trace information

Example: TRACE_LEVEL_SERVER=10

TRACE_DIRECTORY_SERVER

Purpose: Specifies the destination directory of the trace file.

Default Value: $ORACLE_HOME/network/trace

Example: TRACE_DIRECTORY_SERVER=/oracle/traces

TRACE_FILE_SERVER

Purpose: Specifies the name of the server trace file.

Default Value: SERVER.TRC

Example: TRACE_FILE_SERVER= svr_Connection1.trc

Note: Ensure that the name you choose for the TRACE_FILE_SERVER file is different from the name you choose for the TRACE_FILE_CLIENT file.

Third Party Debugging Tools

You can use tools such as JDBCSpy and JDBCTest from Intersolv to troubleshoot at the JDBC API level. These tools are similar to ODBCSpy and ODBCTest.

Transaction Isolation Levels and Access Modes

Read-only connections are supported by the Oracle server, but not by the Oracle JDBC drivers.

For transactions, the Oracle server supports only the `TRANSACTION_READ_COMMITTED` and `TRANSACTION_SERIALIZABLE` transaction isolation levels. The default is `TRANSACTION_READ_COMMITTED`. Use the following methods of the `oracle.jdbc.OracleConnection` interface to get and set the level:

- `getTransactionIsolation()`: Gets this connection's current transaction isolation level.
- `setTransactionIsolation()`: Changes the transaction isolation level, using one of the `TRANSACTION_*` values.

A

Row Set

This appendix describes the following topics:

- Row Set Setup and Configuration
- Runtime Properties for Row Set
- Row Set Listener
- Traversing Through the Rows
- Cached Row Set
- JDBC Row Set

Introduction

A *row set* is an object which encapsulates a set of rows. These rows are accessible though the `javax.sql.RowSet` interface. This interface supports component models of development, like JavaBeans, and is part of JDBC optional package by JavaSoft.

Three kinds of row set are supported by JavaSoft:

- Cached row set
- JDBC row set
- Web row set

> **Note:** Oracle implements cached row set and JDBC row set, but *not* Web row set.

All the row set implementation is in the `oracle.jdbc.rowset` package. *Web row set* is a semi-connected row set. It has a servlet which has a connection open and the `WebRowSet` interface translates the user calls to appropriate request to the servlet over HTTP. This is targeted at Thin clients which have only HTTP implementation in them.

> **Note:** The row set feature is available only in JDK 1.2 or later.

The `RowSet` interface provides a set of properties which can be altered to access the data in the database through a single interface. It supports properties and events which forms the core of JavaBeans. It has various properties like connect string, user name, password, type of connection, the query string itself, and also the parameters passed to the query. The following code executes a simple query:

```
...
rowset.setUrl ("jdbc:oracle:oci:@");
rowset.setUsername ("SCOTT");
rowset.setPassword ("TIGER");
rowset.setCommand (
  "SELECT empno, ename, sal FROM emp WHERE empno = ?");

// empno of employee name "KING"
rowset.setInt (1, 7839);
...
```

In the above example, the URL, user name, password, SQL query, and bind parameter required for the query are set as the command properties to retrieve the employee name and salary. Also, the row set would contain `empno`, `ename`, and `sal` for the employee with the `empno` as `7839` and whose name is `KING`.

Row Set Setup and Configuration

The classes for the row set feature are found in a separate archive, `ocrs12.zip`. This file is located in the `$ORACLE_HOME/jdbc` directory. To use row set, you need to include this archive in your `CLASSPATH`.

For Unix (sh), the command is:

```
CLASSPATH=$CLASSPATH:$ORACLE_HOME/jdbc/lib/ocrs12.zip
export CLASSPATH
```

For Windows 2000 / NT / 98 / 95, the command is:

```
set CLASSPATH=%CLASSPATH%;%ORACLE_HOME%\jdbc\lib\ocrs12.zip
```

This might also be set in the project properties in case you are using an IDE like Jdeveloper.

Oracle row set interfaces are implemented in the `oracle.jdbc.rowset` package. Import this package to use any of the Oracle row set implementations.

The `OracleCachedRowSet` and `OracleJDBCRowSet` classes implement the `javax.sql.RowSet` interface, which extends `java.sql.ResultSet`. Row set not only provides the interfaces of result set, but also some of the properties of the `java.sql.Connection` and `java.sql.PreparedStatement` interfaces. Connections and prepared statements are totally abstracted by this interface. `CachedRowSet` is serializable. This class implements the `java.io.Serializable` interface. This enables the `OracleCachedRowSet` class to be moved over the network or other JVM sessions.

Also available is the `oracle.jdbc.rowset.OracleRowSetListenerAdapter` class.

