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Beginning Oracle PL/SQL

LEARN TO MODEL THE REAL WORLD THROUGH PL/SQL

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Apress®

Contents at a Glance

Introduction (The Big Picture)

This is a book about writing stored procedures for an Oracle database. A stored procedure in this context is a generic term for a program written in the Procedure Language extension for SQL (PL/SQL) that is stored inside the database when it is compiled. This means that you can then execute the program from inside the database. Why would you want to do this? Because your program will run faster inside the database.

Let's slow down for a minute, so I can explain what a stored procedure is and why you would want to use one.

What's a Stored Procedure?

In order for me to talk about stored procedures, I need to cover a little material on databases and networks first. By now, you've probably already seen three of the four diagrams I'm about to show you a few hundred times, but bear with me so I can make sure everyone is on the same page as we start out.

I'm going to assume, since you're ready to start writing programs against an Oracle database, that you already know what a relational database management system (RDBMS) is. For our purposes, an RDBMS, or database as I'll refer to it from here forward, is a hardware/software machine (server) that allows us to store, retrieve, and manipulate data in a predictable and organized manner using Structured Query Language (SQL).

SQL acts as the interface to the database. A client program, whether it exists on the same computer or on another, makes a connection to the database, sends a request in the form of SQL to the server, and in return gets back structured data, as in Figure I-1.

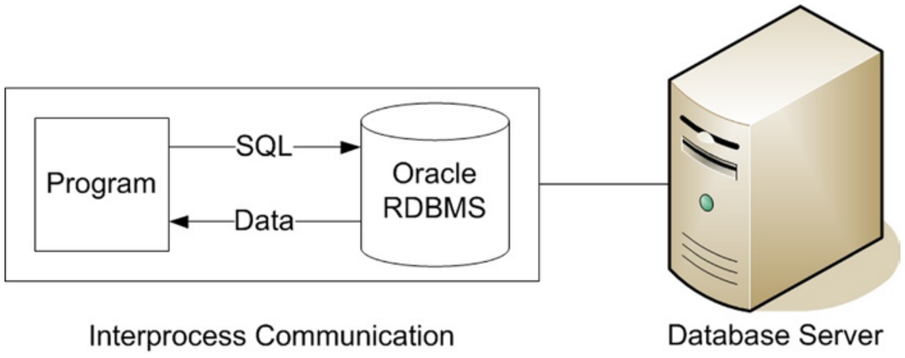


Figure I-1. *Client-server architecture on the same host*

A client program that utilizes Oracle on the same host computer, as in Figure I-1, is a client-server program because it accesses a server program to perform some of the client program's work. The communication between the two processes, client and server, takes place through an interprocess communication (IPC) system provided by the host operating system. This is typically done through memory. Suffice it to say that some communication overhead takes place when communicating between the client and the server in this fashion. This overhead takes time and operating system resources. Regardless, it's pretty fast.

But not everyone can run the program on the same computer, so some applications resort to the use of client-server architecture over a network. This is what is referred to when most people use the term client-server. Figure I-2 is a diagram that shows the communication between the client and server in a networked client-server architecture, specifically, a client-server diagram with one network connection in between the client (program) and server (database).

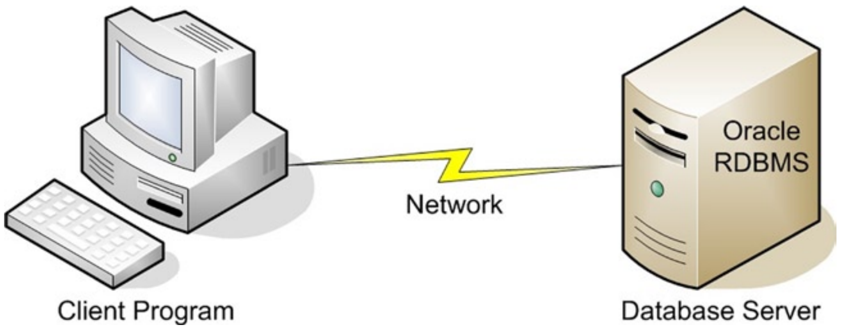


Figure I-2. *Client-server architecture over a network*

The communication between the two processes, client and server, in Figure I-2, is much slower than the architecture shown in Figure I-1, where IPC is used. Even with the best network hardware available, this connection is usually 20 times slower than IPC, or worse. Plus, a second software protocol stack, to allow the network communication, must be added to the use of resources. What's the net result? The connection between the two processes becomes the slowest, most time-consuming part of any application.

Nowadays, not every application can be run on a computer attached to a high-speed network. Nor can any one machine handle all the end-user requests, so architecture has effectively stretched the bus of the good old mainframe on to the network, and created what is commonly called n-tier architecture. In n-tier architecture, client programs communicate with an application server, which in turn communicates with one or more servers. You might call this Client-Server Gone Wild, but don't hold your breath waiting for the video. Figure I-3 is a diagram that shows an example of n-tier architecture where a notebook computer, a cell phone, and a tablet all communicate with an application server in order to use the same application through different devices.

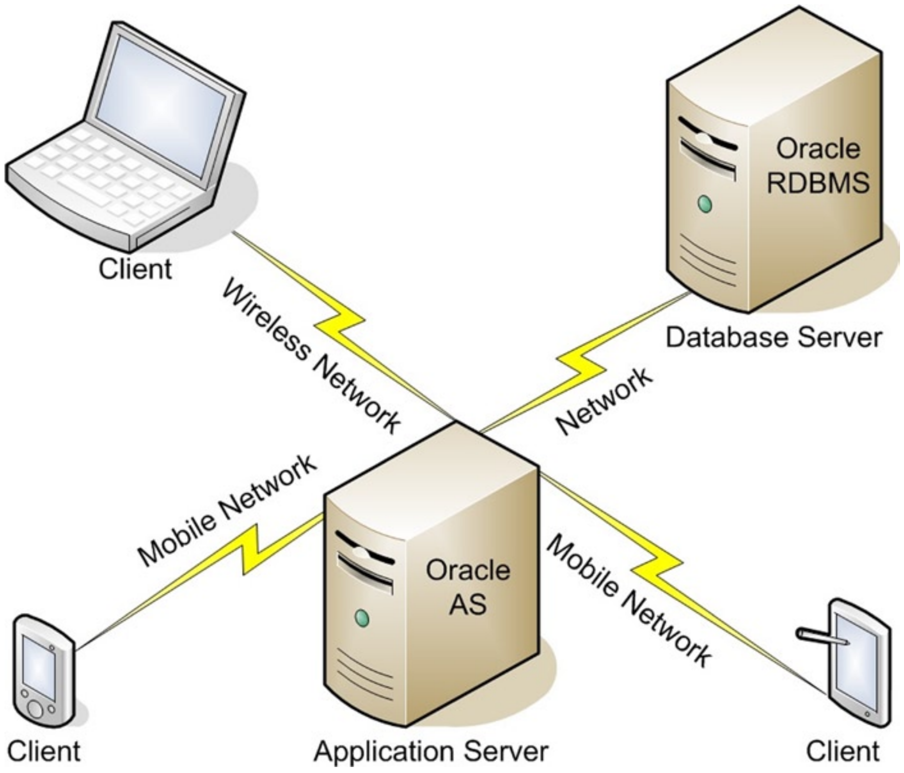


Figure I-3. *N-tier architecture over a network*

Now there are three different kinds of clients, with three different kinds of networks, using networked client-server architecture to communicate with an application server, which in turn uses networked client-server architecture to communicate with a database. Is this complex? Yes, but it's still just networked client-server architecture. Of course, this means that all the various networks involved conspire to slow down the response time of the application!

With the network being a bottleneck for any networked application, if we can perform some of our application's computer processing without using the network at all, that portion will simply run faster. With that in mind, examine Figure I-4. It's a diagram that shows how a stored procedure exists inside the database. Therefore, any computer processing that take place will occur inside the database before data is even sent to a client program, regardless of what type of client-server communication is used. In turn, that portion of the application will simply be more efficient and run faster.

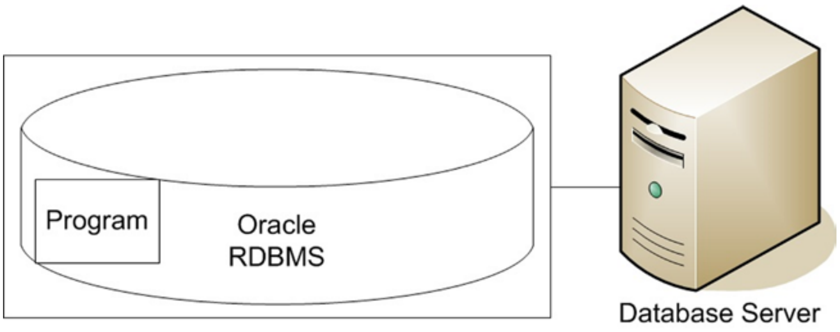


Figure I-4. *A stored procedure resides inside an Oracle database*

So what's a stored procedure? In Figure I-4, it's the box labeled "Program" that exists inside the database. So a stored procedure is a program that resides inside an Oracle database that manipulates data in the database before the data is used outside the database.

Why Use Stored Procedures?

Why use stored procedures? Well, I've already touched on that, haven't I? Here are my favorite reasons to use stored procedures:

They eliminate the net in work.

They allow you to more accurately model the real world in your database.

They provide you with access to functionality that is not available through the standard database interface: SQL.

First, as I already stated in the previous section, using stored procedures allows you to eliminate the network from your data processing work. I can't emphasize this fact enough. If you write a Java Database Connectivity (JDBC) program that retrieves one million rows from the database, then queries the database for three related pieces of information, and then conditionally updates the retrieved rows, it can take days in Java; it will take only minutes inside Oracle using PL/SQL. That's a huge difference in performance. I often like to say, "The difference between any fast and slow application is that the fast application uses stored procedures."

Second, we basically use computers to automate what we do in the real world. Most people use databases to store only the characteristics of the real world, completely ignoring the behavior. Instead, behavior is temporarily kept in the code base for an application. If a change in the code is required, past behavior is lost forever. Yet no one would think of throwing away the data! What's going on here? Is the history of behavior unimportant or are we ignorant of the problem? I argue it's the latter. If you want to save both real-world characteristics and behavior, stored procedures allow you to do just that in either a pseudo-object-oriented or a truly object-oriented manner.

Finally, the standard database interface, SQL, is great, but its use is limited to four operations: insert, update, delete, and select. With stored procedures, you have unlimited possibilities. You are free to create as many new operations as are needed to satisfy requirements. The important point here is to perform work where it is done most efficiently. Presentation code should reside in the presentation layer, application code should reside in the application layer (the application server), and persistence code, like entity behavior, should reside in the persistence layer (the database).

Using PL/SQL, you can write stored procedures for the following:

Data processing

Data migration

Data warehousing

Entity behavior, including so-called business rules

Interfaces

Reports

Service-oriented-architecture routines

Now that you know the what and the why of stored procedures, are you still interested in learning PL/SQL? If so, then please read the next section, where I will tell you what this book is about, how I'm going to teach you PL/SQL, and why.

What's This Book About?

This book is not a reference. It's an immersion-based tutorial that teaches you how to program in PL/SQL by making you mimic successful PL/SQL programming.

Do you know that you have free access to outstanding reference materials directly from Oracle? If you download and install the database on your computer, these reference manuals will be accessible from the installation. Or you can download just the manuals to your computer. Oracle has always had superior technical documentation. I believe that has played a huge part in Oracle's success as a company and a product. Free access to Oracle's documentation and software for trial purposes has removed any barriers from anyone learning how to use Oracle.

How I'm Going to Teach You and Why

What do I mean by "an immersion-based tutorial?" I'm going to require you to read each and every program listing as part of the learning process. I'm going to start showing you program listings right away. Most listings will be complete contexts. By that, I mean there will be a lot of code in them that I have not yet discussed. I do this because I want you to get used to looking at the code and where things belong in the code from the get-go. Concentrate on the subject of the section and ignore the rest.

Whenever possible, I'm going to ask you to do an exercise that will make you think about and apply what I've just covered in the section. You should almost always be able to mimic (or copy and change) code that I've shown you before the exercise. I'm going to ask you to program all along. And the next section will often be dependent on you completing a prior exercise, so there's no skipping an exercise.

Why am I making you look at code, then read code, then try to understand my code, and then ask you to prove you understand my code by having you write code? For several reasons:

- You didn't learn how to speak by having those around you discuss the merits and drawbacks of various languages you might want to speak. You learned by mimicking those who spoke.
- You didn't learn how to read by talking about reading. You learned by reading.

- You don't learn a new language by reading about it. You need to speak it and then write it.
- You don't learn a new concept by reading about it. You must do your homework, where you actually use it.

So, how can you read a reference and be ready to solve business problems using a programming language? You can't. In the beginning, you must learn by mimicking someone else's work (hopefully, good examples)—something that someone has done before you. Then later, using your own creativity, you expand upon your basic knowledge with a reference.

But there's more to learning PL/SQL than just coding. I'm going to teach you good programming habits, such as these:

Document as you go.

Leave bread crumbs.

Keep it simple for the next person's sake.

Make it obvious by using prefixes or suffixes when it helps.

Make it obvious by using a coding style and sticking to it; consistency is important.

Make it obvious by adding comments to your code when it's not obvious.

Prepare for disaster ahead of time.

Prepare for testing ahead of time.

And finally, here are my assumptions:

You've programmed in another programming language, so you already know the difference between a function and a procedure.

You already know SQL.

I'm going to get you started down the right path, not tell you everything about PL/SQL. Your time is precious, so I'm not going to tell you anything that you don't need to know to get started (except for an occasional joke, or perhaps, my poor attempt at one). You may find my style terse. To me, that's a compliment.

This is not Oracle PL/SQL for Dummies. Remember that the examples are shown in a full-blown context. Pay attention to the subject; ignore the rest. You can do it!

What PL/SQL Am I Going to Teach You?

What am I going to teach you? Succinctly, how to get you, a programmer, from a novice to professional PL/SQL programmer in ten chapters." I've spent 25 years hiring programmers and then teaching them how to code properly, the past 15 years focusing on how to code in PL/SQL. In this book, I will apply the 80/20 rule in order to teach you the fundamentals of PL/SQL programming without bogging you down in the ever-so-increasing details.

As a scientist, I gather data about what I do all the time, so I have statistics about all the stored procedures that I and others have written since Oracle 7 became a production product. From these statistics, I've learned what's used often and not at all. In this book, I intend to touch on anything that is used 25% or more of the time when writing stored procedures.

Here, I'd like to share some interesting fun facts derived from over 30,000 stored procedures.

PL/SQL Pie, Anyone?

Figure I-5 shows that on average, only 31% of a stored procedure is actually logic. The rest is declaration, built-ins, and SQL. SQL makes up a whopping 26%. So if you don't know SQL, you're already behind the eight ball when you start to learn how to write stored procedures using PL/SQL.

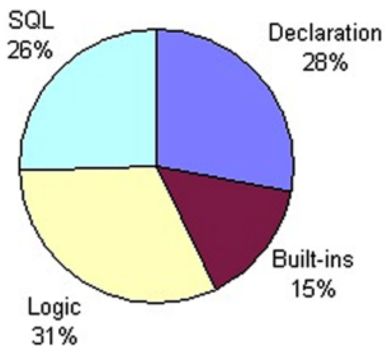


Figure I-5. *What is a PL/SQL stored procedure composed of?*

SQL, SQL, SQL!

The pretty little histogram in Figure I-6 shows the SQL keywords that are used in 25% or more of all stored procedures. So I need to start out with a SQL refresher for those of you who say you know SQL, but don't actually have much SQL experience. After all, I want you to buy this book and then go back and buy *Beginning Oracle SQL*, right?

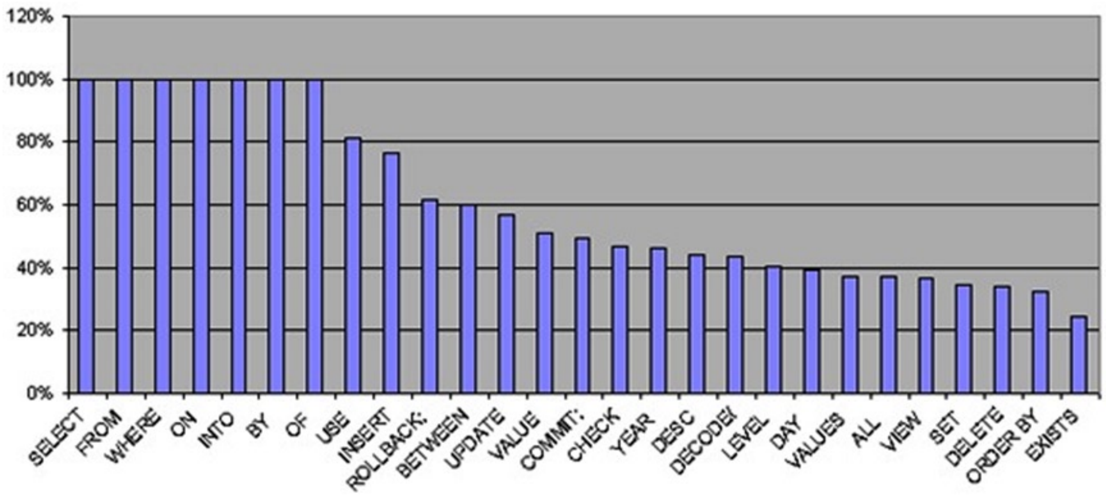


Figure I-6. *SQL keywords used in 25% or more of all stored procedures*

What About Those Declarations?

Figure I-7 shows the PL/SQL declaration keywords that are used in 25% or more of all stored procedures. Why teach any more than these to a beginner?

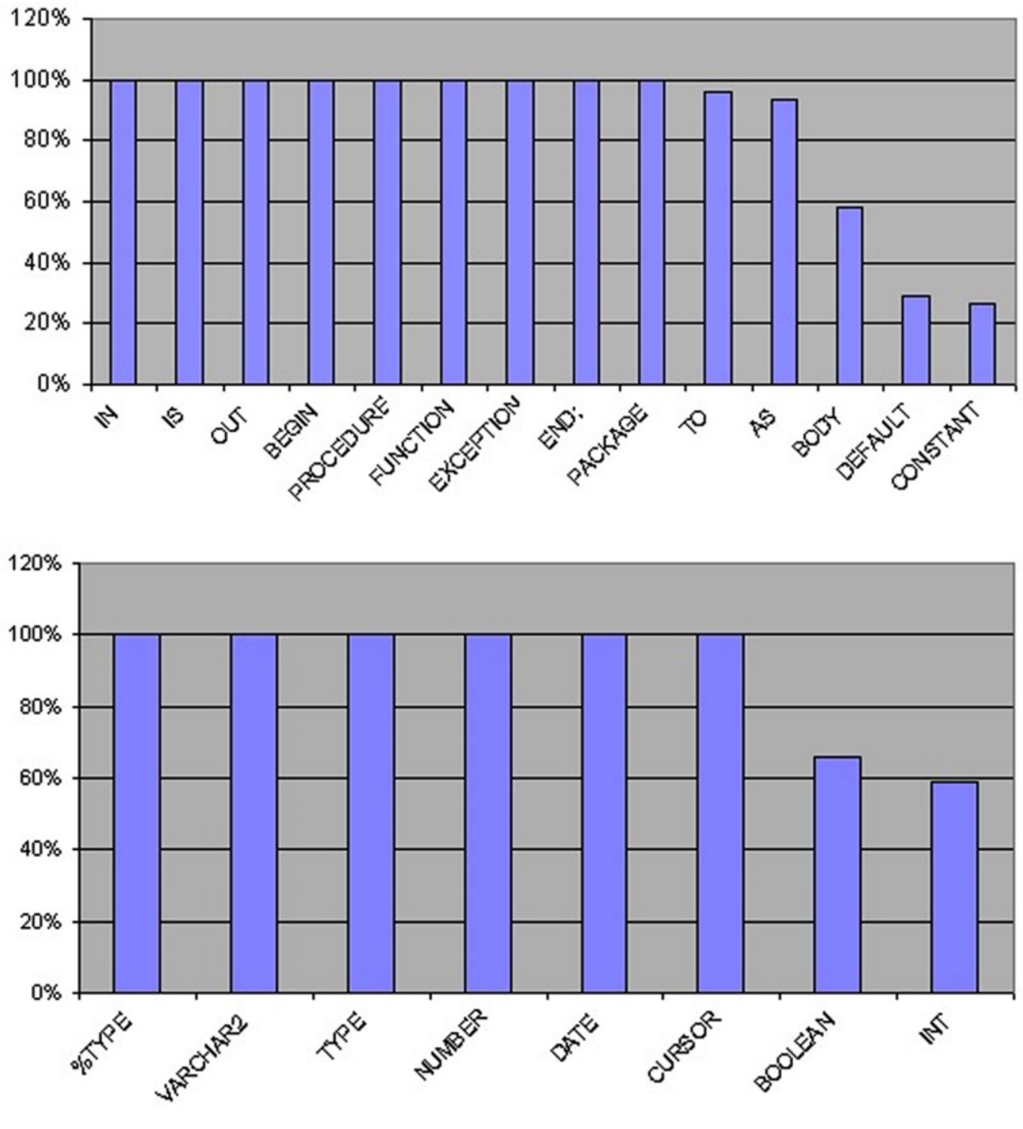


Figure I-7. *PL/SQL declaration keywords that are used in 25% or more of all stored procedures*

And How About Those Built-ins?

Figure I-8 shows the PL/SQL built-ins (functions and procedures that are part of the language) that are used in 25% or more of all stored procedures. Why teach any more than these to a beginner?

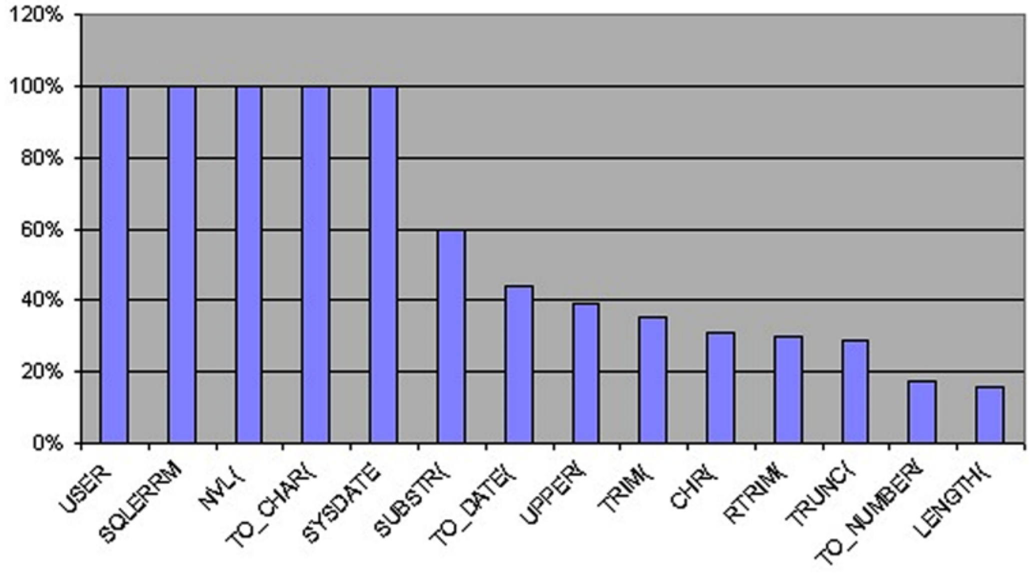


Figure I-8. *PL/SQL built-ins that are used in 25% or more of all stored procedures*

What Exactly Am I Supposed to Be Doing?

And last, but certainly not least, the histogram in Figure I-9 shows the PL/SQL keywords that are used in 25% or more of all stored procedures. The list isn't that large, so introducing these as we go will ease you right into coding logic.

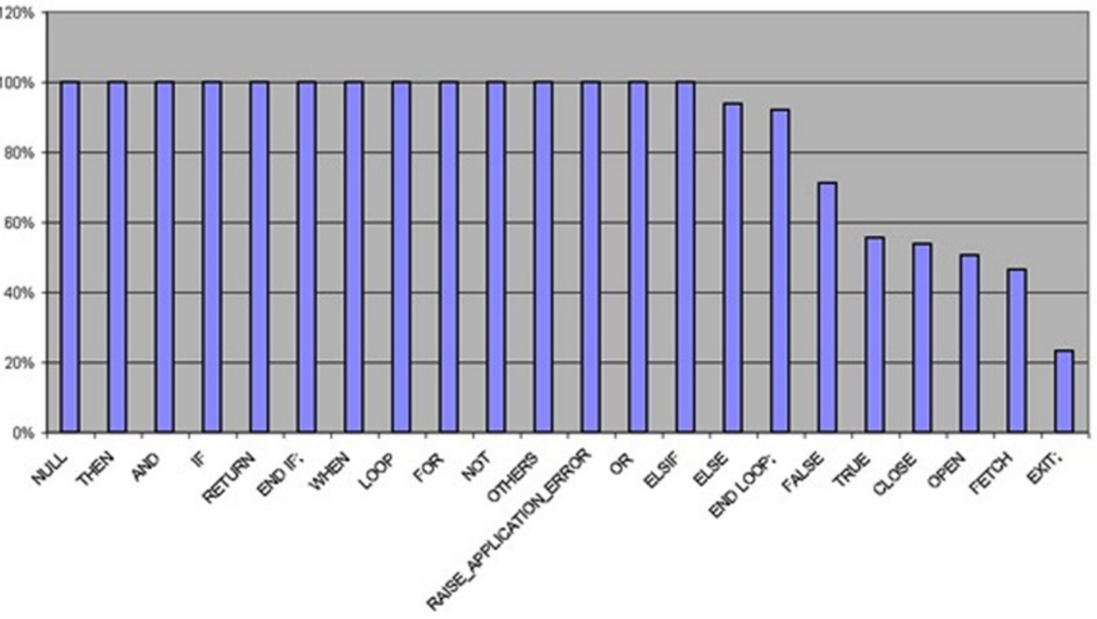


Figure I-9. *PL/SQL logic keywords that are used in 25% or more of all stored procedures*

In What Order Am I Going to Teach You PL/SQL?

First, I'm going to help you review your knowledge of SQL. If you don't understand something in Chapter 1, go buy the Apress book on SQL, as I mentioned earlier, then continue.

Next, I'm going to teach you the basic structure of every PL/SQL program unit type. I'll show you each program unit type. Concentrate on understanding PL/SQL block structure, and you'll be OK. Try to understand all the stuff I show you and don't discuss, and you'll be totally lost. Remember to focus on the subject being discussed. If you were mining for gold, you wouldn't stop and examine every grain of dirt, rock, and sand you encountered along the way; you would concentrate on the gold. So concentrate on the gold!

Assuming you understand block structure, the next chapter discusses the use of memory. Basically, it covers data types and variable declarations. You're a programmer, so there should be nothing really mind-boggling and new for you in this chapter, except maybe `NULL`.

The next topic is the singleton SQL statement. Whether it's a select, an insert, an update, or a delete, a singleton should always return one result. So what happens when it doesn't? Read Chapter 4 to find out!

From singletons to multitons? Something isn't right here. Anyway, Chapter 5 will cover the use of cursors. Cursors allow you to retrieve multiple rows from a database, one row at a time. At this point, you'll have coded a couple stored procedures.

In Chapter 6, you're going to learn to model an entity just as it exists in the real world. You'll be introduced to object-relational technology. And then you can decide which way to go: relational or object-relational.

Chapter 7 is about troubleshooting. It's always nice to know how to find an insect in your program. I'll also show you how to prevent insects in the first place. Oh yeah, did I tell you that I like to call defects defects, not bugs?

Professional programmers create programs with few defects. How do they do that? By testing. Chapter 8 is about automating the testing of your PL/SQL program units. Low error rates mean higher paychecks, too. So don't skip Chapter 8.

Concerning object-oriented development, it allows you to build reusable components, but reusable components are only valuable if you provide others with documentation, so they know the components exist and how they can use them! Professional programmers document as they go! That's what Chapter 9 is all about.

And finally, I'll tell you how use polymorphism to create reusable packages. I'll show you the polymorphic patterns I used for years to more quickly solve previously encountered business problems.

OK, I was lying about that "finally." The book's appendix explains how to acquire and install Oracle RDBMS, and how to use SQL*Plus for PL/SQL programming, in case you really don't have any experience with SQL before you start with PL/SQL (I knew it).

If you have access to an Oracle database where you can create objects like tables, indexes, types, and stored procedures, then you're ready to dive right in to Chapter 1. Otherwise, you may want to flip to the appendix, which tells you how to download and install a trial version of Oracle.

Good skill!

CHAPTER 1

Relational SQL

The question is, “Where do I start?” In the beginning, Codd created the paper “A Relational Model of Data for Large Shared Data Banks.” Now the relational database was formless and empty, darkness was over the surface of the media, and the spirit of Codd was hovering over the requirements. Codd said, “Let there be Alpha,” but as usual, the development team said, “Let there be something else,” so SEQUEL (SQL) was created. Codd saw that SQL wasn’t what he had in mind, but it was too late, for the Ellison separated the darkness from the SQL and called it Oracle. OK, that’s enough of that silliness. But that’s the short of it.

Did you know that about 25% of the average stored procedures written in the Procedural Language for SQL (PL/SQL) is, in fact, just SQL? Well, I’m a metrics junkie. I’ve kept statistics on every program I’ve ever written, and that’s the statistic. After writing more than 30,000 stored procedures, 26% of my PL/SQL is nothing but SQL. So it’s really important for you to know SQL!

OK, maybe you don’t know SQL that well after all. If not, continue reading this light-speed refresher on relational SQL. Otherwise, move on to the exercises in the last section of the chapter (“Your Working Example”).

This chapter covers Data Definition Language (DDL) and Data Manipulation Language (DML), from table creation to queries. Please keep in mind that this chapter is not a tutorial on SQL. It’s simply a review. SQL is a large topic that can be covered fully only with several books. What I’m trying to accomplish here is to help you determine how familiar you are with SQL, so you’ll be able to decide whether you need to spend some additional time learning SQL after or while you learn PL/SQL.

Tables

The core idea behind a relational database and SQL is so simple it’s elusive. Take a look at Tables 1-1 and 1-2.

Table 1-1. *Relational Database Geniuses (Authors)*

ID	Name	Born	Gender
100	Edgar F Codd	1923	Male
200	Chris J Date	1941	Male
300	Hugh Darwen	1943	Male

Table 1-2. *Relational Genius's Publications (Author Publications)*

ID	Author ID	Title	Written
10	100	A Relational Model of Data for Large Shared Data Banks	1970
20	100	The Relational Model for Database Management	1990
30	200	An Introduction to Database Systems	2003
40	200	The Third Manifesto	2000
50	200	Temporal Data and the Relational Model	2002
60	200	Database in Depth: Relational Theory for Practitioners	2005
70	300	The Third Manifesto	2000
80	300	Temporal Data and the Relational Model	2002

You can find which publications were written by each genius simply by using the common datum in both of these tables: the ID. If you look at Codd's data in Table 1-1, you see he has ID 100. Next, if you look at ID 100's (Codd's) data in Table 1-2, you see he has written two titles:

- A Relational Model of Data for Large Shared Data Banks (1970)
- The Relational Model for Database Management (1990)

These two tables have a relationship, because they share an ID column with the same values. They don't have many entries, so figuring out what was written by each author is pretty easy. But what would you do if there were, say, one million authors with about three publications each? Yes! It's time for a computer and a database—*a relational database*.

A relational database allows you to store multiple tables, like Tables 1-1 and 1-2, in a database management system (DBMS). By doing so, you can manipulate the data in the tables using a query language on a computer, instead of a pencil on a sheet of paper. The current query language of choice is Structured Query Language (SQL). SQL is a set of nonprocedural commands, or language if you will, which you can use to manipulate the data in tables in a relational database management system (RDBMS).

A table in a relational database is a logical definition for how data is to be organized when it is stored. For example, in Table 1-3, I decided to order the columns of the database genius data just as it appeared horizontally in Table 1-1.

Table 1-3. *A Table Definition for Table 1-1*

Column Number	Column Name	Data Type
1	ID	Number
2	Name	Character
3	Birth Date	Date
4	Gender	Character

Perhaps I could give the relational table defined in Table 1-3 the name `geniuses`? In practice, a name like that tends to be too specific. It's better to find a more general name, like `authors` or `persons`. So how do you document your database design decisions?

An Entity-Relationship Diagram

Just as home builders have an architectural diagram or blueprint, which enables them to communicate clearly and objectively about what they are going to build, so do relational database builders. In our case, the architectural diagram is called an entity-relationship diagram (ERD).

Figure 1-1 is an ERD for the tables shown in Tables 1-1 and 1-2, now named `authors` and `author_publications`. It shows that one author may have zero or more publications. Additionally, it shows that an author's ID is his primary key (PK), or unique way to identify him, and an author's primary key is also used to identify his publications.

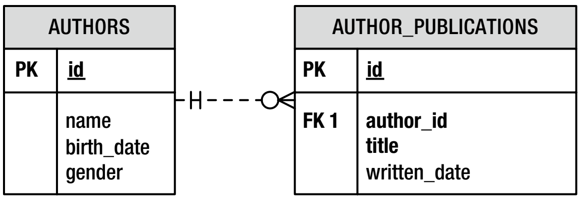


Figure 1-1. *An entity-relationship diagram for the authors and author publications tables*

ERDs, like blueprints, may have varying levels of detail, depending on your audience. For example, to simplify the ERD in Figure 1-1, I've left out the data types.

In an ERD, the tables are called *entities*. The lines that connect the tables—I mean entities—are called *relations*. So given an ERD, or even a narrative documentation as in Table 1-3, you can write a script to create a table.

Data Definition Language (DDL)

To create the `authors` table, as defined in Table 1-3, in Oracle, you'll need to create a SQL script (for SQL*Plus) that in SQL jargon is called Data Definition Language. That is, it's SQL for defining the relational database. Listing 1-1 shows the `authors` table's DDL.

Listing 1-1. DDL for Creating the Author Table, authors.tab

```
CREATE TABLE authors (
id                          number(38),
name                        varchar2(100),
birth_date                  date,
gender                      varchar2(30) );
```

The syntax for the `CREATE TABLE` statement used in Listing 1-1 is as follows:

```
CREATE TABLE <table_name> (
<column_name_1>   <data_type_1>,
<column_name_2>   <data_type_2>,
<column_name_N>   <data_type_N> );
```

where `<table_name>` is the name of the table, `<column_name>` is the name of a column, and `<data_type>` is one of the Oracle data types.

The following are the Oracle data types you'll use most often:

- `VARCHAR2`: Allows you to store up to 32,767 bytes (4,000 in versions prior to 12c) , data like *ABCD...*, in a column. You must define the maximum number of characters (or constrain the number of characters) by specifying the desired number in parentheses after the keyword `VARCHAR2`. For example, in Listing 1-1, line 3 specifies `varchar2(100)`, which means a name can be up to 100 characters in length.
- `NUMBER`: Allows you to store a decimal number with 38 digits of precision. You do not need to constrain the size of a number, but you can. You can specify the maximum number of digits (1, 2, 3, 4 . . .) to the left of a decimal point, followed by a comma (`,`), and optionally the maximum number of decimal digits to the right of the decimal point, by specifying the desired constraint in parentheses after the keyword `NUMBER`. For example, if you want to make sure that the `id` column in Listing 1-1, line 2 is an integer, you could specify `number(38)`.
- `DATE`: Allows you to store a date and time value. One great thing about Oracle `DATE` types is that they allow you to easily perform time calculations between dates; just subtract an earlier date from a later date. In addition, it's also easy to convert between `VARCHAR2` and `DATE` values. For example, if you want to store the date and time of birth for someone born on January 1, 1980 at 8 a.m., you could use the Oracle `to_date()` function to convert a `VARCHAR2` value in a proper format into a `DATE` data type as follows: `to_date('19800101080000', 'YYYYMMDDHH24MISS')`.

Of course, there are other Oracle data types, but you'll end up using `VARCHAR2`, `NUMBER`, and `DATE` most of the time. The rest are specialized versions of these three, or they are designed for specialized uses.

It's Your Turn to Create a Table

OK, it's time to stop reading and start doing. This section gives you chance to put into practice some of what you've learned so far. I'll be asking you to perform exercises like this as we go along in order for you to verify that you understood what you just read well enough to put it into practice.

■ **Tip** First, if you don't have access to Oracle, see this book's appendix. Second, create a directory for the book's source code listings. Next, download the source code listings from the Source Code/Download section of the Apress web site (`www.apress.com`), and work within the book's source code listing directory structure for each chapter. Add your source code listings to the book's directory structure as you work. Last, create a shortcut, an icon, or whatever you want to call it, to start SQL*Plus from your working source code listing directory. Then you won't need to specify the entire path when trying to execute your scripts in SQL*Plus.

To create the `author_publications` table, follow these steps.

1. Start your Oracle database if it's not already running.
2. Start SQL*Plus, logging in as username RPS with password RPS.
3. Open your favorite text editor.
4. Write a DDL script to create a table for `author_publications`, as in Table 1-2.

5. Save the DDL script with the same filename as your table name, but with a `.tab` extension.

6. Execute your script in SQL*Plus by typing an at sign (`@`) followed by the filename at the `SQL>` prompt.

If you didn't have any errors in your script, the table will now exist in the database, just waiting for you to populate it with data. If it didn't work, try to make some sense out of the error message(s) you got, correct your script, and then try again.

Listing 1-2 is my try.

Listing 1-2. DDL for Creating the Publication Table, author_publications.tab

```
CREATE TABLE author_publications (
id                             number(38),
title                          varchar2(100),
written_date                   date );
```

Now you know how to create a table, but what if you put a lot of data in those two tables? Then accessing them will be very slow, because none of the columns in the tables are indexed.

Indexes

Imagine, if you will, that a new phone book shows up on your doorstep. You put it in the drawer and throw out the old one. You pull the phone book out on Saturday evening so you can order some pizza, but when you open it, you get confused. Why? Well, when they printed the last set of phone books, including yours, they forgot to sort it by last name, first name, and street address. Instead, it's not sorted at all! The numbers show up the way they were put into the directory over the years—a complete mess.

You want that pizza! So you start at the beginning of the phone book, reading every last name, first name, and address until you finally find your local pizza place. Too bad it was closed by the time you found the phone number! If only that phone book had been sorted, or properly indexed.

Without an index to search on, you had to read through the entire phone book to make sure you got the right pizza place phone number. Well, the same holds true for the tables you create in a relational database.

You need to carefully analyze how data will be queried from each table, and then create an appropriate set of indexes. You don't want to index everything, because that would unnecessarily slow down the process of inserting, updating, and deleting data. That's why I said "carefully."

DDL Again

You should (*must*, in my opinion) create a unique index on each table's primary key column(s)—you know, the one that uniquely identifies entries in the table. In the `authors` table, that column is `id`. However, you will create a unique index on the `id` column when we talk about constraints in the next section. Instead, let's create a unique index on the `name`, `birth_date`, and `gender` columns of the `authors` table. Listing 1-3 shows the example.

Listing 1-3. DDL for Creating an Index on the Author Table, authors_uk1.ndx.

```
CREATE UNIQUE INDEX authors_uk1
on                  authors (
name,
birth_date,
gender );
```

The syntax for the `CREATE INDEX` statement is as follows:

```
CREATE [UNIQUE] INDEX <index_name>
on                    <table_name> (
<column_name_1>,
<column_name_2>,
<column_name_N> );
```

where `<index_name>` is the name of the index, `<table_name>` is the name of the table, and `<column_name>` is the name of a column. The keyword `UNIQUE` is optional, as denoted by the brackets (`[ ]`) around it. It just means that the database must check to make sure that the column's combination of the values is unique within the table. Unique indexes are old-fashioned; now it's more common to see a unique constraint, which I'll discuss shortly.

It's Your Turn to Create an Index

OK, it's time to stop listening to me talk about indexes, and time for you to start creating one. Here's the drill.

1. Write a DDL script to create a non-unique index on the `author_publications` table.
2. Save the DDL script with the same file name as your index name, but with an `.ndx` extension.
3. Execute your script in SQL*Plus by typing an at sign (`@`) followed by the file name at the `SQL>` prompt.

You should now have a non-unique index in the database, just waiting for you to query against it. If not, try to make some sense out of the error message(s) you got, correct your script, and then try again.

My shot at this is shown in Listing 1-4.

Listing 1-4. DDL for Creating an Index on the Title Column in the Publication Table, author_publications_k1.ndx

```
CREATE INDEX author_publications_k1
on           author_publications (
title );
```

Now you know how to create a table and an index or two, to make accessing it efficient, but what prevents someone from entering bad data? Well, that's what constrains are for.

Constraints

Constraints are rules for a table and its columns that constrain how and what data can be inserted, updated, or deleted. Constraints are available for both columns and tables.

Column Constraints

Columns may have rules that define what list of values or what kind of values may be entered into them. Although there are several types of column constraints, the one you will undoubtedly use most often is `NOT NULL`. The `NOT NULL` constraint simply means that a column must have a value. It can't be unknown, or blank, or in SQL jargon, `NULL`. Listing 1-5 shows the `authors` table script updated with `NOT NULL` constraints on the `id` and `name` columns.

Listing 1-5. DDL for Creating the Authors Table with NOT NULL Column Constraints, authors.tab

```
CREATE TABLE authors (
id                              number(38)                      not null,
name                            varchar2(100)                   not null,
birth_date                      date,
gender                          varchar2(30) );
```

Now if you try to insert data into the `authors` table, but don't supply values for the `id` or `name` column, the database will respond with an error message.

Table Constraints

Tables may have rules that enforce uniqueness of column values and the validity of relationships to other rows in other tables. Once again, although there are many forms of table constraints, I'll discuss only three here: unique key, primary key, and foreign key.

Unique Key Constraint

A unique key constraint (UKC) is a rule against one or more columns of a table that requires their combination of values to be unique for a row within the table. Columns in a unique index or unique constraint may be `NULL`, but that is not true for columns in a primary key constraint.

As an example, if I were going to create a unique key constraint against the `authors` table columns `name`, `birth_date`, and `gender`, the DDL to do that would look something like Listing 1-6.

Listing 1-6. DDL for Creating a Unique Constraint Against the Author Table, authors_uk1.ukc

```
ALTER TABLE authors ADD
CONSTRAINT  authors_uk1
UNIQUE (
name,
birth_date,
gender );
```

Primary Key Constraint

A primary key constraint (PKC) is a rule against one or more columns of a table that requires their combination of values to be unique for a row within the table. Although similar to a unique key, one big difference is that the unique key called the primary key is acknowledged to be the primary key, or primary index, of the table, and may not have NULL values. Semantics, right? No, not really, as you'll see when I talk about foreign keys in the next section.

You should have a primary key constraint defined for every table in your database. I say "should," because it isn't mandatory, but it's a really good idea. Listing 1-7 shows the DDL to create a primary key constraint against the `authors` table.

Listing 1-7. DDL to Create a Primary Key Constraint Against the Authors Table, authors_pk.pkc

```
ALTER TABLE authors ADD
CONSTRAINT  authors_pk
primary key (
id );
```

The syntax used in Listing 1-7 for creating a primary key constraint is as follows:

```
ALTER TABLE <table_name> ADD
CONSTRAINT  <constraint_name>
PRIMARY KEY (
<column_name_1>,
<column_name_2>,...
<column_name_N> );
```

where `<table_name>` is the name of the table, `<constraint_name>` is the name of the primary key constraint, and `<column_name>` is a column to use in the constraint.

Now that you have a primary key defined on the `authors` table, you can point to it from the `author_publications` table.

Foreign Key Constraint

A foreign key is one or more columns from another table that point to, or are connected to, the primary key of the first table. Since primary keys are defined using primary key constraints, it follows that foreign keys are defined with foreign key constraints (FKC). However, a foreign key constraint is defined against a dependent, or child, table.

So what's a dependent or child table? Well, in this example, you know that the `author_publications` table is dependent on, or points to, the `authors` table. So you need to define a foreign key constraint against the `author_publications` table, not the `authors` table. The foreign key constraint is represented by the relation (line with crow's feet) in the ERD in Figure 1-1.

Listing 1-8 shows the DDL to create a foreign key constraint against the `author_publications` table that defines its relationship with the `authors` table in the database.

Listing 1-8. DDL for Creating a Foreign Key Constraint Against the Author Publications Table, author_publications_fk1.fkc

```
ALTER TABLE author_publications ADD
CONSTRAINT  author_publications_fk1
FOREIGN KEY (author_id)
REFERENCES  authors (id);
```

The syntax used in Listing 1-8 for creating a foreign key constraint is as follows:

```
ALTER TABLE <table_name> ADD
CONSTRAINT  <constraint_name>
FOREIGN KEY (
<column_name_1>,
<column_name_2>,...
<column_name_N> )
REFERENCES <referenced_table_name> (
<column_name_1>,
<column_name_2>,...
<column_name_N> );
```

where `<table_name>` is the name of the table to be constrained, `<constraint_name>` is the name of the foreign key constraint, `<referenced_table_name>` is the name of the table to be referenced (or pointed to), and `<column_name>` is a column that is both part of the referenced table's key and corresponds to a column with the same value in the child or dependent table.

Now that you have a foreign key defined on the `author_publications` table, you can no longer delete a referenced row in the `authors` table. Or, put another way, you can't have any parentless children in the `author_publications` table. That's why the primary and foreign key constraints in SQL jargon are called *referential integrity constraints*. They ensure the integrity of the relational references between rows in related tables. In addition, it is a best practice to always create an index on a foreign key column or columns.

It's Your Turn to Create a Constraint

It's time to put you to work creating a primary key constraint against the `author_publications` table.

1. Write a DDL script to create a primary key constraint against the `author_publications` table.
2. Save the DDL script with the same file name as your constraint name, but with a `.pkc` extension.
3. Execute your script in SQL*Plus by typing an at sign (`@`) followed by the file name at the `SQL>` prompt.

The primary key constraint should now exist against the `author_publications` table in the database, just waiting for you to slip up and try putting in a duplicate row. Otherwise, try to make some sense out of the error message(s) you got, correct your script, and then try again.

My version of a DDL script to create a primary key constraint against the `author_publications` table is shown in Listing 1-9.