Runtime Properties for Row Set

Typically, static properties for the applications can be set for a row set at the development time and the rest of the properties which are dynamic (are dependent on runtime) can be set at the runtime. The static properties may include the connection URL, username, password, connection type, concurrency type of the row set, or the query itself. The runtime properties, like the bind parameters for the query, could be bound at runtime. Scenarios where the query itself is a dynamic property is also common.

Row Set Listener

The row set feature supports multiple listeners to be registered with the `RowSet` object. Listeners can be registered using the `addRowSetListener()` method and unregistered through the `removeRowSetListener()` method. A listener should implement the `javax.sql.RowSetListener` interface to register itself as the row set listener. Three types of events are supported by the `RowSet` interface:

1. `cursorMoved` event : Generated whenever there is a cursor movement, which occurs when the `next()` or `previous()` methods are called
2. `rowChanged` event : Generated when a new row is inserted, updated, or deleted from the row set
3. `rowsetChanged` event : Generated when the whole row set is created or changed

The following code shows the registration of a row set listener:

```
MyRowSetListener rowsetListener =
  new MyRowSetListener ();
// adding a rowset listener.
rowset.addRowSetListener (rowsetListener);


// implementation of a rowset listener
public class MyRowSetListener implements RowSetListener
{
  public void cursorMoved(RowSetEvent event)
  {
   // action on cursor movement
  }

  public void rowChanged(RowSetEvent event)
  {
    // action on change of row
  }

  public void rowSetChanged(RowSetEvent event)
  {
    // action on changing of rowset
  }
}// end of class MyRowSetListener
```

Applications which handle only a few events can implement only the required events by using the `OracleRowSetAdapter` class, which is an abstract class with empty implementation for all the event handling methods.

In the following code, only the `rowSetChanged` event is handled. The remaining events are not handled by the application.

```
rowset.addRowSetListener (new OracleRowSetAdapter ()
  {
     public void rowSetChanged(RowSetEvent event)
     {
       // your action for rowsetChanged
     }
  }
 );
```

Traversing Through the Rows

Various methods to traverse through the rows are provided by the `RowSet` interface. These properties are inherited directly from the `java.sql.ResultSet` interface. The `RowSet` interface could be used as a `ResultSet` interface for retrieval and updating of data. The `RowSet` interface provides an optional way to implement a scrolling and updatable result set if they are not provided by the result set implementation.

Note: The scrollable properties of the `java.sql.ResultSet` interface are also provided by the Oracle implementation of `ResultSet`.

Cached Row Set

A *cached row set* is a row set implementation where the rows are cached and the row set does not have a live connection to the database (disconnected) and it is a serializable object, which provides the standard interface as of the `javax.sql.RowSet` interface. `OracleCachedRowSet` is the implementation of `CachedRowSet` by Oracle, and the `OracleCachedRowSet` is used interchangeably with `CachedRowSet`.

In the following code, an `OracleCachedRowSet` object is created and the connection URL, username, password, and the SQL query for the row set is set as properties. The `RowSet` object is populated through the `execute` method. After the `execute` call, the `RowSet` object can be used as a `java.sql.ResultSet` object to retrieve, scroll, insert, delete, or update data.

```
...
RowSet rowset = new OracleCachedRowSet ();
rowset.setUrl ("jdbc:oracle:oci:@");
rowset.setUsername ("SCOTT");
rowset.setPassword ("TIGER");
rowset.setCommand ("SELECT empno, ename, sal FROM emp");
rowset.execute ();
while (rowset.next ())
{
  System.out.println ("empno: " +rowset.getInt (1));
  System.out.println ("ename: " +rowset.getString (2));
  System.out.println ("sal: "   +rowset.getInt (3));
}
...
```

To populate a `CachedRowSet` object with a query, complete the following steps:

1. Instantiate `OracleCachedRowSet`.
2. Set connection `Url`, `Username`, `Password`, connection type (optional), and the query string as properties for the `RowSet` object.
3. Invoke the `execute()` method to populate the `RowSet` object.

`CachedRowSet` can be populated with the existing `ResultSet` object, using the `populate()` method, as shown in the following code:

```
// Executing a query to get the ResultSet object.
ResultSet rset = pstmt.executeQuery ();

OracleCachedRowSet rowset = new OracleCachedRowSet ();
```

```
// the obtained ResultSet object is passed to the
// populate method to populate the data in the
// rowset object.
rowset.populate (rset);
```

In the above example, a `ResultSet` object is obtained by executing a query and the retrieved `ResultSet` object is passed to the `populate()` method of the cached row set to populate the contents of the result set into cached row set.