Listing 1-9. DDL for Creating a Primary Key Constraint Against the Author Publications Table, author_publications_pk.pkc

```
ALTER TABLE author_publications ADD
CONSTRAINT  author_publications_pk
PRIMARY KEY (
id);
```

Now you know how to create a table along with any required indexes and constraints, but what do you do if you need a really complex constraint? Or, what if you need other actions to be triggered when a row or column in a table is inserted, updated, or deleted? Well, that's the purpose of triggers.

Triggers

Triggers are PL/SQL programs that are set up to execute in response to a particular event on a table in the database. The events in question can take place `FOR EACH ROW` or for a SQL statement, so I call them row-level or statement-level triggers.

The actual events associated with triggers can take place `BEFORE`, `AFTER`, or `INSTEAD OF` an `INSERT`, an `UPDATE`, or a `DELETE` SQL statement. Accordingly, you can create triggers for any of the events in Table 1-4.

Table 1-4. *Possible Trigger Events Against a Table*

Event	SQL	Level
BEFORE	DELETE	FOR EACH ROW
BEFORE	DELETE	
BEFORE	INSERT	FOR EACH ROW
BEFORE	INSERT	
BEFORE	UPDATE	FOR EACH ROW
BEFORE	UPDATE	
AFTER	DELETE	FOR EACH ROW
AFTER	DELETE	
AFTER	INSERT	FOR EACH ROW
AFTER	INSERT	
AFTER	UPDATE	FOR EACH ROW
AFTER	UPDATE	
INSTEAD OF	DELETE	FOR EACH ROW
INSTEAD OF	DELETE	
INSTEAD OF	INSERT	FOR EACH ROW
INSTEAD OF	INSERT	
INSTEAD OF	UPDATE	FOR EACH ROW
INSTEAD OF	UPDATE	

So let's say we want to play a practical joke. Are you with me here? We don't want anyone to ever be able to add the name Jonathan Gennick (my editor, who is actually a genius in his own right, but it's fun to mess with him) to the list of database geniuses. Listing 1-10 shows a trigger created to prevent such an erroneous thing from happening.

Listing 1-10. A Trigger Against the Authors Table, authors_bir.trg

```
CREATE OR REPLACE TRIGGER authors_bir
BEFORE INSERT ON          authors
FOR EACH ROW

BEGIN
  if upper(:new.name) = 'JONATHAN GENNICK' then
    raise_application_error(20000, 'Sorry, that genius is not allowed.');
  end if;
END;
/
```

The syntax used in Listing 1-10 is as follows:

```
CREATE [OR REPLACE] TRIGGER <trigger_name>
BEFORE INSERT ON            <table_name>
FOR EACH ROW
BEGIN
  <pl/sql>
END;
```

where `<trigger_name>` is the name of the trigger, `<table_name>` is the name of the table for which you're creating the trigger, and `<pl/sql>` is the PL/SQL program you've written to be executed `BEFORE` someone `INSERT`s `EACH ROW`. The brackets (`[ ]`) around the `OR REPLACE` keyword denote that it is optional. The `OR REPLACE` clause will allow you to re-create your trigger if it already exists.

Views

A view represents the definition of a SQL query (`SELECT` statement) as though it were just another table in the database. Hence, you can `INSERT` into and `UPDATE`, `DELETE`, and `SELECT` from a view just as you can any table. (There are some restrictions on updating a view, but they can be resolved by the use of `INSTEAD OF` triggers.)

Here are just a few of the uses of views:

- Transform the data from multiple tables into what appears to be one table.
- Nest multiple outer joins against different tables, which is not possible in a single `SELECT` statement.
- Implement a seamless layer of user-defined security against tables and columns.

Let's say you want to create a view that combines the `authors` and `author_publications` tables so it's easier for a novice SQL*Plus user to write a report about the publications written by each author. Listing 1-11 shows the DDL to create a view that contains the required SQL `SELECT` statement.

Listing 1-11. DDL to Create an Authors Publications View, authors_publications.vw

```
CREATE OR REPLACE VIEW authors_publications as
SELECT authors.id,
       authors.name,
       author_publications.title,
       author_publications.written_date
FROM   authors,
       author_publications
WHERE  authors.id = author_publications.author_id;
```

The syntax for the `CREATE VIEW` statement used in Listing 1-11 is as follows:

```
CREATE [OR REPLACE] VIEW <view_name> AS
<sql_select_statement>;
```

where `<view_name>` is the name of the view (the name that will be used in other SQL statements as though it's a table name), and `<sql_select_statement>` is a SQL `SELECT` statement against one or more tables in the database. Once again, the brackets around the `OR REPLACE` clause denote that it is optional. Using `OR REPLACE` also preserves any privileges (grants) that exist on a view.

That does it for your DDL review. Now let's move on to the SQL for manipulating data—SQL keywords like `INSERT`, `UPDATE`, `DELETE`, and `SELECT`.

Insert

At this point in your journey, you should have two tables—`authors` and `author_publications`—created in your Oracle database. Now it's time to put some data in them. You do that by using the SQL keyword `INSERT`.

`INSERT` is one of the SQL keywords that are part of SQL's Data Manipulation Language. As the term implies, DML allows you to manipulate data in your relational database. Let's start with the first form of an `INSERT` statement, `INSERT...VALUES`.

Insert . . .Values

First, let's add Codd's entry to the `authors` table. Listing 1-12 is a DML `INSERT` statement that uses a `VALUES` clause to do just that.

Listing 1-12. DML to Insert Codd's Entry into the Authors Table, authors_100.ins

```
INSERT INTO authors (
       id,
       name,
       birth_date,
       gender )
VALUES (
       100,
       'Edgar F Codd',
       to_date('19230823', 'YYYYMMDD'),
       'MALE' );
COMMIT;
```

The syntax for the `INSERT VALUES` statement used in Listing 1-12 is as follows:

```
INSERT INTO <table_name> (
       <column_name_1>,
       <column_name_2>, ...
       <column_name_N> )
VALUES (
       <column_value_1>,
       <column_value_2>,...
       <column_value_N> );
```

where `<table_name>` is the name of the table you wish to `INSERT VALUES INTO`, `<column_name>` is one of the columns from the table into which you wish to insert a value, and `<column_value>` is the value to place into the corresponding column. The `COMMIT` statement that follows the `INSERT VALUES` statement in Listing 1-12 simply commits your inserted values in the database.

So let's break down Listing 1-12 and look at what it does:

- Line 1 specifies the table to insert values into: `authors`.
- Lines 2 through 5 list the columns in which to insert data.
- Line 6 specifies the `VALUES` syntax.
- Lines 7 through 10 supply values to insert into corresponding columns in the list on lines 2 through 5.
- Line 11 commits the `INSERT` statement.

It's Your Turn to Insert with Values

Insert the entries for Codd's publications into the `author_publications` table. Here are the steps to follow.

1. If you haven't actually executed the scripts for the `authors` table yet, you need to do so now. The files are `authors.tab`, `authors_uk1.ndx`, `authors_pk.pkc`, and `authors_100.ins`. Execute them in that order.
2. Write a DML script to insert Codd's two publications from Table 1-2. (Hint: Use January 1 for the month and day of the written date, since you don't know those values.)
3. Save the DML script with the same file name as your table name, but with a `_100` suffix and an `.ins` extension.
4. Execute your script in SQL*Plus by typing an at sign (`@`) followed by the file name at the `SQL>` prompt.

The `author_publications` table should now have two rows in it—congratulations! If it didn't work, try to make some sense out of the error message(s) you got, correct your script, and then try again.

Listing 1-13 shows how I would insert the publications into the table.

Listing 1-13. DML for Inserting Codd's Publications, author_publications_100.ins

```
INSERT INTO author_publications (
       id,
       author_id,
       title,
       written_date )
VALUES (
       10,
       100,
       'A Relation Model of Data for Large Shared Data Banks',
       to_date('19700101', 'YYYYMMDD') );

INSERT INTO author_publications (
       id,
       author_id,
       title,
       written_date )
```

```
VALUES (
       20,
       100,
       'The Relational Model for Database Management',
       to_date('19900101', 'YYYYMMDD') );

COMMIT;

execute SYS.DBMS_STATS.gather_table_stats(USER, 'AUTHOR_PUBLICATIONS');
```

There's a second form of the INSERT statement that can be quite useful. Let's look at it next.

Insert . . . Select

The second form of an INSERT statement uses a SELECT statement instead of a list of column values. Although we haven't covered the SELECT statement yet, I think you're intuitive enough to follow along. Listing 1-14 inserts Chris Date's entry using the INSERT ... SELECT syntax.

Listing 1-14. DML to Insert Date's Entry into the Author Table, authors_200.ins

```
INSERT INTO authors (
       id,
       name,
       birth_date,
       gender )
SELECT 200,
       'Chris J Date',
       to_date('19410101', 'YYYYMMDD')
       'MALE'
FROM   dual;

COMMIT;
```

The syntax for the INSERT SELECT statement used in Listing 1-14 is as follows:

```
INSERT INTO <table_name> (
       <column_name_1>,
       <column_name_2>, ...
       <column_name_N> )
SELECT <column_value_1>,
       <column_value_2>,...
       <column_value_N>
FROM   <from_table_name> ...;
```

where <table_name> is the name of the table you wish to INSERT INTO, <column_name> is one of the columns from the table into which you wish to insert a value, <column_value> is the value to place into the corresponding column, and <from_table_name> is the table or tables from which to select the values. The COMMIT statement that follows the INSERT SELECT statement in Listing 1-14 simply commits your inserted values in the database.

Let's break down Listing 1-14:

- Line 1 specifies the table to insert values into: `authors`.
- Lines 2 through 5 list the columns in which to insert values.
- Line 6 specifies the `SELECT` syntax.
- Lines 6 through 9 supply values to insert into corresponding columns in the list on lines 2 through 5.
- Line 10 specifies the table or tables from which to select the values.
- Line 12 commits the `INSERT` statement.

So what's the big deal about this second `INSERT` syntax? First, it allows you to insert values into a table from other tables. Also, the SQL query to retrieve those values can be as complex as it needs to be. But its most handy use is to create conditional `INSERT` statements like the one in Listing 1-15.

Listing 1-15. Conditional INSERT … SELECT Statement, authors_300.ins

```
01  INSERT INTO authors (
02         id,
03         name,
04         birth_date,
05         gender )
06  SELECT 300,
07         'Hugh Darwen',
08         to_date('19430101', 'YYYYMMDD')09         'MALE'
10  FROM   dual d
11  WHERE not exists (
12    SELECT 1
13    FROM   authors x
14    WHERE  x.id = 300 );
15
16  COMMIT;
```

The subquery in Listing 1-15's SQL `SELECT` statement, in lines 11 through 14, first checks to see if the desired entry already exists in the database. If it does, Oracle does not attempt the `INSERT`; otherwise, it adds the row. You'll see in time, as your experience grows, that being able to do a conditional insert is very useful!

THE DUAL TABLE

Have you noticed that I'm using a table by the name of `dual` in the conditional `INSERT...SELECT` statement? `dual` is a table owned by the Oracle database (owner `SYS`) that has one column and one row. It is very handy, because anytime you select against this table, you get one, and only one, row back.

So if you want to evaluate the addition of 1 + 1, you can simply execute the following SQL `SELECT` statement:

```
SELECT 1 + 1 FROM dual;
```

Oracle will tell you the answer is 2. Not so handy? Say you want to quickly figure out how Oracle will evaluate your use of the built-in function `length()`? Perhaps you might try this:

```
SELECT length(NULL) FROM dual;
```

Oh! It returns `NULL`. You need a number, so you try again. This time, you try wrapping `length()` in the SQL function `nvl()` so you can substitute a zero for a `NULL` value:

```
SELECT nvl(length(NULL), 0) FROM DUAL;
```

Now it returns zero, even if you pass a `NULL` string to it. That's how you want it to work!

See how using `dual` to test how a SQL function might work can be handy? It allows you to hack away without any huge commitment in code.

It's Your Turn to Insert with Select

It's time to practice inserting data once again. This time, insert the publications for Date and Darwen, but use the conditional `INSERT SELECT` syntax with detection for Darwen's publications.

1. Add Darwen's entry to the `authors` table by executing the script `authors_200.ins`.
2. Write the DML scripts to insert the publications by Date and Darwen from Table 1-2.
3. Save each DML script with the same file name as your table name, but with a `_200` suffix for Date and a `_300` suffix for Darwen, and add an `.ins` extension to both files.
4. Execute your scripts in SQL*Plus by typing an at sign (`@`) followed by the file name at the `SQL>` prompt.

The `author_publications` table should now have eight rows. And, if you run the Darwen script again, you won't get any duplicate-value errors, because the SQL detects whether Darwen's entries already exist in the database.

Listings 1-16 and 1-17 show my solutions.

Listing 1-16. DML for Inserting Date's Publications, author_publications_200.ins

```
INSERT INTO author_publications (
       id,
       author_id,
       title,
       written_date )
VALUES (
       30,
       200,
       'An introduction to Database Systems',
       to_date('20030101', 'YYYYMMDD') );

```

```
INSERT INTO author_publications (
       id,
       author_id,
       title,
       written_date )
VALUES (
       40,
       200,
       'The Third Manifesto',
       to_date('20000101', 'YYYYMMDD') );

INSERT INTO author_publications (
       id,
       author_id,
       title,
       written_date )
VALUES (
       50,
       200,
       'Temporal Data and the Relational Model',
       to_date('20020101', 'YYYYMMDD') );

INSERT INTO author_publications (
       id,
       author_id,
       title,
       written_date )
VALUES (
       60,
       200,
       'Database in Depth: Relational Theory for Practitioners',
       to_date('20050101', 'YYYYMMDD') );

COMMIT;

execute SYS.DBMS_STATS.gather_table_stats(USER, 'AUTHOR_PUBLICATIONS');
```

Listing 1-17. DML for Inserting Darwen's Publications, author_publications_300.ins

```
INSERT INTO author_publications (
       id,
       author_id,
       title,
       written_date )
SELECT 70,
       300,
       'The Third Manifesto',
       to_date('20000101', 'YYYYMMDD')
```

```
FROM   dual
where not exists (
  SELECT 1
  FROM   author_publications x
  WHERE  x.author_id = '300'
  AND    x.title     = 'The Third Manifesto' );

INSERT INTO author_publications (
       id,
       author_id,
       title,
       written_date )
SELECT 80,
       300,
       'Temporal Data and the Relational Model',
       to_date('20020101', 'YYYYMMDD')
FROM   dual
where not exists (
  SELECT 1
  FROM   author_publications x
  WHERE  x.author_id = '300'
  AND    x.title     = 'Temporal Data and the Relational Model' );

COMMIT;

execute SYS.DBMS_STATS.gather_table_stats(USER, 'AUTHOR_PUBLICATIONS');
```

It didn't work? Well, try, try again until it does—or look at the examples in the appropriate source code listing directory for the book.

Hey, you know what? I was supposed to put the data in the database in uppercase so we could perform efficient case-insensitive queries. Well, I should fix that. Let's use the UPDATE statement.

Update

An UPDATE statement allows you to selectively update one or more column values for one or more rows in a specified table. In order to selectively update, you need to specify a WHERE clause in your UPDATE statement. Let's first take a look at an UPDATE statement without a WHERE clause.

Fix a Mistake with Update

As I alluded to earlier, I forgot to make the text values in the database all in uppercase. Listing 1-18 is my solution to this problem for the authors table.

Listing 1-18. A DML Statement for Updating the Authors Table, authors.upd

```
UPDATE authors
SET    name = upper(name);

COMMIT;
```

The syntax used by Listing 1-18 is as follows:

```
UPDATE <table_name>
SET    <column_name_1> = <column_value_1>,
       <column_name_2> = <column_value_2>,...
       <column_name_N> = <column_value_N>;
```

where `<table_name>` is the name of the table to update, `<column_name>` is the name of a column to update, and `<column_value>` is the value to which to update the column in question.

In this case, an `UPDATE` statement without a `WHERE` clause is just what I needed. However, in practice, that's rarely the case. And, if you find yourself coding such an SQL statement, think twice.

An unconstrained `UPDATE` statement can be one of the most destructive SQL statements you'll ever execute by mistake. You can turn a lot of good data into garbage in seconds. So it's always a good idea to specify which rows to update with an additional `WHERE` clause. For example, I could have added the following line:

```
WHERE  name <> upper(name)
```

That would have limited the `UPDATE` to only those rows that are not already in uppercase.

It's Your Turn to Update

I've fixed my uppercase mistake in the `authors` table. Now you can do the same for the `author_publications` table. So please update the publication titles to uppercase.

1. Write the DML script.
2. Save the DML script with the same file name as your table name, but add a `.upd` extension.
3. Execute your script in SQL*Plus.

The titles in the `author_publications` table should now be in uppercase—good job.

Listing 1-19 shows how I fixed this mistake.

Listing 1-19. DML for Updating Titles in the Publications Table, author_publications.upd

```
UPDATE author_publications
SET    title = upper(title)
WHERE  title <> upper(title);

COMMIT;
```

`UPDATE` statements can be quite complex. They can pull data values from other tables, for each column, or for multiple columns using subqueries. Let's look at the use of subqueries.

Update and Subqueries

One of the biggest mistakes PL/SQL programmers make is to write a PL/SQL program to update selected values in one table with selected values from another table. Why is this a big mistake? Because you don't need PL/SQL to do it. And, in fact, if you use PL/SQL, it will be slower than just doing it in SQL!

You haven't yet had an opportunity to work with any complex data, nor have I talked much about the SQL SELECT statement, so I won't show you an example yet. But look at the possible syntax:

```
UPDATE <table_name> U
SET    U.<column_name_N> = (
  SELECT S.<subquery_column_name_N>
  FROM   <subquery_table_name> S
  WHERE  S.<column_name_N> = U.<column_name_N>
  AND    ...)
WHERE u.<column_name_N> = <some_value>...;
```

This syntax allows you to update the value of a column in table `<table_name>`, aliased with the name `U`, with values in table `<subquery_table_name>`, aliased with the name `S`, based on the current value in the current row in table `U`. If that isn't powerful enough, look at this:

```
UPDATE <table_name> U
SET   (U.<column_name_1>,
       U.<column_name_2>, ...
       U.<column_name_N> ) = (
  SELECT S.<subquery_column_name_1>,
         S.<subquery_column_name_2>, ...
         S.<subquery_column_name_N>
  FROM   <subquery_table_name> S
  WHERE  S.<column_name_N> = U.<column_name_N>
  AND    ...)
WHERE u.<column_name_N> = <some_value>...;
```

Yes! You can update multiple columns at the same time simply by grouping them with parentheses. The moral of the story is, don't use PL/SQL to do something you can already do with SQL. I'll be harping on this moral throughout the book, so if you didn't get my point, relax, you'll hear it again and again in the coming chapters.

Delete

In practice, data is rarely deleted from a relational database when compared to how much is input, updated, and queried. Regardless, you should know how to delete data. With `DELETE`, however, you need to do things backwards.

A Change in Order

So you don't think Hugh Darwen is a genius? Well I do, but for the sake of our tutorial, let's say you want to delete his entries from the database.

Since you created an integrity constraint on the `author_publications` table (a foreign key), you need to delete Darwen's publications before you delete him from the `authors` table. Listing 1-20 is the DML to delete Darwen's entries from the `author_publications` table.

Listing 1-20. DML to Delete Darwen's Publications, author_publications_300.del

```
DELETE FROM author_publications
WHERE  id = 300;
```

The syntax for the DELETE statement used in Listing 1-20 is as follows:

```
DELETE FROM <table_name>
WHERE  <column_name_N> = <column_value_N>...;
```

where <table_name> is the name of the table to DELETE FROM, and <column_name> is one or more columns for which you specify some criteria.

Did you happen to notice that I didn't include a COMMIT statement? I will wait until you're finished with your part first.

It's Your Turn to Delete

Now that I've deleted the publications, it's time for you to delete the author.

1. Write the DML script without a COMMIT statement.
2. Save the DML script with the same file name as your table name, suffix it with _300, and then add a .del extension.
3. Execute your script in SQL*Plus.

Darwen should no longer be in the database. Listing 1-21 shows how I got rid of him.

Listing 1-21. DML for Deleting Darwen from the Authors Table, authors_300.del

```
DELETE FROM authors
WHERE  id = 300;
```

Oops, no more Darwen. I changed my mind. Let's fix that quickly!

Type ROLLBACK; at your SQL*Plus prompt and then press the Enter key. The transaction—everything you did from the last time you executed a COMMIT or ROLLBACK statement—has been rolled back. So it's as though you never deleted Darwen's entries. You didn't *really* think I was going to let you delete Darwen, did you?

Now we are ready to review the most used SQL statement: SELECT.

Select

In the end, all the power of a relational database comes down to its ability to manipulate data. At the heart of that ability lies the SQL SELECT statement. I could write an entire book about it, but I've got only a couple of pages to spare, so pay attention.

Listing 1-22 is a query for selecting all the author names from the authors table. There's no WHERE clause to constrain which rows you will see.

Listing 1-22. DML to Query the Author Table, author_names.sql

```
SELECT name
FROM   authors
ORDER BY name;
```

```
NAME
-------------------
CHRIS J DATE
EDGAR F CODD
HUGH DARWEN
```

Listing 1-22 actually shows the query (SELECT statement) executed in SQL*Plus, along with the database's response.

The syntax of the SELECT statement in Listing 1-22 is as follows:

```
SELECT <column_name_1>,
       <column_name_2>,
       <column_name_N>
FROM   <table_name>
[ORDER BY <order_by_column_name_N>]
```

where `<column_name>` is one of the columns in the table listed, `<table_name>` is the table to query, and `<order_by_column_name>` is one or more columns by which to sort the results.

In Listing 1-23, I add a WHERE clause to constrain the output to only those authors born before the year 1940.

Listing 1-23. DML to Show Only Authors Born Before 1940, author_names_before_1940.sql

```
SELECT name
FROM   authors
WHERE  birth_date < to_date('19400101', 'YYYYMMDD')
ORDER BY name;
```

```
NAME
------------------
EDGAR F CODD
```

So while this is all very nice, we've only started to scratch the surface of the SELECT statement's capabilities. Next, let's look at querying more than one table at a time.

Joins

Do you remember that way back in the beginning of this chapter you went through the mental exercise of matching the value of the `id` column in the `authors` table against the `author_id` column in the `author_publications` table in order to find out which publications were written by each author? What you were doing back then was *joining* the two tables on the `id` column.

Also recall that to demonstrate views, I created an `authors_publications` view? In that view, I joined the two tables, `authors` and `author_publications`, by their related columns, `authors.id` and `author_publications.author_id`. That too was an example of joining two tables on the `id` column.

Joins in a Where Clause

Listing 1-24 shows the SQL SELECT statement from that view created in Listing 1-11 with an added ORDER BY clause. In this example, I am joining the two tables using the WHERE clause (sometimes called *traditional Oracle join syntax*).

Listing 1-24. DML to Join the Authors and Publications Tables, authors_publications_where_join.sql

```
SQL> SELECT a.id,
  2         a.name,
  3         p.title,
  4         p.written_date
  5  FROM   authors a,
  6         author_publications p
  7  WHERE  a.id = p.author_id
  8  ORDER BY a.name,
  9         p.written_date,
 10         p.title;
```

```
   ID NAME               TITLE
----- ------------------ --------------------------------------------------
  200 CHRIS J DATE       THE THIRD MANIFESTO
  200 CHRIS J DATE       TEMPORAL DATA AND THE RELATIONAL MODEL
  200 CHRIS J DATE       AN INTRODUCTION TO DATABASE SYSTEMS
  200 CHRIS J DATE       DATABASE IN DEPTH: RELATIONAL THEORY FOR PRACTITION
  100 EDGAR F CODD       A RELATION MODEL OF DATA FOR LARGE SHARED DATA BANK
  100 EDGAR F CODD       THE RELATIONAL MODEL FOR DATABASE MANAGEMENT
  300 HUGH DARWEN        THE THIRD MANIFESTO
  300 HUGH DARWEN        TEMPORAL DATA AND THE RELATIONAL MODEL

8 rows selected.
```

Line 7 in Listing 1-24 has this code:

```
WHERE  a.id = p.author_id.
```

Line 7 joins the `authors` table a with the `author_publications` table `p`, on the columns `id` and `author_id` respectively.

However, there's a second, newer form of join syntax that uses the `FROM` clause in a SQL `SELECT` statement instead of the `WHERE` clause.

Joins in a From Clause

Listing 1-25 shows the newer join syntax. The newer join syntax is part of the ANSI standard. If you use it, it may make it easier to move to another ANSI standard compliant SQL database in the future. The join takes place in lines 5 through 6 in the `FROM...ON` clause.

Listing 1-25. DML to Join the Authors and Publications Tables, authors_publications_from_join.sql

```
SQL> SELECT a.id,
  2         a.name,
  3         p.title,
  4         p.written_date
  5  FROM   authors a JOIN
  6         author_publications p
```

```
ON     a.id = p.author_id
ORDER BY a.name,
       p.written_date,
       p.title;
```

Both forms of the join syntax give the same results. I suggest you use the syntax that is consistent with the previous use of join syntax in the application you're currently working on, or follow the conventions of your development team.

It's Your Turn to Select

It's time to for you to try to use the `SELECT` statement. Show me all the authors who have coauthored a book.

1. Write the DML script.
2. Save the DML script with the file name `coauthors.sql`.
3. Execute your script in SQL*Plus.

You should get results something like this:

```
NAME
------------------
CHRIS J DATE
HUGH DARWEN
```

Next, show me all the publications that have been coauthored along with the author's name. Save the script with the file name `coauthor_publications.sql`. You should get results like this:

```
TITLE                                                  NAME
------------------------------------------------------ ------------------
TEMPORAL DATA AND THE RELATIONAL MODEL                 CHRIS J DATE
TEMPORAL DATA AND THE RELATIONAL MODEL                 HUGH DARWEN
THE THIRD MANIFESTO                                    CHRIS J DATE
THE THIRD MANIFESTO                                    HUGH DARWEN
```

You can find my solutions to these two exercises in the source code listings you downloaded for the book. If you had difficulty writing the queries for these two exercises, then you need more experience with SQL queries before you can be proficient with PL/SQL. You'll be able to learn and use PL/SQL, but you'll be handicapped by your SQL skills.

In fact, everything we just covered should have been a review for you. If any of it was new, I recommend that you follow up learning PL/SQL with some additional training in SQL. As I said when we started on this journey together, you need to know SQL really well, because it makes up about 25% of every PL/SQL stored procedure.

Now that we have reviewed the SQL basics, I need to introduce you to a fictional example that you will use in the rest of the book.

Your Working Example

I know it's a lot of work, but you really need to buy into the following fictional example in order to have something realistic to work with as you proceed through this book. I would love to take on one of your real business problems, but I don't work at the same company you do, so that would be very difficult. So let me start by telling you a short story.

Your Example Narrative

You're going to do some software development for a company called Very Dirty Manufacturing, Inc. (VDMI). VDMI prides itself with being able to take on the most environmentally damaging manufacturing jobs (dirty) in the most environmentally responsible way possible (clean).

Of course, VDMI gets paid big bucks for taking on such legally risky work, but the firm is also dedicated to preventing any of its employees from injury due to the work. The managers are so dedicated to the health and well-being of their workforce that they plan on having their industrial hygiene (IH), occupational health (OH), and safety records available on the Internet for public viewing (more on what IH and OH are about in just a moment).

Your job is the development of the worker demographics subsystem for maintaining the IH, OH, and safety records for VDMI. Internally, management will need to review worker data by the following:

- Organization in which a person works
- Location where the employee works
- Job and tasks the employee performs while working

For IH, environmental samples will be taken in the areas where people work to make sure they are not being exposed to hazardous chemicals or noise without the right protections in place. For OH, workers who do work in dirty areas will be under regular medical surveillance to make sure that they are not being harmed while doing their work. And last, any accidents involving workers will also be documented so that no similar accidents take place, and to ensure that the workers are properly compensated for their injuries.

Externally, the sensitivity of the information will prevent the company from identifying for whom the data presented exists, but the information will still be presented by the high-level organization, location, and job. Therefore, the same demographic data and its relationship to workers in the firm need to be in place.

Your Example ERD

Now that you have an overview of the situation, let's take a look at an architectural representation of the demographic subsystem. Figure 1-2 shows the ERD for the demographic subsystem.

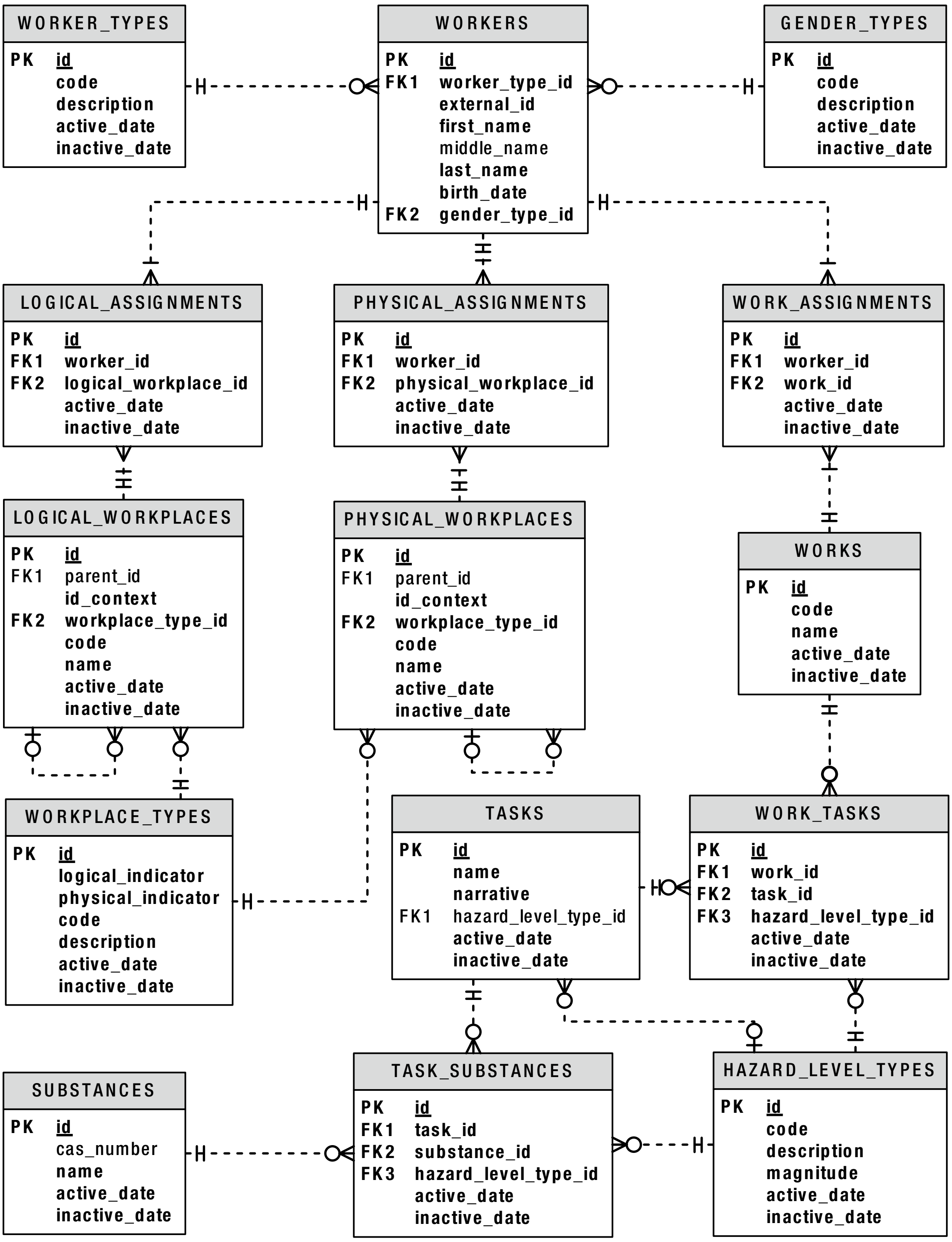


Figure 1-2. *VMDI's IH, OH, and safety demographic subsystem ERD*

In order for you to get a better understanding of the ERD, think of each table in the diagram as one of the following:

- Content
- Codes
- Intersections

What do these terms mean?

Content

Think of content as anything your users may actually need to type into the system, which varies greatly. For example, information like a worker's name and birth date changes a lot from one worker to the next. Since that data is kept in the WORKERS table, think of the WORKERS table as a content table.

Data in the WORKERS table is the kind of information that you're unlikely to translate into another language should you present the information in a report. I would also classify as content tables the LOGICAL_WORKPLACES, PHYSICAL_WORKPLACES, and WORKS tables, which describe the organization, location, and the job of a worker, respectively. However, you might also think of them as codes.

Codes

In order to make the categorization, classification, or typing of data specified in a content table consistent across all entries—for example, workers entered into the WORKERS table—I've added some code tables. There are only a limited number of types of workers, and definitely only a limited number of genders, so I've added a WORKER_TYPES code table and a GENDER_TYPES code table. Code tables act as the definitive source of categories, classes, types, and so on when specifying codified information in a content table like WORKERS.

Here are some of the reasons that it's important to use code tables:

- They constrain the values entered into a table to an authoritative list of entries. This improves quality.
- The primary key of a code table is typically an identifier (ID) that is a sequence-generated number with no inherent meaning other than it is the primary key's value. An ID value is a compact value that can then be stored in the content table to reference the much larger code and description values. This improves performance.
- Storing the sequence-generated ID of a code table in a content table will allow you to later change the code or description values for a particular code without needing to do so in the content table. This improves application maintenance.
- Storing the sequence-generated ID of a code table in a content table will also allow you to later change the code or description for a code on the fly for an internationalized application. This improves flexibility.

Think of the WORKER_TYPES, GENDER_TYPES, WORKPLACE_TYPES, and HAZARD_LEVEL_TYPES tables as code tables. They all have a similar set of behaviors that you will later make accessible with PL/SQL functions and procedures.

Intersections

Think of intersections as a means of documenting history. Understanding that there is a history of information is the single-most portion missing in the analyses of business problems. Most often, a many-to-many relationship table (an intersection) will be created that captures only the "current" relationship between content entities, but there's always a history, and the history is almost always what's actually needed to solve the business problem in question.

In the refresher earlier in this chapter, you worked with two tables (or entities) that did not require you to keep a history. However, in the example here, you definitely need to maintain a history of who workers reported to, where they actually did their work, and what they did. Intersections document timelines, as shown in Figure 1-3.

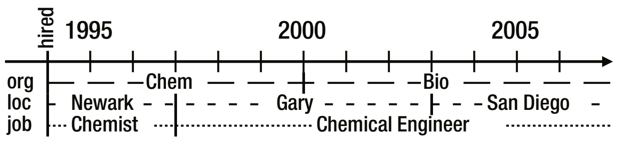


Figure 1-3. *An employment timeline*

Examining Figure 1-3, you can see that the employee in question has the following history:

- Worked in the Chemicals department from 1994 through 1999, and then in the Biologicals department since (logical assignment)
- Worked at the Newark, New Jersey location from 1994 through 1996, in Gary, Indiana through 2002, and then in sunny San Diego since (physical assignment)
- Worked as a chemist from 1994 through 1996, and then as a chemical engineer since (work assignment)

An intersection table has a beginning and end date for every assignment period. Think of the LOGICAL_ASSIGNMENTS, PHYSICAL_ASSIGNMENTS, and WORK_ASSIGNMENTS tables as history tables that hold an intersection in time between the WORKERS table and the LOGICAL_WORKPLACES, PHYSICAL_WORKPLACES, and WORKS tables, respectively.

Now that you're familiar with the ERD, you can start creating the tables.

Create a Code Table

Let's create some code tables. I'll write the script for the first code table, and then you do the other three. Listing 1-26 is a script to create the WORKER_TYPES code table.

Listing 1-26. DDL for Creating the WORKER_TYPES Code Table, worker_types.tab

```
rem worker_types.tab
rem by Donald J. Bales on 2014-10-20
rem

--drop   table WORKER_TYPES;
create table WORKER_TYPES (
id                              number(38)                      not null,
code                            varchar2(30)                    not null,
09  description                  varchar2(80)                  not null,
10  active_date                  date     default SYSDATE      not null,
11  inactive_date                date     default '31-DEC-9999' not null);
12
13  --drop   sequence WORKER_TYPES_ID;
14  create sequence WORKER_TYPES_ID
15  start with 1;
16
17  alter  table WORKER_TYPES add
18  constraint   WORKER_TYPES_PK
19  primary key ( id )
20  using index;
21
22  alter  table WORKER_TYPES add
23  constraint   WORKER_TYPES_UK
24  unique ( code, active_date )
25  using index;
26
27  execute SYS.DBMS_STATS.gather_table_stats(USER, 'WORKER_TYPES');
```

This listing is more complex than the previous ones in this chapter. Here's the breakdown:

- Lines 1 through 3 document the name of the script, the author, and the date it was written. This is typical—everyone wants to know who to blame.
- Lines 5 and 13 have DROP statements that I've commented out. Those were really handy when I was in the iterative development cycle, where I had to edit my script to refine it and then recompile.
- Lines 6 through 11 contain the DDL to create the table WORKER_TYPES.
- Lines 14 and 15 contain the DDL to create WORKER_TYPES_ID, a sequence for the table's primary key column, id.
- Lines 17 through 20 contain the DDL to alter the table in order to add a primary key constraint.
- Lines 22 through 25 contain the DDL to alter the table in order to add a unique key constraint. This constraint will allow only unique code values in the code table.

Since it's a code table, I can seed it with some initial values. I've written a second script for that, shown in Listing 1-27.

Listing 1-27. DML Script to Populate the WORKER_TYPES Code Table, worker_types.ins

```
rem worker_types.ins
rem by Donald J. Bales on 2014-10-20
rem

insert into WORKER_TYPES (
       id,
       code,
       description )
```

```
09  values (
10         WORKER_TYPES_ID.nextval,
11         'C',
12         'Contractor' );
13
14  insert into WORKER_TYPES (
15         id,
16         code,
17         description )
18  values (
19         WORKER_TYPES_ID.nextval,
20         'E',
21         'Employee' );
22
23  insert into WORKER_TYPES (
24         id,
25         code,
26         description )
27  values (
28         WORKER_TYPES_ID.nextval,
29         'U',
30         'Unknown' );
31
32  commit;
33
34  execute SYS.DBMS_STATS.gather_table_stats(USER, 'WORKER_TYPES');
```

Here's what's happening in Listing 1-27:

- In lines 1 through 3, I've added the author and written date.
- In lines 5 through 12, 14 through 21, and 23 through 30, I've added three DML INSERT VALUES statements in order to add three worker types to the WORKER_TYPES table.
- In lines 10, 19, and 28, I'm allocating a new sequence value from the primary key's sequence using the pseudo-column .nextval.
- In line 32, I commit the inserts so they are permanently accessible to everyone on the database.

After I execute these two scripts, I can query WORKER_TYPES and get results like this:

```
SQL> column code          format a4;
SQL> column description   format a13;
SQL> column active_date   format a13;
SQL> column inactive_date format a13;
SQL>
SQL> select *
  2  from   WORKER_TYPES
  3  order by code;
```

```
        ID CODE DESCRIPTION   ACTIVE_DATE   INACTIVE_DATE
---------- ---- ------------- ------------- -------------
         1 C    Contractor    07-DEC-14     31-DEC-99
         2 E    Employee      07-DEC-14     31-DEC-99
         3 U    Unknown       07-DEC-14     31-DEC-99
```

CODING CONVENTIONS

Coding conventions (or standards) are something all professional programmers follow religiously.

SQL Coding Conventions

In the refresher part of this chapter, I capitalized the SQL keywords so it was easy for you to notice them in the syntax statement that followed their use. In practice, I don't do that. When I code SQL, I follow these simple rules:

- I type table names in all caps, literals in uppercase/lowercase/mixed case as required, and everything else in lowercase. Why? First, since SQL is table-centric, I want table names to stick out like a sore thumb. Second, lowercase is actually easier to read. And finally, lowercase is easier to type, and after 30 years of typing, you'll know why that's important.
- I format my code so column names, table names, and parameters in `WHERE` clauses all line up in nice left-justified columns. That way, the text is easy to scan.
- I name scripts with the same name as the object they are creating, dropping, inserting, updating, and so on, and an appropriate filename extension in order to make the names of the scripts as obvious as possible.

SQL Filename Extension Conventions

The following are the filename extensions I use:

- `.tab`: Create table
- `.alt:` Alter table (to add, modify, or drop a column)
- `.ndx`: Create index
- `.pkc`: Alter table/add constraint/primary key (usually included in the create table script)
- `.fkc`: Alter table/add constraint/foreign key (usually included in the create table script)
- `.ukc`: Alter table/add constraint/unique (usually included in the create table script)
- `.drp`: Drop table
- `.ins`: Insert into
- `.upd`: Update
- `.del`: Delete from
- `.sql`: Select from

It's Your Turn to Create Code Tables

Now that you've seen me do it, you should be able to code the scripts to do the same for the GENDER_TYPES, HAZARD_LEVEL_TYPES, and WORKPLACE_TYPES code tables. Code the scripts, saving them with the filenames gender_types.tab, hazard_level_types.tab, and workplace_types.tab, respectively. Then execute each script. You can see my solutions to these scripts in the book's source code directory for Chapter 1. Now let's move on to creating content tables.

Create a Content Table

This time, let's create some content tables. I'll write the first two scripts, and then you do the rest. Listing 1-28 is a script to create the WORKERS table.

Listing 1-28. DDL to Create the WORKERS Table, workers.tab

```
rem workers.tab
rem by Donald J. Bales on 2014-10-20
rem

--drop   table WORKERS;
create table WORKERS (
id                              number(38)                      not null,
worker_type_id                  number(38)                      not null,
external_id                     varchar2(30)                    not null,
first_name                      varchar2(30)                    not null,
middle_name                     varchar2(30),
last_name                       varchar2(30)                    not null,
name                            varchar2(100)                   not null,
birth_date                      date                            not null,
gender_type_id                  number                          not null );

--drop   sequence WORKERS_ID;
create sequence WORKERS_ID
start with 1;

--drop   sequence EXTERNAL_ID_SEQ;
create sequence EXTERNAL_ID_SEQ
start with 100000000 order;

alter  table WORKERS add
constraint   WORKERS_PK
primary key ( id )
using index;

alter  table WORKERS add
constraint   WORKERS_UK1
unique ( external_id )
using index;

```

```
35  alter  table WORKERS add
36  constraint   WORKERS_UK2
37  unique (
38  name,
39  birth_date,
40  gender_type_id )
41  using index;
42
43  alter  table WORKERS add
44  constraint   WORKERS_FK1
45  foreign key   ( worker_type_id )
46  references   WORKER_TYPES ( id );
47
48  alter  table WORKERS add
49  constraint   WORKERS_FK2
50  foreign key   ( gender_type_id )
51  references   GENDER_TYPES ( id );
52
53  execute SYS.DBMS_STATS.gather_table_stats(USER, 'WORKERS');
```

Looks familiar, doesn't it? It looks a lot like the code table scripts you created earlier. The exceptions are lines 43 through 46 and 48 through 51, where I've added DDL to create two foreign key constraints. The first foreign key creates an integrity constraint between the code table `WORKER_TYPES`, while the second does the same for code table `GENDER_TYPES`. These constraints will prevent anyone from deleting a code that is in use by the `WORKERS` table.

Listing 1-29 shows the code to create the `LOGICAL_WORKPLACES` table. I'm showing you this listing because this table has some interesting new columns: `parent_id` and `id_context`.

Listing 1-29. DDL to Create the LOGICAL_WORKPLACES Table, logical_workplaces.tab

```
rem logical_workplaces.tab
rem by Donald J. Bales on 2014-10-20
rem

--drop   table LOGICAL_WORKPLACES;
create table LOGICAL_WORKPLACES (
id                             number(38)                    not null,
parent_id                      number(38),
id_context                     varchar2(100)                 not null,
workplace_type_id              number                        not null,
code                           varchar2(30)                  not null,
name                           varchar2(80)                  not null,
active_date                    date     default SYSDATE      not null,
inactive_date                  date     default '31-DEC-9999' not null );

--drop   sequence LOGICAL_WORKPLACES_ID;
create sequence LOGICAL_WORKPLACES_ID
start with 1;

```

```
alter  table LOGICAL_WORKPLACES add
constraint   LOGICAL_WORKPLACES_PK
primary key (
id )
using index;

alter  table LOGICAL_WORKPLACES add
constraint   LOGICAL_WORKPLACES_UK1
unique (
id_context )
using index;

alter  table LOGICAL_WORKPLACES add
constraint   LOGICAL_WORKPLACES_UK2
unique (
code,
name,
active_date )
using index;

alter  table LOGICAL_WORKPLACES add
constraint   LOGICAL_WORKPLACES_FK1
foreign key              ( parent_id )
references   LOGICAL_WORKPLACES ( id );

alter  table LOGICAL_WORKPLACES add
constraint   LOGICAL_WORKPLACES_FK2
foreign key   ( workplace_type_id )
references   WORKPLACE_TYPES ( id );

execute SYS.DBMS_STATS.gather_table_stats(USER, 'LOGICAL_WORKPLACES');
```

A logical workplace like a department may belong to a business unit, while its business unit may belong to a company. The `parent_id` column allows you to store the `id` of a department's parent business unit with the department, so you can document the organization hierarchy. With this information, you can present an organization chart, find everyone in a business unit, and so on.

The `id_context` column is a convenience or performance column for the mechanics of querying the database. You are going to write a PL/SQL function that will create an ID context string for this column. The ID context string will list all of the parent IDs, plus the logical workplace ID of the current row, separated by a known character, such as a period (.)—for example, `1.13.14`. This will greatly improve the performance of any `LIKE` queries against the hierarchy of the organizations in the table.

It's Your Turn to Create Content Tables

Now that you've seen me do it, you should be able to code the scripts to do the same for the `PHYSICAL_WORKPLACES`, `TASKS`, and `WORKS` tables. So code the scripts, saving them with the filenames `physical_workplaces.tab, tasks.tab`, and `works.tab`, respectively. Then execute each script. You can view my solutions to these scripts in the book's source code directory for Chapter 1.

Now let's move on to creating intersection tables.

Create an Intersection Table

It's time to create some intersection tables. I'll write the first script, and then you write the rest. Listing 1-30 is a script to create the `LOGICAL_ASSIGNMENTS` table.