To populate a `CachedRowSet` object with an already available result set, complete the following steps:

1. Instantiate `OracleCachedRowSet`.
2. Pass the already available `ResultSet` object to the `populate()` method to populate the `RowSet` object.

All the interfaces provided by the `ResultSet` interface are implemented in `RowSet`. The following code shows how to scroll through a row set:

```
/**
 *  Scrolling forward, and printing the empno in
 *  the order in which it was fetched.
 */
// going to the first row of the rowset
rowset.beforeFirst ();
while (rowset.next ())
  System.out.println ("empno: " +rowset.getInt (1));
```

Note: Connection properties like transaction isolation or the concurrency mode of the result set and the bind properties cannot be set in the case where a pre-existent `ResultSet` object is used to populate the `CachedRowSet` object, since the connection or result set on which the property applies would have already been created.

In the example above, the cursor position is initialized to the position before the first row of the row set by the `beforeFirst()` method. The rows are retrieved in forward direction using the `next()` method.

```
/**
 *  Scrolling backward, and printing the empno in
 *  the reverse order as it was fetched.
 */
//going to the last row of the rowset
```

```
rowset.afterLast ();
while (rowset.previous ())
  System.out.println ("empno: " +rowset.getInt (1));
```

In the above example, the cursor position is initialized to the position after the last row of the `RowSet`. The rows are retrieved in reverse direction using the `previous()` method of `RowSet`.

Inserting, updating, and deleting rows are supported by the row set feature as they are in the result set feature. The following code illustrates the insertion of a row at the fifth position of a row set:

```
/**
 * Inserting a row in the 5th position of the rowset.
 */
// moving the cursor to the 5th position in the rowset
if (rowset.absolute(5))
{
  rowset.moveToInsertRow ();
  rowset.updateInt (1, 193);
  rowset.updateString (2, "Ashok");
  rowset.updateInt (3, 7200);

  // inserting a row in the rowset
  rowset.insertRow ();

  // Synchronizing the data in RowSet with that in the
  // database.
  rowset.acceptChanges ();
}
```

In the above example, a call to the `absolute()` method with a parameter `5` takes the cursor to the fifth position of the `row set` and a call to the `moveToInsertRow()` method creates a place for the insertion of a new row into the row set. The `updateXXX()` methods are used to update the newly created row. When all the columns of the row are updated, the `insertRow()` is called to update the row set. The changes are committed through `acceptChanges()` method.

The following code shows how an `OracleCachedRowSet` object is serialized to a file and then retrieved:

```
// writing the serialized OracleCachedRowSet object
{
  FileOutputStream fileOutputStream =
     new FileOutputStream ("emp_tab.dmp");
```

```
  ObjectOutputStream ostream = new
    ObjectOutputStream (fileOutputStream);
  ostream.writeObject (rowset);
  ostream.close ();
  fileOutputStream.close ();
}

// reading the serialized OracleCachedRowSet object
{
  FileInputStream fileInputStream = new
     FileInputStream ("emp_tab.dmp");
  ObjectInputStream istream = new
     ObjectInputStream (fileInputStream);
  RowSet rowset1 = (RowSet) istream.readObject ();
  istream.close ();
  fileInputStream.close ();
}
```

In the above example, a `FileOutputStream` object is opened for a `emp_tab.dmp` file, and the populated `OracleCachedRowSet` object is written to the file using `ObjectOutputStream`. This is retrieved using `FileInputStream` and the `ObjectInputStream` objects.

`OracleCachedRowSet` takes care of the serialization of non-serializable form of data like `InputStream`, `OutputStream`, BLOBS and CLOBS. `OracleCachedRowSets` also implements meta data of its own, which could be obtained without any extra server roundtrip. The following code shows how you can obtain meta data for the row set:

```
ResultSetMetaData metaData = rowset.getMetaData ();
int maxCol = metaData.getColumnCount ();
for (int i = 1; i <= maxCol; ++i)
   System.out.println ("Column (" + i +") "
     +metaData.getColumnName (i));
```

The above example illustrates how to retrieve a `ResultSetMetaData` object and print the column names in the `RowSet`.

Since the `OracleCachedRowSet` class is serializable, it can be passed across a network or between JVMs, as done in Remote Method Invocation (RMI). Once the `OracleCachedRowSet` class is populated, it can move around any JVM, or any environment which does not have JDBC drivers. Committing the data in the row set (through the `acceptChanges()` method) requires the presence of JDBC drivers.

The complete process of retrieving the data and populating it in the `OracleCachedRowSet` class is performed on the server and the populated row set is passed on to the client using suitable architectures like RMI or Enterprise Java Beans (EJB). The client would be able to perform all the operations like retrieving, scrolling, inserting, updating, and deleting on the row set without any connection to the database. Whenever data is committed to the database, the `acceptChanges()` method is called which synchronizes the data in the row set to that in the database. This method makes use of JDBC drivers which require the JVM environment to contain JDBC implementation. This architecture would be suitable for systems involving a Thin client like a Personal Digital Assistant (PDA) or a Network Computer (NC).

After populating the `CachedRowSet` object, it can be used as a `ResultSet` object or any other object which can be passed over the network using RMI or any other suitable architecture.

Some of the other key-features of cached row set are the following:

- Cloning a row set
- Creating a copy of a row set
- Creating a shared copy of a row set

CachedRowSet Constraints

All the constraints which apply to updatable result set are applicable here, except serialization, since `OracleCachedRowSet` is serializable. The SQL query has the following constraints:

- References only a single table in the database
- Contain no join operations
- Selects the primary key of the table it references

In addition, a SQL query should also satisfy the conditions below if inserts are to be performed:

- Selects all of the non-nullable columns in the underlying table
- Selects all columns that do not have a default value

Note: The `CachedRowSet` cannot hold a large quantity of data since all the data is cached in memory.

Properties which apply to the connection cannot be set after populating the row set since the properties cannot be applied to the connection after retrieving the data from the same like, transaction isolation and concurrency mode of the result set.

JDBC Row Set

A *JDBC row set* is another row set implementation. It is a simple, non-serializable connected row set which provides JDBC interfaces in the form of a Bean interface. Any call to `JDBCRowSet` percolates directly to the JDBC interface. The usage of the JDBC interface is the same as any other row set implementation.

Table A–1 shows how the `JDBCRowSet` interface differs from `CachedRowSet` interface.

Table A–1 The JDBC and Cached Row Sets Compared

RowSet Type	Serializable	Connected to Database	Movable Across JVMs	Synchronization of data to database	Presence of JDBC Drivers
JDBC	No	Yes	No	No	Yes
Cached	Yes	No	Yes	Yes	No

The JDBC row set is a connected row set which has a live connection to the database and all the calls on the JDBC row set are percolated to the mapping call in JDBC connection, statement, or result set. A cached row set does not have any connection to the database open.

JDBC row set requires the presence of JDBC drivers where a cached row set does not require JDBC drivers during manipulation, but during population of the row set and the committing the changes of the row set.

The following code shows how a JDBC row set is used:

```
RowSet rowset = new OracleJDBCRowSet ();
rowset.setUrl ("java:oracle:oci:@");
rowset.setUsername ("SCOTT");
rowset.setPassword ("TIGER");
rowset.setCommand (
  "SELECT empno, ename, sal FROM emp");
rowset.execute ();
while (rowset.next ())
{
  System.out.println ("empno: " + rowset.getInt (1));
  System.out.println ("ename: "
    + rowset.getString (2));
  System.out.println ("sal: " + rowset.getInt (3));
}
```

In the above example, the connection URL, username, password, and the SQL query is set as the connection properties to the row set and the query is executed through the `execute()` method and the rows are retrieved and printed.

B

JDBC Error Messages

This appendix briefly discusses the general structure of JDBC error messages, then lists general JDBC error messages and TTC error messages that the Oracle JDBC drivers can return. The appendix is organized as follows:

- General Structure of JDBC Error Messages
- General JDBC Messages
- TTC Messages

Each of the two message lists is first sorted by ORA number, and then alphabetically.

For general information about processing JDBC exceptions, see "Processing SQL Exceptions" on page 3-34.

General Structure of JDBC Error Messages

The general JDBC error message structure allows runtime information to be appended to the end of a message, following a colon, as follows:

```
<error_message>:<extra_info>
```

For example, a "closed statement" error might be output as follows:

```
Closed Statement:next
```

This indicates that the exception was thrown during a call to the `next()` method (of a result set object).

In some cases, the user can find the same information in a stack trace.

General JDBC Messages

This section lists general JDBC error messages, first sorted by ORA number, and then alphabetically.