Listing 1-30. DDL to Create the LOGICAL_ASSIGNMENTS Table, logical_assignments.tab

```
rem logical_assignments.tab
rem by Donald J. Bales on 2014-10-20
rem

--drop   table LOGICAL_ASSIGNMENTS;
create table LOGICAL_ASSIGNMENTS (
id                             number(38)                      not null,
worker_id                      number(38)                      not null,
logical_workplace_id           number(38)                      not null,
active_date                    date     default SYSDATE        not null,
inactive_date                  date     default '31-DEC-9999' not null );

--drop   sequence LOGICAL_ASSIGNMENTS_ID;
create sequence LOGICAL_ASSIGNMENTS_ID
start with 1;

alter  table LOGICAL_ASSIGNMENTS add
constraint   LOGICAL_ASSIGNMENTS_PK
primary key ( id )
using index;

alter  table LOGICAL_ASSIGNMENTS add
constraint   LOGICAL_ASSIGNMENTS_UK
unique (
worker_id,
active_date )
using index;

alter  table LOGICAL_ASSIGNMENTS add
constraint   LOGICAL_ASSIGNMENTS_FK1
foreign key   ( worker_id )
references   WORKERS ( id );

alter  table LOGICAL_ASSIGNMENTS add
constraint   LOGICAL_ASSIGNMENTS_FK2
foreign key   ( logical_workplace_id )
references   LOGICAL_WORKPLACES ( id );

execute SYS.DBMS_STATS.gather_table_stats(USER, 'LOGICAL_ASSIGNMENTS');
```

I know; you don't even need me to explain it anymore. I just wanted to make sure you have a nice pattern to mimic.

It’s Your Turn to Create Intersection Tables

Just do it! Create tables `PHYSICAL_ASSIGNMENTS`, `WORK_ASSIGNMENTS`, and `WORK_TASKS`. Code your scripts with file names `physical_assignments.tab`, `work_assignments.tab`, and `work_tasks.tab`. Then execute your scripts.

Summary

By now you should have a fairly complete set of sample tables that you can work with when programming in PL/SQL. You’ve reviewed the basics of relational SQL, and then put that to work to create your working example. If you had any trouble with the SQL used so far, I sincerely encourage you to get some supplemental materials and/or training in order to improve your SQL skills. You’ve heard the old adage, “A chain is only as strong as its weakest link,” haven’t you?

So you think your SQL is up to the task of programming in PL/SQL? Well, let’s get started!

CHAPTER 2

Blocks, Functions, and Procedures

In this chapter, as the title suggests, you'll learn about the foundational structures of PL/SQL: blocks, functions, and procedures. Blocks define the structures upon which functions and procedures are built. Functions and procedures are very similar, but distinct, in that a function returns a value to a calling function or procedure, while a procedure does not. So let's begin our discussion of PL/SQL by starting with its foundation: the block.

Blocks

The Procedure Language extension for SQL (PL/SQL) has a block structure. Every piece of code executes in a block, similar to Java, JavaScript, and PHP's try-catch clause; Python's try-except clause; or Ruby's begin-rescue-end clause. However, PL/SQL has four keywords:

- `DECLARE`: Every PL/SQL block has a declaration section. This is where you allocate memory for cursors, data type definitions, variables, embedded functions, and procedures (don't worry—you'll learn about all of these in this book, beginning with functions and procedures in this chapter). Sometimes when you code a PL/SQL program, you won't even use the declaration section, but it's still there.
- `BEGIN`: Every PL/SQL block has an executable section. It starts with the keyword `BEGIN.` `BEGIN` marks the beginning of where you put your program logic. And every PL/SQL program must have at least one line of executable code, even if it's the keyword `NULL`, which in this context means no operation.
- `EXCEPTION`: Every PL/SQL block has an exception-handling section. It starts with the keyword `EXCEPTION`. This is where you will catch any database or PL/SQL errors, or as they are affectionately known, *exceptions*. Like the declaration section, sometimes you won't even use an exception-handling section, but it's still there.
- `END`: Every PL/SQL block ends with the keyword `END`.

Anonymous Blocks

We'll start with an anonymous PL/SQL block. It's called *anonymous* because it's not going to be saved in the database, so it will never have a name. In practice, you won't find yourself using anonymous blocks in production, but you'll use them throughout the development process. They're perfect for creating test units that you'll eventually move into your stored PL/SQL blocks. You'll learn more about that in Chapter 8. For now, let's look at an example.

Anonymous Block Example

Listing 2-1 is an example of an anonymous PL/SQL block. Comments describe the different sections.

Listing 2-1. An Anonymous PL/SQL Block, anonymous.sql

```
01 -- This is an anonymous procedure, so it has no name
02 DECLARE
03   /*
04    You declare local cursors, variables, and methods here,
05    but you don't need to have a declaration section.
06   */
07 BEGIN
08   -- You write your executable code here
09
10   NULL;  -- Ahhh, you've got to have at least one command!
11 EXCEPTION
12   when NO_DATA_FOUND then
13     raise_application_error(-20000,
14       'Hey, This is in the exception-handling section!');
15 END;
16 /
17 -- the forward slash on a line by itself says execute this procedure
```

Let's go through Listing 2-1 line by line:

- Line 1 is a single-line comment. Single-line comments start with a double-dash (`--`), but line 1 is not part of the PL/SQL block or program because it exists outside the block structure.
- Line 2 starts the block with the keyword `DECLARE`. This anonymous PL/SQL block could have started with the keyword `BEGIN` because it doesn't have anything to declare.
- Lines 3 through 6 are a multiline comment in the declaration section. Multiline comments start with a slash and asterisk (`/*`) and end with an asterisk and slash (`*/`).
- Line 7 starts the PL/SQL executable section of the PL/SQL block with the keyword `BEGIN`.
- Line 8 is a single-line comment in the executable section.
- Line 10 is the PL/SQL keyword `NULL` followed by a single-line comment. `NULL` in this context means no operation. I put it there because every PL/SQL block must have at least one line of code, or it won't compile. The NULL command is terminated with a semicolon. In PL/SQL, a semicolon denotes the end of a command.
- Line 11 starts the exception-handling section with the keyword `EXCEPTION`. If you code an exception-handling section, you must catch at least one exception. In this case, I've coded a `NO_DATA_FOUND` exception, which will raise an application error with my message should a `NO_DATA_FOUND` exception occur.
- Line 15 ends the PL/SQL block or program with the keyword `END`.

- Line 16 has **a** *single forward slash (/), which is a signal to SQL*Plus* to execute the PL/SQL block. In this case—that is, with an anonymous PL/SQL block—the Oracle database will compile and then run the code in the PL/SQL block.
- Line 17 is another single-line comment that, too, exists outside the PL/SQL block.

It's Your Turn to Execute an Anonymous Block

Now it's time for you to execute an anonymous PL/SQL block/program.

1. Open SQL*Plus and connect to the database with username RPS.
2. At the `SQL>` prompt, type the following:

```
set serveroutput on size 1000000
begin
  SYS.DBMS_OUTPUT.put_line('Hi there genius!');
end;
/
```

After you type the forward slash on a line by itself, you will have executed your very first PL/SQL procedure, and a very complimentary one at that.

The first line tells SQL*Plus to echo the database's output for your session to the screen after the PL/SQL procedure is finished executing. Note that `set serveroutput on size 1000000` is a SQL*Plus command and is not part of the anonymous block.

The line that starts with `begin` starts your PL/SQL procedure's executable code section. The next line calls the `put_line` procedure in package (library of stored procedures) `DBMS_OUTPUT`, owned by user `SYS`:

```
sys.dbms_output.put_line('Hi there genius!');
```

Here, `put_line` stores your text in a buffer until the PL/SQL procedure ends. Then SQL*Plus displays the text from that buffer on the screen for you to see.

The fourth line, which starts with `end`, ends the anonymous PL/SQL procedure. Finally, as stated earlier, the forward slash (`/`) on a line by itself tells SQL*Plus to execute the procedure.

In this example, you didn't code declaration or exception-handling sections, but they're still there! If an error occurs between the `BEGIN` and `END` keywords, PL/SQL will use the default (invisible) exception handler to raise the error to the enclosing program unit, which, in this case, is SQL*Plus.

Exceptions

Exceptions allow you to catch errors as your PL/SQL program executes, so you have control over what happens in response to those errors. PL/SQL predefines more than 20 named exceptions, but you'll probably use only a few.

■ **Note** After you've gained more PL/SQL experience, you may even want to define your own named exceptions. For more information about custom exceptions, see Oracle's *PL/SQL User's Guide and Reference*.

Common Exceptions

As you'll learn in future chapters, there are a handful of commonly seen exceptions. The rest occur only when there are catastrophic problems with the database, the network, or your PL/SQL code.

Two exceptions are very common:

- `NO_DATA_FOUND`: You'll get a `NO_DATA_FOUND` exception anytime you code a SQL `SELECT` statement that does not return any rows.
- `TOO_MANY_ROWS`: If you code a `SELECT` statement where you expect only one row but you get more than one, you'll get a `TOO_MANY_ROWS` exception.

Catching an Exception

You add the keyword `EXCEPTION` between the keywords `BEGIN` and `END` in order to add an exception-handling section to your PL/SQL block. Once you do that, any error that occurs between the keywords `BEGIN` and `EXCEPTION` will be handled by your exception-handling section.

Functions

A `FUNCTION` is a PL/SQL block or method that returns a value, so it can be used on the right-hand side of an assignment. Here is an example:

```
n_value := to_number('123.45');
```

In this line of PL/SQL code, `n_value` is a numeric variable (we'll cover variables in the next chapter). `n_value` is followed by an assignment operator, which is a colon followed by an equal sign (`:=`). Next is the PL/SQL built-in function `to_number(text in varchar2)`, which parses a `varchar2` data type, and then returns its numeric value—that is, if the `varchar2` represents a number; otherwise, the function raises an `INVALID_NUMBER` exception.

Since a `FUNCTION` returns a value, you can also use it in a SQL statement, as in this example:

```
SQL> select to_number('A') from dual;
select to_number('A') from dual
           *
ERROR at line 1:
ORA-01722: invalid number
```

Look, there's that `INVALID_NUMBER` exception I was talking about!

Create a Function

Instead of dealing with errors when we try to convert a `varchar2` (character string) to a `number` on the fly as in a `SELECT` statement, let's create an errorless `to_number()` function. Listing 2-2 is the DDL to do just that.

Listing 2-2. An Errorless to_number( ) Function, to_number_or_null.fun

```
CREATE OR REPLACE FUNCTION to_number_or_null (
aiv_number        IN     varchar2 )
return            number is
```

```
04  /*
05  to_number_or_null.fun
06  by Donald J. Bales on 2014-10-20
07  An errorless to_number( ) method
08  */
09  begin
10    return to_number(aiv_number);
11  exception
12    when OTHERS then
13      return NULL;
14  end to_number_or_null;
15  /
16  @fe.sql to_number_or_null;
```

The DDL syntax used in Listing 2-2 to create the function is as follows:

```
CREATE [OR REPLACE] FUNCTION <function_name> [(
<parameter_name_1>          [IN] [OUT] <parameter_data_type_1>,
<parameter_name_2>          [IN] [OUT] <parameter_data_type_2>,...
<parameter_name_N>          [IN] [OUT] <parameter_data_type_N> )]
RETURN                                 <return_data_type> IS
  --the declaration section
BEGIN
  -- the executable section
  return <return_data_type>;
EXCEPTION
  -- the exception-handling section
END;
/
```

where `<function_name>` is the name of the `FUNCTION`; `<parameter_name>` is the name of a parameter being passed `IN`, `OUT`, or `IN` and `OUT`; `<parameter_data_type>` is the PL/SQL data type of the corresponding parameter; and `<return_data_type>` is the PL/SQL data type of the value that will be returned by the `FUNCTION` when it completes its execution. The brackets (`[]`) around the keywords `OR REPLACE` denote that they are optional. The brackets around the parameters denote that they are optional, too.

The block structure of a `FUNCTION` is exactly the same as an anonymous procedure, except for the addition of the Data Definition Language (DDL) `CREATE FUNCTION` keywords, the optional parameters, and the `RETURN` clause.

Let's take a look at Listing 2-2 line by line:

- Line 1 has the DDL keywords to `CREATE` a stored `FUNCTION`. These take the place of the keyword `DECLARE` used earlier in the anonymous PL/SQL block.
- Line 2 declares one parameter, `aiv_number`, a `varchar2` value passed `IN`to the `FUNCTION`.
- Line 3 contains the `RETURN` clause. In this case, I'm returning a `number`.
- Lines 4 through 8 contain a multiline comment that lists the function's source code filename, the name of the author, the date the function was written, and a description of the function's purpose. So the only thing in the declaration section of this PL/SQL block is the multiline comment.

- On line 9, the keyword `BEGIN` starts the execution section of the PL/SQL block.
- On line 10, I return the built-in `to_number( )`'s return value for converting the `varchar2` variable `aiv_number` to a `number`. Then the program ends. However, if the built-in `to_number( )` raises an exception, the program's execution branches to the exception-handling section.
- On line 11, the keyword `EXCEPTION` starts the exception-handling section of this PL/SQL block.
- On line 12, the exception handler checks to see if the raised exception is the named exception `OTHERS (a catch-all exception)`. If it is, it executes the code that follows it on line 13. It may have sufficed to use the execption `INVALID_NUMBER`; however, in practice, Oracle may define additional numeric conversion exceptions in the future, and consequently, my errorless routine might actually report an error!
- On line 13, I return `NULL` if there is an `OTHERS,` which includes `INVALID_NUMBER`, exception. That's what makes this an errorless `to_number( )` function. If there are any *other* exceptions, the exception hander will not raise the error to the enclosing PL/SQL block or program, which in this case, will be SQL*Plus.
- On line 14, the keyword `END` denotes the end of the PL/SQL block, and hence the `FUNCTION`.
- On line 15, the single slash character (`/`) tells SQL*Plus to execute the DDL, which stores the PL/SQL in the database and then compiles it.
- Line 16 contains a helper SQL script that will list any compilation errors. Most of the time, this script will simply have one line of code that says `show errors`. However, if you're compiling into another schema (other than the username you're logged in with), you may need a more complex SQL script to display errors.

Now let's try using this errorless `FUNCTION` in a `SELECT` statement:

```
SQL> select to_number_or_null('A') from DUAL;
```

```
TO_NUMBER_OR_NULL('A')
----------------------
```

Ta da! It returned a `NULL` value since the letter *A* is not a number. Just in case you're a skeptic, here's a second test:

```
SQL> select to_number_or_null('234.56') from DUAL;
```

```
TO_NUMBER_OR_NULL('234.56')
---------------------------
                     234.56
```

Yes, indeed, it works correctly!

It's Your Turn to Create a Function

For this exercise, you'll create a function that returns a date value. You can use the function in Listing 2-2 as a model. This time, you'll pass this new function a varchar2 value that represents a date in the form *MM/DD/YYYY*. Your function will parse the varchar2 value and return a date data type if the varchar2 value is actually a date in the form *MM/DD/YYYY*; otherwise, it will return NULL.

You can use the PL/SQL built-in function `to_date(text in varchar2, format in varchar2)` in your function to do the actual parsing of the date. In the following form, `to_date( )` will return a date value if it successfully parses the passed varchar2 value, or raise an exception if the passed varchar2 value is not a date in the format *MM/DD/YYYY*:

```
return to_date(aiv_date, 'MM/DD/YYYY');
```

Using this built-in function, create your function by following these steps.

1. Open your text editor, and code the DDL to create your function.
2. Save your new DDL script with the file name `to_mmsddsyyyy_or_null.fun`.
3. At your SQL*Plus prompt, type the at sign (@) followed by the name of your file in order to store and compile your new function.
4. Test your new function by using it in a SELECT statement against table DUAL.

Listing 2-3 shows my solution for this exercise.

Listing 2-3. An Errorless to_date( ) Function, to_mmsddsyyyy_or_null.fun

```
create or replace FUNCTION to_mmsddsyyyy_or_null (
aiv_date             in     varchar2 )
return                      date is
/*
to_mmsddsyyyy_or_null.fun
by Donald J. Bales on 2014-10-20
An errorless to_date( ) method
*/
begin
  return to_date(aiv_date, 'MM/DD/YYYY');
exception
  /*
  There are too many possible errors, for example:
    ORA-01830: date format picture ends before
               converting entire input string
    ORA-01843: not a valid month
    ORA-01847: day of month must be between 1
               and last day of month
    ORA-01858: a non-numeric character was found
               where a numeric was expected
  so I used the exception OTHERS
  */
  when OTHERS then
    return NULL;
end to_mmsddsyyyy_or_null;
/
@fe.sql to_mmsddsyyyy_or_null;
```

First, I'll test it using a `SELECT` statement against `DUAL`:

```
SQL> select to_mmsddsyyyy_or_null('A') from DUAL;
```

```
TO_MMSDDSYYYY_OR
----------------
```

Well, that worked. The `to_mmsddsyyyy_or_null()` function returned a `NULL` because the letter *A* is not a date in the form *MM/DD/YYYY*. So let's try a date string. This time, however, I'll execute the anonymous PL/SQL block in Listing 2-4 as a test unit in order to test the function.

Listing 2-4. A Test Unit for Function to_mmsddsyyyy_or_null( ), to_mmsddsyyyy_or_null.sql

```
01  rem to_mmsddsyyyy_or_null.sql
02  rem by Donald J. Bales on 2014-10-20
03  rem FUNCTION to_mmsddsyyyy_or_null() test unit
04
05  begin
06    sys.dbms_output.put_line(to_mmsddsyyyy_or_null('01/01/1980'));
07    sys.dbms_output.put_line(to_mmsddsyyyy_or_null('02/29/1980'));
08    sys.dbms_output.put_line(to_mmsddsyyyy_or_null('02/29/1981'));
09    sys.dbms_output.put_line(to_mmsddsyyyy_or_null('9/9/2006'));
10    sys.dbms_output.put_line(to_mmsddsyyyy_or_null('9/9/9999'));
11    sys.dbms_output.put_line(to_mmsddsyyyy_or_null('1/1/4712 BC'));
12  end;
13  /
```

The following output from executing function `to_mmsddsyyyy_or_null()`'s test unit shows that it's working great. The tests on lines 8 and 11 should have returned `NULL` because I passed invalid date strings, and they did!

```
SQL> @to_mmsddsyyyy_or_null.sql

01-JAN-80
29-FEB-80
09-SEP-06
09-SEP-99
PL/SQL procedure successfully completed.
```

Up to this point, you've seen an anonymous PL/SQL block and a function's PL/SQL block. The differences between the two are that an anonymous block is not permanently stored in the database with a name, nor can it return a value. Now let's take a look at PL/SQL blocks that do have names, but don't return values: procedures.

Procedures

PL/SQL procedures don't return a value. They just perform their instructions and return. Of course, this means that you can't use procedures on the right-hand side of an assignment statement like a function.

Create a Procedure

Listing 2-5 is a very simple example of a procedure. It's a wrapper around the Oracle `SYS.DBMS_LOCK` package's procedure `sleep(seconds in number)`. This procedure will stop executing (or sleep) without using many CPU cycles for the number of seconds specified. I'll admit, it's kind of lame, but we're just starting out here, so I'm keeping things simple.

■ **Note** By default, the `SYS.DBMS_LOCK` package is not accessible by non-DBA users. The username creation script in this book's appendix will grant you access, but if you don't use that script, you may need to ask your DBA to explicitly grant you execute access to package `SYS.DBMS_LOCK`.

Listing 2-5. A Wrapper Procedure for SYS.DBMS_LOCK.sleep( ), wait.prc

```
CREATE OR REPLACE PROCEDURE wait(
ain_seconds       IN     number) is
/*
wait.prc
by Donald J. Bales on 2014-10-20
Wrapper for SYS.DBMS_LOCK.sleep()
*/
begin
 SYS.DBMS_LOCK.sleep(ain_seconds);
end wait;
/
@pe.sql wait
```

The DDL syntax used by Listing 2-5 is as follows:

```
CREATE [OR REPLACE] PROCEDURE <procedure_name> [(
<parameter_name_1>         [IN] [OUT] <parameter_data_type_1>,
<parameter_name_2>         [IN] [OUT] <parameter_data_type_2>,...
<parameter_name_N>         [IN] [OUT] <parameter_data_type_N> )] IS
  --the declaration section
BEGIN
  -- the executable section
EXCEPTION
  -- the exception-handling section
END;
/
```

where `<procedure_name>` is the name of the `PROCEDURE`; `<parameter_name>` is the name of a parameter being passed `IN`, `OUT`, or `IN` and `OUT`; and `<parameter_data_type>` is the PL/SQL data type of the corresponding parameter. The brackets around the keywords `OR REPLACE` denote that they are optional. In addition, just as with a function, the brackets around the parameters denote that they are optional.

The block structure of a `PROCEDURE` is exactly the same as an anonymous block, except for the addition of the DDL `CREATE PROCEDURE` keywords and the optional parameters. A procedure differs from a function in that it does not have a `RETURN` parameter.

Let's take a look at Listing 2-5, line by line:

- Line 1 contains the DDL keywords to `CREATE` a stored `PROCEDURE`.
- Line 2 passes in one parameter: the number of seconds to wait.
- Lines 3 through 7, in the declaration section, have a multiline comment that documents the procedure's source code filename, author, date the procedure was written, and finally a comment about what the procedure does.
- On line 8, the keyword `BEGIN` starts the executable section.
- On line 9, I call the procedure `sleep()` located in package `DBMS_LOCK`, owned by user `SYS`. `sleep()` calls the host operating system's `sleep()` or wait function and then returns sometime after the specified period in seconds.
- On line 10, the keyword `END` ends the executable section. Did you notice that there is no defined exception-handling section? Since I didn't code one, PL/SQL will use the default exception handler, which will simply raise the error to the enclosing program unit.
- On line 11, the slash (`/`) tells Oracle to store and then compile the procedure.
- Line 12 calls a helper script to show any compilation errors.

The PL/SQL block structure for the stored procedure in Listing 2-5 was really not that much different from the structure of the anonymous procedure and the stored function. The `wait()` procedure has a name and parameters, while an anonymous procedure does not. In addition, `wait()` does not return a value, while a stored function does.

It's Your Turn to Create a Procedure

Now you'll create a procedure that wraps the `SYS.DBMS_OUTPUT.put_line()` procedure, but uses a very short name. You'll end up using the `SYS.DBMS_OUTPUT.put_line()` procedure a lot. It gets tiresome to type a 24-character method name every time you want to display a line of text on the screen in SQL*Plus. So, to save keystrokes, you will give your `SYS.DBMS_OUTPUT.put_line()` wrapper procedure the name `pl()`, as in `p` for put and `l` for line.

You can use the procedure in Listing 2-5 as a model. Just replace the parameter on line 2 with `aiv_text in varchar2`, and write line 9 with a call to `SYS.DBMS_OUTPUT.put_line(aiv_text)`.

1. Write the DDL to create your procedure.
2. Save your new DDL script with the file name `pl.prc`.
3. At your SQL*Plus prompt, type the at sign (`@`) followed by the name of your file to store and compile your new procedure.
4. Test your new procedure by using it in an anonymous procedure.

Listing 2-6 shows my solution for this exercise.

Listing 2-6. A Lazy Typist's SYS.DBMS_OUTPUT.put_line( ), pl.prc

```
create or replace PROCEDURE pl(
aiv_text            in     varchar2 ) is
/*
pl.prc
by Donald J. Bales on 2014-10-20
A wrapper procedure for SYS.DBMS_OUTPUT.put_line()
for the lazy typist.
*/

begin
  SYS.DBMS_OUTPUT.put_line(aiv_text);
end pl;
/
@pe.sql pl
```

Listing 2-7 is my test unit for procedure `pl()`.I've named it with the same file name as my procedure, except for the extension: I used `.prc` for the stored procedure and `.sql` for the anonymous procedure, its test unit. Since this is a wrapper procedure, I'm simply testing the known limits of procedure `SYS.DBMS_OUTPUT.put_line()` to make sure `pl()` is working properly.

Listing 2-7. A Test Unit for Procedure pl( ), pl.sql

```
rem pl.sql
rem by Donald J. Bales on 2014-10-20
rem pl's test unit

declare

  v_max_line varchar2(32767);

begin
  -- The next three lines initialize the
  -- variable v_max_line with 32,767 spaces.
  for i in 1..32767 loop
    v_max_line := v_max_line || ' ';
  end loop;

  pl('Test a line of text.');

  pl('Test a number, such as 1?');
  pl(1);

  pl('Test a date, such as 01/01/1980?');
  pl(to_date('19800101', 'YYYYMMDD'));

  pl('Test a line <= 32767');
  pl(v_max_line);

  pl('Test a line  > 32767');
  pl(v_max_line||' ');

```

```
30    pl('Test a multi-line');
31    pl('12345678901234567890123456789012345678901234567890'||
32       '12345678901234567890123456789012345678901234567890'||chr(10)||
33       '12345678901234567890123456789012345678901234567890'||
34       '12345678901234567890123456789012345678901234567890'||chr(10)||
35       '12345678901234567890123456789012345678901234567890'||
36       '12345678901234567890123456789012345678901234567890');
37  end;
38  /
```

Here's the output from my test unit:

```
SQL> @pl.sql
```

```
Test a line of text.
Test a number, such as 1?
1
Test a date, such as 01/01/1980?
01-JAN-80
Test a line <= 32767
Test a line  > 32767
declare
*
ERROR at line 1:
ORA-20000: ORU-10028: line length overflow, limit of 32767 bytes per line
ORA-06512: at "SYS.DBMS_OUTPUT", line 32
ORA-06512: at "SYS.DBMS_OUTPUT", line 91
ORA-06512: at "SYS.DBMS_OUTPUT", line 112
ORA-06512: at "RPS.PL", line 11
ORA-06512: at line 24
```

The line of text, number 1, date 01/01/1980, and line <= 32767 characters tests ran, but the last test, multiline, didn't because the > 32767 test threw an exception that was not handled. Let's see how the code can handle this problem.

Nested Blocks

You can, and should when necessary, nest PL/SQL blocks. To nest a PL/SQL block means to embed one or more PL/SQL blocks inside another PL/SQL block. Nesting PL/SQL blocks allows you greater control over your PL/SQL program's execution. You can wrap one or more PL/SQL or SQL statements in their own PL/SQL block, so you can catch an exception that is generated within that block. I call this "blocking" code. Let's look at an example.

An Example of Nesting Blocks

As you saw, the test unit for procedure `pl()` in Listing 2-7 stopped executing after line 28 because line 28 caused the following error:

```
ORA-20000: ORU-10028: line length overflow, limit of 32767 bytes per line
```

In Listing 2-8, I've recoded the `pl()` test unit. This time, I've blocked the lines that I expect to fail, so the program will catch any raised exceptions and continue processing the code all the way to the end of the source code listing.

Listing 2-8. The New, Improved pl( ) Test Unit, pl2.sql

```
rem pl2.sql
rem by Donald J. Bales on 2014-10-20
rem Test unit for procedure pl

declare
  v_max_line varchar2(32767);

begin
  -- The next three lines initialize a variable v_max_line with 32,767 spaces.
  for i in 1..32767 loop
    v_max_line := v_max_line || ' ';
  end loop;

  pl('Test a line of text.');

  pl('Test a number, such as 1?');
  pl(1);

  pl('Test a date, such as 01/01/1980?');
  pl(to_date('19800101', 'YYYYMMDD'));

  pl('Test a line <= 32767');
  pl(v_max_line);

  pl('Test a line  > 32767');
  begin
    pl(v_max_line||' ');
  exception
    when OTHERS then
      pl(SQLERRM);
  end;

  pl('Test a multi-line');
  begin
    pl('12345678901234567890123456789012345678901234567890'||
       '12345678901234567890123456789012345678901234567890'||chr(10)||
       '12345678901234567890123456789012345678901234567890'||
       '12345678901234567890123456789012345678901234567890'||chr(10)||
       '12345678901234567890123456789012345678901234567890'||
       '12345678901234567890123456789012345678901234567890');
  exception
    when OTHERS then
      pl(SQLERRM);
  end;
end;
/
```

The changed lines (highlighted in the listing) are as follows:

- Line 26 starts a nested block with the keyword `BEGIN` around the PL/SQL statement that will actually test > 32767.
- Line 28 contains a corresponding keyword `EXCEPTION` in order to create an exception-handling section for the nested PL/SQL block.
- Line 29 has the phrase `when OTHERS then` in order to catch all exceptions that can be generated within the nested block.
- On line 30, I once again call procedure `pl()`, but this time I display the exception error message: `SQLERRM`.
- On line 31, the nested block ends with the keyword `END`.
- Once again, on lines 34 and 41 through 44, I create a nested block around the next PL/SQL statement that I expect may fail.

Let's see the results of these changes:

```
SQL> @pl2.sql
Test a line of text.
Test a number, such as 1?
1
Test a date, such as 01/01/1980?
01-JAN-80
Test a line <= 32767
Test a line  > 32767
ORA-20000: ORU-10028: line length overflow, limit of 32767 bytes per line
Test a multi-line
12345678901234567890123456789012345678901234567890123456789012345678901234567890...

PL/SQL procedure successfully completed.
```

Great! Now my test unit completed successfully, and it reported the errors I expected to see. As we move through the chapters ahead, you'll get plenty of experience nesting PL/SQL blocks.

Rules for Nesting

Here are the rules I employ when it comes to blocking PL/SQL code:

- Block every SQL statement except cursors (you'll learn about cursors in Chapter 5).
- Block any PL/SQL statement where you are converting from one data type to another, or moving a possibly larger character string into a smaller character string variable (you'll learn about variables in Chapter 3).
- Block any PL/SQL statement that you expect will raise an exception.

The important point about these nesting rules is that blocking will enable you to identify the reason for and the location of an exception when it is raised. In turn, that will make your software development easier and the resulting programs more robust.

Packages

In practice, you'll rarely create a stand-alone stored function or procedure. Instead, you'll use a package. What is a package? A package is a means to organize related functions and procedures together, like creating a library, but in PL/SQL jargon the library is called a *package*.

A PL/SQL package has two parts:

- A package specification
- A package body

A package specification (spec) is the public face to the package. It lists any globally accessible constants, cursors, functions, procedures, and variables. By "globally accessible," I mean those procedures, functions, and other items that other PL/SQL programs can access. If you consider a package as a sort of library, then the package spec describes what you can read from that library, while the package body contains the behind-the-scenes code that implements the package spec.

Create a Package Specification

Listing 2-9 is an example of a package spec. It shows the package spec for the package DATE_, which is a utility package for date-related constants and functions.

Listing 2-9. The DATE_ Package Spec, date_.pks

```
create or replace package DATE_ AS
/*
date_.pks
by Donald J. Bales on 2014-10-20
Additional DATE data type methods.
*/

-- The maximum and minimum date values.

d_MAX                        constant date :=
  to_date('99991231235959', 'YYYYMMDDHH24MISS');
d_MIN                        constant date :=
  to_date('-47120101', 'SYYYYMMDD');


-- Returns the specified date with the time set to 23:59:59, therefore,
-- the end of the day.

FUNCTION end_of_day(
aid_date          in     date )
return            date;


-- Returns constant d_MAX. This is useful in SQL statements where the
-- constant DATE_.d_MAX is not accessible.

```

```
FUNCTION get_max
return          date;


-- Returns constant d_MIN. This is useful in SQL statements where the
-- constant DATE_.d_MIN is not accessible.

FUNCTION get_min
return          date;


-- Text-based help for this package. "set serveroutput on" in SQL*Plus.

PROCEDURE help;


-- Returns a randomly generated date that exists between the years specified.

FUNCTION random(
ain_starting_year  in     number,
ain_ending_year    in     number )
return                    date;


-- Returns the specified date with the time set to 00:00:00, therefore, the
-- start of the day.

FUNCTION start_of_day(
aid_date          in     date )
return                   date;


-- Test unit for this package.

PROCEDURE test;


end DATE_;
/
@se.sql DATE_
```

The DDL syntax used to create the package spec in Listing 2-9 is as follows:

```
CREATE [OR REPLACE] PACKAGE <package_name> AS
-- one or more: constant, cursor, function, procedure, or variable declarations
END <package_name>;
```

where <package_name> is the name of the package you're creating.

Not much to a package spec? Sure there is. Now, instead of using the DDL `CREATE FUNCTION` or `CREATE PROCEDURE`, you'll use the keywords `FUNCTION` and `PROCEDURE` for each PL/SQL method you want to declare globally.

Let's take a look at the package spec in Listing 2-9:

- Line 1 uses the DDL keywords to `CREATE` a stored `PACKAGE` specification.
- Lines 10 and 12 declare two global constants (ones available to any other PL/SQL stored procedure), `d_MAX` and `d_MIN`, which are the current maximum and minimum date values supported by Oracle.
- Lines 19, 27, 34, 45, and 54 declare five date functions. Please note that these are only declarations; they have no code. The code will be found in the package body.
- Lines 40 and 61 declare two "helper" procedures. I will discuss these helper procedures in great length in Chapters 7, 8, and 9.
- Line 64 ends the `PACKAGE` declaration with the keyword `END`.
- On line 65, I tell Oracle to store and compile the package spec.
- Line 66 calls a helper SQL script to show any errors.

You may also have noticed that I took the time to document the purpose of every declaration in the package spec. You should do the same. Documenting as you go is one of the major characteristics of a professional PL/SQL programmer.

It's Your Turn to Create a Package Specification

Do you remember the function `to_number_or_null()` in Listing 2-2? Now you will create a package called `NUMBER_` that has it as one of its methods. Mimic what I just showed you as you follow these steps.

1. Write the DDL to create a package spec called `NUMBER_`.
2. Save your DDL script as `number_.pks`.
3. Execute your DDL script in SQL*Plus: `SQL> @number_.pks`.
4. Type `desc number_` at the SQL*Plus prompt to verify that your package spec exists.

As usual, if you get any errors, figure out what's wrong so you can compile the script successfully. Remember to use the script in Listing 2-9 as a model. Listing 2-10 shows my solution.

Listing 2-10. The NUMBER_ Package Spec, number_.pks

```
create or replace package NUMBER_ as
/*
number_.pks
by Donald J. Bales on 2014-10-20
A utility package for the data type NUMBER
*/

/*
Returns the passed varchar2 as a number if it represents a number,
otherwise, it returns NULL
*/
```

```
FUNCTION to_number_or_null (
aiv_number          in     varchar2 )
return                     number;

end NUMBER_;
/
@se.sql
```

There's no way to test the package spec, because there's no code yet. The code goes in the package body.

Create a Package Body

A package body is the implementation for a package spec. It must contain the code for any functions or procedures declared in its corresponding package spec. In addition, the body can also contain any constant, cursor, function, procedure, or variable that should be accessible within the package body (that is, not publicly accessible). Let's take a look at the corresponding package body for package DATE_.

I'm about to show you a package body that has a lot of PL/SQL code that we haven't covered yet. Don't worry too much about the code itself. You won't understand it all now, but you'll be able to understand it after finishing this book. What you need to take away from this example is the package body structure, which is also a PL/SQL block structure. Let's look at Listing 2-11.

Listing 2-11. The DATE_ Package Body, date_.pkb

```
create or replace package body DATE_ AS
/*
date_.pkb
by Donald J. Bales on 2014-10-20
Additional DATE data type methods
*/


FUNCTION end_of_day(
aid_date          in     date )
return                   date is

begin
 return to_date(to_char(aid_date, 'SYYYYMMDD')||'235959',
   'SYYYYMMDDHH24MISS');
end end_of_day;


FUNCTION get_max
return            date is

begin
 return d_MAX;
end get_max;


```

```
FUNCTION get_min
return            date is

begin
 return d_MIN;
end get_min;


FUNCTION random(
ain_starting_year in     number,
ain_ending_year   in     number )
return                   date is

d_random                 date;
n_day                    number;
n_month                  number;
n_year                   number;

begin
  n_year    := round(DBMS_RANDOM.value(
    ain_starting_year, ain_ending_year), 0);
  --pl('n_year='||n_year);
  loop
    n_month := round(DBMS_RANDOM.value(1, 12), 0);
    --pl('n_month='||n_month);
    n_day   := round(DBMS_RANDOM.value(1, 31), 0);
    --pl('n_day='||n_day);
    begin
      d_random := to_date(lpad(to_char(n_year),  4, '0')||
                          lpad(to_char(n_month), 2, '0')||
                          lpad(to_char(n_day),   2, '0'),
                          'YYYYMMDD');
      exit;
    exception
      when OTHERS then
        if SQLCODE <> -1839 then
          pl(SQLERRM);
        --else
        --  pl('29-31');
        end if;
    end;
  end loop;
  return d_random;
end random;


FUNCTION start_of_day(
aid_date            in     date )
return                     date is

```

```
begin
 return trunc(aid_date);
end start_of_day;


-- Write up the help text here in this help method
PROCEDURE help is

begin
--   1234567890123456789012345678901234567890123456789012345678901234567890
  pl('============================== PACKAGE ==============================');
  pl(chr(9));
  pl('DATE_');
  pl(chr(9));
  pl('------------------------------ CONSTANTS ----------------------------');
  pl(chr(9));
  pl('d_MAX');
  pl(chr(9)||'Represents the maximum value for the DATE data type.');
  pl('d_MIN');
  pl(chr(9)||'Represents the minimum value for the DATE data type.');
  pl(chr(9));
  pl('------------------------------ FUNCTIONS ----------------------------');
  pl(chr(9));
  pl('DATE_.end_of_day(');
  pl('aid_date            in     date)');
  pl('return                     date;');
  pl(chr(9)||'Returns the passed date with the time portion set to the end ');
  pl(chr(9)||'of the day:');
  pl(chr(9)||'23:59:59 (HH24:MI:SS).');
  pl(chr(9));
  pl('DATE_.get_max( )');
  pl('return                     date;');
  pl(chr(9)||'Returns the constant DATE_.d_MAX.');
  pl(chr(9));
  pl('DATE_.get_mim( )');
  pl('return                     date;');
  pl(chr(9)||'Returns the constant DATE_.d_MIN.');
  pl(chr(9));
  pl('DATE_.random(');
  pl('ain_starting_year   in     number,');
  pl('ain_ending_year     in     number)');
  pl('return                                date;');
  pl(chr(9)||'Returns a random date that exists between the specified years.');
  pl(chr(9));
  pl('DATE_.start_of_day(');
  pl('aid_date            in     date)');
  pl('return                     date;');
  pl(chr(9)||'Returns the passed date with the time portion set to the start');
  pl(chr(9)||'of the day:');
  pl(chr(9)||'00:00:00 (HH24:MI:SS).');
  pl(chr(9));
  pl('------------------------------ PROCEDURES ----------------------------');
  pl(chr(9));
  pl('DATE_.help( );');
  pl(chr(9)||'Displays this help text if set serveroutput is on.');
  pl(chr(9));
  pl('DATE_.test( );');
  pl(chr(9)||'Built-in test unit. It will report success or error for each');
  pl(chr(9)||'test if set');
  pl(chr(9)||'serveroutput is on.');
  pl(chr(9));
end help;


PROCEDURE test is

d_date            date;

begin
  pl('============================== PACKAGE ===============================');
  pl(chr(9));
  pl('DATE_');
  pl(chr(9));
  pl('1. Testing constants d_MIN and d_MAX');
  if d_MIN < d_MAX then
   pl('SUCCESS');
  else
   pl('ERROR: d_MIN is not less than d_MAX');
  end if;

  pl('2. Testing end_of_day()');
  if to_char(end_of_day(SYSDATE), 'HH24MISS') = '235959' then
   pl('SUCCESS');
  else
   pl('ERROR: end_of_day is not 23:59:59');
  end if;

  pl('3. Testing get_max()');
  if get_max() = d_MAX then
   pl('SUCCESS');
  else
   pl('ERROR: get_max() is not equal to d_MAX');
  end if;

  pl('4. Testing get_min()');
  if get_min() = d_MIN then
   pl('SUCCESS');
  else
   pl('ERROR: get_min() is not equal to d_MIN');
  end if;

  pl('5. Testing random() 1000 times');
  for i in 1..1000 loop
    d_date := random(1, 9999);
    --pl(to_char(d_date, 'YYYY-MM-DD HH24:MI:SS'));
  end loop;
  pl('SUCCESS');

  pl('6. Testing start_of_day()');
  if to_char(start_of_day(SYSDATE), 'HH24MISS') = '000000' then
   pl('SUCCESS');
  else
   pl('ERROR: start_of_day is not 00:00:00');
  end if;
end test;


end DATE_;
/
@be.sql DATE_
```

The DDL syntax used to create the package body in Listing 2-11 is as follows:

```
CREATE [OR REPLACE] PACKAGE BODY <package_name> AS
-- one or more constant, cursor, or variable declarations
-- one or more function, or procedure implementations
[BEGIN]
-- you can code a PL/SQL block called an initialization section that is
-- executed only once per session, when the package is first instantiated
-- into memory
[EXCEPTION]
-- you can code an exception-handling section for the initialization section
END <package_name>;
```

where <package_name> is the name of the package body you're creating.

Did you notice the two optional sections? If you have some initialization code that you want to run the first time a package is loaded into memory, you can use the keyword `BEGIN` to start an initialization section. And if you want an exception-handling section for your initialization section, you can add it by using the keyword `EXCEPTION`. This is classic PL/SQL block structure.

Your implementations of functions and procedures are actually embedded functions and procedures in the declaration section of a PL/SQL block! Any constant, cursor, or variable that you declare in the declaration section of the package body is accessible to all the declared functions and procedures in that section, but not globally to other stored procedures. Only the items you declared in the package spec are accessible to other stored procedures.

As I noted at the beginning of this section, Listing 2-11 contains a lot of code that we haven't yet discussed, so I'll leave its explanation for later chapters.

■ **Note** In Listing 2-11, if I had declared any package body (or instance) functions or procedures—ones not accessible outside the package body—I would take time to document the purpose of the instance declaration in the package body. You should do the same. Once again, I declare that professional PL/SQL programmers document as they go.

It's Your Turn to Create a Package Body

You should already have a package spec created for the `NUMBER_` package, as in Listing 2-10. Now it's time create the corresponding package body. It's almost like the package spec, except for the keyword `BODY` in the DDL and the function `to_number_or_null()`'s implementation, as in Listing 2-2. Create your package body by following these steps.

1. Write the DDL to create a package body called `NUMBER_`.
2. Save your DDL script as `number_.pkb`.
3. Execute your DDL script in SQL*Plus: `SQL> @number_.pkb`.
4. Test your function using a `SELECT` statement, just as you did way back in the section on functions. This time, however, you'll prefix the function name with the name of your package.

Again, if you get any errors, work on your script until you figure out what's wrong so you can compile the script successfully. Listing 2-12 shows my solution.

Listing 2-12. The NUMBER_ Package Body, number_.pkb

```
create or replace package body NUMBER_ as
/*
number_.pkb
by Donald J. Bales on 2014-10-20
A utility package for the data type NUMBER
*/

FUNCTION to_number_or_null (
aiv_number           in     varchar2 )
return                      number is
begin
  return to_number(aiv_number);
exception
  when OTHERS then
    return NULL;
end to_number_or_null;

end NUMBER_;
/
@be.sql
```

Benefits of Using Packages

As I mentioned earlier, anything declared in a package spec can be seen by any username that has execute privileges on the package. Package specs also reduce dependency invalidation issues. What does that mean?

Say that `procedure1` calls `function1` and is called by `procedure2`. Then if you change `function1`, `function1` becomes invalid, and so do `procedure1` and `procedure2`. This means you need to recompile all three PL/SQL programs. This chain of dependency can be broken by using packages.

Now suppose that you use packages: `package1.procedure1` calls `package2.function1`, and it is called by `package3.procedure2`. If you change the package implementation, or body, of `package2.function1`, it will not cause the invalidation of the function, nor any dependent PL/SQL blocks. You will cause dependent PL/SQL blocks to be invalidated only if you change the package spec.

Summary

Table 2-1 shows a side-by-side comparison of the syntax used for the various types of PL/SQL blocks covered in this chapter. The point here is that PL/SQL code always exists in a PL/SQL block, and that PL/SQL blocks are quite consistent in their structure. Even nested PL/SQL blocks are consistent with the ones shown in Table 2-1.

Table 2-1. *A Comparison of PL/SQL Block Syntax*

ANONYMOUS [DECLARE]	CREATE FUNCTION	CREATE PROCEDURE	CREATE PACKAGE	CREATE PACKAGE BODY
	[parameters]	[parameters]		
	`RETURN`			
[declaration section]	declaration section	declaration section	declaration section	declaration section
`BEGIN`	`BEGIN`	`BEGIN`		`[BEGIN]`
executable section	executable section	executable section		executable section]
`[EXCEPTION]`	`[EXCEPTION]`	`[EXCEPTION]`		`[EXCEPTION]`
[exception-handling section]	[exception-handling section]	[exception-handling section]		[exception-handling section]
`END;`	`END;`	`END;`	`END;`	`END;`
`/`	`/`	`/`	`/`	`/`

Now that you have a firm understanding of the block structure of PL/SQL, you're ready to move on to the next step: learning about PL/SQL data types and variables.

CHAPTER 3

Types, Variables, and Scope

This chapter is all about how to keep track of variables in a PL/SQL program. Before this chapter ends, you'll learn about PL/SQL data types, variables, scope, types, and parameters. Let's get started.

PL/SQL Data Types

Given that PL/SQL is the Procedural Language extension for SQL, you would think that it supports and uses the same data types as SQL does for the database, right? Right! It turns out that is almost the case, but not quite. PL/SQL can handle any database data type and also some data types of its own.

Do you remember the "Data Definition Language (DDL)" section in Chapter 1? In it, I talked about the three basic data types that you will use all the time: character (`VARCHAR2`), numeric (`NUMBER`), and time (`DATE`). Here's how those types work in PL/SQL:

- `VARCHAR2`: Just as in the database, most of the time you'll work with character strings in PL/SQL using the data type `VARCHAR2`. However, unlike the database `VARCHAR2` type, a PL/SQL `VARCHAR2` can hold as many as 32,767 characters, whereas the database type prior to Oracle12c only holds up to 4,000.
- `NUMBER`: Just as in the database, most of the time you'll work with numbers in PL/SQL using the data type `NUMBER`. And, just like the database, PL/SQL has additional numeric data types available. For example, you can use the type `PLS_INTEGER`, which has an integer range from –2147483648 to 2147483647. `PLS_INTEGER` also uses the computer's hardware to do its calculations instead of library routines, so it's faster. However, until you're comfortable writing stored procedures with PL/SQL, I don't think you need to bother with them. You can always take a look at them in Oracle's *PL/SQL User's Guide and Reference* when you're ready.
- `DATE`: Just as in the database, most of the time you'll work with dates and times in PL/SQL using data type `DATE`. Like `NUMBER`, PL/SQL has additional time-related data types. Check them out in Oracle's reference once you're up and coding confidently.