JDBC Messages Sorted by ORA Number

ORA Number	Message
ORA-17001	Internal Error
ORA-17002	Io exception
ORA-17003	Invalid column index
ORA-17004	Invalid column type
ORA-17005	Unsupported column type
ORA-17006	Invalid column name
ORA-17007	Invalid dynamic column
ORA-17008	Closed Connection
ORA-17009	Closed Statement
ORA-17010	Closed Resultset
ORA-17011	Exhausted Resultset
ORA-17012	Parameter Type Conflict
ORA-17014	ResultSet.next was not called
ORA-17015	Statement was cancelled
ORA-17016	Statement timed out
ORA-17017	Cursor already initialized
ORA-17018	Invalid cursor
ORA-17019	Can only describe a query
ORA-17020	Invalid row prefetch
ORA-17021	Missing defines
ORA-17022	Missing defines at index

ORA Number	Message
ORA-17023	Unsupported feature
ORA-17024	No data read
ORA-17025	Error in defines.isNull ()
ORA-17026	Numeric Overflow
ORA-17027	Stream has already been closed
ORA-17028	Can not do new defines until the current ResultSet is closed
ORA-17029	setReadOnly: Read-only connections not supported
ORA-17030	READ_COMMITTED and SERIALIZABLE are the only valid transaction levels
ORA-17031	setAutoClose: Only support auto close mode on
ORA-17032	cannot set row prefetch to zero
ORA-17033	Malformed SQL92 string at position
ORA-17034	Non supported SQL92 token at position
ORA-17035	Character Set Not Supported !!
ORA-17036	exception in OracleNumber
ORA-17037	Fail to convert between UTF8 and UCS2
ORA-17038	Byte array not long enough
ORA-17039	Char array not long enough
ORA-17040	Sub Protocol must be specified in connection URL
ORA-17041	Missing IN or OUT parameter at index:
ORA-17042	Invalid Batch Value
ORA-17043	Invalid stream maximum size
ORA-17044	Internal error: Data array not allocated
ORA-17045	Internal error: Attempt to access bind values beyond the batch value

ORA Number	Message
ORA-17046	Internal error: Invalid index for data access
ORA-17047	Error in Type Descriptor parse
ORA-17048	Undefined type
ORA-17049	Inconsistent java and sql object types
ORA-17050	no such element in vector
ORA-17051	This API cannot be be used for non-UDT types
ORA-17052	This ref is not valid
ORA-17053	The size is not valid
ORA-17054	The LOB locator is not valid
ORA-17055	Invalid character encountered in
ORA-17056	Non supported character set
ORA-17057	Closed LOB
ORA-17058	Internal error: Invalid NLS Conversion ratio
ORA-17059	Fail to convert to internal representation
ORA-17060	Fail to construct descriptor
ORA-17061	Missing descriptor
ORA-17062	Ref cursor is invalid
ORA-17063	Not in a transaction
ORA-17064	Invalid Sytnax or Database name is null
ORA-17065	Conversion class is null
ORA-17066	Access layer specific implementation needed
ORA-17067	Invalid Oracle URL specified
ORA-17068	Invalid argument(s) in call
ORA-17069	Use explicit XA call
ORA-17070	Data size bigger than max size for this type
ORA-17071	Exceeded maximum VARRAY limit

ORA Number	Message
ORA-17072	Inserted value too large for column
ORA-17073	Logical handle no longer valid
ORA-17074	invalid name pattern
ORA-17075	Invalid operation for forward only resultset
ORA-17076	Invalid operation for read only resultset
ORA-17077	Fail to set REF value
ORA-17078	Cannot do the operation as connections are already opened
ORA-17079	User credentials doesn’t match the existing ones
ORA-17080	invalid batch command
ORA-17081	error occurred during batching
ORA-17082	No current row
ORA-17083	Not on the insert row
ORA-17084	Called on the insert row
ORA-17085	Value conflicts occurs
ORA-17086	Undefined column value on the insert row
ORA-17087	Ignored performance hint: setFetchDirection()
ORA-17088	Unsupported syntax for requested resultset type and concurrency level
ORA-17089	internal error
ORA-17090	operation not allowed
ORA-17091	Unable to create resultset at the requested type and/or concurrency level
ORA-17092	JDBC statements cannot be created or executed at end of call processing
ORA-17093	OCI operation returned OCI_SUCCESS_WITH_INFO
ORA-17094	Object type version mismatched

ORA Number	Message
ORA-17095	Statement Caching is not enabled for this Connection object
ORA-17096	Statement Caching cannot be enabled for this logical connection
ORA-17097	Invalid PL/SQL Index Table element type
ORA-17098	Invalid empty lob operation
ORA-17099	Invalid PL/SQL Index Table array length
ORA-17100	Invalid database Java Object
ORA-17101	Invalid properties in OCI Connection Pool Object
ORA-17102	Bfile is read only
ORA-17103	invalid connection type to return via getConnection. Use getJavaSqlConnection instead
ORA-17104	SQL statement to execute cannot be empty or null
ORA-17105	connection session time zone was not set
ORA-17106	invalid combination of connections specified
ORA-17107	invalid proxy type specified
ORA-17108	No max length specified in defineColumnType
ORA-17109	standard Java character encoding not found
ORA-17110	execution completed with warning
ORA-17111	Invalid connection cache TTL timeout specified
ORA-17112	Invalid thread interval specified
ORA-17113	Thread interval value is more than the cache timeout value
ORA-17114	could not use local transaction commit in a global transaction

ORA Number	Message
ORA-17115	could not use local transaction rollback in a global transaction
ORA-17116	could not turn on auto-commit in an active global transaction
ORA-17117	could not set savepoint in an active global transaction
ORA-17118	could not obtain ID for a named Savepoint
ORA-17119	could not obtain name for an un-named Savepoint
ORA-17120	could not set a Savepoint with auto-commit on
ORA-17121	could not rollback to a Savepoint with auto-commit on
ORA-17122	could not rollback to a local txn Savepoint in a global transaction
ORA-17123	Invalid statement cache size specified
ORA-17124	Invalid connection cache Inactivity timeout specified
ORA-17125	Improper statement type returned by explicit cache
ORA-17126	Fixed Wait timeout elapsed
ORA-17127	Invalid Fixed Wait timeout specified

JDBC Messages Sorted Alphabetically

ORA Number	Message
ORA-17066	Access layer specific implementation needed
ORA-17102	Bfile is read only
ORA-17038	Byte array not long enough
ORA-17084	Called on the insert row
ORA-17028	Can not do new defines until the current ResultSet is closed
ORA-17019	Can only describe a query
ORA-17078	Cannot do the operation as connections are already opened
ORA-17032	cannot set row prefetch to zero
ORA-17039	Char array not long enough
ORA-17035	Character Set Not Supported !!
ORA-17008	Closed Connection
ORA-17057	Closed LOB
ORA-17010	Closed Resultset
ORA-17009	Closed Statement
ORA-17105	connection session time zone was not set
ORA-17065	Conversion class is null
ORA-17118	could not obtain ID for a named Savepoint
ORA-17119	could not obtain name for an un-named Savepoint
ORA-17122	could not rollback to a local txn Savepoint in a global transaction
ORA-17121	could not rollback to a Savepoint with auto-commit on
ORA-17120	could not set a Savepoint with auto-commit on

ORA Number	Message
ORA-17117	could not set savepoint in an active global transaction
ORA-17116	could not turn on auto-commit in an active global transaction
ORA-17114	could not use local transaction commit in a global transaction
ORA-17115	could not use local transaction rollback in a global transaction
ORA-17017	Cursor already initialized
ORA-17070	Data size bigger than max size for this type
ORA-17025	Error in defines.isNull ()
ORA-17047	Error in Type Descriptor parse
ORA-17081	error occurred during batching
ORA-17071	Exceeded maximum VARRAY limit
ORA-17036	exception in OracleNumber
ORA-17110	execution completed with warning
ORA-17011	Exhausted Resultset
ORA-17060	Fail to construct descriptor
ORA-17037	Fail to convert between UTF8 and UCS2
ORA-17059	Fail to convert to internal representation
ORA-17077	Fail to set REF value
ORA-17126	Fixed Wait timeout elapsed
ORA-17087	Ignored performance hint: setFetchDirection()
ORA-17125	Improper statement type returned by explicit cache
ORA-17049	Inconsistent java and sql object types
ORA-17072	Inserted value too large for column
ORA-17089	internal error

ORA Number	Message
ORA-17001	Internal Error
ORA-17045	Internal error: Attempt to access bind values beyond the batch value
ORA-17044	Internal error: Data array not allocated
ORA-17046	Internal error: Invalid index for data access
ORA-17058	Internal error: Invalid NLS Conversion ratio
ORA-17068	Invalid argument(s) in call
ORA-17080	invalid batch command
ORA-17042	Invalid Batch Value
ORA-17055	Invalid character encountered in
ORA-17003	Invalid column index
ORA-17006	Invalid column name
ORA-17004	Invalid column type
ORA-17106	invalid combination of connections specified
ORA-17124	Invalid connection cache Inactivity timeout specified
ORA-17111	Invalid connection cache TTL timeout specified
ORA-17103	invalid connection type to return via getConnection. Use getJavaSqlConnection instead
ORA-17018	Invalid cursor
ORA-17100	Invalid database Java Object
ORA-17007	Invalid dynamic column
ORA-17098	Invalid empty lob operation
ORA-17127	Invalid Fixed Wait timeout specified
ORA-17074	invalid name pattern
ORA-17075	Invalid operation for forward only resultset