PL/SQL also has a `BOOLEAN` data type that allows you to store the logical values `FALSE` or `TRUE` in a variable. SQL has no equivalent. So you can pass `BOOLEAN` values between methods and use them as variables in your PL/SQL program units, but you can't store them in the database.

Of course, there are many more Oracle SQL and PL/SQL data types, but the ones I just covered are the ones you'll use most often.

Variables

Variables are named temporary storage locations that support a particular data type in your PL/SQL program. You must declare them in the declaration section of a PL/SQL block.

By "named," I mean that you give each of your variables a name. They are temporary because the values you assign to variables typically exist only in memory (or are accessible in memory) while the PL/SQL block in which they are declared is executing. They are storage locations in memory. And they are declared to store a particular data type so PL/SQL knows how to create, store, access, and destroy them.

Let's start by looking at how to name your variables.

Variable Naming

Like a SQL or database data type, PL/SQL variables must follow the identifier naming rules:

- A variable name must be less than 31 characters in length.
- A variable name must start with an uppercase or lowercase ASCII letter: A–Z or a–z. PL/SQL is not case-sensitive.
- A variable name may be composed of 1 letter, followed by up to 29 letters, numbers, or the underscore (_) character. You can also use the number (#) and dollar sign ($) characters.

As a matter of fact, all PL/SQL identifiers, like stored function and procedure names, must follow these naming rules!

I like to use the following conventions when naming variables:

- Use the two-character prefix for each data type, as defined in Table 3-1.
- Make its purpose obvious. If the variable will hold a value from the database, use the same name as in the database, but with the appropriate prefix.

Table 3-1. *My PL/SQL Variable Naming Prefixes*

Prefix	Data Type
`c_`	`CURSOR`
`d_`	`DATE`
`n_`	`NUMBER`
`r_`	`ROW`
`t_`	`TABLE`
`v_`	`VARCHAR2`

For example, if I were to declare variables to hold data from the columns in the `AUTHORS` table, I would use the following identifier names:

- `n_id`
- `v_name`
- `d_birth_date`
- `v_gender`

The advantage of using these prefixes is that you'll always know the variable's data type and its scope. (I'll cover scope shortly.) In addition, since you made the name obvious, you'll also know where it comes from or where it's going.

By "obvious," I mean that you shouldn't use a synonym for an already existing identifier. For example, don't create variables named `d_born`, `d_date_of_birth`, and `d_bday` for a value from the `birth_date` column in the database. Why? All those name variations will just make what you're referring to unclear, and all professional PL/SQL programmers want to make it absolutely clear what is going on in their code!

Now that you know how to name your variables, let's look at how to declare them.

Variable Declarations

To declare a variable, type the variable name (identifier) followed by the data type definition, as you would use in SQL, terminated by a semicolon (`;`). The data type definition is the name of the data type, possibly followed by length constraints in a set of parentheses. For example, to declare variables to hold the data from columns in the `AUTHORS` table, I could code the following in a PL/SQL block's declaration section:

```
declare

  n_id                                  number;
  v_name                                varchar2(100);
  d_birth_date                          date;
  v_gender                              varchar2(30);

begin
  ...
end;
```

The DDL syntax used to declare the preceding variables is as follows:

```
<variable_name>  <data_type>;
```

where `<variable_name>` is the name of the variable (or identifier), and `<data_type>` is one of the PL/SQL data types.

You'll notice that if you get rid of the data type prefixes, variable declarations look just like the SQL in the table definition for `AUTHORS` in Chapter 1, and that's the whole point. They should! It wouldn't make much sense to declare `varchar2` variables that are smaller than the ones in the database because that could cause an error. And it doesn't make much sense to name them differently than what they're named in the database because that would just make things confusing. That's why I use those prefixes shown in Table 3-1.

Most of the time, you'll end up declaring variables that temporarily hold values from or that are going into the database, and PL/SQL has a keyword for simplifying just that situation: `%TYPE`.

Variable Anchors

An *anchor* refers to the use of the keyword `%TYPE` to "anchor" a PL/SQL data type definition in a PL/SQL variable to the corresponding SQL data type definition of a column in a table. Steven Feuerstein coined the term *anchor*, and I've always liked it, so I use it whenever I talk about the keyword `%TYPE`.

Here's an example of the PL/SQL variables for the table AUTHORS declared using column anchors (the %TYPE keyword):

```
n_id                                AUTHORS.id%TYPE;
v_name                              AUTHORS.name%TYPE;
d_birth_date                        AUTHORS.birth_date%TYPE;
v_gender                            AUTHORS.gender%TYPE;
```

The syntax used to declare the preceding variables is as follows:

```
<variable_name>  <table_name>.<column_name>%TYPE;
```

where `<variable_name>` is the name of the variable (or identifier), `<table_name>` is the name of the table used to anchor the data type, and `<column_name>` is the name of the column used to anchor the data type.

Programming in PL/SQL just keeps getting better, doesn't it? By using anchors, you now know that the variables use the same data types and sizes as the table that will be the source of, or permanent storage for, each variable's value. Even when I use anchors, I still use data type prefixes in order to remind me of the variables' data types.

Now that you've seen how to declare variables, let's talk about how to assign values to them.

Variable Assignments

To assign a literal value to a variable in PL/SQL, you use the assignment operator, which is a colon (`:`) followed by an equal sign (=): `:=`. For example, I can make the following assignments:

```
declare
  ...
begin

  n_id         := 400;
  v_name       := 'STEVEN FEUERSTEIN';
  d_birth_date := to_date('19800101', 'YYYYMMDD');
  v_gender     := 'M';

end;
```

What do I mean by "a literal value"? OK, let's back up a second.

- A numeric literal is just a number without any formatting, such as 400.
- A character literal is just a string of characters enclosed in a pair of tick (`'`) characters (or single quotes), such as `'STEVEN FEUERSTEIN'`.

There is no such thing as a date literal. You can assign a character literal and hope the format you decided to use matches the current NLS_DATE_FORMAT (automatic type conversion—dangerous, very dangerous), or you can use the built-in function,

```
to_date(aiv_date in varchar2, aiv_date_format in varchar2)
```

A second way to assign a value to a variable is to use an INTO clause in a SQL SELECT statement. Here's an example:

```
select id,
       name,
       birth_date,
       gender
into   n_id
       v_name,
       d_birth_date,
       v_gender
from   AUTHORS
where  AUTHORS.id = (
  select AUTHOR_PUBLICATIONS.author_id
  from   AUTHRO_PUBLICATIONS
  where  title = 'ORACLE PL/SQL PROGRAMMING');
```

In this example, the PL/SQL keyword INTO moves the values from the SELECT statement's column list into the corresponding PL/SQL variables. I'll talk a lot more about this in Chapter 4.

By default, variables are uninitialized and hence are NULL. You can initialize them to a value when they are declared by simply assigning them a value in the declaration section. For example, you could initialize the AUTHORS variables as follows:

```
declare

  n_id          AUTHORS.id%TYPE         := 400;
  v_name        AUTHORS.name%TYPE       := 'STEVEN FEUERSTEIN';
  d_birth_date  AUTHORS.birth_date%TYPE := to_date('19800101', 'YYYYMMDD');
  v_gender      AUTHORS.gender%TYPE     := NULL;

begin
  ...
end;
```

The syntax used to declare the preceding variables is as follows:

```
<variable_name>  <table_name>.<column_name>%TYPE := <value>;
```

where <variable_name> is the name of the variable (or identifier), <table_name> is the name of the table used to anchor the data type, <column_name> is the name of the column used to anchor the data type, and <value> is the initial value for the variable. But what exactly is NULL?

NULL Value

The term `NULL` *value* is a bit of a misnomer. The keyword `NULL` means *I don't know!* The keyword `NULL` means *you don't know!* The keyword NULL means *it is not possible to know what the value is*, so how can there be something such as a `NULL` value? Let's further define `NULL`:

- `NULL` is not equal to anything, not even `NULL`.
- `NULL` is not less than or greater than anything else, not even `NULL`.
- `NULL` means nothing knows, not even `NULL`.

You can test for `NULL` values in a SQL statement or PL/SQL code by using one of two phrases:

- `is NULL`
- `is not NULL`

Although the PL/SQL compiler may let you, you cannot use a logical operator with `NULL`, like

```
= NULL
```

or

```
<> NULL
```

and get the logical results you're seeking.

You must use `is NULL` and `is not NULL`. Remember this and you will save yourself many hours of troubleshooting erratic behavior.

It's Your Turn to Declare Variables

Now that you're familiar with the declaration of variables, let's put you to work. Create an anonymous PL/SQL procedure where you declare variables using anchors, and with default values, for the columns in the `WORKERS` table. Follow these steps.

1. Code your anonymous procedure.
2. Save it with the file name `workers_variables.sql`.
3. Execute your script in SQL*Plus: `SQL> @workers_variables.sql`.

Listing 3-1 is my solution for this problem.

Listing 3-1. An Anonymous PL/SQL Procedure with Variable Declarations, workers_variables.sql

```
declare
  n_id              WORKERS.id%TYPE             := 1;
  n_worker_type_id  WORKERS.worker_type_id%TYPE := 3;
  v_external_id     WORKERS.external_id%TYPE    := '6305551212';
  v_first_name      WORKERS.first_name%TYPE     := 'JANE';
  v_middle_name     WORKERS.middle_name%TYPE    := 'E';
  v_last_name       WORKERS.last_name%TYPE      := 'DOE';
  v_name            WORKERS.name%TYPE           := 'JANEDOEE';
  d_birth_date      WORKERS.birth_date%TYPE     :=
    to_date('19800101', 'YYYYMMDD');
```

```
11    n_gender_type_id  WORKERS.gender_type_id%TYPE := 1;
12  begin
13    null;
14  end;
15  /
```

Let's break Listing 3-1 down line by line:

- Line 1 uses the keyword `DECLARE` to start an anonymous PL/SQL procedure.
- Lines 2 through 11 declare variables to hold the contents of the columns from the `WORKERS` table.
- Line 12 starts the executable section of the procedure with the keyword `BEGIN`.
- On line 13, I coded a no operation (`NULL`) so the block will compile.
- Line 14 ends the procedure with the keyword `END`.
- On line 15, I tell Oracle to compile and execute the procedure.

Now that you're an expert at declaring variables, let's take a look at when they are in scope.

Scope

In this context, *scope* refers to when a declared item can be seen by another PL/SQL block. And yes, I'm not just talking about variables here; I'm talking about any kind of declared item: a constant, cursor, function, procedure, or variable.

Scope Rules

The following is a list of rules for scope. As you go through the list, it may be helpful for you to examine Figure 3-1.

- Any item declared in the declaration section of a function or procedure is visible only within the same function or procedure.
- Any item declared in the declaration section of a package body is visible only within any other item in the same package body.
- Any item declared in a package specification is visible to any other stored function, stored procedure, and package for which the owner of the calling method has execute privileges.

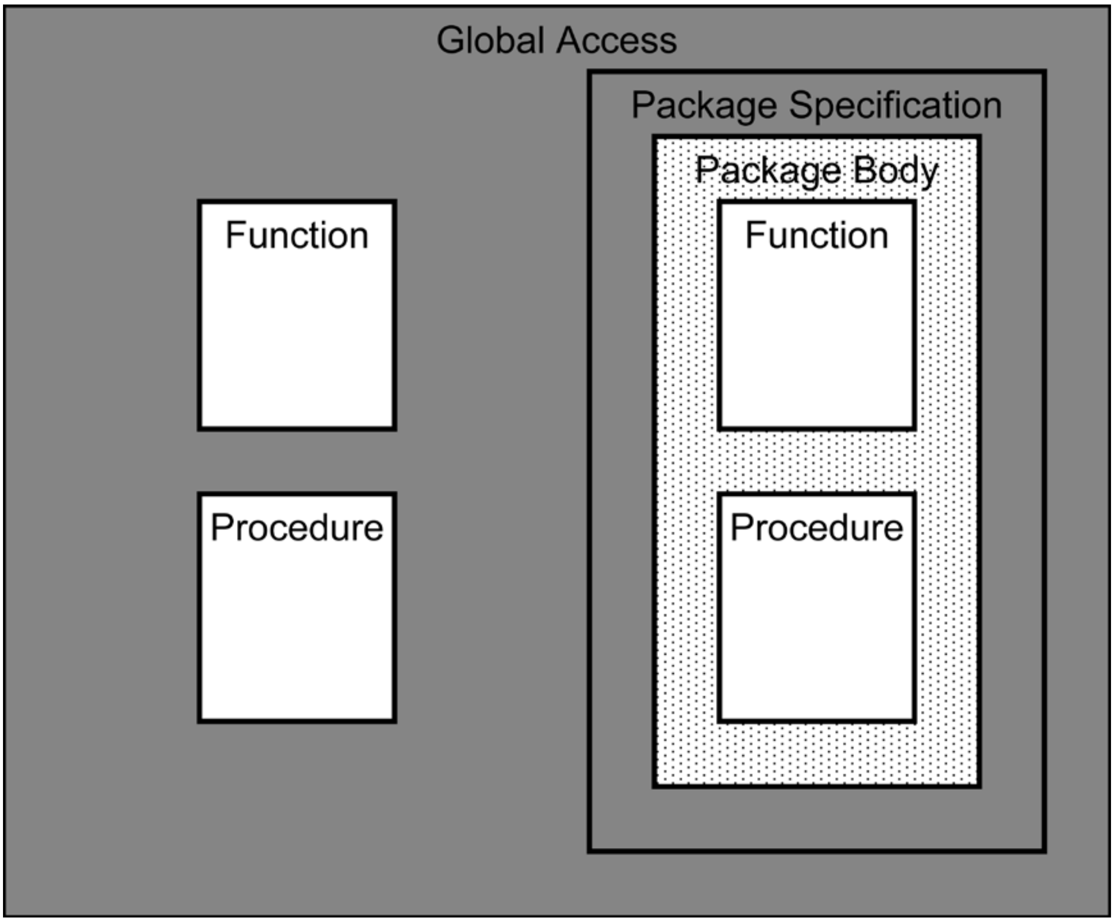


Figure 3-1. *Where an item is declared detemines its scope*

Listings 3-2 and 3-3 are a package spec and package body, respectively, to test scope. Listing 3-2 declares a global function, procedure, and variable in the package spec. Listing 3-3 declares an instance function, a procedure, and a variable. And, in the function and procedure implementations, I've declared local variables.

Listing 3-2. A Package Spec to Test Scope, scope.pks

```
create or replace package SCOPE as
/*
scope.pks
by Donald J. Bales on 2014-10-20
A package to test scope
*/

```

```
-- Here's a global variable declaration
gv_scope                              varchar2(80) :=
  'I''m a global (or package spec) variable';

-- Here's a global (or package spec) function declaration
FUNCTION my_scope_is_global
return                                varchar2;

-- Here's a global (or package spec) procedure declaration
PROCEDURE my_scope_is_global;


end SCOPE;
/
@se.sql SCOPE
```

Listing 3-3. A Package Body to Test Scope, scope.pkb

```
create or replace package body SCOPE as
/*
scope.pkb
by Donald J. Bales on 2014-10-20
A package to test scope
*/

-- Here's an instance (or package body) variable declaration
iv_scope                              varchar2(80) :=
  'I''m an instance (or package body) variable';


-- Here's an instance (or package body) function declaration
FUNCTION my_scope_is_instance
return                                varchar2 is
v_answer_1                            varchar2(3) := 'Yes';
begin
  pl(chr(9)||'Can function my_scope_is_instance see variable gv_scope?');
  pl(chr(9)||gv_scope);
  return v_answer_1;
end my_scope_is_instance;


-- Here's a global (or package spec) function declaration
FUNCTION my_scope_is_global
return                                varchar2 is
v_answer_2                            varchar2(3) := 'Yes';
begin
  pl(chr(9)||'Can function my_scope_is_global see variable iv_scope?');
  pl(chr(9)||iv_scope);
  return v_answer_2;
end my_scope_is_global;
```

```


-- Here's an instance (or package body) procedure declaration
PROCEDURE my_scope_is_instance is
v_answer_3                            varchar2(3) := 'Yes';
begin
  pl(chr(9)||'Can procedure my_scope_is_instance see variable gv_scope?');
  pl(chr(9)||gv_scope);
  pl(v_answer_3);
end my_scope_is_instance;


-- Here's a global (or package spec) procedure declaration
PROCEDURE my_scope_is_global is
v_answer_4                            varchar2(3) := 'Yes';
begin
  pl(chr(9)||'Can procedure my_scope_is_global see variable iv_scope?');
  pl(chr(9)||iv_scope);
  pl(v_answer_4);
end my_scope_is_global;


end SCOPE;
/
@se.sql SCOPE
```

Take some time to look over the two code listings. At this point, you should be able to understand the PL/SQL block structure of the package, and the methods declared and implemented in it, along with the variable declarations. The point now is to understand when a given function, procedure, or variable is in scope.

Listing 3-4 is an anonymous PL/SQL procedure that I wrote as a test unit for package SCOPE, specifically to help you understand when a declared item is in scope.

Listing 3-4. A Test Unit for Package SCOPE, scope.sql

```
rem scope.sql
rem by Donald J. Bales on 2014-10-20
rem Test unit for package scope

declare

-- ANONYMOUS PL/SQL BLOCK'S DECLARATION SECTION --

v_scope                               varchar2(40) :=
  'I''m a local variable';

```

```
-- This is a local (or embedded) function
FUNCTION my_scope_is_local
return                                varchar2 is
v_answer_0                            varchar2(3) := 'Yes';
begin
  return v_answer_0;
end my_scope_is_local;

-- This is a local (or embedded) procedure
PROCEDURE my_scope_is_local is
v_answer                              varchar2(3) := 'Yes';
begin
  pl(v_answer);
end my_scope_is_local;

begin

-- ANONYMOUS PL/SQL BLOCK'S EXECUTABLE SECTION --

  pl('Can I access my local variable?');
  pl(v_scope);
  pl('Can I access SCOPE'' global variable?');
  pl(SCOPE.gv_scope);
  pl('Can I access SCOPE'' instance variable?');
  --pl(SCOPE.iv_scope);
  pl('No!');

  pl('Can I access my local function?');
  pl(my_scope_is_local());
  pl('Can I access SCOPE'' global function?');
  pl(SCOPE.my_scope_is_global());
  pl('Can I access SCOPE'' instance function?');
  --pl(SCOPE.my_scope_is_instance());
  pl('No!');

  pl('Can I access my local procedure?');
  my_scope_is_local();
  pl('Can I access SCOPE'' global procedure?');
  SCOPE.my_scope_is_global();
  pl('Can I access SCOPE'' instance procedure?');
  --SCOPE.my_scope_is_instance();
  pl('No!');

end;
/
```

After I have compile `scope.pks` and `scope.pkb`, when I execute `scopes.sql` from Listing 3-4, I get the following output from SQL*Plus:

```
SQL> @scopes.sql
```

```
Can I access my local variable?
I'm a local variable
Can I access SCOPE' global variable?
I'm a global (or package spec) variable
Can I access SCOPE' instance variable?
No!
Can I access my local function?
Yes
Can I access SCOPE' global function?
        Can function my_scope_is_global see variable iv_scope?
        I'm an instance (or package body) variable
Yes
Can I access SCOPE' instance function?
No!
Can I access my local procedure?
Yes
Can I access SCOPE' global procedure?
        Can procedure my_scope_is_global see variable iv_scope?
        I'm an instance (or package body) variable
Yes
Can I access SCOPE' instance procedure?
No!

PL/SQL procedure successfully completed.
```

If you examine all three code listings and the SQL*Plus output carefully, you'll see that you can access any item

- Declared in a package specification, granted you have access to it.
- Declared in a package body, if the calling declared item also exists in the same package body.
- Declared in a function or procedure, if you're trying to access it from the same function or procedure.

Perhaps you would like to try testing the scope rules yourself?

It's Your Turn to Scope Things Out

There's nothing like hacking to see how things work. So put on your hacker's hat and take the anonymous procedure in `scope.sql` for a ride.

1. Compile `scope.pks`.
2. Compile `scope.pkb`.
3. Try alternatively removing the single-line comments characters on lines 36, 44, and 52 in `scopes.sql`, and then execute the script.

Each time you try to access a declared item that is out of scope, PL/SQL will let you know exactly where the coding problem exists in you source code.

Now that you have a firm understanding of scope, let's step it up a notch.

Types

No discussion of declaring variables would be complete, nor would any programming language itself be complete, without mentioning arrays. PL/SQL supports three kinds of arrays, or as they are known in PL/SQL jargon, *collections*. I will discuss only one kind here: *associative arrays*. Originally called PL/SQL tables, associative arrays provide you with the means to create a single-dimension array. Associative arrays can be based on almost any data type. However, you'll typically use one of the data types already covered.

Table Types

By table TYPEs, I'm not referring to SQL tables that are used to permanently store data, but PL/SQL tables (or associative arrays), which are used to temporarily store data in memory. Listing 3-5 is an anonymous PL/SQL procedure that demonstrates how to declare an associative array (or PL/SQL table). You'll see that declaring an associative array consists of two steps.

1. Declare the new TYPE.
2. Declare a new variable of that TYPE.

Listing 3-5. Declaring a PL/SQL Table with a Column Data Type, table.sql

```
rem table.sql
rem by Don Bales on 2014-10-20
rem An anonymous PL/SQL procedure to demonstrate
rem the elementary use of PL/SQL tables

declare

TYPE name_table IS TABLE OF WORKERS.name%TYPE
INDEX BY BINARY_INTEGER;

t_name                              name_table;

n_name                              binary_integer;

begin
  t_name(1)  := 'DOE, JOHN';
  t_name(10) := 'DOE, JANE';

  pl(t_name(1));
  pl(t_name(10));
  pl('There are '||t_name.count()||' elements.');
  n_name := t_name.first();
  pl('The first element is '||n_name||'.');
  n_name := t_name.next(n_name);
  pl('The next element is '||n_name||'.');
  n_name := t_name.last();
```

```
27    pl('The last element is '||n_name||'.');
28    n_name := t_name.prior(n_name);
29    pl('The prior element is '||n_name||'.');
30    if t_name.exists(1) then
31      pl('Element 1 exists.');
32    end if;
33    pl('I''m deleting element 10');
34    t_name.delete(10);
35    pl('There are '||t_name.count()||' elements.');
36    if not t_name.exists(10) then
37      pl('Element 10 no longer exists.');
38    end if;
39    pl('There are '||t_name.count()||' elements.');
40    pl('I''m deleting all elements');
41    t_name.delete();
42    pl('There are '||t_name.count()||' elements.');
43  end;
44  /
```

The syntax used in Listing 3-5 on lines 8 and 9 to declare the associative array is as follows:

```
TYPE <plsql_table_type_name> IS TABLE OF <data_type>
INDEX BY BINARY_INTEGER;
```

where `<plsql_table_type_name>` is the name you are giving to the new PL/SQL table `TYPE`, and `<data_type>` is the data type to use for the elements in the table (or associative array).

Then, on line 11, I declare an associative array based on the new type with the following syntax:

```
<variable_name>                      <plsql_table_type_name>;
```

where `<variable_name>` is an identifier for the PL/SQL table, and `<plsql_table_type_name>` is the name of the `TYPE`.

One of the unique characteristics of an associative array is that it can be sparsely populated. That means you don't need to add items consecutively to the array. Instead, you can add them to any index value between –2,147,483,647 and 2,147,483,647. Did you notice how I did just that in Listing 3-5, on lines 16 and 17? This can be very handy when copying values from a database table into a PL/SQL table because database tables are generally sparsely populated. You can then use the commands `FIRST` and `NEXT` to iterate through the list consecutively, or look up a value using the index randomly. (You can find more information about the `FIRST` and `NEXT` commands in the *PL/SQL User's Guide and Reference*.)

Table 3-2 lists the PL/SQL table built-in functions and procedures. With PL/SQL tables, it's also possible to use a `varchar2` data type as the index value. So anywhere you see a reference to `binary_integer`, you can replace it with `varchar2` (up to 32,767 characters long).

Table 3-2. *PL/SQL Table (Associative Array) Built-in Functions and Procedures*

Method	Description
`count()`	Returns the number of elements
`delete(ain_index in binary_integer)`	Deletes the specified element
`delete()`	Deletes all elements
`exists(ain_index in binary_integer)`	Returns `TRUE` if the element exists; otherwise, `FALSE`
`first()`	Returns the index of the first element
`last()`	Returns the index of the last element
`prior(ain_index in binary_integer)`	Returns the index of the first element before the specified element
`next(ain_index in binary_integer)`	Returns the index of the first element after the specified element

The following is the output from SQL*Plus when I execute `table.sql` from Listing 3-5:

```
SQL> @table.sql
```

```
DOE, JOHN
DOE, JANE
There are 2 elements.
The first element is 1.
The next element is 10.
The last element is 10.
The prior element is 1.
Element 1 exists.
I'm deleting element 10
There are 1 elements.
Element 10 no longer exists.
There are 1 elements.
I'm deleting all elements
There are 0 elements.

PL/SQL procedure successfully completed.
```

As you can see from the output, the procedure in the `table.sql` script exercises each of the associative array's methods.

Do you remember that I said it was possible to declare a PL/SQL table of almost any data type? Let's look at creating one with a composite data type next. Listing 3-6 is an example of a PL/SQL table (associative array) based on a row-level anchor.

Listing 3-6. Declaring a PL/SQL Table with a Row Type Anchor, row.sql

```
rem row.sql
rem by Don Bales on 2014-10-20
rem An anonymous PL/SQL procedure to demonstrate
rem the elementary use of PL/SQL tables

declare

TYPE name_table IS TABLE OF WORKERS%ROWTYPE
INDEX BY BINARY_INTEGER;

t_name                                name_table;

n_name                                binary_integer;

begin
  t_name(1).name  := 'DOE, JOHN';
  t_name(10).name := 'DOE, JANE';
  pl(t_name(1).name);
  pl(t_name(10).name);
  pl('There are '||t_name.count()||' elements.');
  n_name := t_name.first();
  pl('The first element is '||n_name||'.');
  n_name := t_name.next(n_name);
  pl('The next element is '||n_name||'.');
  n_name := t_name.last();
  pl('The last element is '||n_name||'.');
  n_name := t_name.prior(n_name);
  pl('The prior element is '||n_name||'.');
  if t_name.exists(1) then
    pl('Element 1 exists.');
  end if;
  pl('I''m deleting element 10');
  t_name.delete(10);
  pl('There are '||t_name.count()||' elements.');
  if not t_name.exists(10) then
    pl('Element 10 no longer exists.');
  end if;
  pl('There are '||t_name.count()||' elements.');
  pl('I''m deleting all elements');
  t_name.delete();
  pl('There are '||t_name.count()||' elements.');
end;
/
```

A couple of new things are happening in Listing 3-6. First, line 8 uses the keyword `%ROWTYPE` to anchor to a composite record type based on the columns in the `WORKERS` table. Second, on lines 16 and 17 I appended the composite record's field name `name` with a dot operator (`.`) to the PL/SQL table's name and index, in order to store the name value in the associative array. Other than those items, the procedures in Listing 3-5 and Listing 3-6 are identical. I did this to point out how to address the fields in a PL/SQL record in a PL/SQL table, and also to show that the use of the PL/SQL table operators remains the same, regardless of which data type is used.

Perhaps you would like to declare your own composite record type. Let's see how you can do that next.

Record Types

Just as you can use the `TYPE` keyword to declare a new PL/SQL table, you can also use it to declare a PL/SQL record. Listing 3-7 is an example of doing just that.

Listing 3-7. Declaring a PL/SQL Record, record.sql

```
rem record.sql
rem by Don Bales on 2014-10-20
rem An anonymous PL/SQL procedure to demonstrate
rem the use of PL/SQL records

declare

TYPE name_record is record (
first_name                      WORKERS.first_name%TYPE,
middle_name                     WORKERS.middle_name%TYPE,
last_name                       WORKERS.last_name%TYPE );

TYPE name_table is table of name_record
index by binary_integer;

t_name                          name_table;

begin
 t_name(1).first_name  := 'JOHN';
 t_name(1).last_name   := 'DOE';
 t_name(2).first_name  := 'JANE';
 t_name(2).last_name   := 'DOE';

 pl(t_name(1).last_name||', '||t_name(1).first_name);
 pl(t_name(2).last_name||', '||t_name(2).first_name);
end;
/
```

The syntax used in Listing 3-7 to declare a PL/SQL record is as follows:

```
TYPE <plsql_record_type_name> IS RECORD (
<field_name_1>                      <data_type_1>,
<field_name_2>                      <data_type_2>,...
<field_name_N>                      <data_type_N>);
```

where `<plsql_record_type_name>` is the name for the new PL/SQL record type, `<field_name>` is the name of a field in the record, and `<data_type>` is the data type for the corresponding field.

As with the program in Listing 3-6, on lines 19 through 25 in Listing 3-7 I use the dot operator (`.`) followed by the name of the field in the record to address the composite data type values in the PL/SQL table.

WHAT'S WITH THIS NOMENCLATURE INCONSISTENCY ANYWAY?

I like things, especially programming code, to be consistent. Consistency makes things obvious. Obvious makes program code easy to maintain. Along those lines, I would feel much better if Oracle had called the syntax for creating a composite data type in a PL/SQL block a *row* instead of a *record*. Then we could refer to a *field* as *column*. The syntax would then be as follows:

```
TYPE <plsql_row_type_name> IS ROW (
<column_name_1>                      <data_type_1>,
<column_name_2>                      <data_type_2>,...
<column_name_N>                      <data_type_N>);
```

OK, now I feel better. I just needed to share how much that irritates me!

Multidimensional Arrays

Earlier, I said that associative arrays will support only a single dimension. In other words, you can't declare a multidimensional array and address it like this: `t_name(1, 7).name`. Well, there's a way around that limitation. Every good problem deserves a good hack. Listing 3-8 demonstrates how to use a PL/SQL table inside a PL/SQL record in order to work around the one-dimension limit.

Listing 3-8. A Hack to Work Around the PL/SQL Table One-Dimension Limit, multidimensional.sql

```
rem multidimensional.sql
rem Copyright by Don Bales on 2014-10-20
rem An anonymous PL/SQL procedure to demonstrate
rem the use of nested PL/SQL tables

declare

TYPE name_table is table of WORKERS.name%TYPE
index by binary_integer;

TYPE name_record is record (
dim2 name_table );

```

```
14  TYPE dim1 is table of name_record
15  index by binary_integer;
16
17  t_dim1                                dim1;
18
19  begin
20    t_dim1(1).dim2(1) := 'DOE, JOHN';
21    t_dim1(1).dim2(2) := 'DOE, JANE';
22
23    t_dim1(2).dim2(1) := 'DOUGH, JAYNE';
24    t_dim1(2).dim2(2) := 'DOUGH, JON';
25
26    pl(t_dim1(1).dim2(1));
27    pl(t_dim1(1).dim2(2));
28    pl(t_dim1(2).dim2(1));
29    pl(t_dim1(2).dim2(2));
30  end;
31  /
```

Here's how Listing 3-8 works:

- Lines 8 and 9 declare a table type, `name_table`, to hold a list of names.
- Lines 11 and 12 declare a record type, `name_record`, with one field named `dim2`, where the data type is `name_table`, a PL/SQL table.
- Lines 14 and 15 declare a second table type, `dim1`, which is based on record type `dim2`.
- On lines 20 through 29, with the pseudo-two-dimension table in place, I exercise accessing it using two indexes.

Since the use of arrays is a rather advanced topic, I'm going to skip the exercise here.
Next, let's look at the most temporary of variables, which aren't really variables at all: parameters.

Parameters

Parameters allow you to pass values into (`IN`), pass values out of (`OUT`), or pass values into and out of (`IN OUT`) a cursor, function, or procedure. (Cursors are covered in Chapter 5.) You've already seen parameters used in earlier code listings. I'm covering parameters here because they use declaration syntax similar to variables, and they themselves are variables.

Parameter Naming

Parameters follow the same PL/SQL identifier naming rules as variables. In practice, however, I like to use a couple of additional prefix characters on parameter names so I can also tell their scope, along with the data type. Table 3-3 is a list of those parameter prefix values.

Table 3-3. *My PL/SQL Parameter Naming Prefixes*

Prefix	Description
ai	Argument IN
ao	Argument OUT
aio	Argument IN OUT

For example, if I were to declare parameters to pass data from the columns in the AUTHORS table into and/or out of a method, I would use the identifier names in Table 3-4.

Table 3-4. *Parameter Name Examples Using My Prefixing Scheme*

Scope		
IN	**OUT**	**IN OUT**
ain_id	aon_id	aion_id
aiv_name	aov_name	aiov_name
aid_birth_date	aod_birth_date	aiod_birth_date
aiv_gender	aov_gender	aiov_gender

The advantage of using these prefixes is that you'll always know the scope and data type of the parameter with which you're working.

Parameter Declarations

Listing 3-9 and 3-10 create a package named PARAMETER, which I'll use to explain the parameter declaration syntax and parameter scope.

Listing 3-9. A Package Spec to Test Parameter Scope, parameter.pks

```
create or replace package PARAMETER as
/*
parameter.pks
by Donald J. Bales on 2014-10-20
A packge to test parameter scope
*/

-- A function that execises the scope of parameters
FUNCTION in_out_inout(
aiv_in                        in     varchar2,
aov_out                          out varchar2,
aiov_inout                    in out varchar2)
return                               varchar2;


```

```
-- A procedure that execises the scope of parameters
PROCEDURE in_out_inout(
aiv_in                         in     varchar2,
aov_out                           out varchar2,
aiov_inout                     in out varchar2);


end PARAMETER;
/
@se.sql PARAMETER
```

The syntax used to declare the parameters in the function and procedure in Listing 3-9 is as follows:

```
(
<parameter_name_1>          [IN][OUT] <data_type_1>,
<parameter_name_2>          [IN][OUT] <data_type_2>,...
<parameter_name_N>          [IN][OUT] <data_type_N>)
```

where `<parameter_name>` is the name of the parameter; the scope is `IN`, `OUT`, or `IN OUT`; and `<data_type>` is the data type of the parameter. As you have already seen in previous listings, you can use column or row anchors to specify the data type (you know—`%TYPE` or `%ROWTYPE`). However, the value of the parameter will not be constrained by the specified size in the anchor. Only the data type is used from the anchor.

Parameter Scope

The parameter keywords `IN` and `OUT` determine the accessibility, or scope, of the parameters.

- `IN` makes your parameters' data available to the called cursor, function, or procedure.
- `OUT` allows the called function or procedure to set the parameter's value within the called PL/SQL block.
- The combination of `IN` and `OUT` allows both levels of accessibility.

Seeing is believing, so take some time to study Listings 3-10 and 3-11, and the output of Listing 3-11.

Listing 3-10. A Package Body to Test Parameter Scope, parameter.pkb

```
create or replace package body PARAMETER as
/*
parameter.pkb
by Donald J. Bales on 2014-10-20
A packge to test parameter scope
*/

FUNCTION in_out_inout(
aiv_in                         in     varchar2,
aov_out                           out varchar2,
aiov_inout                     in out varchar2)
return                                varchar2 is
```

```
begin
  pl(chr(9)||'Before assignments...');
  pl(chr(9)||'Inside function in_out_inout, aiv_in     = '||aiv_in);
  pl(chr(9)||'Inside function in_out_inout, aov_out    = '||aov_out);
  pl(chr(9)||'Inside function in_out_inout, aiov_inout = '||aiov_inout);
  -- You can only assign a value (write) to an OUT
  -- parameter, you can't read it!
  aov_out   := 'OUT';

  -- You can only read an IN parameter
  aiov_inout := aiv_in;

  -- You can read and write an IN OUT parameter
  aiov_inout := aiov_inout||'OUT';

  pl(chr(9)||'After assignments...');
  pl(chr(9)||'Inside function in_out_inout, aiv_in     = '||aiv_in);
  pl(chr(9)||'Inside function in_out_inout, aov_out    = '||aov_out);
  pl(chr(9)||'Inside function in_out_inout, aiov_inout = '||aiov_inout);
  return 'OK'; -- a function must return a value!
end in_out_inout;


PROCEDURE in_out_inout(
aiv_in                         in     varchar2,
aov_out                           out varchar2,
aiov_inout                     in out varchar2) is
begin
  pl(chr(9)||'Before assignments...');
  pl(chr(9)||'Inside procedure in_out_inout, aiv_in     = '||aiv_in);
  pl(chr(9)||'Inside procedure in_out_inout, aov_out    = '||aov_out);
  pl(chr(9)||'Inside procedure in_out_inout, aiov_inout = '||aiov_inout);
  -- You can only assign a value (write) to an OUT
  -- parameter, you can't read it!
  aov_out   := 'OUT';

  -- You can only read an IN parameter
  aiov_inout := aiv_in;

  -- You can read and write an IN OUT parameter
  aiov_inout := aiov_inout||'OUT';
  pl(chr(9)||'After assignments...');
  pl(chr(9)||'Inside procedure in_out_inout, aiv_in     = '||aiv_in);
  pl(chr(9)||'Inside procedure in_out_inout, aov_out    = '||aov_out);
  pl(chr(9)||'Inside procedure in_out_inout, aiov_inout = '||aiov_inout);
end in_out_inout;


end PARAMETER;
/
@be.sql PARAMETER
```

Listing 3-11 is an anonymous PL/SQL procedure to test the scope defined by the use of IN, OUT, or IN OUT.

Listing 3-11. A Test Unit for Package PARAMETER, parameter.sql

```
rem parameter.sql
rem by Donald J. Bales on 2014-10-20
rem A test unit for package PARAMETER

declare

v_in                         varchar2(30) := 'IN';
v_out                        varchar2(30) :=
  'Na na, you can''t see me!';
v_inout                      varchar2(30) :=
  'But you can see me!';
v_return                     varchar2(30);

begin
  pl('Before calling the function...');
  pl('Inside test unit parameter v_in    = '||v_in);
  pl('Inside test unit parameter v_out   = '||v_out);
  pl('Inside test unit parameter v_inout = '||v_inout);
  pl('Test function PARAMETER.in_out_inout(v_in, v_out, v_inout).');
  v_return := PARAMETER.in_out_inout(v_in, v_out, v_inout);
  pl(v_return);
  pl('After calling the function...');
  pl('Inside test unit parameter v_in    = '||v_in);
  pl('Inside test unit parameter v_out   = '||v_out);
  pl('Inside test unit parameter v_inout = '||v_inout);
  pl('Resetting initial values...');
  v_out   := 'Na na, you can''t see me!';
  v_inout := 'But you can see me!';
  pl('Before calling the procedure...');
  pl('Inside test unit parameter v_in    = '||v_in);
  pl('Inside test unit parameter v_out   = '||v_out);
  pl('Inside test unit parameter v_inout = '||v_inout);
  pl('Test procedure PARAMETER.in_out_inout(v_in, v_out, v_inout).');
  PARAMETER.in_out_inout(v_in, v_out, v_inout);
  pl('OK');
  pl('After calling the procedure...');
  pl('Inside test unit parameter v_in    = '||v_in);
  pl('Inside test unit parameter v_out   = '||v_out);
  pl('Inside test unit parameter v_inout = '||v_inout);
end;
/
```

Here's the SQL*Plus output from the `parameter.sql` script (Listing 3-11):

```
SQL> @parameter.sql
```

```
Before calling the function...
Inside test unit parameter v_in    = IN
Inside test unit parameter v_out   = Na na, you can't see me!
Inside test unit parameter v_inout = But you can see me!
Test function PARAMETER.in_out_inout(v_in, v_out, v_inout).
        Before assignments...
        Inside function in_out_inout, aiv_in     = IN
        Inside function in_out_inout, aov_out    =
        Inside function in_out_inout, aiov_inout = But you can see me!
        After assignments...
        Inside function in_out_inout, aiv_in     = IN
        Inside function in_out_inout, aov_out    = OUT
        Inside function in_out_inout, aiov_inout = INOUT
OK
After calling the function...
Inside test unit parameter v_in    = IN
Inside test unit parameter v_out   = OUT
Inside test unit parameter v_inout = INOUT
Resetting initial values...
Before calling the procedure...
Inside test unit parameter v_in    = IN
Inside test unit parameter v_out   = Na na, you can't see me!
Inside test unit parameter v_inout = But you can see me!
Test procedure PARAMETER.in_out_inout(v_in, v_out, v_inout).
        Before assignments...
        Inside procedure in_out_inout, aiv_in     = IN
        Inside procedure in_out_inout, aov_out    =
        Inside procedure in_out_inout, aiov_inout = But you can see me!
        After assignments...
        Inside procedure in_out_inout, aiv_in     = IN
        Inside procedure in_out_inout, aov_out    = OUT
        Inside procedure in_out_inout, aiov_inout = INOUT
OK
After calling the procedure...
Inside test unit parameter v_in    = IN
Inside test unit parameter v_out   = OUT
Inside test unit parameter v_inout = INOUT

PL/SQL procedure successfully completed.
```

As you can verify from studying Listing 3-11 and the output from test unit `parameter.sql`,

- An `IN` parameter can be used to pass a value into a cursor, function, or procedure.
- An `OUT` parameter can be used to pass a value out of a function or procedure.
- An `IN OUT` parameter can be used to do both.

It's Your Turn to Declare Parameters

You'll have plenty of practice declaring parameters in the coming chapters. So I want you to do this instead:

1. Start on Chapter 4.

Summary

At this point, you should be a master of variable and parameter declarations. And you should understand the scope in which they are accessible. Next, let's start working with some SQL in your PL/SQL.

CHAPTER 4

Single Row Processing

Now you'll begin your journey of using SQL in PL/SQL. You'll start out slowly, inserting one row at a time, then updating one row at a time, then deleting one row at a time, and finally selecting one row at a time. I take this approach because you first have to insert data into a database before you can update, delete, or select it. I call these kinds of SQL statements *singletons* because they return one row of results. So let's get started by putting some data into the database.

Inserts

The context here is inserting data into a relational database. To insert data into a relational database from PL/SQL, you simply write a SQL `INSERT` statement, where the values are PL/SQL literals, PL/SQL variables, or SQL columns.

I begin with examples that represent what is most commonly done, and then continually improve the architecture and design as you progress through the chapter. To start out, you'll see what most PL/SQL programmers do, and then how to improve the code. Please keep in mind that there is a time and place for each of these solutions. In the end, you're the one who will need to make the decision about which is the best solution based on the business problem you're solving.

Rarely do you just perform a simple atomic `INSERT` statement in PL/SQL. You can do that using a SQL*Plus script, without using PL/SQL at all. More often, you'll want to insert or update depending on whether the data you intend to insert already exists in the database. If it does, you'll probably want to check if you need to update the values already in the database. So the process you decide to use to insert and/or update becomes a proverbial chicken vs. egg dilemma—which do you do first? Let's start by looking at what can happen if a duplicate row already exists.

You're going to see me use `SELECT` when I `INSERT` because, in a modern database design, you need to `SELECT` sequence and code ID values to use them in an `INSERT` statement. Let's check it out. Listing 4-1 is an anonymous PL/SQL procedure that inserts values into the `WORKERS` table.

Listing 4-1. An Insert Example Using PL/SQL Literals and Variables, insert.sql

```
rem insert.sql
rem by Donald J. Bales on 2014-10-20
rem An anonymous PL/SQL procedure to insert
rem values using PL/SQL literals and variables

set serveroutput on size 1000000;

declare

```

```
-- I declared these variables so I can get
-- the required ID values before I insert.
n_id                                  WORKERS.id%TYPE;
n_worker_type_id                      WORKERS.worker_type_id%TYPE;
v_external_id                         WORKERS.external_id%TYPE;
n_gender_type_id                      WORKERS.gender_type_id%TYPE;

-- I'll use this variable to hold the result
-- of the SQL insert statement.
n_count                               number;

begin

  -- First, let's get the WORKER_TYPES id for a contractor
  begin
    select id
    into   n_worker_type_id
    from   WORKER_TYPES
    where  code = 'C';
  exception
    when OTHERS then
      raise_application_error(-20002, SQLERRM||
        ' on select WORKER_TYPES'||
        ' in filename insert.sql');
  end;

  -- Next, let's get the  GENDER_TYPES id for a male
  begin
    select id
    into   n_gender_type_id
    from   GENDER_TYPES
    where  code = 'M';
  exception
    when OTHERS then
      raise_application_error(-20004, SQLERRM||
        ' on select GENDER_TYPES'||
        ' in filename insert.sql');
  end;

  -- Now, let's get the next WORKERS id sequence
  begin
    select WORKERS_ID.nextval
    into   n_id
    from   SYS.DUAL;
  exception
    when OTHERS then
      raise_application_error(-20001, SQLERRM||
        ' on select WORKERS_ID.nextval'||
        ' in filename insert.sql');
  end;

  -- And then, let's get the next external_id sequence
  begin
    select lpad(to_char(EXTERNAL_ID_SEQ.nextval), 9, '0')
    into   v_external_id
    from   SYS.DUAL;
  exception
    when OTHERS then
      raise_application_error(-20003, SQLERRM||
        ' on select EXTERNAL_ID_SEQ.nextval'||
        ' in filename insert.sql');
  end;

  -- Now that we have all the necessary ID values
  -- we can finally insert a row!
  begin
    insert into WORKERS (
           id,
           worker_type_id,
           external_id,
           first_name,
           middle_name,
           last_name,
           name,
           birth_date,
           gender_type_id )
    values (
           n_id,                            -- a variable
           n_worker_type_id,                -- a variable
           v_external_id,                   -- a variable
           'JOHN',                          -- a literal
           'J.',                            -- a literal
           'DOE',                           -- a literal
           'DOE, JOHN J.',                  -- a literal
           to_date('19800101', 'YYYYMMDD'), -- a function
           n_gender_type_id );              -- a variable

    n_count := sql%rowcount;
  exception
    when OTHERS then
      raise_application_error(-20005, SQLERRM||
        ' on insert WORKERS'||
        ' in filename insert.sql');
  end;

  pl(to_char(n_count)||' row(s) inserted.');
end;
/

commit;
```

The SQL INSERT syntax used in Listing 4-1 is as follows:

```
INSERT INTO <table_name> (
       <column_name_1>,
       <column_name_2>,...
       <column_name_N> )
VALUES (
       <column_value_1>,
       <column_value_2>,...
       <column_value_N> );
```

where `<table_name>` is the name of the table to `INSERT VALUES INTO`, `<column_name>` is the name of a column in the table, and `<column_value>` is the value for a corresponding `<column_name>`. The column values can be PL/SQL literals, variables, qualifying function results, or SQL column values.

You should always use a list of columns in your `INSERT` statements in order to maintain the validity of your code, in case someone later adds a column to a table definition (and, in practice, that happens).

Let's break down the code in Listing 4-1:

- Lines 12 through 15 declare four variables to hold the ID values from related sequence and code tables.
- Line 19 declares a number to hold the resulting row count from the INSERT statement.
- Lines 25 through 28 contain a `SELECT` statement to get the `worker_type_id` value for a contractor.
- On lines 24 through 34, I've blocked (put the code in a nested PL/SQL block) the `SELECT` statement so I can catch any catastrophic error, and report it to the presentation layer with an error number and message that are unique to the PL/SQL program. This practice greatly simplifies troubleshooting. You'll know exactly what went wrong and where it went wrong, and that's nice.
- On lines 37 through 47, I get the `gender_type_id` value for a male.
- On lines 50 through 59, I get the next `id` sequence value, storing that value in variable `n_id`.
- On lines 62 through 71, I get the next `external_id` value. I use the SQL function `to_char()` to do an explicit data type conversion from numeric to character. I wrap the character value with the SQL function `lpad()` in order to left-pad the number string with zeros so it's nine characters long.
- Lines 76 through 95 contain an `INSERT` statement to insert John Doe's data into the `WORKERS` table.
- Lines 77 through 85 list the names of the columns I'm going to insert values `INTO`. This is an important practice. If I didn't list the columns, the procedure would become invalid any time someone modified the `WORKERS` table.
- Lines 87 through 95 specify the column values using a combination of PL/SQL literals, PL/SQL variables, and even the return value of the SQL function `to_date()` for the value of column `birth_date`.

- On line 97, I store the result value of the INSERT statement, which is the number of rows inserted. To accomplish this, I use the pseudo-cursor name sql% and its variable rowcount.
- On lines 75 through 103 collectively, I've blocked the INSERT statement so I can detect and report the exact type and location of an error in the PL/SQL procedure.

The following is the output from the first time the insert.sql script is executed:

```
SQL> @insert.sql
```

```
1 row(s) inserted.
PL/SQL procedure successfully completed.
```

If you examine the code in Listing 4-1 and its output, you'll see that the procedure inserted one row into the database, as reported by the output from the INSERT statement through the sql%rowcount variable. But what happens if we run the script again? Here's the output from the script's second execution:

```
SQL> @insert.sql
```

```
declare
*
ERROR at line 1:
ORA-20005: ORA-00001: unique constraint (RPS.WORKERS_UK2) violated on insert WORKERS in
filename insert.sql
ORA-06512: at line 93
```

No PL/SQL procedure successfully completed message this time! An unhandled unique constraint exception was raised as an application error, number 20005, along with a meaningful message.

Now if you want to handle this particular kind of exception, you can use one of three tactics:

- Catch exception DUP_VAL_ON_INDEX (good).
- Use additional PL/SQL code to predetect the duplicate's presence (better).
- Use additional SQL code to predetect the duplicate's presence (best).

Let's take a look at these solutions, from good to best.

Catching a DUP_VAL_ON_INDEX Exception

When it comes to dealing with code that may raise a DUP_VAL_ON_INDEX exception (or any exception, for that matter), catching the exception is the laziest of solutions, yet perfectly legitimate. Actually, catching a DUP_VAL_ON_INDEX exception during an INSERT is the only way to determine that a duplicate row exists. So regardless of which process you use to insert a row, you always need to catch any possible exceptions during the execution of a SQL statement and handle them appropriately.

Figure 4-1 shows a simple process flow diagram for inserting a row and catching a DUP_VAL_ON_INDEX exception if a duplicate row already exists in the database. The process in Figure 4-1 starts out by executing a SQL INSERT statement. When you do this, Oracle will check for duplicate values in any existing unique index or unique key entries for the table in question. If a duplicate entry is found, PL/SQL will raise a DUP_VAL_ON_INDEX exception. So how do you handle that?

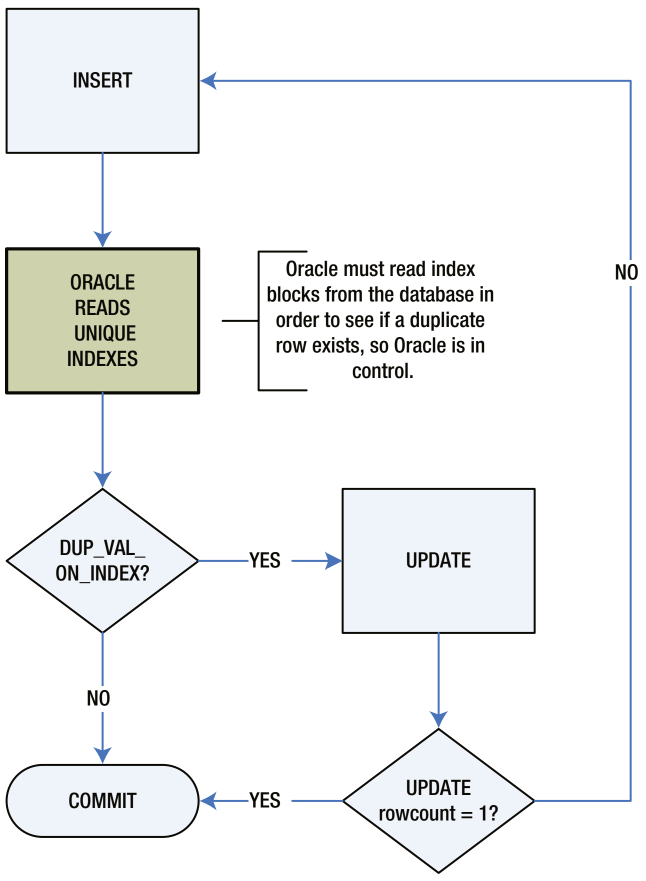

INSERT
ORACLE READS UNIQUE INDEXES
Oracle must read index blocks from the database in order to see if a duplicate row exists, so Oracle is in control.
NO
DUP_VAL_ ON_INDEX?
YES
UPDATE
NO
COMMIT
YES
UPDATE rowcount = 1?

Figure 4-1. *Updating after an insert fails*

What you know at this point in your program is that a duplicate entry existed at the moment the SQL engine tried to insert your row. But that does not guarantee that the same duplicate row exists microseconds later in the exception handler. Someone or something else using the database could have deleted it in the meantime.

So perhaps you decide to try to `UPDATE` the supposedly existing entry. If you choose that tactic, you can be 100% sure that the entry was updated only if you examine `sql%rowcount` for the number of rows updated after your attempted update. If the row count isn't equal to one, then you need to try to insert the row again.

This "classic" solution is perfectly legitimate and arguably the only correct way to insert values. Or is it? I don't like this approach because it's a reactive solution where you are not in complete control of the process. Is it better to gain control after an error or to maintain control all along? Let's look at an example in order to get a better understanding of the problem, before you decide on a solution. Listing 4-2 shows a modified version of Listing 4-1, where the `ORA-00001: unique constraint ... violated`, or `DUP_VAL_ON_INDEX` exception, is handled.

Listing 4-2. An Insert Example, Modified to Catch DUP_VAL_ON_INDEX, insert_with_handled_exception.sql

```
073    -- Now that we have all the necessary ID values
074    -- we can finally insert a row!
075    begin
076      insert into WORKERS (
077             id,
078             worker_type_id,
079             external_id,
080             first_name,
081             middle_name,
082             last_name,
083             name,
084             birth_date,
085             gender_type_id )
086      values (
087             n_id,                          -- a variable
088             n_worker_type_id,              -- a variable
089             v_external_id,                 -- a variable
090             'JOHN',                        -- a literal
091             'J.',                          -- a literal
092             'DOE',                         -- a literal
093             'DOE, JOHN J.',                -- a literal
094             to_date('19800101', 'YYYYMMDD'), -- a function
095             n_gender_type_id );            -- a variable
096
097      n_count := sql%rowcount;
098    exception
099      when DUP_VAL_ON_INDEX then
100        n_count := 0;
101        pl('Caught a DUP_VAL_ON_INDEX exception');
102      when OTHERS then
103        raise_application_error(-20005, SQLERRM||
104          ' on insert WORKERS'||
105          ' in filename insert_with_handled_exception.sql');
106    end;
```

■ **Note** Listing 4-2 is a partial code listing. I'll use this technique whenever there's a lot of repeated code from one listing to the next. Because of this, you didn't have to pay as much for this book, nor did we have to kill as many trees; less paper, fewer dead trees, lower cost.

So what changed?

- Line 99 now has a `WHEN DUP_VAL_ON_INDEX` clause, which catches a `DUP_VAL_ON_INDEX` exception. The scope of the clause extends until the next use of the keyword `WHEN` or the keyword `END` for the enclosing PL/SQL block.

- On line 100, I set the row count variable, `n_count`, to 0 because lines 96 and 97 are not executed when an exception occurs. Instead, the program's execution jumps from line 95, where the error takes place, directly to line 98, in order to start handling exceptions.
- On line 101, I display a custom error message, but I don't raise the exception, so the program executes successfully.

Here's the output of the modified script, `insert_with_handled_exception.sql`:

```
SQL> @insert_with_handle_exception.sql
```

```
Caught a DUP_VAL_ON_INDEX exception
0 row(s) inserted.

PL/SQL procedure successfully completed.
```

But a nagging question remains. Is it better to gain control after an error or to maintain control all along? Let's take a look at tactic number two.

Using PL/SQL to Predetect a Duplicate

Using additional PL/SQL code to predetect the presence of duplicate values is, in my opinion, better than catching a `DUP_VAL_ON_INDEX` exception, for these reasons:

- You maintain control of your PL/SQL program's execution.
- You can conditionally decide how to handle duplicate values.
- You can use your detection scheme to acquire the primary key for the row that is a duplicate, and then update that row.

Figure 4-2 is a simple process flow diagram for predetecting a duplicate entry using PL/SQL, and then acting accordingly—that is, inserting or updating as needed. In this process, you start out by selecting the primary key value from the database for the table entry in question. If you find an existing entry, you can determine whether the entry needs to be updated, and then execute an `UPDATE` statement. Alternatively, you execute an `INSERT` statement if the `SELECT` statement raises a `NO_DATA_FOUND` exception.

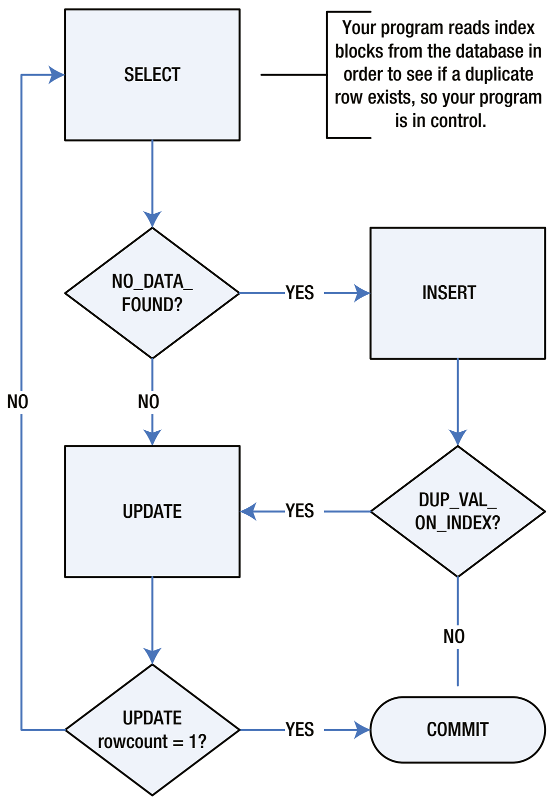

SELECT
Your program reads index blocks from the database in order to see if a duplicate row exists, so your program is in control.
NO_DATA_ FOUND?
YES
INSERT
NO
NO
UPDATE
YES
DUP_VAL_ ON_INDEX?
NO
UPDATE rowcount = 1?
YES
COMMIT

Figure 4-2. *Select, then insert or update as needed*

However, you cannot ignore the possibility that, even though a duplicate entry did not exist at the moment you executed a SELECT statement against the database, someone or something has since inserted a duplicate entry. This could happen in the microseconds between the raised exception and the execution of your INSERT statement, so you must still catch any possible exceptions on the execution of the INSERT statement and act accordingly.

This time, if the sql%rowcount variable is not equal to one, you need to try selecting the entry again.

So which solution is better? Once again, let's look at an example before you decide. Listing 4-3 is another modification of Listing 4-1. This time, I've added a nested block of PL/SQL code to detect possible duplicate values.

Listing 4-3. An Insert Example, Modified to Detect Duplicates with PL/SQL, insert_with_plsql_detection.sql

```
v_first_name                     WORKERS.first_name%TYPE;
v_middle_name                    WORKERS.middle_name%TYPE;
v_last_name                      WORKERS.last_name%TYPE;
v_name                           WORKERS.name%TYPE;
d_birth_date                     WORKERS.birth_date%TYPE;
...
  v_first_name  := 'JOHN';
  v_middle_name := 'J.';
  v_last_name   := 'DOE';
```

```
v_name        :=
  rtrim(v_last_name||', '||v_first_name||' '||v_middle_name);
d_birth_date  :=
  to_date('19800101', 'YYYYMMDD'); -- I'm guessing
...
-- Detect any existing entries with the unique
-- combination of columns as in this constraint:
-- constraint   WORKERS_UK2
-- unique (
-- name,
-- birth_date,
-- gender_type_id )
begin
  select count(1)
  into   n_count
  from   WORKERS
  where  name           = v_name
  and    birth_date     = d_birth_date
  and    gender_type_id = n_gender_type_id;
exception
  when OTHERS then
    raise_application_error(-20005, SQLERRM||
      ' on select WORKERS'||
      ' in filename insert_with_plsql_detection.sql');
end;

-- Conditionally insert the row
if n_count = 0 then
  -- Now, let's get the next id sequence
  begin
    select WORKERS_ID.nextval
    into   n_id
    from   SYS.DUAL;
  exception
    when OTHERS then
      raise_application_error(-20001, SQLERRM||
        ' on select WORKERS_ID.nextval'||
        ' in filename insert_with_plsql_detection.sql');
  end;

  -- And then, let's get the next external_id sequence
  begin
    select lpad(to_char(EXTERNAL_ID_SEQ.nextval), 9, '0')
    into   v_external_id
    from   SYS.DUAL;
  exception
    when OTHERS then
      raise_application_error(-20003, SQLERRM||
        ' on select EXTERNAL_ID_SEQ.nextval'||
        ' in filename insert_with_plsql_detection.sql');
  end;

```

```
108      -- Now that we have all the necessary ID values
109      -- we can finally insert a row!
110      begin
111        insert into WORKERS (
112               id,
113               worker_type_id,
114               external_id,
115               first_name,
116               middle_name,
117               last_name,
118               name,
119               birth_date,
120               gender_type_id )
121        values (
122               n_id,
123               n_worker_type_id,
124               v_external_id,
125               v_first_name,
126               v_middle_name,
127               v_last_name,
128               v_name,
129               d_birth_date,
130               n_gender_type_id );
131
132        n_count := sql%rowcount;
133      exception
134        when OTHERS then
135          raise_application_error(-20006, SQLERRM||
136            ' on insert WORKERS'||
137            ' in filename insert_with_plsql_detection.sql');
138      end;
139    else
140      n_count := 0;
141    end if;
```

Let's review the modifications:

- On lines 15 through 19, I've added variables to hold column values. I've done this because I need to specify the column values more than once. This way, I can set their values once, and then know that I will consistently use the same values twice.
- Lines 27 through 33 initialize the variables I added on lines 15 through 19. A particularly troublesome issue is the variable `v_name` for column `WORKERS.name`. It's a computed value that will be stored in the database in order to improve performance. This tactic will cause any relational database purist to have a hissy fit. But that's not what I find troublesome. Since it's a computed value, you must make sure it's always computed the same way. Hmm, that sounds like a job for a function dedicated to the `WORKERS` table. You'll create one to handle this issue in Chapter 5, so don't sweat it yet.

- Lines 68 through 80 contain a new nested PL/SQL block that queries the `WORKERS` table against the columns that make up the unique constraint in question, to see if an entry with duplicate values already exists in the table. The SQL statement simply counts the number of rows with duplicate values, storing the count in variable `n_count`.
- Line 83 has a new `IF` statement, which determines whether to insert a row. If the value of the variable `n_count` is 0, I go ahead and insert the row. Otherwise, on line 140, I set `n_count` to 0 in order to correctly report the number of rows inserted.

In Listing 4-3, I was able to maintain control of the execution of my PL/SQL program. But what if I wanted to update the row that already existed? Then I would have coded the detection block as shown in Listing 4-4.

Listing 4-4. An Insert Example, Modified to Detect Duplicates with PL/SQL for Update, insert_with_plsql_detection_for_update.sql

```
069     begin
070       select id
071       into   n_id
072       from   WORKERS
073       where  name           = v_name
074       and    birth_date     = d_birth_date
075       and    gender_type_id = n_gender_type_id;
076     exception
077       when NO_DATA_FOUND then
078         n_id := NULL; -- Is this really needed?
079       when OTHERS then
080         raise_application_error(-20003, SQLERRM||
081           ' on select WORKERS'||
082           ' in filename insert_with_plsql_detection_for_update.sql');
083     end;
084
085     -- Conditionally insert the row
086     if n_id is NULL then
087       -- Now, let's get the next id sequence
088       begin
089         select WORKERS_ID.nextval
090         into   n_id
091         from   SYS.DUAL;
092       exception
093         when OTHERS then
094           raise_application_error(-20004, SQLERRM||
095             ' on select WORKERS_ID.nextval'||
096             ' in filename insert_with_plsql_detection_for_update.sql');
097       end;
098
099       -- And then, let's get the next external_id sequence
100       begin
101         select lpad(to_char(EXTERNAL_ID_SEQ.nextval), 9, '0')
102         into   v_external_id
103         from   SYS.DUAL;
104       exception
105         when OTHERS then
```

```
        raise_application_error(-20005, SQLERRM||
          ' on select EXTERNAL_ID_SEQ.nextval'||
          ' in filename insert_with_plsql_detection_for_update.sql');
    end;

    -- Now that we have all the necessary ID values
    -- we can finally insert a row!
    begin
      insert into WORKERS (
             id,
             worker_type_id,
             external_id,
             first_name,
             middle_name,
             last_name,
             name,
             birth_date,
             gender_type_id )
      values (
             n_id,
             n_worker_type_id,
             v_external_id,
             v_first_name,
             v_middle_name,
             v_last_name,
             v_name,
             d_birth_date,
             n_gender_type_id );

      n_inserted := sql%rowcount;
    exception
      when OTHERS then
        raise_application_error(-20006, SQLERRM||
          ' on insert WORKERS'||
          ' in filename insert_with_plsql_detection_for_update.sql');
    end;
  else
    begin
      update WORKERS
      set    worker_type_id  = n_worker_type_id
      where  id              = n_id;

      n_updated := sql%rowcount;
    exception
      when OTHERS then
        raise_application_error(-20007, SQLERRM||
          ' on update WORKERS'||
          ' in filename insert_with_plsql_detection_for_update.sql');
    end;
  end if;
```

On lines 69 through 83, I've recoded the detection block to retrieve the primary key value for a row with duplicate values. If a duplicate row exists, variable `n_id`, initially `NULL`, will be set to the value of the primary key. Otherwise, if a duplicate row does not exist, a `NO_DATA_FOUND` exception will be raised. In turn, the exception will be handled by the `WHEN NO_DATA_FOUND` clause in the enclosing PL/SQL block's exception-handling section. There, in the `EXCEPTION` clause, I set the value of variable `n_id` to `NULL` to flag that I did not find a duplicate. I actually don't need to set it `NULL` because it remained `NULL` when the exception was raised. But the Oracle PL/SQL documentation does not explicitly guarantee this behavior, so I set it to `NULL`.

Also, on line 86, now I use the `n_id` variable to determine if I found a duplicate row. If `n_id` is `NULL`, I insert the row. Otherwise, on lines 143 through 154, I update the duplicate row with the `worker_type_id` value.

So if this was a better tactic, what's best? Before I answer that question, let's first digress a moment so I can finally explain the syntax of all those `IF` statements I've been using all along!

IF I Don't Tell You Now, When ELSE Can I?

This seems a good a time as any to finally get around to defining just what an `IF` statement is. Let's look at the `IF` statement syntax used in Listing 4-4:

```
IF <boolean_evaluation> THEN
  -- do this if it's TRUE
[ELSE
  -- do this if it's not TRUE]
END IF;
```

where `<boolean_evaluation>` is PL/SQL that evaluates to a Boolean value. If the `<boolean_evaluation>` is `TRUE`, then the lines of code between the `THEN` and `ELSE` keywords are executed. Otherwise, if the `<boolean_evaluation>` is not `TRUE` or `NULL`, then the lines of code between keywords `ELSE` and `END IF` are executed.

In Listing 4-4, on line 86, I evaluate `id is NULL`. If it's `TRUE`, PL/SQL executes lines 87 through 141; otherwise (`ELSE`), it executes lines 143 through 154. You can also use the following syntaxes:

```
IF <boolean_evaluation> THEN
  -- do this if it's TRUE
END IF;
```

or

```
IF     <boolean_evaluation> THEN

  -- do this if it's TRUE
[ELSIF <boolean_evaluation> THEN
  -- do this if it's TRUE
ELSIF ...

ELSE
  -- do this if it's not TRUE]
END IF;
```

Now, let's get back to the subject of inserting.

Using SQL to Predetect a Duplicate

It's almost always best to let SQL simply do its job! You can't imagine how much PL/SQL code I've seen that can be replaced by one SQL statement—for example, all the code you've seen so far in this chapter in Listings 4-1 through 4-4.

Figure 4-3 is a simple process flow diagram for predetecting a duplicate entry using SQL. In this process, SQL performs the work of predetection using an `EXISTS` clause. If a duplicate entry does not exist at the moment the `EXISTS` clause is executed, the SQL engine immediately follows with an `INSERT`. Regardless, this does not mean you can't get a `DUP_VAL_ON_INDEX` exception. In the microseconds between the evaluation of the `EXISTS` clause and the `INSERT`, it is possible that someone or something has inserted a duplicate value into the database. So you must still catch any exceptions from the `SELECT...INTO` statement and act accordingly.

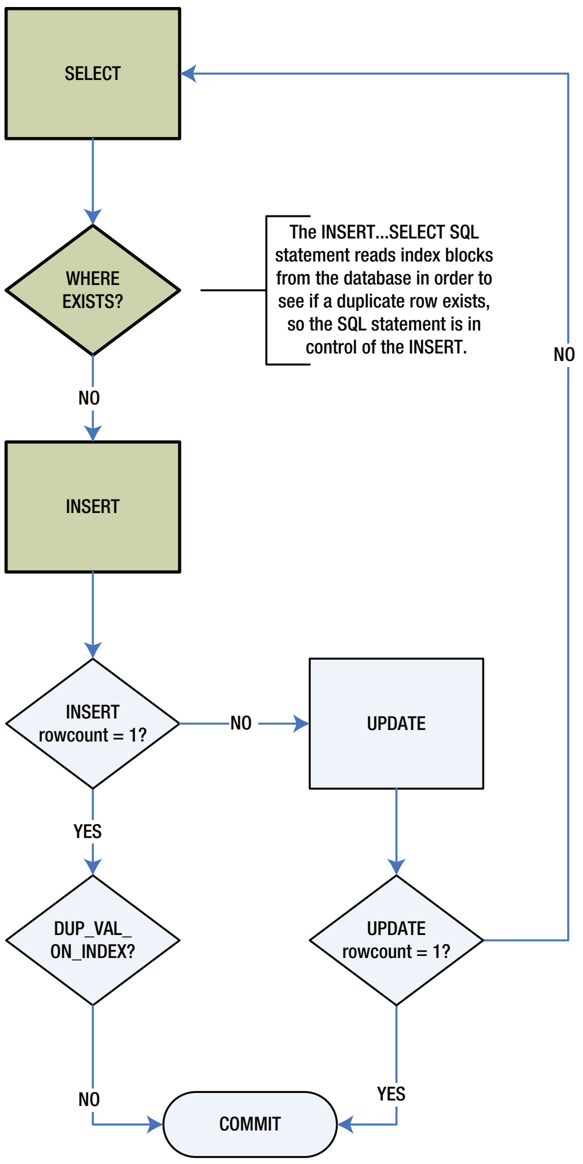

SELECT
WHERE EXISTS?
The INSERT...SELECT SQL statement reads index blocks from the database in order to see if a duplicate row exists, so the SQL statement is in control of the INSERT.
NO
NO
INSERT
INSERT rowcount = 1?
NO
UPDATE
YES
DUP_VAL_ ON_INDEX?
UPDATE rowcount = 1?
NO
COMMIT
YES

Figure 4-3. *INSERT...SELECT, then update if needed*

There appears to be no “perfect” solution, and indeed, that is the case. It’s always possible that someone or something has deleted or inserted an entry in the database between your duplicate row detection and corresponding action. Now let’s take a look at an example that uses SQL predetection.

Listing 4-5 is an example of letting SQL determine whether there’s a duplicate row, and then conditionally inserting values into the `WORKERS` table.

Listing 4-5. An Insert Example, Modified to Detect Duplicates with SQL, insert_with_sql_detection.sql

```
rem insert_with_sql_detection.sql
rem by Donald J. Bales on 2014-10-20
rem An anonymous PL/SQL procedure to insert
rem values using PL/SQL literals and variables

set serveroutput on size 1000000;

declare

v_first_name                          WORKERS.first_name%TYPE;
v_middle_name                         WORKERS.middle_name%TYPE;
v_last_name                           WORKERS.last_name%TYPE;
v_name                                WORKERS.name%TYPE;
d_birth_date                          WORKERS.birth_date%TYPE;

-- I'll use this variable to hold the result
-- of the SQL insert statement.
n_count                               number;

begin
  -- Since I use these values more than once,
  -- I set them here, and then use the variables
  v_first_name  := 'JOHN';
  v_middle_name := 'J.';
  v_last_name   := 'DOE';
  v_name        :=
    rtrim(v_last_name||', '||v_first_name||' '||v_middle_name);
  d_birth_date  :=
    to_date('19800101', 'YYYYMMDD'); -- I'm guessing

  -- Now I can just let SQL do all the work.  Who needs PL/SQL!
  begin
    insert into WORKERS (
           id,
           worker_type_id,
           external_id,
           first_name,
           middle_name,
           last_name,
           name,
           birth_date,
           gender_type_id )
    select WORKERS_ID.nextval,
           c1.id,
           lpad(to_char(EXTERNAL_ID_SEQ.nextval), 9, '0'),
           v_first_name,
           v_middle_name,
           v_last_name,
           v_name,
           d_birth_date,
           c2.id
    from   WORKER_TYPES c1,
           GENDER_TYPES c2
    where  c1.code = 'C'
    and    c2.code = 'M'
    and not exists (
      select 1
      from   WORKERS x
      where  x.name           = v_name
      and    x.birth_date     = d_birth_date
      and    x.gender_type_id = c2.id );

    n_count := sql%rowcount;
  exception
    when OTHERS then
      raise_application_error(-20006, SQLERRM||
        ' on insert WORKERS'||
        ' in filename insert_with_sql_detection.sql');
  end;

  pl(to_char(n_count)||' row(s) inserted.');
end;
/

commit;
```

Listing 4-5 isn't a partial listing; it's the whole program! Where did all the PL/SQL go? Well, let's see. First, I'm using a different syntax for this program's INSERT statement, as follows:

```
INSERT INTO <insert_table_name> (
       <column_name_1>,
       <column_name_2>,...
       <column_name_N> )
SELECT <column_name_or_value_1>,
       <column_name_or_value_2>,...
       <column_name_or_value_N>
FROM   <select_table_name_1> <select_table_alias_1>,
       <select_table_name_2> <select_table_alias_2>,...
       <select_table_name_N> <select_table_alias_N>
WHERE  <where _clause>;
```

where <insert_table_name> is the name of the table to INSERT INTO, <column_name> is the name of a column in that table, <column_name_or_value> is the value for a corresponding <column_name> from one of the SELECT statement's tables, <select_table_name> is one of the tables being queried by the SELECT statement, <select_table_alias> is a corresponding table name alias, and <where_clause> is the SELECT statement's WHERE clause. The column values can be PL/SQL literals, variables, qualifying function results, or SQL column values.

I'll say it again: you should always use a list of columns in your INSERT statements in order to maintain the validity of your code in the event that someone later adds a column to the table.

Back to the SQL statement:

- On lines 54 and 55, since the WHERE clause selects one row from the WORKER_TYPES and GENDER_TYPES tables, the SELECT statement will return only one row of values.
- On lines 56 through 61, the NOT EXISTS subquery performs the detection of a duplicate entry and, accordingly, the conditional insert of a row.

All the work that was done by five other SQL SELECT statements is now accomplished in one INSERT SELECT statement. What's the moral of this story? Know thy SQL! Each solution presented here has its strengths and weaknesses. As I stated earlier, it's up to you to decide which is the best tactic to apply to each situation.

I favor predetection instead of postdetection (reacting to the DUP_VAL_ON_INDEX exception) because I can maintain control of my program. And I have never found a situation where my PL/SQL batch programs were working on inserting and/or updating the exact same set of data at the same time. So, in 20 plus years of writing stored procedures, and after more than 40,000 stored procedures, I've never seen a DUP_VAL_ON_INDEX exception when using predetection. This means you must also consider the nature of the business environment in which you are going to run your stored procedures when deciding whether to use postdetection or predetection.

■ **Tip** You should check out the functionality of the newer SQL DML statement MERGE. It can do a lot of what has already been covered in this chapter, using just SQL. However, it suffers from the same predetection issues I just covered.

It's Your Turn to Insert

Are you just going to watch me do all the work? No way! Here's what I need you to do, and you've got to do it, or the coming examples won't work.

1. Use whatever PL/SQL insert technique you want to code a script to insert rows into the WORKERS table for four workers: JANE J. DOE, her husband JOHN J. DOE, her daughter JANIE E. DOE, and her son JOHNNIE E. DOE.
2. Save your script as `insert_the_doe_family.sql`.
3. Execute your script.
4. Test your script by executing it again. Make sure you don't get any errors but still get the desired rows in the WORKERS table.

Listing 4-6 is my solution to this exercise.

Listing 4-6. An Anonymous Procedure to Insert the Doe Family into the Worker Table, insert_the_doe_family.sql

```
rem insert_the_doe_family.sql
rem by Donald J. Bales on 2014-10-20
rem An anonymous PL/SQL procedure to insert
rem values using PL/SQL literals and variables

```

```
set serveroutput on size 1000000;

declare

-- I'll use this variable to hold the result
-- of the SQL insert statement.
n_count                               number := 0;

-- I've declared this local (or embedded) function to
-- do the actual work of inserting values.  It uses
-- SQL detection to prevent DUP_VAL_ON_INDEX exceptions.
FUNCTION add_worker(
aiv_first_name                        WORKERS.first_name%TYPE,
aiv_middle_name                       WORKERS.middle_name%TYPE,
aiv_last_name                         WORKERS.last_name%TYPE,
aid_birth_date                        WORKERS.birth_date%TYPE,
aiv_gender_code                       GENDER_TYPES.code%TYPE,
aiv_worker_type_code                  WORKER_TYPES.code%TYPE)
return                                number is

v_name                                WORKERS.name%TYPE;

begin
  v_name        :=
    rtrim(aiv_last_name||', '||aiv_first_name||' '||aiv_middle_name);

  -- Now I can just let SQL do all the work.  Who needs PL/SQL!
  begin
    insert into WORKERS (
           id,
           worker_type_id,
           external_id,
           first_name,
           middle_name,
           last_name,
           name,
           birth_date,
           gender_type_id )
    select WORKERS_ID.nextval,
           c1.id,
           lpad(to_char(EXTERNAL_ID_SEQ.nextval), 9, '0'),
           aiv_first_name,
           aiv_middle_name,
           aiv_last_name,
           v_name,
           aid_birth_date,
           c2.id
    from   WORKER_TYPES c1,
           GENDER_TYPES c2
    where  c1.code = aiv_worker_type_code
    and    c2.code = aiv_gender_code
    and not exists (
      select 1
      from   WORKERS x
      where  x.name           = v_name
      and    x.birth_date     = aid_birth_date
      and    x.gender_type_id = c2.id );

    return sql%rowcount;
  exception
    when OTHERS then
      raise_application_error(-20001, SQLERRM||
        ' on insert WORKERS'||
        ' in add_worker');
  end;
end add_worker;

begin
  -- All I have to do now, is call the add_worker function
  -- four times with each Doe family member's values.
  n_count := n_count + add_worker(
    'JOHN',   'J.', 'DOE', to_date('19800101', 'YYYYMMDD'), 'M', 'C');
  n_count := n_count + add_worker(
    'JANE',   'J.', 'DOE', to_date('19800101', 'YYYYMMDD'), 'F', 'E');
  n_count := n_count + add_worker(
    'JOHNNY', 'E.', 'DOE', to_date('19980101', 'YYYYMMDD'), 'M', 'E');
  n_count := n_count + add_worker(
    'JANIE',  'E.', 'DOE', to_date('19980101', 'YYYYMMDD'), 'F', 'E');

  pl(to_char(n_count)||' row(s) inserted.');
end;
/

commit;
```

In practice, you'll find that you primarily use an INSERT statement in PL/SQL when you do the following:

- Move data from one application to another for data migration
- Transform data for data processing

Beyond those two applications, a program written in some other programming language like Java or a data-loading utility like SQL*Loader will be used to insert values into the database.

Now that you have four entries in the WORKERS table, let's update a couple of them!

Updates

Here, I'm talking about updating a row or rows of data in a relational database from PL/SQL. Let's start with a simple update.

Updating a Row

Listing 4-7 is an example of using a SQL UPDATE statement in PL/SQL. It's just a good, old-fashioned UPDATE statement, where you can also use PL/SQL literals, PL/SQL variables, or SQL functions.

Listing 4-7. An Update Example Using Variables, insert_with_plsql_detection_for_update.sql

```
143      begin
144        update WORKERS
145        set    worker_type_id  = n_worker_type_id
146        where  id              = n_id;
147
148        n_updated := sql%rowcount;
149      exception
150        when OTHERS then
151          raise_application_error(-20007, SQLERRM||
152            ' on update WORKERS'||
153            ' in filename insert_with_plsql_detection_for_update.sql');
154      end;
```

The syntax used for the SQL UPDATE statement in Listing 4-7 is as follows:

```
UPDATE <table_name>
SET    <column_name_1> = <column_value_1>,
       <column_name_2> = <column_value_2>,...
       <column_name_N> = <column_value_N>
WHERE  <where_clause>;
```

where `<table_name>` is the name of the table to be updated, `<column_name>` is the name of a column to update, `<column_value>` is the corresponding value to use for the column, and `<where_clause>` is a WHERE clause that appropriately selects the rows to be updated.

I said it earlier, and I'll say it again: you should almost always have a WHERE clause with an UPDATE statement. I've seen some really catastrophic disasters in my day when someone has executed an UPDATE statement without a WHERE clause. I even go so far as to run a PL/SQL program against the database's source table, SYS.DBA_SOURCE, to look for UPDATE statements without WHERE clauses.

As for the code in this listing, well, there's nothing earth-shattering about it:

- Lines 144 through 146 contain a SQL UPDATE statement to update a worker's type if a duplicate row already exists in the database.
- Line 148 gets the result of the UPDATE statement: the number of rows updated.
- On lines 143 through 154 collectively, I've blocked the UPDATE statement in order to capture and report the exact type and location of any unexpected error.

The number one abuse of PL/SQL when used for data processing is using it to update values in a table in a row-by-row fashion. Why is that an abuse of PL/SQL? Because that's what SQL is for.

Using SQL to Perform Complex Updates

The SQL UPDATE statement is very powerful. It can update one or more columns for a predetermined set of rows in a single statement. Why am I spending so much time on this soapbox about knowing SQL? The whole purpose of PL/SQL is to control when to execute an appropriate SQL statement. It is *not* intended to replace SQL with a bunch of poorly performing PL/SQL statements.

You can update multiple columns at a time in a SQL UPDATE statement, as demonstrated in Listing 4-8.

Listing 4-8. Updating Multiple Columns with an UPDATE Statement, update_multiple.sql

```
1  update WORKERS u
2  set   ( u.worker_type_id,  u.gender_type_id ) = (
3  select c1.id,             c2.id
4  from   WORKER_TYPES c1,
5         GENDER_TYPES c2
6  where  c1.code = decode(instr(u.first_name, 'JOHN'), 0, 'E', 'C')
7  and    c2.code = decode(instr(u.first_name, 'JOHN'), 0, 'F', 'M') )
8  where  u.last_name = 'DOE';
```

The syntax used in the UPDATE statement in Listing 4-8 is as follows:

```
UPDATE <update_table_name>
SET ( <update_column_name_1>, <update_column_name_2>,... <update_column_name_N> ) =
(SELECT <select_column_name_1>, <select_column_name_2>,... <select_column_name_N>
FROM   <select_table_name_1>,
       <select_table_name_2>,...
       <select_table_name_N>
WHERE  <select_column_name_3> = <update_column_name_3>
AND    <select_column_name_4> = <update_column_name_4>
AND    <select_column_name_N> = <update_column_name_N> )
WHERE  <update_column_name_4> = ... ;
```

The UPDATE statement in Listing 4-8 will set the worker type and gender type to C (contractor) and M (male), respectively, for anyone with the first name John and the last name Doe. Yes, this is a silly example, but the point here is that the use of subqueries in the SET and WHERE clauses of a SQL UPDATE statement make it possible to update almost anything. All you should need PL/SQL for is deciding when to execute an appropriate SQL UPDATE statement.

Let's take a close look at Listing 4-8:

- Line 1 specifies the name of the table to be updated.
- Line 2 specifies a list of columns in that table to be updated. The list is enclosed in parentheses followed by an equal sign, and then an opening parenthesis, which is the start of a subquery.
- Lines 3 through 7 contain a subquery that will conditionally select which values to update the columns with based on information in the table to be updated.
- Line 3 has a list of the same number of values (columns) in the SELECT statement's column list as in the UPDATE statement's SET list.
- Lines 4 and 5 specify two code tables from which to draw update values.
- On line 6, I conditionally specify the code value for C (contractor) or E (employee), based on whether or not the worker's `first_name` contains the string `'JOHN'`.
- On line 7, I conditionally specify the code value for F (female) or M (male), based on whether or not the worker's first name contains the string `'JOHN'`.
- On line 8, I constrain the rows that will be updated to those with the `last_name` equal to `'DOE'`.

The lesson here: know thy SQL!

As I stated earlier, in practice, you'll primarily use an UPDATE statement in PL/SQL in the following situations:

- The conditions for updating are too complex to be determined using a SQL WHERE clause; that is, you need a more procedural decision-making process.
- Deriving the values to use to update a table's column values is too complex to be done by SQL; that is, you need a more procedural decision-making process.
- You need to use a PL/SQL program unit's ability to formulate a larger and more complex multistatement transaction context.

Hence, the reason PL/SQL exists: to add procedure decision-making capabilities to the use of nonprocedural SQL statements!

Guess what? There's even less to say about deleting rows.

Deletes

In practice, the SQL DELETE command is rarely used when compared to its siblings INSERT, UPDATE, and SELECT. However, for completeness, let's look at how you use it in PL/SQL. Listing 4-9 is an example of using a DELETE statement in PL/SQL, where I use a PL/SQL literal, a SQL function, and a subquery that uses a PL/SQL variable.

Listing 4-9. A Delete Example Using a PL/SQL Literal and Variable, delete.sql

```
01  rem delete.sql
02  rem by Donald J. Bales on 2014-10-20
03  rem An anonymous PL/SQL procedure to delete
04  rem rows using PL/SQL literals and variables
05
06  set serveroutput on size 1000000;
07
08  declare
09
10  -- I'll use this variable to hold the result
11  -- of the SQL delete statement.
12  n_count                               number;
13
14  v_code                                GENDER_TYPES.code%TYPE := 'M';
15
16  begin
17
18    begin
19      delete from WORKERS d
20      where  d.name           = 'DOE, JOHN J.'                 -- a literal
21      and    d.birth_date     = to_date('19800101', 'YYYYMMDD')  -- a function
22      and    d.gender_type_id  = (                             -- a sub-query
23      select c.id
24      from   GENDER_TYPES c
25      where  c.code           = v_code );                      -- a variable
26
27      n_count := sql%rowcount;
28    exception
```

```
29      when OTHERS then
30        raise_application_error(-20001, SQLERRM||
31          ' on delete WORKERS'||
32          ' in filename delete.sql');
33    end;
34
35    pl(to_char(n_count)||' row(s) deleted.');
36  end;
37  /
38
39  commit;
```

The syntax for the SQL DELETE statement used in Listing 4-9 is as follows:

```
DELETE [FROM] <delete_table_name>
WHERE <where_clause> ;
```

where <delete_table_name> is the name of the table from which to delete rows, and <where_clause> is a SQL WHERE clause that appropriately specifies the rows within the table to delete.

On line 27, I capture the result of the SQL DELETE statement: the number of rows deleted. Just as with an UPDATE statement, every DELETE statement should have a WHERE clause.

Let's discuss how you might apply a DELETE statement in PL/SQL. In practice, you'll primarily use a DELETE statement in PL/SQL when the conditions for deleting are too complex to be determined by using a WHERE clause. So you'll find that you rarely use DELETE at all!

Finally, let's look at the SELECT statement.

Selects

The SQL SELECT statement is the most used SQL statement in PL/SQL, and for a good reason. PL/SQL is all about encompassing set-based operations with procedural logic. Yet a SQL SELECT statement is a nonprocedural construct, hence the need for the PL in PL/SQL. In this section, I'll discuss the singleton SELECT statement—the one that is supposed to return one row.

You've seen me use SELECT statements over and over again at this point. As I've said, I assume you already know SQL. Regardless, I've tried to take some time to review what you know about SQL, so you'll be ready for PL/SQL. Most PL/SQL stored procedures you write will have one or more SELECT statements in them. So what you can accomplish using PL/SQL—whether it's object-oriented architecture, service-oriented architecture, data processing, data migration, or reporting—will be constrained by your competency in writing a SQL SELECT statement.

Let's look back at the first source code listing in this chapter, Listing 4-3. For your convenience (and mine), I'm going to show part of it to you again in Listing 4-10.

Listing 4-10. An Example of Using Singleton SELECT Statements in PL/SQL, insert_with_plsql_detection.sql

```
048    -- Next, let's get the GENDER_TYPES id for a male
049    begin
050      select id
051      into   n_gender_type_id
052      from   GENDER_TYPES
053      where  code = 'M';
054    exception
055      when OTHERS then
```

```
      raise_application_error(-20004, SQLERRM||
        ' on select GENDER_TYPES'||
        ' in filename insert_with_plsql_detection.sql');
  end;

  -- Detect any existing entries with the unique
  -- combination of columns as in this constraint:
  -- constraint   WORKERS_UK2
  -- unique (
  -- name,
  -- birth_date,
  -- gender_type_id )
  begin
    select count(1)
    into   n_count
    from   WORKERS
    where  name           = v_name
    and    birth_date     = d_birth_date
    and    gender_type_id = n_gender_type_id;
  exception
    when OTHERS then
      raise_application_error(-20005, SQLERRM||
        ' on select WORKERS'||
        ' in filename insert_with_plsql_detection.sql');
  end;

  -- Conditionally insert the row
  if n_count = 0 then
    -- Now, let's get the next id sequence
    begin
      select WORKERS_ID.nextval
      into   n_id
      from   SYS.DUAL;
    exception
      when OTHERS then
        raise_application_error(-20001, SQLERRM||
          ' on select WORKERS_ID.nextval'||
          ' in filename insert_with_plsql_detection.sql');
    end;
```

The syntax used for the SQL SELECT statements in Listing 4-10 is as follows:

```
SELECT <column_name_1>,
       <column_name_2>,...
       <column_name_N>
INTO   <plsql_variable_1>,
       <plsql_variable_2>,...
       <plsql_variable_N>
FROM   <table_name_1>,
       <table_name_2>,...
       <table_name_N>
WHERE  <where_clause>... ;
```

where `<column_name>` is the name of a column in one of the tables in the `FROM` list, `<plsql_variable>` is the corresponding variable to copy the column value to, `<table_name>` is a table to query, and `<where_clause>` is an appropriate `WHERE` clause.

Let's examine the three SQL `SELECT INTO` statements in Listing 4-10:

- Lines 50 through 53 get the corresponding `gender_type_id` value for the code `'M'`.
- Line 50 selects the column name, `GENDER_TYPES.id`.
- Line 51 specifies the PL/SQL variable `n_gender_type_id` in the `INTO` clause.
- Line 52 specifies the code table's name, `GENDER_TYPES`.
- Line 53 specifies a `WHERE` clause, where the code is equal to `'M'`.
- On lines 49 through 59 collectively, I block the SQL `SELECT` statement in order to catch and report any catastrophic errors (`WHEN OTHERS`). This is a `SELECT` statement where I don't expect any exceptions. I always expect the corresponding values to exist in the database.
- On lines 69 through 74, I use a SQL group operator, `count()`, to determine the number of rows in the table that match the criteria of the associated `WHERE` clause.
- On lines 68 through 80 collectively, I block the SQL `SELECT` statement for `OTHERS`. This is a safe SQL `SELECT` statement. It will always have a result, except in the case of some unforeseeable database error.
- Lines 86 through 88 get the next sequence value for the column `id` from sequence `WORKERS_ID`.
- On lines 85 through 94 collectively, I block the SQL `SELECT` statement for any unforeseeable errors, but I never expect this SQL `SELECT` statement to raise an exception.