ORA Number	Message
ORA-17076	Invalid operation for read only resultset
ORA-17067	Invalid Oracle URL specified
ORA-17099	Invalid PL/SQL Index Table array length
ORA-17097	Invalid PL/SQL Index Table element type
ORA-17101	Invalid properties in OCI Connection Pool Object
ORA-17107	invalid proxy type specified
ORA-17020	Invalid row prefetch
ORA-17123	Invalid statement cache size specified
ORA-17043	Invalid stream maximum size
ORA-17064	Invalid Sytnax or Database name is null
ORA-17112	Invalid thread interval specified
ORA-17002	Io exception
ORA-17092	JDBC statements cannot be created or executed at end of call processing
ORA-17073	Logical handle no longer valid
ORA-17033	Malformed SQL92 string at position
ORA-17021	Missing defines
ORA-17022	Missing defines at index
ORA-17061	Missing descriptor
ORA-17041	Missing IN or OUT parameter at index:
ORA-17082	No current row
ORA-17024	No data read
ORA-17108	No max length specified in defineColumnType
ORA-17050	no such element in vector
ORA-17056	Non supported character set
ORA-17034	Non supported SQL92 token at position

ORA Number	Message
ORA-17063	Not in a transaction
ORA-17083	Not on the insert row
ORA-17026	Numeric Overflow
ORA-17094	Object type version mismatched
ORA-17093	OCI operation returned OCI_SUCCESS_WITH_INFO
ORA-17090	operation not allowed
ORA-17012	Parameter Type Conflict
ORA-17030	READ_COMMITTED and SERIALIZABLE are the only valid transaction levels
ORA-17062	Ref cursor is invalid
ORA-17014	ResultSet.next was not called
ORA-17031	setAutoClose: Only support auto close mode on
ORA-17029	setReadOnly: Read-only connections not supported
ORA-17104	SQL statement to execute cannot be empty or null
ORA-17109	standard Java character encoding not found
ORA-17096	Statement Caching cannot be enabled for this logical connection
ORA-17095	Statement Caching is not enabled for this Connection object
ORA-17016	Statement timed out
ORA-17015	Statement was cancelled
ORA-17027	Stream has already been closed
ORA-17040	Sub Protocol must be specified in connection URL
ORA-17054	The LOB locator is not valid
ORA-17053	The size is not valid

ORA Number	Message
ORA-17051	This API cannot be be used for non-UDT types
ORA-17052	This ref is not valid
ORA-17113	Thread interval value is more than the cache timeout value
ORA-17091	Unable to create resultset at the requested type and/or concurrency level
ORA-17086	Undefined column value on the insert row
ORA-17048	Undefined type
ORA-17005	Unsupported column type
ORA-17023	Unsupported feature
ORA-17088	Unsupported syntax for requested resultset type and concurrency level
ORA-17069	Use explicit XA call
ORA-17079	User credentials doesn’t match the existing ones
ORA-17085	Value conflicts occurs

HeteroRM XA Messages

The following are the JDBC error messages that are specific to the HeteroRM XA feature.

HeteroRM XA Messages Sorted by ORA Number

ORA Number	Message
ORA-17200	Unable to properly convert XA open string from Java to C
ORA-17201	Unable to properly convert XA close string from Java to C
ORA-17202	Unable to properly convert RM name from Java to C
ORA-17203	Could not cast pointer type to jlong
ORA-17204	Input array too short to hold OCI handles
ORA-17205	Failed to obtain OCISvcCtx handle from C-XA using xaoSvcCtx
ORA-17206	Failed to obtain OCIEnv handle from C-XA using xaoEnv
ORA-17207	The tnsEntry property was not set in DataSource
ORA-17213	C-XA returned XAER_RMERR during xa_open
ORA-17215	C-XA returned XAER_INVAL during xa_open
ORA-17216	C-XA returned XAER_PROTO during xa_open
ORA-17233	C-XA returned XAER_RMERR during xa_close
ORA-17235	C-XA returned XAER_INVAL during xa_close
ORA-17236	C-XA returned XAER_PROTO during xa_close

HeteroRM XA Messages Sorted Alphabetically

ORA Number	Message
ORA-17203	Could not cast pointer type to jlong
ORA-17235	C-XA returned XAER_INVAL during xa_close
ORA-17215	C-XA returned XAER_INVAL during xa_open
ORA-17236	C-XA returned XAER_PROTO during xa_close
ORA-17216	C-XA returned XAER_PROTO during xa_open
ORA-17233	C-XA returned XAER_RMERR during xa_close
ORA-17213	C-XA returned XAER_RMERR during xa_open
ORA-17206	Failed to obtain OCIEnv handle from C-XA using xaoEnv
ORA-17205	Failed to obtain OCISvcCtx handle from C-XA using xaoSvcCtx
ORA-17204	Input array too short to hold OCI handles
ORA-17207	The tnsEntry property was not set in DataSource
ORA-17202	Unable to properly convert RM name from Java to C
ORA-17201	Unable to properly convert XA close string from Java to C
ORA-17200	Unable to properly convert XA open string from Java to C

TTC Messages

This section lists TTC error messages, first sorted by ORA number, and then alphabetically.