But what do you do if you expect an error? For example, perhaps a row matching the `WHERE` clause criteria is not in the table! Or maybe too many rows match the `WHERE` clause criteria. What do you do then?

No Data Found

As I stated earlier when I first discussed exceptions in Chapter 2, there are two very commonly used exceptions. The most commonly used exception is `NO_DATA_FOUND`. When a singleton `SELECT` statement can't find a row to match its `WHERE` clause's criteria, it will raise a `NO_DATA_FOUND` exception. You saw an example of this earlier in Listing 4-4. Listing 4-11 highlights the `SELECT` statement in question.

Listing 4-11. An Example of a SELECT Statement That May Raise a NO_DATA_FOUND Exception, insert_with_plsql_detection_for_update.sql

```
069    begin
070      select id
071      into   n_id
072      from   WORKERS
073      where  name           = v_name
074      and    birth_date     = d_birth_date
075      and    gender_type_id = n_gender_type_id;
076    exception
077      when NO_DATA_FOUND then
```

```
    n_id := NULL; -- Is this really needed?
  when OTHERS then
    raise_application_error(-20003, SQLERRM||
      ' on select WORKERS'||
      ' in filename insert_with_plsql_detection_for_update.sql');
end;
```

This SELECT statement may raise a NO_DATA_FOUND exception because the database might not contain a matching row. As a matter of fact, that's just what I'm trying to determine here. If the SELECT statement returns an id value, then the program knows that an entry already exists, so it will update the existing entry. Otherwise, the program will insert a new entry. It's the otherwise condition that will raise the exception.

When the NO_DATA_FOUND exception is raised, program execution jumps from the SELECT statement directly to the enclosing WHEN NO_DATA_FOUND clause. In this case, I set the n_id to NULL in that clause, and then later in the program, I use that fact to conditionally insert a new row.

Since the SELECT statement returns one set of columns—one row—from the database, there's no way for it to report the number of rows found, right? No, you can still get the number of rows returned from sql%rowcount. Take a look at Listing 4-12.

Listing 4-12. An Example of a SELECT Statement That Captures the Selected Row Count, select_no_data_found.sql

```
40  begin
41    select id
42    into   n_id
43    from   WORKERS
44    where  name           = v_name
45    and    birth_date     = d_birth_date
46    and    gender_type_id = n_gender_type_id;
47
48    n_selected := sql%rowcount;
49  exception
50    when NO_DATA_FOUND then
51      n_selected := sql%rowcount;
52      pl('Caught raised exception NO_DATA_FOUND');
53    when OTHERS then
54      raise_application_error(-20002, SQLERRM||
55        ' on select WORKERS'||
56        ' in filename select_no_data_found.sql');
57  end;
```

In Listing 4-12, I initially set the value of n_selected to –1 just so I can prove the value is changed later in the program. If the SELECT statement executes successfully, n_selected is equal to 1 because its value is set on line 48. However, if the SELECT statement raises the NO_DATA_FOUND exception, n_selected is equal to 0 because I set its value on line 51.

The number of rows returned from the SELECT statement is reported by the database, so why do I need a NO_DATA_FOUND exception? Why does it even exist? Quite frankly, I don't know. I think the exception exists as a matter of programming convenience. It's syntactic sugar. So even though it breaks my "You should always maintain control in your program" rule, it's commonly used to detect that no matching row was found for a WHERE clause's criteria. Even I use it.

I'll show you another tactic for detecting no data found for a singleton in the next chapter when I cover cursors. If you're going to rely on the NO_DATA_FOUND exception, you must keep in mind that any code that comes after your SELECT statement will not be executed if your SELECT statement raises NO_DATA_FOUND.

Next, let's look at the other singleton SELECT issue: too many rows are returned.

Too Many Rows

In the context of a singleton SELECT, PL/SQL is always going to expect your SELECT statement to return one and only one row. I just finished discussing what happens when a SELECT statement doesn't get at least one row. So what happens when a SELECT statement gets one (or more) too many? It raises the exception TOO_MANY_ROWS. Listing 4-13 is an example of a SELECT statement that will raise the exception TOO_MANY_ROWS.

Listing 4-13. An Example of a SELECT Statement That Raises a TOO_MANY_ROWS Exception, select_too_many_rows.sql

```
40   begin
41     select id
42     into   n_id
43     from   WORKERS;
44  -- Let's comment the WHERE clause so I get all the rows
45  --    where  name           = v_name
46  --    and    birth_date     = d_birth_date
47  --    and    gender_type_id = n_gender_type_id;
48     n_selected := sql%rowcount;
49   exception
50     when NO_DATA_FOUND then
51       n_selected := sql%rowcount;
52       pl('Caught raised exception NO_DATA_FOUND');
53     when TOO_MANY_ROWS then
54       n_selected := sql%rowcount;
55       pl('Caught raised exception TOO_MANY_ROWS');
56     when OTHERS then
57       raise_application_error(-20002, SQLERRM||
58         ' on select WORKERS'||
59         ' in filename select_too_many_rows.sql');
60   end;
```

In Listing 4-13, I've commented out the WHERE clause so the SELECT statement will see all four Doe family entries and will raise a TOO_MANY_ROWS exception. On lines 53 through 55, I've also added a WHEN TOO_MANY_ROWS clause to catch the raised exception and, in turn, capture the number of rows returned by the SELECT statement.

Guess what? On line 53, sql%rowcount reports that only one row was selected. So PL/SQL has no idea how many rows actually match the query. It only knows that more than one exists, and that's a problem—where will PL/SQL put the data from rows 2 and on? There's actually no place for the data, so PL/SQL appropriately throws an exception. After all, the query was supposed to be a singleton query!

You can add PL/SQL code to predetect too many rows, similar to the technique demonstrated in Listing 4-3, when I was trying to predetect a duplicate row.

If count() returns a value greater than one, the program will know that there's more than one row. But once again, PL/SQL provides some syntactic sugar that allows me to use an exception to detect a condition. Yes, again that syntactic sugar—catching a TOO_MANY_ROWS exception—breaks my rule of "You should always maintain control over your program!" I'll admit it, I use it. I catch the exception. I don't like it. But as I'll show you in the next chapter, you'll need to write a lot of extra code to maintain control, so PL/SQL programmers commonly use the exception TOO_MANY_ROWS.

Once again, if you're going to rely on the TOO_MANY_ROWS exception, you must keep in mind that any code that comes after your SELECT statement will not be executed if your SELECT statement raises TOO_MANY_ROWS!

That's enough of that. Now let's see you put what I just said to work.

It's Your Turn to Select

Your assignment is to write an anonymous procedure that displays the first name of each of the Doe family members from the WORKERS table—remember, the ones you added in the previous exercise? To that end, follow these steps.

1. Write you script using at least one singleton SELECT.
2. Save your script as `select_the_doe_family.sql`.
3. Execute your script.
4. Test your script by executing it again. Make sure you don't get any errors but still get the desired rows from the WORKERS table.

Listing 4-14 is my lousy solution. Why lousy? Because my solution involves repeatedly executing a singleton SELECT statement in order to read multiple rows from the WORKERS table. I really need a better way to handle this situation, and a better solution for this problem is just what I'll cover in the next chapter.

Listing 4-14. A Really Bad Way to Select Multiple Rows from a Table, select_the_doe_family.sql

```
rem select_the_doe_family.sql
rem by Donald J. Bales on 2014-10-20
rem An anonymous PL/SQL procedure to select
rem the first names for the Doe family from
rem the Worker table.

set serveroutput on size 1000000;

declare

v_first_name                          WORKERS.first_name%TYPE;
n_id                                  WORKERS.id%TYPE;

-- A local function that will be called over-and-over again
-- to find the next first_name for the specified id
-- and last_name.
FUNCTION get_first_name(
aion_id                        in out WORKERS.id%TYPE,
aiv_last_name                  in     WORKERS.last_name%TYPE)
return                                WORKERS.first_name%TYPE is

v_first_name                          WORKERS.first_name%TYPE;

begin
  -- Use SQL pseudo-column rownum in order
  -- to limit the SELECT to the first row
  select id,
         first_name
  into   aion_id,
         v_first_name
  from   WORKERS
  where  id           > aion_id
  and    last_name like aiv_last_name||'%'
  and    rownum       = 1;

  return v_first_name;
exception
  when NO_DATA_FOUND then
    return v_first_name;
  when OTHERS then
    raise_application_error(-20001, SQLERRM||
      ' on select WORKERS'||
      ' in show_worker');
end get_first_name;

begin
  -- Keep track of the primary key so you
  -- only retrieve the SELECTed row once
  n_id := 0;
  -- Loop until there's NO_DATA_FOUND
  loop
    -- get the first name from the local function
    v_first_name := get_first_name(n_id, 'DOE');
    -- detect NO_DATA_FOUND
    if v_first_name is NULL then
      exit;  -- Exit the loop
    end if;
    -- show the first_name
    pl(v_first_name);
  end loop;
end;
/
```

In practice, you'll find that you primarily use a singleton SELECT statement in PL/SQL when you want to do the following:

- Select the IDs for some code values that you will reference repeatedly
- Allocate a sequence value for a new primary key value
- Predetect the presence of a matching row

Let's review what you've learned.

Summary

At this point, it should be evident that a singleton is a SQL statement that returns one row of results. Table 4-1 is a side-by-side comparison of the results returned by each of the singletons I've covered: INSERT, UPDATE, DELETE, and SELECT.

Table 4-1. *Singleton Results for INSERT, UPDATE, DELETE, and SELECT*

Statement	Returns	Common Exceptions
`INSERT INTO`	Row count	`DUP_VAL_ON_INDEX`
`UPDATE`	Row count	
`DELETE FROM`	Row count	
`SELECT...INTO`	Row count and column values	`NO_DATA_FOUND`, `TOO_MANY_ROWS`

When you're working with the `INSERT INTO` and `SELECT...INTO` statements, you may as well expect an exception and write your PL/SQL accordingly. Of the four singletons, you'll use the `SELECT` statement the most. After all, you are working with a database.

The last exercise left me looking for a better solution to selecting more than one row at a time. In the next chapter, I'll look at the PL/SQL solution to this problem: a `CURSOR`.

CHAPTER 5

Multirow Processing

In the last chapter, you left off trying to retrieve the first names of the Doe family members from table WORKERS using a singleton SELECT. As you may have already guessed, Oracle has a better way to handle this multi-row processing problem.

Cursors

A *cursor* in this context is a named SQL SELECT statement that you can use in your PL/SQL program to access multiple rows from a table, yet retrieve them one row at a time.

Cursor Declarations

You declare cursors in the declaration section of a PL/SQL block just as you declare functions, procedures, and variables. And you should declare them with parameters, if required, just as you do with functions and procedures.

Listing 5-1 is a better solution to the last exercise in Chapter 4, where you were assigned the task of listing the Doe family's first names.

Listing 5-1. An Example of Using a Cursor to Select Multiple Rows from a Table, cursor_the_doe_family.sql

```
rem cursor_the_doe_family.sql
rem by Donald J. Bales on 2014-10-20
rem An anonymous PL/SQL procedure to select
rem the first names for the Doe family from
rem the Worker table.

set serveroutput on size 1000000;

declare

cursor c_workers(
aiv_last_name                  in     WORKERS.last_name%TYPE) is
select first_name
from   WORKERS
where  last_name like aiv_last_name||'%'
order by id;

```

```
v_first_name                         WORKERS.first_name%TYPE;

begin
  open c_workers('DOE');
  loop
    fetch c_workers into v_first_name;

    if c_workers%notfound then
      close c_workers;
      exit;
    end if;

    pl(v_first_name);
  end loop;
end;
/
```

There's a lot of new PL/SQL in this example. Let's start with syntax. The syntax used in Listing 5-1 to declare `CURSOR c_worker` is as follows:

```
CURSOR <cursor_name> [(
<parameter_name_1>         [IN]       <parameter_data_type_1>,
<parameter_name_2>         [IN]       <parameter_data_type_2>,...
<parameter_name_N>         [IN]       <parameter_data_type_N> )] IS
<select_statement>;
```

where `<cursor_name>` is the name of the `CURSOR`, `<parameter_name>` is the name of a parameter being passed `IN`, `<parameter_data_type>` is the PL/SQL data type of the corresponding parameter, and `<select_statement>` is a SQL `SELECT` statement. The brackets (`[]`) around the parameters denote that they are optional.

Of course, there's more to using cursors than just declaring them. Read on, as the next few subsections tell you all about what you can accomplish using cursors.

Fetching Rows from a Cursor Manually

The procedural PL/SQL, or control structure, syntax used to retrieve rows using the declared `CURSOR` in Listing 5-1 is as follows:

```
OPEN <cursor_name> [(
  <parameter_value_1,
  <parameter_value_2>,...
  <parameter_value_N> )];

LOOP
  -- loop until you manually EXIT;
FETCH <cursor_name> INTO
  <variable_name_1>,
  <variable_name_2>,...
  <variable_name_N>;
```

```
END LOOP;

CLOSE <cursor_name>;

EXIT;
```

where `<cursor_name>` is the name of a declared `CURSOR`, `<parameter_value>` is a value to pass in to the `CURSOR` that will be utilized somewhere in its SQL `SELECT` statement, and `<variable_name>` is a PL/SQL variable to receive one of the SQL `SELECT` statement's column values from the `CURSOR`.

The keyword `OPEN` is used to pass parameters to, and then execute, the cursor's SQL `SELECT` statement. `FETCH` retrieves one row of column values from the cursor's `SELECT` statement into a comma-separated list of PL/SQL variables. `CLOSE` does just that—it closes a `CURSOR`, releasing the cursor's resources back to PL/SQL and the database.

The keyword `LOOP` is used to start an unconstrained loop. In this context, any PL/SQL code between the keywords `LOOP` and `END LOOP` will continue to be executed over and over again until you manually exit the loop with the keyword `EXIT`. It's what I call a manual loop.

Here's the output from the `cursor_the_doe_family.sql` script (Listing 5-1):

```
SQL> @cursor_the_doe_family
```

```
JOHN
JANE
JOHNNY
JANIE

PL/SQL procedure successfully completed.
```

Let's take a moment to look at Listing 5-1, line by line:

- Lines 11 through 16 declare `CURSOR c_workers`, which will select the first name column from the table `WORKERS`, where the last name is like the one passed in.
- Line 18 declares a variable to hold the column value from the cursor.
- On line 21, I open the cursor, passing it the last name `'DOE'`. This should give me all the first names for anyone with a name like DOE.
- Line 22 starts a manual loop. Lines 23 through 30 will be repeated endlessly until I exit manually, as I do on line 27.
- On line 23, I fetch the value of the column `first_name` into variable `v_first_name`.
- On line 25, I test the cursor `c_workers` for `%notfound`. If the `SELECT` statement did not find a row in the database for the current loop, the cursor `c_worker` will report no data found through the cursor variable `%notfound`.
- On line 26, if there is no data found, I `CLOSE` the cursor, and then `EXIT` the loop on line 27.
- On line 30, if a row is found, I display the first name on the screen using `pl()`.
- On line 31, the keywords `END LOOP` signify the end of the `LOOP`.

Using a cursor for this type of problem—that is, retrieving multiple rows one row at a time—is definitely a better solution, if for no other reason than it was easier to maintain control over the program. But PL/SQL's solutions to this problem are going to get even better.

Cursor Records

On line 18 in Listing 5-1, I declared the variable `v_first_name` to hold the value from the database during each iteration of the `LOOP`. You can also use the keyword `%ROWTYPE` to declare a record for a cursor. So with one declaration, you can declare a record that has as many columns as the cursor it is defined for, with the same field names as the column names in the `SELECT` statement of the cursor. For example, I could have declared a record for `CURSOR c_workers` on line 18 as follows:

```
r_worker                              c_workers%ROWTYPE;
```

Pretty neat, huh? You'll see an example of this later in the chapter in Listing 5-7. Now let's take a look at using a cursor as a singleton `SELECT`.

A Singleton Cursor

By using a cursor, you can eliminate having to give up control of your programs when a `NO_DATA_FOUND` exception is raised because one is never raised. Instead, you can check the cursor variable for the status `%notfound`. Listing 5-2 is an example of using a cursor for a singleton `SELECT`. As you will see as you review the listing, sometimes using a cursor to retrieve one row can cost more in code than it's worth.

Listing 5-2. An Example of Using a Cursor for a Singleton SELECT, insert_with_plsql_cursor_detection_for_update.sql

```
rem insert_with_plsql_cursor_detection_for_update.sql
rem by Donald J. Bales on 2014-10-20
rem An anonymous PL/SQL procedure to insert
rem values using PL/SQL literals and variables

set serveroutput on size 1000000;

declare

cursor c_worker_types(
aiv_code                       in     WORKER_TYPES.code%TYPE) is
select id
from   WORKER_TYPES
where  code = aiv_code;

cursor c_gender_types(
aiv_code                       in     GENDER_TYPES.code%TYPE) is
select id
from   GENDER_TYPES
where  code = aiv_code;

cursor c_workers(
aiv_name                       in     WORKERS.name%TYPE,
aid_birth_date                 in     WORKERS.birth_date%TYPE,
ain_gender_type_id             in     WORKERS.gender_type_id%TYPE) is
select id
```

```
from   WORKERS
where  name           = aiv_name
and    birth_date     = aid_birth_date
and    gender_type_id = ain_gender_type_id;

cursor c_worker_ids is
select WORKERS_ID.nextval worker_id
from   SYS.DUAL;

cursor c_external_ids is
select lpad(to_char(EXTERNAL_ID_SEQ.nextval), 9, '0') external_id
from   SYS.DUAL;

-- I declared these variables so I can get
-- the required ID values before I insert.
n_id                                 WORKERS.id%TYPE;
n_worker_type_id                     WORKERS.worker_type_id%TYPE;
v_external_id                        WORKERS.external_id%TYPE;
v_first_name                         WORKERS.first_name%TYPE;
v_middle_name                        WORKERS.middle_name%TYPE;
v_last_name                          WORKERS.last_name%TYPE;
v_name                               WORKERS.name%TYPE;
d_birth_date                         WORKERS.birth_date%TYPE;
n_gender_type_id                     WORKERS.gender_type_id%TYPE;

-- I'll use these variables to hold the result
-- of the SQL insert and update statements.
n_inserted                           number := 0;
n_updated                            number := 0;

begin
  v_first_name  := 'JOHN';
  v_middle_name := 'J.';
  v_last_name   := 'DOE';
  v_name        :=
    rtrim(v_last_name||', '||v_first_name||' '||v_middle_name);
  d_birth_date  :=
    to_date('19800101', 'YYYYMMDD'); -- I'm guessing

  -- First, let's get the worker_type_id for a contractor
  begin
    open  c_worker_types('C');
    fetch c_worker_types
    into  n_worker_type_id;
    if    c_worker_types%notfound then
     raise_application_error(-20001,
       'Can''t find the worker types ID for Contractor.'||
       ' on select WORKER_TYPES'||
       ' in filename insert_with_plsql_cursor_detection_for_update.sql');
    end if;
    close c_worker_types;
```

```
exception
  when OTHERS then
    raise_application_error(-20002, SQLERRM||
      ' on select WORKER_TYPES'||
      ' in filename insert_with_plsql_cursor_detection_for_update.sql');
end;

-- Next, let's get the gender_id for a male
begin
  open  c_gender_types('M');
  fetch c_gender_types
  into  n_gender_type_id;
  if    c_gender_types%notfound then
   raise_application_error(-20003,
     'Can''t find the gender ID for Male.'||
     ' on select GENDER_TYPES'||
     ' in filename insert_with_plsql_cursor_detection_for_update.sql');
  end if;
  close c_gender_types;
exception
  when OTHERS then
    raise_application_error(-20004, SQLERRM||
      ' on select GENDER_TYPES'||
      ' in filename insert_with_plsql_cursor_detection_for_update.sql');
end;

-- Detect any existing entries with the unique
-- combination of columns as in this constraint:
-- constraint   WORKERS_UK2
-- unique (
-- name,
-- birth_date,
-- gender_id )
begin
  open  c_workers(v_name, d_birth_date, n_gender_type_id);
  fetch c_workers
  into  n_id;
  if    c_workers%notfound then
    n_id := NULL;
  end if;
  close c_workers;
exception
  when OTHERS then
    raise_application_error(-20005, SQLERRM||
      ' on select WORKERS'||
      ' in filename insert_with_plsql_cursor_detection_for_update.sql');
end;

```

```
    -- Conditionally insert the row
    if n_id is NULL then
      -- Now, let's get the next worker_id sequence
      begin
      open  c_worker_ids;
      fetch c_worker_ids
      into  n_id;
      close c_worker_ids;
      exception
        when OTHERS then
          raise_application_error(-20006, SQLERRM||
            ' on select WORKER_IDS.nextval'||
            ' in filename insert_with_plsql_cursor_detection_for_update.sql');
      end;

      -- And then, let's get the next external_id sequence
      begin
      open  c_external_ids;
      fetch c_external_ids
      into  v_external_id;
      if    c_external_ids%notfound then
        v_external_id := NULL;
      end if;
      close c_external_ids;
      exception
        when OTHERS then
          raise_application_error(-20006, SQLERRM||
            ' on select EXTERNAL_ID_SEQ.nextval'||
            ' in filename insert_with_plsql_cursor_detection_for_update.sql');
      end;

      -- Now that we have all the necessary ID values
      -- we can finally insert a row!
      begin
        insert into WORKERS (
               id,
               worker_type_id,
               external_id,
               first_name,
               middle_name,
               last_name,
               name,
               birth_date,
               gender_type_id )
        values (
               n_id,
               n_worker_type_id,
               v_external_id,
               v_first_name,
               v_middle_name,
               v_last_name,
177               v_name,
178               d_birth_date,
179               n_gender_type_id );
180
181         n_inserted := sql%rowcount;
182       exception
183         when OTHERS then
184           raise_application_error(-20007, SQLERRM||
185             ' on insert WORKERS'||
186             ' in filename insert_with_plsql_cursor_detection_for_update.sql');
187       end;
188     else
189       begin
190         update WORKERS
191         set    worker_type_id = n_worker_type_id
192         where  id             = n_id;
193
194         n_updated := sql%rowcount;
195       exception
196         when OTHERS then
197           raise_application_error(-20008, SQLERRM||
198             ' on update WORKERS'||
199             ' in filename insert_with_plsql_cursor_detection_for_update.sql');
200       end;
201     end if;
202
203     pl(to_char(n_inserted)||' row(s) inserted.');
204     pl(to_char(n_updated)||' row(s) updated.');
205   end;
206   /
207
208   commit;
```

Listing 5-2 doesn't have any new syntax, but it does show a different utilization of the keywords OPEN, FETCH, and CLOSE. You may recall seeing a form of this source code originally in Listing 4-4. Now it has been modified to use cursors for its singleton SELECT statements, so I can argue when it's a good idea to use cursors for singletons and when it's not.

Let's break down the listing:

- Lines 10 through 14 declare a cursor for table WORKER_TYPES.
- Lines 16 through 20 declare a cursor for table GENDER_TYPES.
- Lines 22 through 30 declare a cursor for table WORKERS. Later in the executable section, I'll pass parameters for the worker's name, birth date, and gender in order to try to find an existing row in the database.
- Lines 32 through 34 declare a cursor for allocating the next worker ID sequence value.
- Lines 36 through 38 declare a cursor for allocating the external ID sequence value.
- On line 68, I open the cursor for the worker type, passing the code value C as a parameter.

- On line 69 and 70, I try to fetch the corresponding `worker_type_id` value into variable `n_worker_type_id`.
- On line 71, I test the cursor variable `c_worker_types%notfound` to see if a corresponding ID value was found. If not, I raise an application error, which stops the execution of the program.
- Line 77 closes the cursor (that's a mandatory programming task).
- On lines 68 through 83 collectively, I've blocked `OPEN`, `FETCH`, and `CLOSE` in order to capture any unusual errors.
- On lines 86 through 102 collectively, I do the same for table `GENDER_TYPES` as I have done for table `WORKER_TYPES`. *My assessment: using a cursor for getting the code IDs gains me nothing.* I don't expect there to be an exception, so I really don't gain any more control over the program by using a cursor for singleton `SELECT` as in this situation.
- On lines 111 through 124 collectively, I use a cursor to select a matching `id` from `WORKERS`. *This time, there is an advantage in using a cursor for a singleton SELECT.* Since I expect that the `SELECT` may not find any data, I can query the cursor variable `c_workers%notfound` to determine this. If the `SELECT` statement did not find a matching entry in the table, I set variable `n_id` to `NULL` to flag that no matching entry exists. In this instance, I no longer needed to code a `WHEN NO_DATA_FOUND` exception.
- On lines 129 through 139, and 142 through 155 collectively, I've used cursors to select the next sequence values from the database. Once again, since I don't expect any possible errors, using cursors for singleton `SELECT` statements adds a lot of code but little value.

The moral of the story is that you may want to use a cursor for a singleton `SELECT` if you expect a `NO_DATA_FOUND` exception may be raised; otherwise, you may as well stick to a simple `SELECT` statement. In practice, I personally have no problem with utilizing the exception `NO_DATA_FOUND`, syntactic sugar that it is, but the choice is now yours.

It's Your Turn to Fetch Manually

In this section, your assignment is to write a program using cursors. But first, I'll present a point of view on why good use of cursors is so important.

Do you ever think about how many times you've written a given SQL statement? Do you ever find yourself writing the same statement more than once in your program? Just how many times should you write the same SQL statement? In my opinion, the answer is just once! There are a lot of reasons to avoid writing the same statement more than once. Let's start with these:

- One SQL statement to accomplish one goal means fewer cursors in use on your database, and that means better performance.
- One SQL statement to accomplish one task means consistent behavior across your application's presentation layers.
- One SQL statement to accomplish one requirement means it will be easier to maintain and modify your application's code.
- One SQL statement to attain the goals just mentioned means saving money, and saved money is profit.

To attain better performance, consistent behavior, more maintainable code, and profit, you're going to have to start thinking like an object-oriented programmer.

What's your assignment? Write three packages for three tables. I'll show you two out of the three so you have some models for your coding, but I expect you to stretch during the third exercise and it all on your own. Let's start by *modularizing* a code table.

A Code Table Package

In the listings in Chapter 4 and now Chapter 5, I've repeatedly coded the same SQL SELECT statement in order to get the corresponding ID value for a given code. So rather than keep writing the same code over and over, I've created a package called WORKER_TYPE for table WORKER_TYPES. This is what I call a pseudo-object-oriented approach to programming in PL/SQL. Listing 5-3 is the worker type codes package spec, and Listing 5-4 is its implementation, or package body.

Listing 5-3. The WORKER_TYPE Package Spec, worker_type.pks

```
create or replace PACKAGE WORKER_TYPE as
/*
worker_type.pks
by Don Bales on 2014-10-20
Code Table WORKER_TYPES' methods.
*/


-- Returns the id for the specified code value.

FUNCTION get_id(
aiv_code                       in     WORKER_TYPES.code%TYPE )
return                                WORKER_TYPES.id%TYPE;


end WORKER_TYPE;
/
@se.sql WORKER_TYPE
```

In Listing 5-3, I've declared one function, `get_id(aiv_code) return id`. Now if programmers—whether they are coding in a PL/SQL program, a JDBC program, C, C++, Perl, PowerScript, and so on—want to get the `id` value for a corresponding code value, all they need to do is call the PL/SQL function `WORKER_TYPE.get_id()`, passing it an existing code value.

Listing 5-4. The WORKER_TYPE Package Body, worker_type.pkb

```
create or replace PACKAGE BODY WORKER_TYPE as
/*
worker_type.pkb
by Don Bales on 2014-10-20
Table WORKER_TYPES' methods
*/


```

```
09  -- FUNCTIONS
10
11  FUNCTION get_id(
12  aiv_code                       in     WORKER_TYPES.code%TYPE )
13  return                                WORKER_TYPES.id%TYPE is
14
15  n_id                                  WORKER_TYPES.id%TYPE;
16
17  begin
18    select id
19    into   n_id
20    from   WORKER_TYPES
21    where  code = aiv_code;
22
23    return n_id;
24  end get_id;
25
26
27  end WORKER_TYPE;
28  /
29  @be.sql WORKER_TYPE
```

Let's look at the implementation, Listing 5-4:

- Line 11 declares the implementation for function `get_id()`.
- Line 12 specifies that a calling program must pass in a code value.
- Line 13 specifies that the function will return a worker type ID value.
- Line 15 declares a local variable called `n_id` to hold the ID value retrieved from the database.
- Lines 18 through 21 contain a SQL `SELECT` statement to retrieve a corresponding ID value for the given code value in parameter `aiv_code`.
- On line 23, I return the retrieved ID value to the calling program unit.
- Lines 11 through 24 collectively implement a SQL `SELECT` statement to retrieve an ID value for a corresponding code value. I have not blocked this SQL statement, so it will raise a `NO_DATA_FOUND` exception should one occur. This means the calling program may want to block the call to `WORKER_TYPE.get_id()` in order to be able to report the exact error and the location where it occurred in the program.

Now, anywhere I would have coded another SQL statement to select an ID from table `WORKER_TYPES` for a given code, I can simply code

```
n_worker_type_id := WORKER_TYPE.get_id('C');
```

or better yet

```
begin
  n_worker_type_id := WORKER_TYPE.get_id('C');
exception
  when OTHERS then
    raise_application_error(-20???, SQLERRM||
      ' on call WORKERT_TYPE.get_id()'||
      ' in <my_program_unit>');
end;
```

The latter example, although more code, will make it easier to troubleshoot your program when an error does occur.

So what's part one of your assignment? Create a code package for table GENDER_TYPES, and that includes compiling and testing it. When you're finished, continue reading for part two.

A Worker Table Package

In a similar fashion to the code tables, I've written SQL SELECT statements numerous times in order to allocate database-generated sequence values. So I've created package WORKER to hold functions and procedures for table WORKERS. The first function I've added is get_id(). However, this time, get_id() is called without parameters and returns the next available sequence number for the WORKERS id column.

Take a look at package WORKER. Listing 5-5 is its package spec, and Listing 5-6 is its implementation.

Listing 5-5. The WORKER Package Spec, worker.pks

```
create or replace PACKAGE WORKER as
/*
worker.pks
by Donald J. Bales on 2014-10-20
Table WORKERS' methods.
*/


-- Return the next ID sequence value

FUNCTION get_id
return                                WORKERS.id%TYPE;


end WORKER;
/
@se.sql WORKER
```

In Listing 5-5, I've declared one function: get_id(). It will return the next WORKERS_ID sequence value.

Listing 5-6. The WORKER Package Body, worker.pkb

```
create or replace PACKAGE BODY WORKER as
/*
worker.pkb
by Donald J. Bales on 2014-10-20
Table WORKERS' methods
*/


-- FUNCTIONS

FUNCTION get_id
return                              WORKERS.id%TYPE is

n_id                                WORKERS.id%TYPE;

begin
  select WORKERS_ID.nextval
  into   n_id
  from   SYS.DUAL;

  return n_id;
end get_id;


end WORKER;
/
@be.sql WORKER
```

In Listing 5-6, I've coded a function that queries and returns the sequence value from `WORKERS_ID.nextval`. Remember that the `SYS.DUAL` table has one row, so selecting any value against it will return one value.

Your assignment for part two is to add three functions to package `WORKER`:

- A `get_external_id()` function, which will return a value from sequence `EXTERNAL_ID_SEQ` as a properly zero-left-padded `varchar2`.
- A `get_unformatted_name()` function, which will return a concatenated value for three parameters: `aiv_first_name`, `aiv_middle_name`, and `aiv_last_name`. Use the concatenation operator—two vertical bars (`||`)—to concatenate the `varchar2` values together. (Hint: I've already coded this concatenation time and time again in the previous listings.)
- An `is_duplicate()` function, which you will pass three parameters: `aiv_name`, `aid_birth_date`, and `ain_gender_type_id`. It should return a Boolean value of `TRUE` if a duplicate exists; otherwise, it should return `FALSE`.

Remember to test all three functions. Yes, write a test unit for each one!

Let's move on to part three of your assignment.

Write a Modularized Version of Insert with PL/SQL Detection

Do you remember Listing 4-3? Now that you have functions for five out of the five blocked singleton `SELECT` statements, rewrite Listing 4-3 (`insert_with_plsql_detection.sql`), but this time replace all the singletons and the creation of the value for `v_name` with function calls to the appropriate packages. Save your script as `insert_with_modularity.sql`. Then execute it until it works.

My Solution

Listing 5-7 is my solution to this third part of the exercise.

Listing 5-7. A Modular Approach to Inserting, insert_with_modularity.sql

```
rem insert_with_modularity.sql
rem by Donald J. Bales on 2014-10-20
rem An anonymous PL/SQL procedure to insert
rem values using PL/SQL functions

set serveroutput on size 1000000;

declare

-- I declared this record, so I can get
-- the required ID values before I insert.
r_worker                              WORKERS%ROWTYPE;

-- I'll use this variable to hold the result
-- of the SQL insert statement.
n_count                               number := 0;

begin
  r_worker.first_name  := 'JOHN';
  r_worker.middle_name := 'J.';
  r_worker.last_name   := 'DOE';
  -- Using the same function to get this derived value
  -- from all programs will ensure its value is consistent
  r_worker.name        := WORKER.get_formatted_name(
    r_worker.first_name, r_worker.middle_name, r_worker.last_name);
  r_worker.birth_date  :=
    to_date('19800101', 'YYYYMMDD'); -- I'm guessing

  -- First, let's get the worker_type_id for a contractor
  begin
    r_worker.worker_type_id := WORKER_TYPE.get_id('C');
  exception
    when OTHERS then
      raise_application_error(-20001, SQLERRM||
        ' on call WORKER_TYPE.get_id(''C'')'||
        ' in filename insert_with_modularity.sql');
  end;

  -- Next, let's get the gender_id for a male
  begin
    r_worker.gender_type_id := GENDER_TYPE.get_id('M');
  exception
    when OTHERS then
      raise_application_error(-20002, SQLERRM||
        ' on call GENDER_TYPE.get_id(''M'')'||
        ' in filename insert_with_modularity.sql');
  end;

  -- Detect any existing entries, and
  -- then conditionally insert the row
  if not WORKER.is_duplicate(
    r_worker.name, r_worker.birth_date, r_worker.gender_type_id) then
    -- I'm not going to block the next two calls,
    -- because it's highly unlikely that I could
    -- ever get an error allocating a sequnce.

    -- Now, let's get the next id sequence.
    -- no parameters, so no parentheses needed
    r_worker.id          := WORKER.get_id;

    -- And then, let's get the next external_id sequence
    -- no parameters, so no parentheses needed
    r_worker.external_id := WORKER.get_external_id;

    -- Now that we have all the necessary ID values
    -- we can finally insert a row!
    begin
      -- Since I declared r_worker based on WORKERS, I
      -- can skip the column list and just use the record.
      insert into WORKERS values r_worker;

      n_count := sql%rowcount;
    exception
      when OTHERS then
        raise_application_error(-20003, SQLERRM||
          ' on insert WORKERS'||
          ' in filename insert_with_modularity.sql');
    end;
  end if;

  pl(to_char(n_count)||' row(s) inserted.');
end;
/

commit;
```

I'm not going to explain Listing 5-7 in detail, because it's well commented and you should be able to understand it by now. But I will say that, unless there's more you have to do between the selection of codes and sequences and before the insert, you're probably still better off using SQL to do all the work!

Now let me introduce you to the star of the PL/SQL show: `CURSOR FOR LOOP`.

Fetching Rows from a Cursor Automatically

CURSOR FOR LOOP is the heart and soul of PL/SQL's abilities. The CURSOR FOR LOOP allows you to work with a cursor that returns multiple rows, one row at a time, using a very nice and neat structure that does everything for you automatically.

Listing 5-8 is a revision of Listing 5-1. The difference is that Listing 5-8 utilizes the "automatic" CURSOR FOR LOOP, instead of the manually coded loop involving OPEN, FETCH, and CLOSE.

Listing 5-8. An Example of Using a CURSOR FOR LOOP, cursor_for_loop_the_doe_family.sql

```
01  rem cursor_for_loop_the_doe_family.sql
02  rem by Donald J. Bales on 2014-10-20
03  rem An anonymous PL/SQL procedure to select
04  rem the first names for the Doe family from
05  rem the Workers table.
06
07  set serveroutput on size 1000000;
08
09  declare
10
11  cursor c_workers(
12  aiv_last_name                  in     WORKERS.last_name%TYPE) is
13  select first_name
14  from   WORKERS
15  where  last_name like aiv_last_name||'%'
16  order by id;
17
18  begin
19    for r_worker in c_workers('DOE') loop
20      pl(r_worker.first_name);
21    end loop;
22  end;
23  /
```

The CURSOR FOR LOOP syntax used in Listing 5-8 is as follows:

```
FOR <record_name> IN <cursor_name> [(<cursor_parameters>)] LOOP
  -- Put your PL/SQL to be executed for each row here
END LOOP;
```

where <record_name> is the name of the record that will contain fields that correspond to columns in the associated cursor's SELECT statement, <cursor_name> is the name of the associated CURSOR, and <cursor_parameters> is a list of zero or more parameters to be passed to the CURSOR. The brackets around the parameters denote that they are optional; they are needed only if the associated CURSOR was declared with parameters.

Listing 5-8 is short but powerful. In lines 11 through 16, I declare a CURSOR c_workers. Then, on line 19, I use the CURSOR FOR LOOP syntax to automatically OPEN the CURSOR and LOOP until there's no data found, placing any column values in an automatically declared record r_worker that is in scope only inside the FOR LOOP. If at least one row was retrieved from the database, the CURSOR FOR LOOP automatically CLOSEs the OPEN CURSOR when the LOOP ENDs. As I documented earlier in Table 3-1, I use the prefix c_ for cursors and the prefix r_ for records. This naming convention makes it easy to see exactly what is going on in PL/SQL.

I told you PL/SQL's solution to the last exercise in Chapter 4 was going to get even better. As you can see, the CURSOR FOR LOOP represents some powerfully compact syntax!

You can use a CURSOR FOR LOOP as long as you don't need the values of the fields in the automatically declared record outside the loop. And it will do you no good to declare the record outside the loop because the CURSOR FOR LOOP will still declare its own. If you do need the cursor values beyond the fetch, you'll need to assign the record values to variables declared outside the loop or use a manual loop, as I did earlier in Listing 5-1.

Enough talk—it's time you put CURSOR FOR LOOP to work for you.

It's Your Turn to Fetch Automatically

In the development process, you'll eventually need to test what you've built with some realistic data; otherwise, you won't know how your code will perform in production. So your assignment here is to create a PL/SQL procedure that will populate table WORKERS with test data.

If you combine 100 last names, 100 first names, and 26 different middle initials, you get 260,000 entries for table WORKERS. A quarter of a million entries in a table is a fair amount of data for testing.

To help you out with this assignment, I've created three scripts to create the TOP_100_FIRST_NAMES, TOP_100_LAST_NAMES, and A_THRU_Z tables for you. I've placed these table scripts in the downloaded source code directory for Chapter 5, as top_100_first_names.tab, top_100_last_names.tab, and a_thru_z.tab, respectively. You can create those tables by running these scripts.

In order to populate table WORKERS, I suggest you create a PL/SQL procedure that uses nested CURSOR FOR LOOPs to iterate through each table's entries, inserting an entry into the table for each loop, in the most nested FOR LOOP. Your executable code will look something like this:

```
begin
  for r_last in c_last loop
    for r_first in c_first loop
      for r_middle in c_middle loop
        -- initialize the variables to be used in the insert statement here.
        insert into WORKERS ...
      end loop;
    end loop;
  end loop;
end;
```

Of course, you'll need to supply values for other columns. For those, I suggest you do the following:

- For id, call function WORKER.get_id().
- For worker_type_id, use an IF statement to flip back and forth between the ID values for an employee vs. contractor on every other entry.
- For external_id, call function WORKER.get_external_id().
- For birth_date, call function DATES.random(1940, 1990); this will give you a randomly generated date between the years 1940 and 1990.
- For gender_type_id, use an IF statement to specify the correct ID value for the corresponding code found in the TOP_100_FIRST_NAME table.

Add a variable to keep track of how many inserts you've made, and then display that number on the screen when you're finished inserting. Save the script as worker cursor_for_loop.ins, and then execute it. I know this is a hard assignment, but you have everything you need to get it done.

Listing 5-9 is my solution to this exercise. When I ran this script on my computer, it inserted 260,000 rows in an average time of 72 seconds—that's about 3,611 rows per second.

Listing 5-9. Using CURSOR FOR LOOPs to Insert Test Data, workers _cursor_for_loop.ins

```
rem workers_cursor_for_loop.ins
rem by Donald J. Bales on 2014-10-20
rem Seed the Workers table with the top 100 names
rem 100 last x 100 first x 26 middle = 260,000 entries

set serveroutput on size 1000000;

declare

-- This is the cursor for the last names.
cursor c_last is
select last_name
from   TOP_100_LAST_NAMES;

-- This is the cursor for the first names.
cursor c_first is
select first_name,
       gender_code
from   TOP_100_FIRST_NAMES;

-- This is the cursor for the middle initials.
cursor c_middle is
select letter
from   A_THRU_Z;

-- This is the number of seconds since midnight
-- I'll use it to profile my code's performance.
n_start                               number :=
  to_number(to_char(SYSDATE, 'SSSSS'));

-- Here, I declare four psuedo-constants to hold the
-- ID values from the code tables, rather than look
-- them up repeatedly during the insert process.
n_G_FEMALE                            GENDER_TYPES.id%TYPE;
n_G_MALE                              GENDER_TYPES.id%TYPE;
n_WT_CONTRACTOR                       WORKER_TYPES.id%TYPE;
n_WT_EMPLOYEE                         WORKER_TYPES.id%TYPE;

-- I'll use this to keep track of the number of
-- rows inserted.
n_inserted                            number := 0;

-- Here, I declare a record anchored to the table so
-- I can set the column values and then insert using
-- the record.
r_worker                              WORKERS%ROWTYPE;

```

```
begin
  -- Get the ID values for the codes
  n_G_FEMALE      := GENDER_TYPE.get_id('F');
  n_G_MALE        := GENDER_TYPE.get_id('M');
  n_WT_CONTRACTOR := WORKER_TYPE.get_id('C');
  n_WT_EMPLOYEE   := WORKER_TYPE.get_id('E');

  -- Loop through the last names
  for r_last in c_last loop

    -- While looping through the last names,
    -- loop through the first names
    for r_first in c_first loop

      -- While looping through the last and first names
      -- loop through the 26 letters in the English
      -- Alphabet in order to get middle initials
      -- As an alternative, I could have used a FOR LOOP:
--      for i in ascii('A')..ascii('Z') loop
      for r_middle in c_middle loop

        -- Initialize the record

        -- Get the PK using the table's package
        r_worker.id               := WORKER.get_id();

        -- Flip flop from contractor to employee and back again
        if r_worker.worker_type_id = n_WT_CONTRACTOR then
          r_worker.worker_type_id := n_WT_EMPLOYEE;
        else
          r_worker.worker_type_id := n_WT_CONTRACTOR;
        end if;

        -- Get the External ID using the table's package
        r_worker.external_id      := WORKER.get_external_id();

        -- The first, middle, and last names come from the cursors
        r_worker.first_name       := r_first.first_name;
--        r_worker.middle_name      := chr(i)||'.';
        r_worker.middle_name      := r_middle.letter||'.';
        r_worker.last_name        := r_last.last_name;

        -- get the name using the table's package
        r_worker.name             := WORKER.get_formatted_name(
          r_worker.first_name, r_worker.middle_name, r_worker.last_name);

        -- get a random date for a birth date
        r_worker.birth_date       := DATES.random(
          to_number(to_char(SYSDATE, 'YYYY')) - 65,
          to_number(to_char(SYSDATE, 'YYYY')) - 18);

    -- selecrt the corresponding ID value
    if r_first.gender_code = 'F' then
     r_worker.gender_type_id := n_G_FEMALE;
    else
     r_worker.gender_type_id := n_G_MALE;
    end if;

    -- Insert the row into the database
    insert into WORKERS values r_worker;

    -- keep track of the number of inserts
    n_inserted := n_inserted + sql%rowcount;
   end loop; -- c_middle
--  end loop; -- for i
   commit;  -- commit every 26 rows

  end loop; -- c_first

 end loop; -- c_last
 -- Display the results
 pl(to_char(n_inserted)||' rows inserted in '||
  (to_number(to_char(SYSDATE, 'SSSSS')) - n_start)||
  ' seconds.');
end;
/
```

I won't elaborate on my solution here, because I've commented the code heavily. Notice that I've added a variable to hold the start time in seconds, so I can test the performance of this solution against others. You'll see me profile code this way as we move forward. It's part of the testing process. The question now is, "Can we make this PL/SQL procedure faster?"

In Oracle8, some additional functionality was added to PL/SQL to improve performance. Let's look at one of those additions next.

Bulk Collect

In this context, `BULK COLLECT` is about reducing the number of transitions between the PL/SQL engine and SQL engine in order to improve efficiency and speed of your PL/SQL program.

The idea is simple. Every time you execute SQL from your PL/SQL program, PL/SQL must hand off the SQL statement to the Oracle database's SQL engine. When the SQL engine is finished, it returns its result to the PL/SQL engine. Flip-flopping back and forth from PL/SQL to SQL and back again takes time.

Since version 8 of Oracle, you can reduce the number of transitions between PL/SQL and SQL by using the `BULK COLLECT` command. Rather than fetch one row at a time from the SQL engine, you can fetch perhaps 100 at a time into a PL/SQL collection, which can be a PL/SQL table (or array).

Although three types of PL/SQL collections exist, I'm going to cover only the use of associative arrays, or as they were once called, PL/SQL tables. Once you're comfortable programming in PL/SQL, I recommend you go back and learn about the other two in a good reference (such as *PL/SQL Programming* by Steven Feuerstein and Bill Pribyl).

Bulk Collect with a Cursor

Since we've been working with cursors, let's continue to talk about them. Listing 5-10 is yet another incarnation of Listing 5-1, the "select the Doe family" assignment. This time, however, it has been coded to use `BULK COLLECT`.