TTC Messages Sorted by ORA Number

ORA Number	Message
ORA-17401	Protocol violation
ORA-17402	Only one RPA message is expected
ORA-17403	Only one RXH message is expected
ORA-17404	Received more RXDs than expected
ORA-17405	UAC length is not zero
ORA-17406	Exceeding maximum buffer length
ORA-17407	invalid Type Representation(setRep)
ORA-17408	invalid Type Representation(getRep)
ORA-17409	invalid buffer length
ORA-17410	No more data to read from socket
ORA-17411	Data Type representations mismatch
ORA-17412	Bigger type length than Maximum
ORA-17413	Exceding key size
ORA-17414	Insufficient Buffer size to store Columns Names
ORA-17415	This type hasn’t been handled
ORA-17416	FATAL
ORA-17417	NLS Problem, failed to decode column names
ORA-17418	Internal structure’s field length error
ORA-17419	Invalid number of columns returned
ORA-17420	Oracle Version not defined

ORA Number	Message
ORA-17421	Types or Connection not defined
ORA-17422	Invalid class in factory
ORA-17423	Using a PLSQL block without an IOV defined
ORA-17424	Attempting different marshaling operation
ORA-17425	Returning a stream in PLSQL block
ORA-17426	Both IN and OUT binds are NULL
ORA-17427	Using Uninitialized OAC
ORA-17428	Logon must be called after connect
ORA-17429	Must be at least connected to server
ORA-17430	Must be logged on to server
ORA-17431	SQL Statement to parse is null
ORA-17432	invalid options in all7
ORA-17433	invalid arguments in call
ORA-17434	not in streaming mode
ORA-17435	invalid number of in_out_binds in IOV
ORA-17436	invalid number of outbinds
ORA-17437	Error in PLSQL block IN/OUT argument(s)
ORA-17438	Internal - Unexpected value
ORA-17439	Invalid SQL type
ORA-17440	DBItem/DBType is null
ORA-17441	Oracle Version not supported. Minimum supported version is 7.2.3.
ORA-17442	Refcursor value is invalid
ORA-17443	Null user or password not supported in THIN driver
ORA-17444	TTC Protocol version received from server not supported

TTC Messages Sorted Alphabetically

ORA Number	Message
ORA-17424	Attempting different marshaling operation
ORA-17412	Bigger type length than Maximum
ORA-17426	Both IN and OUT binds are NULL
ORA-17411	Data Type representations mismatch
ORA-17440	DBItem/DBType is null
ORA-17437	Error in PLSQL block IN/OUT argument(s)
ORA-17413	Exceding key size
ORA-17406	Exceeding maximum buffer length
ORA-17416	FATAL
ORA-17414	Insufficient Buffer size to store Columns Names
ORA-17438	Internal - Unexpected value
ORA-17418	Internal structure’s field length error
ORA-17433	invalid arguments in call
ORA-17409	invalid buffer length
ORA-17422	Invalid class in factory
ORA-17419	Invalid number of columns returned
ORA-17435	invalid number of in_out_binds in IOV
ORA-17436	invalid number of outbinds
ORA-17432	invalid options in all7
ORA-17439	Invalid SQL type
ORA-17408	invalid Type Representation(getRep)
ORA-17407	invalid Type Representation(setRep)
ORA-17428	Logon must be called after connect
ORA-17429	Must be at least connected to server

ORA Number	Message
ORA-17430	Must be logged on to server
ORA-17417	NLS Problem, failed to decode column names
ORA-17410	No more data to read from socket
ORA-17434	not in streaming mode
ORA-17443	Null user or password not supported in THIN driver
ORA-17402	Only one RPA message is expected
ORA-17403	Only one RXH message is expected
ORA-17420	Oracle Version not defined
ORA-17441	Oracle Version not supported. Minimum supported version is 7.2.3.
ORA-17401	Protocol violation
ORA-17404	Received more RXDs than expected
ORA-17442	Refcursor value is invalid
ORA-17425	Returning a stream in PLSQL block
ORA-17431	SQL Statement to parse is null
ORA-17415	This type hasn’t been handled
ORA-17444	TTC Protocol version received from server not supported
ORA-17421	Types or Connection not defined
ORA-17405	UAC length is not zero
ORA-17423	Using a PLSQL block without an IOV defined
ORA-17427	Using Uninitialized OAC

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