Listing 5-10. An Example of Using BULK COLLECT with a CURSOR, cursor_bulk_collect_the_doe_family.sql.

```
rem cursor_bulk_collect_the_doe_family.sql
rem by Donald J. Bales on 2014-10-20
rem An anonymous PL/SQL procedure to select
rem the first names for the Doe family from
rem the Workers table.

set serveroutput on size 1000000;

declare

cursor c_workers(
aiv_last_name                  in     WORKERS.last_name%TYPE) is
select first_name
from   WORKERS
where  last_name like aiv_last_name||'%'
order by id;

TYPE c_worker_table is table of c_workers%ROWTYPE
index by binary_integer;

t_workers                             c_worker_table;

begin
  open c_workers('DOE');
  loop
    fetch c_workers bulk collect into t_workers limit 2;

    exit when t_workers.count = 0;

    for i in t_workers.first..t_workers.last loop
      pl(t_workers(i).first_name);
    end loop;
  end loop;
end;
/
```

The `FETCH` syntax used in the manual loop in Listing 5-10 is as follows:

```
FETCH <cursor_name> BULK COLLECT INTO <plsql_table_name> LIMIT <limit>;
```

where `<cursor_name>` is the name of an open cursor from which to fetch, and `<plsql_table_name>` is the name of the associative array in which to fetch the `<limit>` number of rows.

And the `FOR LOOP` syntax used in the listing is as follows:

```
FOR <index> IN <from_index>..<through_index> LOOP
  -- Put your PL/SQL code to execute during the loop here.
END LOOP
```

where `<index>` is an index value to use in the loop to address PL/SQL table elements, `<from_index>` is a valid index value to start with, and `<through_index>` is a valid index value to end with.

There's nothing like dissecting a program line by line to help explain it, so here it is:

- Lines 11 through 16 declare a cursor to select the first names of a specified family. There's nothing new here. You've seen this time and again.
- Lines 18 and 19 declare an associative array, or PL/SQL table, based on the row type of `CURSOR c_workers`.
- Line 21 declares a variable of `TYPE c_worker_table` that will be the target of the `FETCH ... BULK COLLECT` command.
- Line 24 opens the cursor `c_workers`.
- Line 25 starts a manual `LOOP`.
- On line 26, I fetch rows from the database, two rows at a time, into table `t_workers`. Because I've reduce the number of transitions, or context switches, by two, this PL/SQL program will run roughly twice as fast. I specified the number of rows to retrieve with the `LIMIT` clause at the end of the `FETCH ... BULK COLLECT` statement. I could have set the limit to 10, 100, 1000, 9999, or whatever. But keep in mind that the limit also determines how much memory will be consumed by holding the rows in memory between each call, so you need to use a reasonable value or bring your database to a screeching halt—it's your choice.
- On line 28, instead of checking the cursor variable `c_workers%notfound`, I need to check the PL/SQL table `t_workers`' `%count` variable to see how many rows were inserted into the table from the last `FETCH`. If `t_workers%count` is zero, there are no more rows to retrieve from the cursor, so I `EXIT` the `LOOP`.
- On line 30, now that the fetched data resides in PL/SQL table `t_workers`, I use a `FOR LOOP` to iterate through the entries, from the first, `t_worker.first` through (`..`) the last, `t_worker.last`. In this context, `first` and `last` are PL/SQL table variables that tell you the first and last rows in the table, respectively.
- Line 31, inside the `FOR LOOP`, displays the first names on the screen. However, this time, since the PL/SQL table was based on a cursor's row type, I need to use the form table name, index, dot, field name—`t_workers(i).first_name`—in order to address the field.

Using `BULK COLLECT` with a `FETCH` statement for a cursor can lead to a significant performance improvement if you set a moderately sized `LIMIT`. If you specify too large of a `LIMIT`, you'll use up memory needed for other database sessions.

Another thing to consider is that using `BULK COLLECT` requires additional programming. So is the extra memory consumption and additional programming worth the investment? Or will a simple `CURSOR FOR LOOP` do the job?

In practice, I always start out with a `CURSOR FOR LOOP`. If I find that a particular PL/SQL program is a performance bottleneck, or needs to run faster for business purposes, I take the extra time to transform the PL/SQL module to use `BULK COLLECT`. But then I test its performance gains against every other PL/SQL program's performance loss due to the additional consumption of memory. Yes, I test, test, and test again.

■ **Note** Oracle Database 10*g* introduced an "auto bulk collect" feature. I suggest you investigate this later by reading Oracle's PL/SQL *User's Guide and Reference* for a version of Oracle Database 10*g* or later.

Bulk Collect with a Select Statement

If you know that the result of your SQL SELECT statement will always be a small number of rows, you can simplify your PL/SQL programming by using BULK COLLECT with a SELECT statement. The result is a SELECT statement that looks a lot like a singleton SELECT, with the difference being that rather than returning only one row at a time, your use of BULK COLLECT allows the statement to return a number of rows at a time.

Listing 5-11 demonstrates the use of BULK COLLECT with a SELECT statement. The difference with this listing compared to Listing 5-10 is that I no longer use an explicit CURSOR.

Listing 5-11. An Example of Using BULK COLLECT with a SELECT statement, bulk_collect_the_doe_family.sql

```
rem bulk_collect_the_doe_family.sql
rem by Donald J. Bales on 2014-10-20
rem An anonymous PL/SQL procedure to select
rem the first names for the Doe family from
rem the Workers table.

set serveroutput on size 1000000;

declare

TYPE worker_table is table of WORKERS.first_name%TYPE
index by binary_integer;

t_workers                             worker_table;

begin
  select first_name
  BULK COLLECT
  into   t_workers
  from   WORKERS
  where  last_name like 'DOE%'
  order by id;

  for i in t_workers.first..t_workers.last loop
    pl(t_workers(i));
  end loop;
end;
/
```

The BULK COLLECT syntax used in Listing 5-11 is as follows:

```
SELECT <column_list>
BULK COLLECT
INTO   <plsql_table_name>
FROM   <table_name>
WHERE  <where_clause>
ORDER BY <order_by_colunmn_list>;
```

where <column_list> is a single column name from the table or an asterisk (*) to denote all columns from the table (or row), <plsql_table_name> is the name of one or more associative array(s) declared to match the column list's data types, <table_name> is the name of the table to query, <where_clause> is an appropriate WHERE clause for the query, and <order_by_column_list> is a list of column(s) by which to order the SELECT statement's results.

Let's break down Listing 5-11:

- Lines 11 and 12 declare a TYPE based on the first_name column of the WORKERS table.
- Line 14 declares a table for the TYPE worker_table specified on lines 11 and 12.
- On lines 17 through 22, the magic occurs. This is where I've used the SELECT BULK COLLECT INTO syntax to load all the resulting rows from the query into the PL/SQL table t_workers in just one context switch!
- Lines 24 through 26 contain a FOR LOOP to iterate through the rows in PL/SQL table t_workers, displaying the results on the screen.

Sweet and simple, from disk to memory in one context switch, this is indeed a powerful syntax. However, it has all the same baggage as its CURSOR-based sibling in the previous section. So use it carefully, if at all.

In practice, I never use this syntax because I can't guarantee that the tables I'm coding against won't grow to require an unreasonable amount of memory for the BULK COLLECT. Instead, I play it safe and use the CURSOR BULK COLLECT syntax. But now it's your choice.

It's Your Turn to Bulk Collect

Now that you know how to make your code more efficient by using BULK COLLECT, put it to the test by taking your solution to the last exercise and modifying it to use BULK COLLECT. This means you'll get rid of the three cursors you declared in that solution and replace them with three TYPE and three PL/SQL table declarations. Next, you'll change your CURSOR FOR LOOPs to FOR LOOPs, as in the following example:

```
begin
  for l in t_last.first..t_last.last loop
    for f in t_first.first..t_first.last loop
      for m in t_middle.first..t_middle.last loop
        -- initialize the variables to be used in the insert statement here.
        insert into WORKERS ...
      end loop;
    end loop;
  end loop;
end;
```

Listing 5-12 is my solution to this exercise. When I ran this script on my computer, it inserted 260,000 rows in an average time of 65 seconds—that's about 4000 rows per second, for an 11% improvement. The small amount of improvement is understandable here, because while there were 223 context switches saved by using `BULK COLLECT`, there were still 260,000 context switches due to inserts.

Listing 5-12. Using BULK COLLECT to Improve the Insertion of Test Data, workers_bulk_collect.ins

```
rem workers_bulk_collect.ins
rem by Donald J. Bales on 2014-10-20
rem Seed the Workers table with the top 100 names
rem 100 last x 100 first x 26 middle = 260,000 entries

set serveroutput on size 1000000;

declare

-- Declare a type for a PL/SQL table of last names
TYPE last_name_table is table of TOP_100_LAST_NAMES%ROWTYPE
index by binary_integer;

-- Declare a type for a PL/SQL table of first names
TYPE first_name_table is table of TOP_100_FIRST_NAMES%ROWTYPE
index by binary_integer;

-- Declare a type for a PL/SQL table of middle initials
TYPE middle_name_table is table of A_THRU_Z%ROWTYPE
index by binary_integer;

-- This is the number of seconds since midnight
-- I'll use it to profile my code's performance.
n_start                               number :=
  to_number(to_char(SYSDATE, 'SSSSS'));

-- Here, I declare four psuedo-constants to hold the
-- ID values from the code tables, rather than look
-- them up repeatedly during the insert process.
n_G_FEMALE                            GENDER_TYPES.id%TYPE;
n_G_MALE                              GENDER_TYPES.id%TYPE;
n_WT_CONTRACTOR                       WORKER_TYPES.id%TYPE;
n_WT_EMPLOYEE                         WORKER_TYPES.id%TYPE;

-- I'll use this to keep track of the number of
-- rows inserted.
n_inserted                            number := 0;

-- Here, I declare a record anchored to the table so
-- I can set the column values and then insert using
-- the record.
r_worker                              WORKERS%ROWTYPE;

-- Declare the three PL/SQL tables that replace cursors
t_first                               first_name_table;
```

```
t_middle                              middle_name_table;
t_last                                last_name_table;

begin
  -- Get the ID values for the codes
  n_G_FEMALE      := GENDER_TYPE.get_id('F');
  n_G_MALE        := GENDER_TYPE.get_id('M');
  n_WT_CONTRACTOR := WORKER_TYPE.get_id('C');
  n_WT_EMPLOYEE   := WORKER_TYPE.get_id('E');

  -- Bulk collect the tables into the PL/SQL tables
  select * bulk collect into t_last   from TOP_100_LAST_NAMES;
  select * bulk collect into t_first  from TOP_100_FIRST_NAMES;
  select * bulk collect into t_middle from A_THRU_Z;

  -- Loop through the last names
  for l in t_last.first..t_last.last loop

    -- While looping through the last names,
    -- loop through the first names
    for f in t_first.first..t_first.last loop

      -- While looping through the last and first names
      -- loop through the 26 letters in the English
      -- Alphabet in order to get middle initials
      for m in t_middle.first..t_middle.last loop

        -- Initialize the record

        -- Get the PK using the table's package
        r_worker.id               := WORKER.get_id();

        -- Flip flop from contractor to employee and back again
        if r_worker.worker_type_id = n_WT_CONTRACTOR then
          r_worker.worker_type_id := n_WT_EMPLOYEE;
        else
          r_worker.worker_type_id := n_WT_CONTRACTOR;
        end if;

        -- Get the External ID using the table's package
        r_worker.external_id      := WORKER.get_external_id();

        -- The first, middle, and last names come from the cursors
        r_worker.first_name       := t_first(f).first_name;
        r_worker.middle_name      := t_middle(m).letter||'.';
        r_worker.last_name        := t_last(l).last_name;

        -- get the name using the table's package
        r_worker.name             := WORKER.get_formatted_name(
          r_worker.first_name, r_worker.middle_name, r_worker.last_name);

        -- get a random date for a birth date
        r_worker.birth_date          := DATES.random(
          to_number(to_char(SYSDATE, 'YYYY')) - 65,
          to_number(to_char(SYSDATE, 'YYYY')) - 18);

        -- selecrt the corresponding ID value
        if t_first(f).gender_code = 'F' then
          r_worker.gender_type_id := n_G_FEMALE;
        else
          r_worker.gender_type_id := n_G_MALE;
        end if;

        -- Insert the row into the database
        insert into WORKERS values r_worker;

        -- keep track of the number of inserts
        n_inserted := n_inserted + sql%rowcount;
      end loop; -- t_middle
      commit;  -- commit every 26 rows

    end loop; -- t_first

  end loop; -- t_last
  -- Display the results
  pl(to_char(n_inserted)||' rows inserted in '||
    (to_number(to_char(SYSDATE, 'SSSSS')) - n_start)||
    ' seconds.');
end;
/
```

Once again, I won't elaborate on my solution here because I've commented the code heavily. The question remains, "Can we make this PL/SQL procedure faster?"

Well, we've already used BULK COLLECT. What else is in PL/SQL's bag of tricks?

FORALL

For the sake of completeness, I'm going to mention the FORALL statement here. It's kind of like the inverse of the BULK COLLECT statement. Given that you have a populated collection, like an associative array, you can bulk execute the same SQL statement for every entry or for selected entries in your collection(s).

For example, if you have 26 entries in your PL/SQL table, you can write a FORALL statement that will execute the same SQL statement 26 times, once for each row in your PL/SQL table. The assumption here is that you'll use the values from your PL/SQL table in each SQL statement.

The problem I have with FORALL is that the data for a collection usually comes from a table in the database in the first place. If that's the case, then a complex SQL statement can do everything a FORALL statement can do, with one context switch, just like FORALL, but using less memory. So why does FORALL exist? Frankly, I don't know. Perhaps it's syntactic sugar for PL/SQL programmers that have weak SQL skills. Or maybe I've just never run across a need for it. That's always possible. However, in practice, I never use it. I always seem to find a better solution using a complex SQL statement.

Let me show you what I mean. Listing 5-13 is a rewrite of the "populate the Worker table" assignment, where I use FORALL to bind 26 SQL statements per context switch. I could have rearranged my code some more so I could do 100 at a time, but the improvement from doing so is not significant.

Listing 5-13. Using FORALL to Improve the Insertion of Test Data, workers_forall.ins

```
rem workers_forall.ins
rem by Donald J. Bales on 2014-10-20
rem Seed the Workers table with the top 100 names
rem 100 last x 100 first x 26 middle = 260,000 entries

set serveroutput on size 1000000;

declare

-- Declare a type for a PL/SQL table of last names
TYPE last_name_table   is table of TOP_100_LAST_NAMES%ROWTYPE
index by binary_integer;

-- Declare a type for a PL/SQL table of first names
TYPE first_name_table  is table of TOP_100_FIRST_NAMES%ROWTYPE
index by binary_integer;

-- Declare a type for a PL/SQL table of middle initials
TYPE middle_name_table is table of A_THRU_Z%ROWTYPE
index by binary_integer;

-- Declare a type for a PL/SQL table of workers
TYPE worker_table      is table of WORKERS%ROWTYPE
index by binary_integer;

-- This is the number of seconds since midnight
-- I'll use it to profile my code's performance.
n_start                               number :=
  to_number(to_char(SYSDATE, 'SSSSS'));

-- Here, I declare four psuedo-constants to hold the
-- ID values from the code tables, rather than look
-- them up repeatedly during the insert process.
n_G_FEMALE                            GENDER_TYPES.id%TYPE;
n_G_MALE                              GENDER_TYPES.id%TYPE;
n_WT_CONTRACTOR                       WORKER_TYPES.id%TYPE;
n_WT_EMPLOYEE                         WORKER_TYPES.id%TYPE;

-- I'll use this to keep track of the number of
-- rows inserted.
n_inserted                            number := 0;

-- Declare the four PL/SQL tables that replace cursors
-- and the worker record
t_first                               first_name_table;
t_middle                              middle_name_table;
t_last                                last_name_table;
t_workers                             worker_table;

begin
```

```
-- Get the ID values for the codes
n_G_FEMALE      := GENDER_TYPE.get_id('F');
n_G_MALE        := GENDER_TYPE.get_id('M');
n_WT_CONTRACTOR := WORKER_TYPE.get_id('C');
n_WT_EMPLOYEE   := WORKER_TYPE.get_id('E');

-- Bulk collect the tables into the PL/SQL tables
select * bulk collect into t_last   from TOP_100_LAST_NAMES;
select * bulk collect into t_first  from TOP_100_FIRST_NAMES;
select * bulk collect into t_middle from A_THRU_Z;

-- Loop through the last names
for l in t_last.first..t_last.last loop

  -- While looping through the last names,
  -- loop through the first names
  for f in t_first.first..t_first.last loop

    -- While looping through the last and first names
    -- loop through the 26 letters in the English
    -- Alphabet in order to get middle initials
    for m in t_middle.first..t_middle.last loop

      -- Initialize the table's rows

      -- Get the PK using the table's package
      t_workers(m).id               := WORKER.get_id();

      -- Flip flop from contractor to employee and back again
      if t_workers(m).worker_type_id = n_WT_CONTRACTOR then
        t_workers(m).worker_type_id := n_WT_EMPLOYEE;
      else
        t_workers(m).worker_type_id := n_WT_CONTRACTOR;
      end if;

      -- Get the External ID using the table's package
      t_workers(m).external_id      := WORKER.get_external_id();

      -- The first, middle, and last names come from the cursors
      t_workers(m).first_name       := t_first(f).first_name;
      t_workers(m).middle_name      := t_middle(m).letter||'.';
      t_workers(m).last_name        := t_last(l).last_name;

      -- get the name using the table's package
      t_workers(m).name             := WORKER.get_formatted_name(
        t_workers(m).first_name,
        t_workers(m).middle_name,
        t_workers(m).last_name);

```

```
100          -- get a random date for a birth date
101          t_workers(m).birth_date       := DATES.random(
102            to_number(to_char(SYSDATE, 'YYYY')) - 65,
103            to_number(to_char(SYSDATE, 'YYYY')) - 18);
104
105          -- select the corresponding ID value
106          if t_first(f).gender_code = 'F' then
107            t_workers(m).gender_type_id := n_G_FEMALE;
108          else
109            t_workers(m).gender_type_id := n_G_MALE;
110          end if;
111
112        end loop; -- t_middle
113
114        -- Now bulk bind the 26 insert statements
115        forall i in t_workers.first..t_workers.last
116          insert into WORKERS values t_workers(i);
117
118        n_inserted := n_inserted + sql%rowcount;
119
120      end loop; -- t_first
121
122    end loop; -- t_last
123    commit;
124    -- Display the results
125    pl(to_char(n_inserted)||' rows inserted in '||
126      (to_number(to_char(SYSDATE, 'SSSSS')) - n_start)||
127      ' seconds.');
128  end;
129  /
```

In Listing 5-13, the magic happens on lines 74 through 110, where I populate a PL/SQL table's records with values, and then, on lines 115 and 116, where I bulk bind the insert statements, so I have only one context switch for each set of 26 records. Using `FORALL`, my program now inserts 260,000 rows in an average time of 38 seconds. That's about 6,842 rows per second, for a 71% improvement. That's great, right? Well, what if I just use SQL?

Listing 5-14 is the "populate the Worker table" assignment, where I use a single SQL statement. How does it fare?

Listing 5-14. Using SQL to Improve the Insertion of Test Data, workers.ins

```
01  rem workers.ins
02  rem by Donald J. Bales on 2014-10-20
03  rem Seed the Worker table with the top 100 names
04  rem 100 last x 100 first x 26 middle = 260,000 entries
05
06  set serveroutput on size 1000000;
07
08  declare
09
10  -- This is the number of seconds since midnight
11  -- I'll use it to profile my code's performance.
```

```
n_start                              number :=
  to_number(to_char(SYSDATE, 'SSSSS'));

-- Here, I declare four psuedo-constants to hold the
-- ID values from the code tables, rather than look
-- them up repeatedly during the insert process.
n_G_FEMALE                           GENDER_TYPES.id%TYPE;
n_G_MALE                             GENDER_TYPES.id%TYPE;
n_WT_CONTRACTOR                      WORKER_TYPES.id%TYPE;
n_WT_EMPLOYEE                        WORKER_TYPES.id%TYPE;

-- I'll use this to keep track of the number of
-- rows inserted.
n_inserted                           number := 0;

begin
  -- Get the ID values for the codes
  n_G_FEMALE      := GENDER_TYPE.get_id('F');
  n_G_MALE        := GENDER_TYPE.get_id('M');
  n_WT_CONTRACTOR := WORKER_TYPE.get_id('C');
  n_WT_EMPLOYEE   := WORKER_TYPE.get_id('E');

  -- Use an INSERT INTO SELECT SQL statement
  insert into WORKERS (
         id,
         worker_type_id,
         external_id,
         first_name,
         middle_name,
         last_name,
         name,
         birth_date,
         gender_type_id)
  select WORKERS_ID.nextval,
         decode(mod(WORKERS_ID.currval, 2),
           0, n_WT_EMPLOYEE, n_WT_CONTRACTOR),
         lpad(to_char(EXTERNAL_ID_SEQ.nextval), 9, '0'),
         first_name,
         letter||'.',
         last_name,
         WORKER.get_formatted_name(
           first_name, letter||'.', last_name),
         DATES.random(
           to_number(to_char(SYSDATE, 'YYYY')) - 65,
           to_number(to_char(SYSDATE, 'YYYY')) - 18),
         decode(gender_code, 'F', n_G_FEMALE, n_G_MALE)
  from   TOP_100_LAST_NAMES,
         TOP_100_FIRST_NAMES,
         A_THRU_Z;

  n_inserted := n_inserted + sql%rowcount;

```

```
    commit;

    pl(to_char(n_inserted)||' rows inserted in '||
      (to_number(to_char(SYSDATE, 'SSSSS')) - n_start)||
      ' seconds.');
  end;
  /
```

In Listing 5-14, a single INSERT ... SELECT statement, albeit a complex one, does almost all the work done by lines and lines of PL/SQL. But how does it perform? It inserts 260,000 rows in an average time of 21 seconds. That's about 12,381 rows per second, for a 200% improvement. You can't get any faster than using plain-old SQL. So what's the moral of this story? Let me hear you say it. Know thy SQL!

When you're comfortable with PL/SQL and are up to challenging yourself, pull out a good PL/SQL reference and read up on FORALL. For now, I think you'll do better by improving your SQL skills instead.

Summary

In this chapter, you've gone from curs(or)ing, to fetching, to bulk collecting, to bulk binding, and then back to SQL again. CURSORs allow you to FETCH multiple rows from a SQL SELECT statement. You can FETCH rows manually or automatically, using a CURSOR FOR LOOP. You can use BULK COLLECT to improve the efficiency of loading an array with values from the database, and you can use FORALL to improve the efficiency of executing SQL statements with values from an array. But most important, you probably realize by now that when I stated in Chapter 1 that "knowing SQL is a prerequisite to learning PL/SQL," I wasn't joking.

All too often, I see poorly performing PL/SQL programs that are bloated with PL/SQL code that tries to do what SQL can simply do better. After all, it is the Procedural Language extension to SQL. PL/SQL's job is to handle the procedural tasks, while SQL's job is to handle manipulating data. Keep that in mind whenever you write a PL/SQL program.

Up to this point, although you've been keeping functions and procedures in a package for each table, you've still been acting as though these behaviors were something apart from the data they work with. In fact, in the real world, the opposite is true. Things in the real world don't keep their behavior or actions someplace away from themselves; they are part of a whole, and that's what you are going to look at next. You'll explore storing the behavior with the attributes, or as I like to think of it: object-relational technology.

CHAPTER 6

Object-Relational SQL

It was the philosopher George Santayana who stated, "Those who cannot remember the past are condemned to repeat it." Philosophy is an interesting pursuit from my point of view because it looks at very high-level abstract patterns of behavior. Patterns are repeated data or behavior of a simple or complex nature.

When we build an application, we attempt to model the workflow of the real world in order to automate or organize the workflow to improve how quickly or accurately we can perform its associated work. However, modeling is not only representing what data is used, but also recognizing the patterns of usage: behavior. Restated simply, we attempt to model the real world, and those who get modeling right profit from it the most.

Information Modeling

As business analysts and computer scientists, we have come a long way. Relational database technology has freed us from the tyranny of the high priests of database administration, so we are all capable of storing and retrieving data in sets of highly organized, two-dimensional tables. But, up to this point, we store only the data we use, for the most part ignoring the behavior.

As an analyst, I know that the accuracy of a real-world model depends on its use of the following:

- *Current data*: Data (words, numbers, and dates) about what happened last. I say "last" because usually, by the time you record the information, it's data about what just happened, not what's about to happen.
- *Hierarchical data*: Data about the relationships of like datum. For example, in a business organization, a department may belong to a subdivision, which may in turn belong to a division, which may in turn belong to a particular operating company; these are all levels of organization that have a hierarchical relationship to each other.
- *Historical data*: Multiple occurrences of "current" data; that is, data about what has happened over time, not just the last occurrence of behavior. Yes, data is about behavior.
- *Current behavior*: Methods (functions or procedures) used to accomplish the last act of work. Once again, I say "last" because by the time the act of work is recorded, these are the methods just used, not what will be used in the future.
- *Hierarchical behavior*: Methods used with hierarchical data.
- *Historical behavior*: Multiple occurrences of "current" methods; that is, methods used to accomplish acts of work at a particular point in time.

So I submit that in order for you to have an accurate model of the real world, you need to employ all six facets of information in your model. Is that what we do today? For the most part, no.

Today, simple applications store current data in a database and store current methods (behavior) in a presentation layer's codebase. When I say presentation layer, I mean the software you use to enter data into the application (data entry) or to view data from an application (reporting).

More sophisticated applications may store hierarchical data and try to separate the code (program logic) used to present information from the rules of work, or so-called business (busyness) rules. Then they have one database and two codebases: a database for the persistence of data, a codebase for the "current" business rules or behavior, and a second codebase for presenting or interfacing with a human role player. When business rules are changed in the mid-tier codebase, the old rules are lost forever.

Rarely do applications store the behavior that belongs to an entity with the entity. And even more rarely is the behavior that is stored with an entity temporal in nature; that is, sensitive to at what time the behavior takes place. Yet, that's how the real world is. No wonder business people have problems with our software solutions. We're not modeling the real world as it is!

To make matters worse, there's a disturbing trend toward the presentation layer defining the model. Mapping tools like Hibernate (java) or Django (Python) will create database entities for you. That's very convenient. However, what may be a convenient way to pass current data for data entry is not necessarily an accurate model of the real world.

Often, using the presentation layer to build the underlying real-world model leads to denormalized data, which leads to fat rows in a database, which because of physics, leads to poor performance. The mantra behind tools like Enterprise JavaBeans (EJB), Hibernate, Django and so on is database independence—as if to suggest that all databases are created equal, which they certainly are not.

Oracle is dominant among its peers because it is superior. It's that simple. If you're not going to use Oracle, I suggest checking out PostgreSQL, which is a high-quality, object-relational, open source alternative, but it's not Oracle by any stretch of imagination.

We've had the capability of modeling the real world accurately in object-relational databases for some time now, so why don't we? The following are my answers to that question:

- *"Lex I: Corpus omne perseverare in statu suo quiescendi vel movendi uniformiter in directum, nisi quatenus a viribus impressis cogitur statum illum mutare."*: Newton's first law translated for our purposes: everyone uses relational databases, so everyone will continue to use relational databases unless there is a compelling enough reason to move in a different direction.

- *Ignorance, not stupidity (business community)*: The level of awareness that the real world is a combination of fact and action, or data and methods, and the value of that information is not commonly understood by business people. Yet, they are the ones who drive the need for applications. If the business community doesn't understand its own work problems, then no information technology department within that community will ever understand the associated work problems either because the business community defines applications of business.

- *Ignorance, not stupidity (technical community)*: The level of awareness that technology developers have currently attained does not commonly include object-relational technology. Heck, most techies I talk to don't even know what *object-relational* means. You'll hear more evidence about this in this chapter.

In order for you to understand and communicate these newer ideas (my answers), you need to come up to speed on some technology jargon. Let's start with object orientation.

Object Orientation

What's the big deal about object orientation anyway? First and foremost, it's about modeling the real world. Here are some examples:

- Rather than being concerned about a particular process, the emphasis is on independent entities that can actually perform the process.
- Rather than write one large procedure that does everything, and would also need to be tossed if the process in question changed, it's about assigning the appropriate parts of a procedure to the various role players in the procedure.
- Instead of having one large program, it's about modularity—having multiple, independent, and reusable components that act appropriately together to complete an act of work.

So it's about teamwork.

Key Tenets

Object orientation has three key tenets:

- *Encapsulation*: This refers to packaging related data and methods together. Object orientation is the natural way to think about things; natural, as in nature. It's the way nature does it. Nature creates things that have both attributes and behavior. For example, I don't think about what I'd like to eat for dinner, and then you go eat it for me. It doesn't work that way. My thoughts about food affect me, not you. We are separate entities. All my attributes and behaviors are encapsulated in me. All your attributes and behaviors are encapsulated in you. If someone tells each of us to do something, odds are, we'll do it differently, or may not do it at all. How's that for modularity?
- *Inheritance*: This is the ability to reuse the data and methods of a more abstract type. If we continue on about the idea of asking each of us to perform a particular task, we'll most likely do it differently because we inherited different genetic attributes from our parents, and they taught us different behaviors, too. So we inherited different attributes and behaviors from our parents, upon which we will add new ones, or override what our parents taught us and do it our own way.
- *Polymorphism*: This refers to hiding different implementations behind a common interface. Polymorphism is the use of the same name for a particular behavior, yet knowing that each object, or person in our case, may perform the behavior differently. If I'm asked to clean the floor, I'll get out the vacuum cleaner, and then follow up by washing the floor with a bucket of clear water, while you may hire someone to do the job. All the same, the floor gets cleaned, and that's the behavior that was requested.

Using these three tenets, you can naturally model both the attributes and behavior, or data and methods, for any real-world entity. Let's talk more about reuse.

Reuse

What is reuse anyway? I consider it reuse any time you can abstract multiple lines of code into a larger block of code that will then be called by more than one actor. I also think there are multiple levels of reuse. Let's start with the smallest unit of reuse: method-level reuse.

Method-Level Reuse

I always tell programmers who I work with that if they must code the same lines of code more than once to accomplish the same task, then they need to create a method. That's what I call method-level reuse.

The trick is where to put the method. That's an easy question to answer for an object-oriented programmer: put the method with the entity that's executing the behavior! That's what object-orientation is all about.

Next up is what I call component-level reuse.

Component-Level Reuse

Component-level reuse is when you can reuse a particular class of an entity, or in SQL jargon, a `TYPE`. You can reuse a class in two ways: through direct application (composition) or inheritance. Direct application would be where you create a `TYPE` called `PERSON`, and then create a table based on that type, called `PERSONS`. In this case, you'll have used the `TYPE PERSON` directly.

On the other hand, you could create a sub-`TYPE` called `WORKER` based on `TYPE PERSON`. Now `TYPE WORKER` would inherit all the data attributes and methods from its parent `PERSON`, possibly adding some of its own attributes and methods. This would be a case where you reused component `PERSON` by using inheritance.

Finally, if you define these `TYPE`s, and then reuse them in more than one application, that's also an example of component reuse, and an example of reuse at the most intriguing level. For example, if a human resource information system (HRIS) uses the `TYPE PERSON` in its `TYPE` hierarchy for `TYPE EMPLOYEE`, and then a safety application on the same database uses `PERSON` in its `TYPE` hierarchy for `TYPE WORKER`, then both applications can `TREAT` their sub-`TYPE`s as a `PERSON` in order to share (or reuse) related information.

The last example sounds like it could also be called application-level reuse.

Application-Level Reuse

You can also design an entire set of applications such that they all use the same underlying abstract `TYPE`s. This allows each application to share a common set of applications that act as infrastructure for more complex applications. The use of common `TYPE`s in the inheritance hierarchy of sub-`TYPE`s would allow the common use of the same tables for all related applications. Now that's what I call reuse!

Service Orientation

Object-oriented programmers have been building service-oriented applications for ages. That's the entire nature of object-oriented programming. You build independent components that provide supporting services through their method calls. You test them, and then you don't have to recode the same service ever again.

Even if you continue to build relational instead of object-relational databases, you can still provide service-oriented routines by properly associating your methods with your data. That's what I've been having you do up to this point. I've asked you to create what I called a "table package" for each table. Each "table package" contains a set of methods that logically belong to the data that is stored in the associated table.

For example, I named the relational Worker table `WORKERS`. Then I asked you to create a package called `WORKER` that contained a method for allocating a new primary key value. I've been using this pseudo-object orientation since PL/SQL became available, and it's a tactic that has worked well. Every programmer I've worked with has quickly come up to speed on the technique, and then reused the methods in the table package over and over again to accomplish the same logical task consistently every time.

In addition, although applications have been written in multiple programming languages and tools, all of them call the same "table package" methods to perform a particular service. Once again, even though different presentation layers are coded in different languages by different programmers, the same consistent behavior is seen across all presentations for all services—and that is reuse of the best kind.

Do these varying presentation layers recode the same behavior in varying languages? No. They all use the same code stored with the data. That's object orientation and service orientation in use. So how do you get there from here?

A Roadmap to Reality

So how do you get to using object-relational technology from relational technology? It's not as hard as you might think. Just like the function of life, *f(l)*, you'll get out whatever you put in to it. You can fully implement object-oriented technology in four progressive steps.

1. Create table packages.
2. Create user-defined types.
3. Create object views.
4. Create object tables.

Yes, you can implement four different levels of object orientation in your database, and based on what you implement, gain a level of consistency and reusability equal to your level of implementation.

Step 1: Table Packages

The first step is to start thinking in an object-oriented fashion, or as I call it, thinking naturally. This means organizing your data and methods in a related fashion, as I had you do earlier with table packages. I always name tables with a plural name, and then name their related packages with a singular name, so the package names are the singular of the table names. You can use whatever convention you want. By doing so, you should at least be able to employ encapsulation and polymorphism.

Table Method Encapsulation

You'll be employing encapsulation by gathering behavior and hiding it behind a public method call specification. Create a table package for every table in your database that has the same SQL statement executed on it more than once. Create a method for such a SQL statement, so the same behavior can be shared by multiple program units. Also, add any other related methods that perform calculations, concatenations, or locale-specific behavior.

Table Method Polymorphism

Next, look at the bigger picture. Notice the patterns of use of your table package methods, and use the same names for a particular pattern of use across all table packages.

For example, I use a `FUNCTION` named `get_id()` in every table package where I need a method that allocates a new primary key sequence value. Then, for a code table like `WORKER_TYPES`, if I need to get an ID value for a new entry, I call `WORKER_TYPE.get_id()`. Similarly, getting an ID value for a new `WORKERS` table entry will be a different package name, but the same method name: `WORKER.get_id()`.

That's polymorphism in action.

Step 2: User-Defined Types

The second step is to create a new object type, a user-defined type, that encapsulates both data attributes and method call specifications in a permanent new "data" or object type in the database.

Gather the list of column names you use in the relational table, and then collect the methods you specify in each table's package specification. Use this information along with the keyword `TYPE` to create a new object type in the database.

Unlike the table's associated package specification, where all methods are essentially `STATIC` (always available), you'll need to decide whether methods will operate on an instance of an object, a `MEMBER` method, or will be available through the object's `TYPE` definition, a `STATIC` method. In addition, you may want to add your own `CONSTRUCTOR` method(s) in order to make it easier to create a new object instance. And you may also want to define a `MAP MEMBER` method to specify how objects are sorted.

When you create user-defined types, you have the opportunity to use all three facets of object orientation. As with table packages, you'll be employing encapsulation and polymorphism. But you may also be able to leverage inheritance, so keep on the lookout for higher-level patterns between user-defined types. If you see a high-level pattern, consider defining a super-`TYPE`, and then inheriting from that super-`TYPE` for similar sub-`TYPE`s.

If you stop at this level of implementation, you'll still be able to use data from relational tables as objects by `TREAT`ing the relational data as objects on the fly in your SQL statements. But, if you get this far, I would at least do step 3.

Step 3: Object Views

The third step involves creating object views for your relational tables. An object view presents the underlying relational table data as a table of the newly created user-defined object type.

If you use more than one table in an object view, you can write `INSTEAD OF` triggers that will then appropriately update the underlying relational tables if you execute a SQL `INSERT`, `UPDATE`, or `DELETE` statement against an object view.

One of the advantages to using object views is that you can still use object-relational-ignorant tools against the relational tables. But if I were you, and you went this far, I would go all the way and reap the full benefit of object-oriented technology in an Oracle database; I would do step 4.

Step 4: Object Tables

The last step is where you create an object-relational database or *objectbase*, one where real-world entities are accurately modeled for both attributes and behavior. I'm not advocating moving all of an application's code into the database—I mean objectbase; actually, just the opposite. The only items that should reside in the objectbase are the entities, along with their data attributes and methods that are in scope for the particular application.

This means that what is normally thought of as data in a relational database should be stored in the objectbase, along with its associated entity business rules. Whatever code is used to present the object-relational model—data-entry screens, reports, graphics, and so on—should continue to reside in an external codebase. Regardless of the presentation layer, any entity-related business rule should be executed in the objectbase, not in the presentation layer.

That may seem like a radical departure from what you're currently doing, or perhaps not. If you're using EJBs, you're already making a remote procedure call to employ business rules in a so-called middle tier. Why not do it correctly, and employ the authoritative rules that permanently reside side by side with the data attributes, instead of supposedly recoding the same rules again and again (with inconsistency) in another codebase?

A Change in Order

Building an object-relational database, or objectbase, calls for a change in order. When building a relational database, you follow this order:

1. Create tables with columns (attributes).
2. Create table packages with methods (behavior).
3. Code presentation by accessing the data in tables and the behaviors in their associated packages.

When you build an object-relational database, or objectbase, you follow this order:

1. Create user-defined types with attributes and behaviors.
2. Create tables based on your user-defined types.
3. Code presentation by accessing attributes and behaviors in user-defined type tables.

With that change of order in mind, I think it's time I actually show you example of what I'm talking about. Enough philosophy—it's time for action. We'll begin with how to create a new user-defined type, an object type.

Object Types

You remember the keyword `TYPE` from Chapter 3, right? You used it to declare the equivalent of an array in PL/SQL: a PL/SQL table. Well in this context, you're going to use it to permanently create a new user-defined data type in the database. Using the term *data type* is a bit of a misnomer. You're really going to be creating new types of classes of entities, or object types. Yes, here's a new word for your vocabulary: *object type*. An object type defines both data attributes and related methods. So the SQL keywords you'll use to create user-defined object types are `CREATE TYPE`.

By creating a user-defined type, you'll permanently marry data and its associated methods in the database so they can't be separated, not even accidentally. It's a marriage for life; no divorce allowed. Of course, you'll be able to change data and behavior over time, but you'll be coding behavior so it will be time-dependent, and therefore be coding behavior over time.

Some day, we will store universal behavioral executables the same way we store data. But today, the best we can do is to store our code with our data, not as separate entities, and to modify our code to be point-in-time-dependent, so we can reproduce behavior as it existed at any point in time.

Since you probably have little experience with this form of SQL, I'm going to show you two examples, with you doing some of the coding along the way. First, let's create a user-defined TYPE for one of your code tables: Gender Type.

■ **Note** In Chapters 1–5, you were using an Oracle username of RPS to log into the database. This meant you were using the RPS schema. In this chapter, you need to use Oracle username OPS to log into the database so you won't encounter naming conflicts. By the end of this chapter, you will have object-relational types and tables in schema OPS that have the same names as relational packages and tables in schema RPS.

Create a User-Defined Type Specification

Creating a user-defined type takes two steps. First, you create a specification, and then you create a type body, or implementation, similar to creating a package. Listing 6-1 is an example of a CREATE TYPE specification script for creating a user-defined type for code table Gender.

Listing 6-1. An Example of a CREATE TYPE Statement for a Code Table, gender_type.tps

```
create TYPE GENDER_TYPE as object (
/*
gender_type.tps
by Don Bales on 2014-10-20
Type GENDER's attributes and methods.
*/
id                                    number,
code                                  varchar2(30),
description                           varchar2(80),
active_date                           date,
inactive_date                         date,
/*
A constructor for creating a new instance of type GENDER_TYPE with NULL
values.
*/
CONSTRUCTOR FUNCTION gender_type(
self                           in out gender_type)
return                                self as result,
/*
A constructor for creating a new instance of type GENDER_TYPE for insert.
*/
CONSTRUCTOR FUNCTION gender_type(
self                           in out gender_type,
aiv_code                              varchar2,
aiv_description                       varchar2)
return                                self as result,
/*
Gets the code and decription values for the specified id.
*/
STATIC PROCEDURE get_code_descr(
ain_id                         in     number,
aov_code                          out varchar2,
aov_description                   out varchar2),
/*
Verifies that the passed code value is an exact or like match on the
date specified.
*/
STATIC PROCEDURE get_code_id_descr(
aiov_code                      in out varchar2,
aon_id                            out number,
aov_description                   out varchar2,
aid_on                         in     date),
/*
Verifies that the passed code value is currently an exact or like match.
*/
STATIC PROCEDURE get_code_id_descr(
aiov_code                      in out varchar2,
aon_id                            out number,
aov_description                   out varchar2),
/*
Returns a new primary key id value for a row.
*/
MEMBER FUNCTION get_id
return                                number,
/*
Returns the id for the specified code value.
*/
STATIC FUNCTION get_id(
aiv_code                       in     varchar2)
return                                number,
/*
Test-based help for this package.  "set serveroutput on" in SQL*Plus.
*/
STATIC PROCEDURE help,
/*
Test units for this package.
*/
STATIC PROCEDURE test,
/*
A MAP function for sorting at the object level.
*/
MAP MEMBER FUNCTION to_varchar2
return                                varchar2
);
/
@se.sql GENDER_TYPE
```

The CREATE TYPE specification syntax used by Listing 6-1 is as follows:

```
CREATE [OR REPLACE] TYPE <type_name> AS OBJECT (
<attribute_name_1>                  <attribute_type_1>,
<attribute_name_2>                  <attribute_type_2>,...
<attribute_name_N>                  <attribute_type_N>,
[MAP]MEMBER or STATIC FUNCTION or PROCEDURE <method_name> [(
SELF                         [IN OUT][NOCOPY]<type_name>,
<parameter_name_1>           [IN OUT] <parameter_type_1>,
<parameter_name_2>           [IN OUT] <parameter_type_2>,...
<parameter_name_N>           [IN OUT] <parameter_type_N>)]
[RETURN                               <return_type>],
CONSTRUCTOR FUNCTION <type_name> (
SELF                         [IN OUT][NOCOPY]<type_name>,[
<parameter_name_1>           [IN OUT] <parameter_type_1>,
<parameter_name_2>           [IN OUT] <parameter_type_2>,...
<parameter_name_N>           [IN OUT] <parameter_type_N>)],
);
```

where

- `<type_name>` is the name of your user-defined `TYPE`.
- `<attribute_name>` is the name of a data item in your user-defined `TYPE`.
- `<attribute_type>` is a predefined scalar data type or a user-defined type.
- `<method_name>` is the name of a `MEMBER` or `STATIC`, `FUNCTION` or `PROCEDURE`.
- `<parameter_name>` is the name of a parameter being passed into or out of a method.
- `<parameter_type>` is a predefined scalar data type or a user-defined type.
- `<return_type>` is also a predefined scalar data type or a user-defined type to be returned by an associated `FUNCTION`.

Wow! As you can see by Listing 6-1, I've added a lot of methods to my Gender Type code user-defined `TYPE`. Let's take a look at the listing line by line:

- Line 1 uses the DDL keywords `CREATE TYPE ... AS OBJECT` to declare a new user-defined `TYPE` specification for my schema in the database. I call my new type `GENDER_TYPE`, as in it's the Gender Type code's user-defined object type.
- Lines 2 through 6 contain my usual source code preamble that documents the name of the source file, the author, date written, and purpose.
- On lines 7 through 11, I list the attributes for the `TYPE`. Theses are the names of the columns from the original relational table. Did you notice that I ended the last attribute with a comma (`,`), which means I intend to continue specifying attributes or methods for the `TYPE`?
- Lines 12 through 18 declare a user-defined `CONSTRUCTOR` method. You'll call a `CONSTRUCTOR` any time you want to create a new instance of a `TYPE`. For example, all user-defined `TYPE`s come with a default `CONSTRUCTOR`, where you pass in attribute values in the order they are specified in the `TYPE` specification. So to create a new instance of Gender Type using the default `CONSTRUCTOR`, you would code something like this:

  o_gender_type := GENDER_TYPE(3, 'U', 'Unknown', SYSDATE, NULL);

  The `CONSTRUCTOR` I've declared here will create an instance of the `TYPE` with all its attributes initialized to `NULL` values. This is handy when I want to access a member function without actually working with a permanent instance of a `TYPE`.

- Lines 12 through 15 hold a multiline comment that documents the purpose of the method. Remember to document as you go.
- Lines 19 through 26 declare a user-defined `CONSTRUCTOR` for coding convenience. Using it, you can create a new instance of Gender Type by simply passing the code and description like this:

  o_gender_type := GENDER_TYPE('U', 'Unknown');
- On lines 27 through 33, I specify my first `STATIC` method for the `TYPE`. If I specify a method as `STATIC`, it's available for execution through the `TYPE`'s name, like a package, but not available through an instance of the type. For example, to execute `PROCEDURE get_code_descr()`, I would code `GENDER_TYPE.get_code_desc(...)`, not using a variable of the `TYPE` in the method call like this: `o_gender_type.get_code_desc(...)`.
- Skipping down, lines 50 through 54 declare a `MEMBER` method, `get_id()`, to allocate the next primary key value. This is the same method I asked you to create in a table package in Chapter 5. Now it has become a `MEMBER` method for the `TYPE`.
- Finally, lines 69 through 73 declare a `MAP MEMBER FUNCTION`. This method will be used by the Oracle database any time it needs to sort object-level instances of the `TYPE`.

Let's review. How did I get here, to a `TYPE` specification, from there, a relational table and associated table package? Here's what I did:

1. Took the columns from the relational table and made them the attributes of the `TYPE`.
2. Took the methods from the relational table's package specification and made them `MEMBER` or `STATIC` methods of the `TYPE`.
3. Added a `MAP MEMBER FUNCTION` for sorting.
4. Added user-defined `CONSTRUCTOR FUNCTION`s for convenience.

Now that you've seen the specification, let's look at the implementation!

Create a User-Defined Type Implementation

Listing 6-2 is a `CREATE TYPE BODY ... AS` (implementation) script for the `TYPE GENDER_TYPE` specification shown in Listing 6-1. I'll cover all the methods implemented in this `TYPE` in subsequent chapters, when I take a polymorphic look at methods required by the `TYPE` and presentation layers: data entry, data migration, data processing, reporting, graphing, and so on. For now, it's important for you to focus on the method implementations that are unique to a `TYPE`, namely the `MAP MEMBER` and `CONSTRUCTOR FUNCTION`s.

Listing 6-2. An Example of a CREATE TYPE BODY Statement for a Code Table, gender_type.tpb

```
001  create or replace TYPE BODY GENDER_TYPE as
002  /*
003  gender_type.tpb
004  by Don Bales on 2014-10-20
005  Type GENDER_TYPE's attributes and methods
006  */
007
```

```
CONSTRUCTOR FUNCTION gender_type(
self                           in out gender_type)
return                                self as result is

begin
  id            := NULL;
  code          := NULL;
  description   := NULL;
  active_date   := NULL;
  inactive_date := NULL;
  return;
end gender_type;


CONSTRUCTOR FUNCTION gender_type(
self                           in out gender_type,
aiv_code                              varchar2,
aiv_description                       varchar2)
return                                self as result is

begin
  id            := get_id();
  code          := aiv_code;
  description   := aiv_description;
  active_date   := SYSDATE;
  inactive_date := DATE_.d_MAX;
  return;
end gender_type;


STATIC PROCEDURE get_code_descr(
ain_id                         in     number,
aov_code                          out varchar2,
aov_description                   out varchar2 ) is

begin
  select code,
         description
  into   aov_code,
         aov_description
  from   GENDER_TYPES
  where  id = ain_id;
end get_code_descr;


STATIC PROCEDURE get_code_id_descr(
aiov_code                      in out varchar2,
aon_id                            out number,
aov_description                   out varchar2,
aid_on                         in     date ) is

v_code                                varchar2(30);
```

```

begin
  select id,
         description
  into   aon_id,
         aov_description
  from   GENDER_TYPES
  where  code = aiov_code
  and    aid_on between active_date and nvl(inactive_date, DATE_.d_MAX);
exception
  when NO_DATA_FOUND then
    select id,
           code,
           description
    into   aon_id,
           v_code,
           aov_description
    from   GENDER_TYPES
    where  code like aiov_code||'%'
    and    aid_on between active_date and nvl(inactive_date, DATE_.d_MAX);
    aiov_code := v_code;
end get_code_id_descr;


STATIC PROCEDURE get_code_id_descr(
aiov_code                      in out varchar2,
aon_id                            out number,
aov_description                   out varchar2 ) is

begin
 get_code_id_descr(
  aiov_code,
  aon_id,
  aov_description,
  SYSDATE );
end get_code_id_descr;


MEMBER FUNCTION get_id
return                                number is

n_id                                  number;

begin
  select GENDERS_ID.nextval
  into   n_id
  from   SYS.DUAL;

  return n_id;
end get_id;


```

```
STATIC FUNCTION get_id(
aiv_code                       in     varchar2 )
return                                number is

n_id                                  number;

begin
  select id
  into   n_id
  from   GENDER_TYPES
  where  code = aiv_code;

  return n_id;
end get_id;


STATIC PROCEDURE help is

begin
 pl('No help at this time.');
end help;


STATIC PROCEDURE test is

begin
  pl('No tests coded at this time');
end test;


MAP MEMBER FUNCTION to_varchar2
return                                varchar2 is

begin
  return description||to_char(active_date, 'YYYYMMDDHH24MISS');
end to_varchar2;


end;
/
@be.sql GENDER_TYPE
```

The CREATE TYPE BODY syntax used by Listing 6-2 is as follows:

```
CREATE [OR REPLACE] TYPE BODY <type_name> AS
[MAP]MEMBER or STATIC FUNCTION or PROCEDURE <method_name> [(
SELF                          [IN OUT][NOCOPY]<type_name>,
<parameter_name_1>            [IN OUT] <parameter_type_1>,
<parameter_name_2>            [IN OUT] <parameter_type_2>,...
<parameter_name_N>            [IN OUT] <parameter_type_N>),]
[RETURN                                <return_type>],
CONSTRUCTOR FUNCTION <type_name> (
SELF                        [IN OUT][NOCOPY]<type_name>,[
<parameter_name_1>          [IN OUT] <parameter_type_1>,
<parameter_name_2>          [IN OUT] <parameter_type_2>,...
<parameter_name_N>          [IN OUT] <parameter_type_N>),]
END;
```

where

- `<type_name>` is the name of your user-defined `TYPE`.
- `<method_name>` is the name of a `MEMBER` or `STATIC`, `FUNCTION` or `PROCEDURE`.
- `<parameter_name>` is the name of a parameter being passed `IN`to or `OUT` of a method.
- `<parameter_type>` is a predefined scalar data type or a user-defined type.
- `<return_type>` is also a predefined scalar data type or a user-defined type to be returned by an associated `FUNCTION`.

As you can see by Listing 6-2, I've added quite a bit of behavior to my Gender Type code user-defined type. Let's break down the listing:

- Line 1 uses the DDL keywords `CREATE TYPE BODY ... AS` to create a `TYPE BODY` for `TYPE` specification `GENDER_TYPE`. The `BODY` consists of method implementations for the methods declare in the `TYPE` specification.
- Lines 9 through 19 implement a `CONSTRUCTOR FUNCTION` that will return an instance of a Gender Type object initialized to `NULL` values.
- Lines 22 through 35 implement a `CONSTRUCTOR FUNCTION` for coding convenience that requires you to pass in only a code and description in order to create a new Gender Type object instance. As you can see on line 29, the method initializes the `id` attribute using the `MEMBER FUNCTION get_id()`.
- Lines 98 through 109 implement the `MEMBER FUNCTION get_id()` in order to allocate the next primary key value.
- Lines 198 through 203 implement the `MAP MEMBER FUNCTION to_varchar2()`, which returns the description for a given code along with its creation date, all as one long `varchar2` value. Oracle will use this value to determine precedence when ordering object instances in a SQL `SELECT` statement. You don't need to declare and implement a `MAP MEMBER FUNCTION`, but I always do.

Which came first, the chicken or the egg? Now, if you're real sharp, you may have noticed that I have some dependency issues with the implementation. In order for the `TYPE BODY` to compile, an object table named `GENDER_TYPES` must already exist! Yes, the `STATIC` methods refer to an object table `GENDER_TYPES`, based on object `TYPE GENDER_TYPE`. This isn't a big problem. I can address it one of two ways:

- Compile the `TYPE` specification, create the object table based on the `TYPE` specification, and then compile the `TYPE BODY`.
- Use dynamic SQL in the `STATIC` methods so the dependent table name in the SQL statements doesn't get resolved until runtime.

I normally choose the first alternative, for performance reasons.

It's Your Turn to Create a User-Defined Type

Now that you've seen me transform the Gender Type table and table package into a user-defined TYPE, it's time for you to do the same for the Worker Type table.

1. Make sure to log into the database using username OPS, password OPS.
2. Get the list of columns from the relational SQL WORKER_TYPES table (from Chapter 5), and at least the one method you created in table package WORKER_TYPE, and use that information to code a WORKER_TYPE TYPE specification.
3. Save your specification script as worker_type.tps.
4. Compile your specification: @worker_type.tps.
5. Create a WORKER_TYPE TYPE BODY script, which will contain the implementation for your method get_id().
6. Save you body script as worker_type.tpb.
7. Compile your body: @worker_type.tpb.
8. Test your user-defined type to at least see that it compiled.

To test your user-defined type, you can use an anonymous PL/SQL procedure like the following.

```
declare
-- Declare a worker_type_o variable
o_worker_type                         WORKER_TYPE;

begin
  -- Now use the default constructor to create a new instance
  -- of the object
  o_worker_type := new WORKER_TYPE(
    NULL, 'H', 'A hard worker', SYSDATE, NULL);
  -- Now allocate a new ID using the member function get_id()
  o_worker_type.id := o_worker_type.get_id();
  -- Now show the values of the attributes in the instance
  pl('o_worker_type.id            = '||o_worker_type.id);
  pl('o_worker_type.code          = '||o_worker_type.code);
  pl('o_worker_type.description   = '||o_worker_type.description);
  pl('o_worker_type.active_date   = '||o_worker_type.active_date);
  pl('o_worker_type.inactive_date = '||o_worker_type.inactive_date);
end;
/
```

Your results should look something like this:

```
o_worker_type.id            = 111
o_worker_type.code          = H
o_worker_type.description   = A hard worker
o_worker_type.active_date   =  20070223 100918
o_worker_type.inactive_date =

PL/SQL procedure successfully completed.
```

Listings 6-3 and 6-4 demonstrate my solution for this exercise. Once again, I'm showing you a fully implemented TYPE.

Listing 6-3. A Worker Type Used-Defined TYPE Specification, worker_type.tps

```
create TYPE WORKER_TYPE as object (
/*
worker_type.tps
by Don Bales on 2014-10-20
Type WORKER_TYPE's attributes and methods.
*/
id                                    number,
code                                  varchar2(30),
description                           varchar2(80),
active_date                           date,
inactive_date                         date,
-- Gets the code and decription values for the specified work_type_id.
STATIC PROCEDURE get_code_descr(
ain_id                         in     number,
aov_code                          out varchar2,
aov_description                   out varchar2 ),
-- Verifies the passed aiov_code value is an exact or like match on the
-- date specified.
STATIC PROCEDURE get_code_id_descr(
aiov_code                      in out varchar2,
aon_id                            out number,
aov_description                   out varchar2,
aid_on                         in     date ),
-- Verifies the passed aiov_code value is currently an exact or like match.
STATIC PROCEDURE get_code_id_descr(
aiov_code                      in out varchar2,
aon_id                            out number,
aov_description                   out varchar2 ),
-- Returns a newly allocated id value.
MEMBER FUNCTION get_id
return                                number,
-- Returns the id for the specified code value.
STATIC FUNCTION get_id(
aiv_code                       in     varchar2 )
return                                number,
-- Test-based help for this package.  "set serveroutput on" in SQL*Plus.
STATIC PROCEDURE help,
-- Test units for this package.
STATIC PROCEDURE test,
-- A MAP function for sorting at the object level.
MAP MEMBER FUNCTION to_varchar2
return                                varchar2,
-- A constructor for creating a new instance of type WORKER_TYPE
-- with NULL values.
CONSTRUCTOR FUNCTION worker_type(
self                           in out worker_type)
return                                self as result,
-- A constructor for creating a new instance of type WORKER_TYPE
-- for insert.
CONSTRUCTOR FUNCTION worker_type(
self                           in out worker_type,
aiv_code                       in     varchar2,
aiv_description                in     varchar2)
return                                self as result
);
/
@se.sql WORKER_TYPE
```

Listing 6-4. A Worker Type User-Defined TYPE BODY, worker_type.tpb

```
create or replace TYPE BODY WORKER_TYPE as
/*
worker_type.tpb
by Don Bales on 2014-10-20
Type WORKER_TYPE's methods
*/


MEMBER FUNCTION get_id
return                                number is

n_id                                  number;

begin
  select WORKER_TYPES_ID.nextval
  into   n_id
  from   SYS.DUAL;

  return n_id;
end get_id;


STATIC FUNCTION get_id(
aiv_code                       in     varchar2 )
return                                number is

n_id                                  number;

begin
  select id
  into   n_id
  from   WORKER_TYPES
  where  code = aiv_code;

  return n_id;
end get_id;


```

```
STATIC PROCEDURE get_code_descr(
ain_id                         in     number,
aov_code                          out varchar2,
aov_description                   out varchar2 ) is

begin
  select code,
         description
  into   aov_code,
         aov_description
  from   WORKER_TYPES
  where  id = ain_id;
end get_code_descr;


STATIC PROCEDURE get_code_id_descr(
aiov_code                      in out varchar2,
aon_id                            out number,
aov_description                   out varchar2,
aid_on                         in     date ) is

v_code                                varchar2(30);

begin
  select id,
         description
  into   aon_id,
         aov_description
  from   WORKER_TYPES
  where  code = aiov_code
  and    aid_on between active_date and nvl(inactive_date, DATE_.d_MAX);
exception
  when NO_DATA_FOUND then
    select id,
           code,
           description
    into   aon_id,
           v_code,
           aov_description
    from   WORKER_TYPES
    where  code like aiov_code||'%'
    and    aid_on between active_date and nvl(inactive_date, DATE_.d_MAX);

    aiov_code := v_code;
end get_code_id_descr;


STATIC PROCEDURE get_code_id_descr(
aiov_code                      in out varchar2,
aon_id                            out number,
aov_description                   out varchar2 ) is

```

```
begin
 get_code_id_descr(
  aiov_code,
  aon_id,
  aov_description,
  SYSDATE );
end get_code_id_descr;


STATIC PROCEDURE help is

begin
 pl('No help coded at this time.');
end help;


STATIC PROCEDURE test is

begin
  pl('No tests coded at this time.');
end test;


MAP MEMBER FUNCTION to_varchar2
return                                varchar2 is

begin
  return description||to_char(active_date, 'YYYYMMDDHH24MISS');
end to_varchar2;


CONSTRUCTOR FUNCTION worker_type(
self                           in out worker_type)
return                                self as result is

begin
  id            := NULL;
  code          := NULL;
  description   := NULL;
  active_date   := NULL;
  inactive_date := NULL;
  return;
end worker_type;


CONSTRUCTOR FUNCTION worker_type(
self                           in out worker_type,
aiv_code                       in     varchar2,
aiv_description                in     varchar2)
return                                self as result is

```

```
begin
  id            := get_id();
  code          := aiv_code;
  description   := aiv_description;
  active_date   := SYSDATE;
  inactive_date := DATE_.d_MAX;
  return;
end worker_type;


end;
/
@be.sql WORKER_TYPE
```

Why don't we create an object view next!

Object Views

Think of this as a cloning project. You can seamlessly transition into the use of user-defined objects by intelligently overlaying your relational database structure with a set of object views. An object view takes the columns from one or more relational tables and morphs them into a pseudo-table of user-defined objects, complete with attributes and behavior.

Create an Object View

Listing 6-5 is a script to create an object view for the relational Gender Type code table `GENDER_TYPES`. This view automatically maps the column values in table `GENDER_TYPES` to the attributes of user-defined `TYPE GENDER_TYPE`, producing what appears to be a table of `GENDER_TYPE` objects called `GENDER_TYPEZ`.

Listing 6-5. An Example of an Object View Script for Table GENDER_TYPES, gender_typez.vw

```
rem gender_typez.vw
rem by Donald J. Bales on 2014-10-20
rem Create an object view for relational table GENDER_TYPES

create view GENDER_TYPEZ of GENDER_TYPE
with object identifier (id) as
select id,
       code,
       description,
       active_date,
       inactive_date
from   RPS.GENDER_TYPES;
```

The `CREATE VIEW` syntax used in Listing 6-5 is as follows:

```
CREATE [OR REPLACE] VIEW <view_name> OF <type_name>
WITH OBJECT IDENTIFIER (<primary_key_attributes>) AS
SELECT <column_name_1>,
       <column_name_2>,...
       <column_name_N>
FROM   <table_name>;
```

where

- `<view_name>` is the name of the view to create.
- `<type_name>` is the user-defined `TYPE` to map the columns to in the relational table.
- `<primary_key_attributes>` is one or more attributes in the user-defined `TYPE` that map to the primary key column(s) of the underlying table.
- `<column_name>` is the name of a column in the table to map to the attributes of the user-defined `TYPE`.
- `<table_name>` is the underlying table to map to the user-defined `TYPE`.

That wasn't much work, was it? OK, now let's test the view. Listing 6-6 is an anonymous PL/SQL procedure to test the object view. It's well commented, so you can see what is being tested. Note that you can execute `INSERT`, `UPDATE`, `DELETE`, and `SELECT` statements against an object view or its underlying table and get the same results. An object view therefore provides a means for your database to be both relational and object-oriented at the same time!

■ **Note** On line 12, I've added `RPS.` to `GENDER_TYPES` so the anchor points to the relational SQL schema's `GENDER_TYPES` table.

Listing 6-6. A Test Unit for View GENDER_TYPEZ, gender_typez.sql

```
01  rem gender_typez.sql
02  rem by Donald J. Bales on 2014-10-20
03  rem test unit for object view GENDER_TYPEZ
04
05  declare
06  -- Declare a variable of the user-define type
07  o_gender_type                        GENDER_TYPE;
08  -- Declare a variable for the underlying table
09  r_gender_type                        RPS.GENDER_TYPES%ROWTYPE;
10
11  begin
12    -- Insert a test object using the convenience constructor
13    insert into GENDER_TYPEZ
14    values ( GENDER_TYPE( 'T', 'Test') );
15
16    -- Now update the inactive date on the object
17    update GENDER_TYPEZ
18    set    inactive_date = SYSDATE
19    where  code          = 'T';
20
21    -- Retrieve the object in order to show its values
22    select value(g)
23    into   o_gender_type
24    from   GENDER_TYPEZ g
25    where  code          = 'T';
26
```

```
  -- Show the object's values
  pl('o_gender_type.id            = '||o_gender_type.id);
  pl('o_gender_type.code          = '||o_gender_type.code);
  pl('o_gender_type.description   = '||o_gender_type.description);
  pl('o_gender_type.active_date   = '||o_gender_type.active_date);
  pl('o_gender_type.inactive_date = '||o_gender_type.inactive_date);

  -- Delete the test object
  delete GENDER_TYPEZ
  where  code          = 'T';

  -- This time insert the test object using the instance variable
  insert into GENDER_TYPEZ
  values ( o_gender_type );

  -- Now, select the values from the underlying relational table
  select *
  into   r_gender_type
  from   RPS.GENDER_TYPES
  where  code          = 'T';

  -- Show the record's values
  pl('r_gender_type.id            = '||r_gender_type.id);
  pl('r_gender_type.code          = '||r_gender_type.code);
  pl('r_gender_type.description   = '||r_gender_type.description);
  pl('r_gender_type.active_date   = '||r_gender_type.active_date);
  pl('r_gender_type.inactive_date = '||r_gender_type.inactive_date);

  -- Last, delete the object from the relational table
  delete RPS.GENDER_TYPES
  where  code          = 'T';

  -- Commit all these operations
  commit;

  -- Confirm that the test completed successfully
  pl('Test completed successfully.');
end;
/
```

And, here are the results of the test unit in Listing 6-6:

```
SQL> @gender_ov.sql
```

```
o_gender.id            = 131
o_gender.code          = T
o_gender.description   = Test
o_gender.active_date   =  20070223 140020
o_gender.inactive_date =  20070223 140020
r_gender.id            = 131
r_gender.code          = T
r_gender.description   = Test
r_gender.active_date   =  20070223 140020
r_gender.inactive_date =  20070223 140020
Test completed successfully.

PL/SQL procedure successfully completed.
```

■ **Note** On line 9, I've added `RPS.` to `GENDER_TYPES%ROWTYPE` so the anchor points to the relational SQL schema's `GENDER_TYPES` table.

It's Your Turn to Create an Object View

Yes, it's your turn. Can you guess what I'm going to ask you to do next? I thought so.

1. Make sure you are logged in to the database using Oracle username OPS.
2. Create a script to create an object view for table `RPS.WORKER_TYPES` that maps its values to user-defined type `WORKER_TYPE`. You know, the `TYPE` you just finished creating in the previous exercise.
3. Save your script as `worker_typez.vw`.
4. Execute your script to create the object view: `@worker_typez.vw`.
5. Create a test unit script and test your new object view.

Nope, I'm not going to show you my solution. This is so simple you don't need my help!
Next, let's do step four of the four-step transformation to object-orientation.

Object Tables

Once you've created a `TYPE`, it's no harder to create an object (-relational) table than it is to build a relational table.

Create an Object Table

As a matter of fact, Listing 6-7 is nothing more than my table-creation script for the Gender Types table, `gendertypes.tab`, from Chapter 5, with a few minor changes.

Listing 6-7. An Example of an Object Table Script for GENDER_TYPES, gender_types.tab

```
01  rem gender_types.tab
02  rem by Donald J. Bales on 2014-10-20
03  rem Create an object table for the Gender Type codes
04
05  --drop   table GENDER_TYPES;
06  create table GENDER_TYPES of GENDER_TYPE;
07
08  --drop   sequence GENDERS_ID;
09  create sequence GENDERS_ID
10  start with 1;
11
12  alter  table GENDER_TYPES add
13  constraint   GENDER_TYPES_PK
14  primary key ( id )
15  using index;
16
17  alter  table GENDER_TYPES add
18  constraint   GENDER_TYPES_UK
19  unique ( code, active_date )
20  using index;
21
22  execute SYS.DBMS_STATS.gather_table_stats(USER, 'GENDER_TYPES');
```

The `CREATE TABLE` syntax used in Listing 6-7 is as follows:

```
CREATE TABLE <table_name> OF <type_name>;
```

where `<table_name>` is the name of the table to create, and `<type_name>` is the user-defined `TYPE` to use instead of column names for the table.

There isn't a lot of extra work to creating an object table vs. a relational table, now is there? Here's the rundown:

- On line 6, I use the new syntax to create a table of one user-defined `TYPE` instead of one or more predefined scalar data types.
- On lines 10 through 12, I create a sequence for the object (-relational) table.
- On lines 12 through 15, I create a primary key on the object table, just as I did on the relational table.
- On lines 17 through 20, I create a unique key on the object table, just as I did on the relational table.

It's Your Turn to Create an Object Table

Once again, it's your turn. For this exercise, create an object table named WORKER_TYPES for the Worker Type code table.

1. Write a script to create an object table based on user-defined TYPE WORKER_TYPE.
2. Save your script as worker_types.tab.
3. Execute your script to create the object view: @worker_types.tab.
4. Create a test unit script and test your new object table.

I'll indulge you. Listing 6-8 is my solution to this exercise.

Listing 6-8. An Example of an Object Table Script for WORKER_TYPES, worker_types.tab

```
rem worker_type.tab
rem copyright by Donald J. Bales on 2014-10-20
rem Create an object table for the Worker Type codes

--drop   table WORKER_TYPES;
create table WORKER_TYPES of WORKER_TYPE;

--drop   sequence WORKER_TYPES_ID;
create sequence WORKER_TYPES_ID
start with 1;

alter  table WORKER_TYPES add
constraint   WORKER_TYPES_PK
primary key ( id )
using index;

alter  table WORKER_TYPES add
constraint   WORKER_TYPES_UK
unique ( code )
using index;

execute SYS.DBMS_STATS.gather_table_stats(USER, 'WORKER_TYPES');
```

To test this object table, I just save my object view test unit as worker_types.sql, change the object view name to the object table name, and get rid of the relational table tests, and then ta da! Listing 6-9 shows my test unit for WORKER_TYPES.

Listing 6-9. A Test Unit for Table WORKER_TYPES, worker_types.sql

```
rem worker_types.sql
rem by Donald J. Bales on 2014-10-20
rem test unit for object table WORKER_TYPES

declare
-- Declare a variable of the user-define type
o_worker_type                        WORKER_TYPE;

```

```
begin
  -- Insert a test object using the convenience constructor
  insert into WORKER_TYPES
  values ( WORKER_TYPE( 'T', 'Test') );

  -- Now update the inactive date on the object
  update WORKER_TYPES
  set    inactive_date = SYSDATE
  where  code          = 'T';

  -- Retrieve the object in order to show its values
  select value(g)
  into   o_worker_type
  from   WORKER_TYPES g
  where  code          = 'T';

  -- Show the object's values
  pl('o_worker_type.id             = '||o_worker_type.id);
  pl('o_worker_type.code           = '||o_worker_type.code);
  pl('o_worker_type.description    = '||o_worker_type.description);
  pl('o_worker_type.active_date    = '||o_worker_type.active_date);
  pl('o_worker_type.inactive_date  = '||o_worker_type.inactive_date);

  -- Delete the test object
  delete WORKER_TYPES
  where  code          = 'T';

  -- This time insert the test object using the instance variable
  insert into WORKER_TYPES
  values ( o_worker_type );

  -- Last, delete the object from the relational table
  delete WORKER_TYPES
  where  code          = 'T';

  -- Commit all these operations
  commit;

  -- Confirm that the test completed successfully
  pl('Test completed successfully.');
end;
/
```

The results of the test unit in Listing 6-9 should look something like this:

```
SQL> @worker_types.sql
```

```
o_worker_type.id            = 1
o_worker_type.code          = T
o_worker_type.description   = Test
o_worker_type.active_date   = 29-DEC-14
o_worker_type.inactive_date = 29-DEC-14
Test completed successfully.

PL/SQL procedure successfully completed.
```

Come on, you have to admit it. It's pretty easy to make a transition to object orientation, right? Perhaps, or perhaps not. Some argue that there is a problem between how object-oriented languages represent data and how data is stored in a relational database, calling it an *impedance mismatch*.

Impedance Mismatch?

I argue that if done properly, there is little so-called "mismatch" between the classes used in an object-oriented language like Java and object-relational user-defined types in Oracle—that is, if they both properly model the real world.

I have an entire section dedicated to the use of Java Database Connectivity (JDBC) and object-relational user-defined types in one of my previous books (*Java Programming with Oracle JDBC,* OReilly, 2001). My 30 plus years of experience in both programming with object-oriented languages and using relational and now object-relational databases has led me to the conclusion that the mismatch is one of improper analysis vs. the reality of the problem domain.

The only time I see a mismatch is when one of the following occurs:

- "Catchall" classes are used in the presentation layer, which make it easy to represent and move objects around in the presentation layer, but they don't actually model the real world at all.
- Denormalized attributes in classes, which once again make it easier to work with data in the presentation layer, but don't even remotely represent the cardinality of the real world.
- No time is taken to do a proper analysis. It's build a presentation and then create a database that fits it, or restated, shoot, ready, aim! Right.
- Target databases use a different programming language from the presentation layer's object-oriented programming environment, so the database programming language is misunderstood, misused, or ignored altogether.

Don't take these in any particular order, because there are more reasons than I am willing to list. I seem to remember the same phenomena—you know, all the reasons not to adopt better technology—years ago when relational technology first appeared, say 1984?

So what haven't I told you? There are, in fact, a few topics I have not covered yet. Let's delve into those next.

Nested Types and Collections

First, I haven't shown any examples with nested types. For example, I could create a `TYPE ADDRESS` for address information, and then use that `TYPE` as an attribute in another `TYPE` like `CONTACT`. You can do that; it's not a problem.

Nor have I shown you any examples of a `TYPE` that contain arrays of other `TYPE`s. That's certainly possible. You can create what is called a nested `TYPE`, and implement it as a nested table where you can have an unlimited number of entries, or as a varying array that has a fixed number of entries. I don't like the sound of the latter. It's not very relational in nature. And nesting is where all the so-called impedance mismatch occurs.

In the minds of some object-oriented programmers, it's necessary to create huge, complex, object types that contain everything remotely similar. You know this; if you're an object-oriented programmer, you've seen them, or worse, created them.

Consider Figure 6-1, a class diagram to replace the ERD for the problem domain from Chapter 1. Are all three historical entities—`LocgicalAssignment`, `PhysicalAssignment`, and `WorkAssignment`—part of `Worker` in an object-oriented setting? No, they may be related, but you won't find them on any particular worker, will you? They are actually stand-alone entities. However, in most cases, someone would create a class `Worker` that contained these three entities as arrays. There's the mismatch. It's a break between reality and programming convenience.

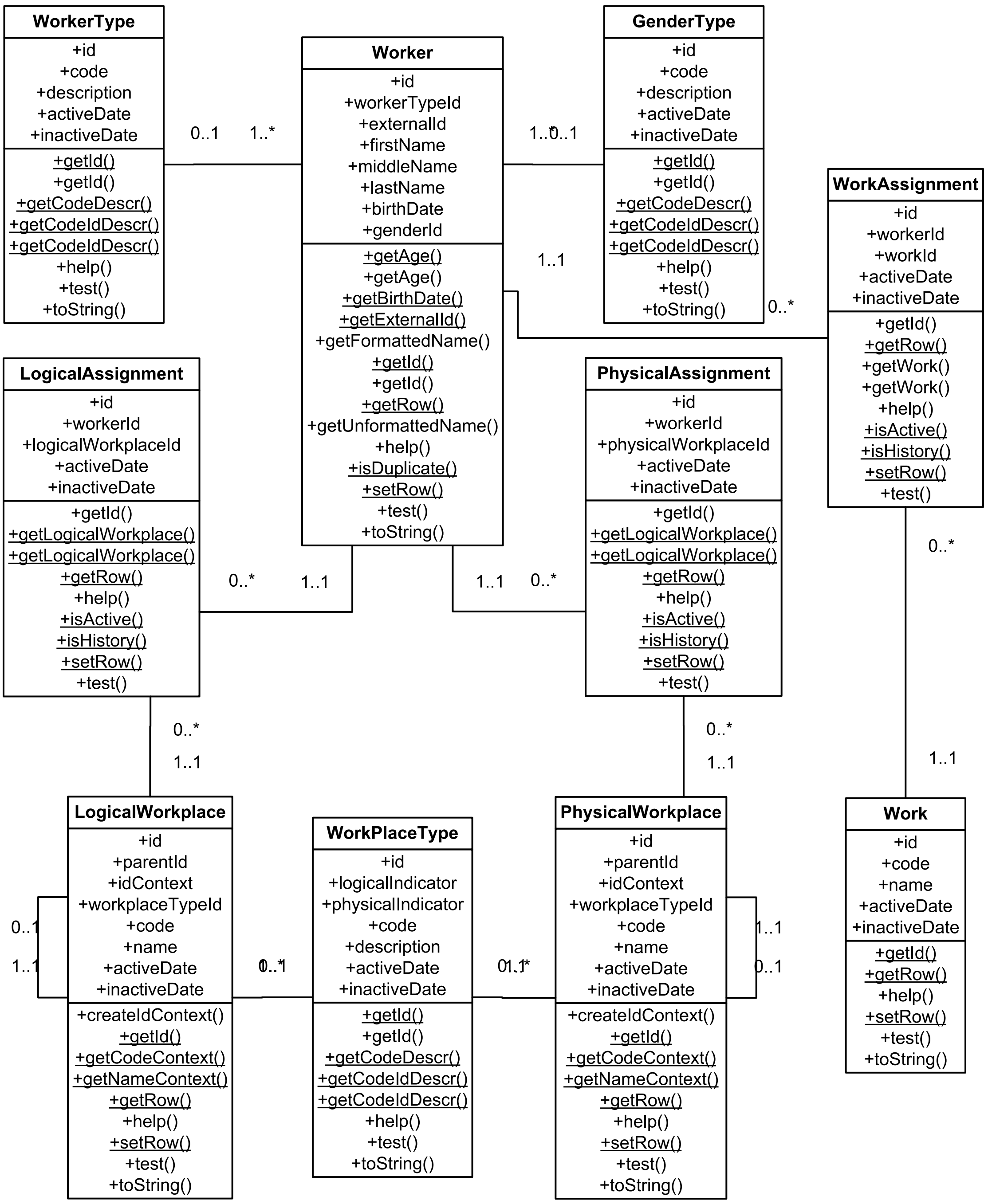


Figure 6-1. *A partial class diagram for the sample problem domain*

It's Your Turn to Prove There's No Impedance Mismatch

At this point, I've coded the scripts to create the Gender code object table, and you've done the same for the Worker Type object table. Now you can put these to work as you code the scripts for and create a Worker object table. Here's what to do.

1. Verify that you successfully executed the following scripts: `gender_type.tps`, `gender_type.tpb`, `gender_types.tab`, and `gender_types.ins`.
2. Verify that you successfully coded and executed the following scripts: `worker_type.tps`, `worker_type.tpb`, `worker_types.tab`, and `worker_types.ins`.
3. Write a script to create a `TYPE` specification for the Worker entity. You can get the attributes from the column names in file `worker_types.tab` from Chapter 5. You can get the method names from package file `worker_type.pks` from Chapter 5.
4. Save your script as `worker.tps`.
5. Compile your script: `@worker.tps`.
6. Write a script to create an object table named `WORKERS` using the user-defined type `WORKER` you just created.
7. Save your script as `workers.tab`.
8. Compile your script: `@workers.tab`.
9. Write a script to implement the `TYPE BODY` for the Worker entity. You can get the method implementations from package file `worker_type.pkb` from Chapter 5.
10. Save your script as `worker.tpb`.
11. Compile your script: `@worker.tps`.
12. At this point, you should have a valid `WORKERS` object table. So now modify the script you used to populate the `WORKERS` table in Chapter 5, `workers.ins`, to populate the `WORKERS` object table.
13. Save your script as `workers.ins`.
14. Execute your script in order to populate the object table: `@workers.ins`.
15. Create a test unit script and test your new object table.

Listings 6-10 through 6-13 show my solutions for this exercise. Listing 6-10 is my specification for the `TYPE WORKER`.

Listing 6-10. The Specification Script for User-Defined TYPE WORKER, worker.tps

```
create type WORKER as object (
/*
worker.tps
by Don Bales on 2014-10-20
Type WORKER's attributes and methods.
*/
id                                  number(38),
worker_type_id                      number(38),
external_id                         varchar2(30),
first_name                            varchar2(30),
middle_name                           varchar2(30),
last_name                             varchar2(30),
name                                  varchar2(100),
birth_date                            date,
gender_type_id                        number(38),
/*
Get the worker's current age.
*/
MEMBER FUNCTION get_age
return                                number,
/*
Get the worker's age on the specified date.
*/
MEMBER FUNCTION get_age(
aid_on                                date)
return                                number,
/*
Calculate a worker's age for the given birth date
and point in time.
*/
STATIC FUNCTION get_age(
aid_birth_date                 in     date,
aid_on                         in     date)
return                                number,
/*
Calculate a worker's current age for the given bith date.
*/
STATIC FUNCTION get_age(
aid_birth_date                 in     date)
return                                number,
/*
Get the specified worker's age at the given point in time.
*/
STATIC FUNCTION get_age(
ain_id                         in     number,
aid_on                         in     date)
return                                number,
/*
Get the specified worker's current age.
*/
STATIC FUNCTION get_age(
ain_id                         in     number)
return                                number,
/*
Get the specified worker's birth date.
*/
STATIC FUNCTION get_birth_date(
ain_id                         in     number)
return                                date,
/*
```

```
Get the specified worker's external ID.
*/
STATIC FUNCTION get_external_id
return                          varchar2,
/*
Calculate the locale specific formatted name.
*/
STATIC FUNCTION get_formatted_name(
aiv_first_name                in     varchar2,
aiv_middle_name               in     varchar2,
aiv_last_name                 in     varchar2)
return                          varchar2,
/*
Get the specified worker's formatted name.
*/
STATIC FUNCTION get_formatted_name(
ain_id                        in     number)
return                          varchar2,
/*
Get the next primary key value for the table.
*/
STATIC FUNCTION get_id
return                          number,
/*
Get the specified worker's internal ID.
*/
STATIC FUNCTION get_id(
aiv_external_id               in     varchar2)
return                          number,
/*
Get the specified worker's row object.
*/
STATIC FUNCTION get_row(
aio_worker                    in     WORKER)
return                          WORKER,
/*
Calculate the non-locale specific unformmated name.
*/
STATIC FUNCTION get_unformatted_name(
aiv_first_name                in     varchar2,
aiv_middle_name               in     varchar2,
aiv_last_name                 in     varchar2)
return                          varchar2,
/*
Display the help text for this TYPE.
*/
MEMBER PROCEDURE help,
/*
Check to see if a worker with the same name, birth_date and
gender already exists in the database.
*/
```

```
STATIC FUNCTION is_duplicate(
aiv_name                       in     varchar2,
aid_birth_date                 in     varchar2,
ain_gender_type_id             in     varchar2)
return                                boolean,
/*
Set the specified worker's row object.
*/
STATIC PROCEDURE set_row(
aioo_worker                    in out WORKER),
/*
Execute the test unit for this TYPE.
*/
MEMBER PROCEDURE test,
/*
The MAP function for this TYPE.
*/
MAP MEMBER FUNCTION to_varchar2
return                                varchar2,
/*
A convenience constructor for this TYPE.
*/
CONSTRUCTOR FUNCTION worker(
self                           in out worker,
ain_worker_type_id             in     number,
aiv_first_name                 in     varchar2,
aiv_middle_name                in     varchar2,
aiv_last_name                  in     varchar2,
aid_birth_date                 in     date,
ain_gender_type_id             in     number)
return                                self as result,
/*
A NULL values constructor for this TYPE.
*/
CONSTRUCTOR FUNCTION worker(
self                           in out worker)
return                                self as result
);
/
@se.sql
```

Listing 6-11. The CREATE TABLE Script for Object Table WORKERS, workers.tab

```
rem worker_ot.tab
rem by Donald J. Bales on 2014-10-20
rem Create an object table for Workers

--drop   table WORKERS;
create table WORKERS of WORKER;

```

```
--drop   sequence WORKERS_ID;
create sequence WORKERS_ID
start with 1;

--drop   sequence EXTERNAL_ID_SEQ;
create sequence EXTERNAL_ID_SEQ
start with 100000000 order;

alter  table WORKERS add
constraint   WORKERS_PK
primary key ( id )
using index;

alter  table WORKERS add
constraint   WORKERS_UK1
unique ( external_id )
using index;

alter  table WORKERS add
constraint   WORKERS_UK2
unique (
name,
birth_date,
gender_type_id )
using index;

alter  table WORKERS add
constraint   WORKERS_FK1
foreign key   ( worker_type_id )
references   WORKER_TYPES ( id );

alter  table WORKERS add
constraint   WORKERS_FK2
foreign key   ( gender_type_id )
references   GENDER_TYPES ( id );

execute SYS.DBMS_STATS.gather_table_stats(USER, 'WORKERS');
```

Listing 6-12. The BODY Implementation Script for TYPE WORKER , worker.tpb

```
create or replace type body WORKER as
/*
worker.tpb
by Don Bales on 2014-10-20
TYPE WORKER's methods
*/

MEMBER FUNCTION get_age(
aid_on                         in     date)
return                                number is

```

```
begin
  return WORKER.get_age(birth_date, aid_on);
end get_age;


MEMBER FUNCTION get_age
return                                number is

begin
  return WORKER.get_age(birth_date, SYSDATE);
end get_age;


STATIC FUNCTION get_age(
aid_birth_date                 in     date,
aid_on                         in     date)
return                                number is

begin
 if aid_birth_date is not NULL and
    aid_on         is not NULL then
   return trunc(months_between(aid_on, aid_birth_date) / 12);
 else
   return NULL;
 end if;
exception
 when OTHERS then
   return NULL;
end get_age;


STATIC FUNCTION get_age(
aid_birth_date                 in     date)
return                                number is

begin
  return WORKER.get_age(aid_birth_date, SYSDATE);
end get_age;


STATIC FUNCTION get_age(
ain_id                         in     number,
aid_on                         in     date)
return                                number is

begin
  return WORKER.get_age(WORKER.get_birth_date(ain_id), aid_on);
end get_age;
```

```
STATIC FUNCTION get_age(
ain_id                        in     number)
return                               number is

begin
  return WORKER.get_age(WORKER.get_birth_date(ain_id));
end get_age;


STATIC FUNCTION get_birth_date(
ain_id                        in     number)
return                               date is

d_birth_date                         date;

begin
  select birth_date
  into   d_birth_date
  from   WORKERS
  where  id = ain_id;

  return d_birth_date;
end get_birth_date;


STATIC FUNCTION get_external_id
return                               varchar2 is

v_external_id                        varchar2(30);

begin
  select lpad(to_char(EXTERNAL_ID_SEQ.nextval), 9, '0')
  into   v_external_id
  from   SYS.DUAL;

  return v_external_id;
end get_external_id;


STATIC FUNCTION get_id
return                               number is

n_id                                 number;

begin
  select WORKERS_ID.nextval
  into   n_id
  from   SYS.DUAL;

  return n_id;
end get_id;
```

```


STATIC FUNCTION get_id(
aiv_external_id                in     varchar2)
return                                number is

n_id                                  number;

begin
  select id
  into   n_id
  from   WORKERS
  where  external_id = aiv_external_id;

  return n_id;
end get_id;


STATIC FUNCTION get_formatted_name(
aiv_first_name                 in     varchar2,
aiv_middle_name                in     varchar2,
aiv_last_name                  in     varchar2)
return                                varchar2 is

begin
 return aiv_last_name||', '||aiv_first_name||' '||aiv_middle_name;
end get_formatted_name;


STATIC FUNCTION get_formatted_name(
ain_id                         in     number)
return                                varchar2 is

v_first_name                          varchar2(30);
v_middle_name                         varchar2(30);
v_last_name                           varchar2(30);

begin
  select first_name,
         middle_name,
         last_name
  into   v_first_name,
         v_middle_name,
         v_last_name
  from   WORKERS
  where  id = ain_id;

  return get_formatted_name(
          v_first_name,
          v_middle_name,
          v_last_name);
```

```
end get_formatted_name;


STATIC FUNCTION get_row(
aio_worker                     in     WORKER)
return                                WORKER is

o_worker                              WORKER;

begin
  if    aio_worker.id is not NULL then
    -- retrieve the row by the primary key
    select value(w)
    into   o_worker
    from   WORKERS w
    where  id = aio_worker.id;
  elsif aio_worker.external_id is not NULL then
    -- retrieve the row by the external unique key
    select value(w)
    into   o_worker
    from   WORKERS w
    where  external_id = aio_worker.external_id;
  else
    -- retrieve the row by the name, birth_date, and gender
    select value(w)
    into   o_worker
    from   WORKERS w
    where  name       = worker.get_formatted_name(
                          aio_worker.first_name,
                          aio_worker.middle_name,
                          aio_worker.last_name)
    and    birth_date = aio_worker.birth_date
    and    gender_type_id  = aio_worker.gender_type_id;
  end if;
  return o_worker;
exception
  when NO_DATA_FOUND then
    raise;
  when OTHERS then
    raise_application_error(-20001, SQLERRM||
      ' on select WORKERS'||
      ' in WORKER.get_row()');
end get_row;


STATIC FUNCTION get_unformatted_name(
aiv_first_name                 in     varchar2,
aiv_middle_name                in     varchar2,
aiv_last_name                  in     varchar2)
return                                varchar2 is

```

```
begin
  return upper(replace(replace(replace(replace(replace(
    aiv_last_name||aiv_first_name||aiv_middle_name,
      '''', NULL), ',', NULL), '-', NULL), '.', NULL), ' ', NULL));
end get_unformatted_name;


STATIC FUNCTION is_duplicate(
aiv_name                       in     varchar2,
aid_birth_date                 in     varchar2,
ain_gender_type_id                  in     varchar2)
return                                boolean is

n_selected                            number;

begin
  execute immediate
   'select count(1)
    from   WORKERS
    where  name       = aiv_name
    and    birth_date = aid_birth_date
    and    gender_type_id  = ain_gender_type_id'
    into   n_selected
    using  in aiv_name,
           in aid_birth_date,
           in ain_gender_type_id;

  if nvl(n_selected, 0) > 0 then
    return TRUE;
  else
    return FALSE;
  end if;
end is_duplicate;


MEMBER PROCEDURE help is

begin
--   12345678901234567890123456789012345678901234567890123456789012345678901234567890
  pl('================================== PACKAGE ===================================');
  pl(chr(9));
  pl('WORKER');
  pl(chr(9));
  pl('---------------------------------- FUNCTIONS ---------------------------------');
  pl(chr(9));
  pl('YOU GOTTA CODE THIS BUDDY WORKER.get_id');
  pl('return                                number;');
  pl(chr(9)||'Returns a newly allocated sequence value for id.');
  pl(chr(9));
  pl('WORKER.get_id(');
  pl('aiv_external_id                in     varchar2 )');
  pl('return                                number;');
  pl(chr(9)||'Returns the corresponding id for the specified external_id.');
  pl(chr(9));
  pl('------------------------------------ PROCEDURES ---------------------------------');
  pl(chr(9));
  pl('WORKER.get_external_id_descr(');
  pl('ain_id                         in     number,');
  pl('aov_external_id                   out varchar2,');
  pl('aov_description                   out WORKERS.description%TYPE );');
  pl(chr(9)||'Gets the corresponding external_id and description for the specified');
  pl(chr(9)||'id.');
  pl(chr(9));
  pl('WORKER.get_external_id_id_descr(');
  pl('aiov_external_id                      in out varchar2,');
  pl('aon_id                out number,');
  pl('aov_description                   out WORKERS.description%TYPE,');
  pl('aid_on                         in     WORKERS.active%TYPE );');
  pl(chr(9)||'Gets the corresponding external_id, id, and description for');
  pl(chr(9)||'the specified external_id.  First it trys to find an exact match.
  If one');
  pl(chr(9)||'cannot be found, it trys to find a like match.  It may throw a');
  pl(chr(9)||'NO_DATA_FOUND or a TOO_MANY_ROWS exception if a match cannot be');
  pl(chr(9)||'found for the specified external_id and point in time.');
  pl(chr(9));
  pl('WORKER.get_external_id_id_descr(');
  pl('aiov_external_id               in out varchar2,');
  pl('aon_id                            out number,');
  pl('aov_description                   out WORKERS.description%TYPE );');
  pl(chr(9)||'Gets the corresponding external_id, id, and description for');
  pl(chr(9)||'the specified external_id.  First it trys to find an exact match.
  If one');
  pl(chr(9)||'cannot be found, it trys to find a like match.  It may throw a');
  pl(chr(9)||'NO_DATA_FOUND or a TOO_MANY_ROWS exception if a match cannot be');
  pl(chr(9)||'found for the specified external_id at the current point in time.');
  pl(chr(9));
  pl('WORKER.help( );');
  pl(chr(9)||'Displays this help text if set serveroutput is on.');
  pl(chr(9));
  pl('WORKER.test( );');
  pl(chr(9)||'Built-in test unit.  It will report success or error for each test
  if set');
  pl(chr(9)||'serveroutput is on.');
  pl(chr(9));
end help;


STATIC PROCEDURE set_row(
aioo_worker                     in out WORKER) is

d_null                        constant date        := DATE_.d_MIN;
n_null                        constant number      := 0;
```

```
v_null                       constant varchar2(1) := ' ';
o_worker                              WORKER;

begin
  -- set the formatted name
  aioo_worker.name := worker.get_formatted_name(
                        aioo_worker.first_name,
                        aioo_worker.middle_name,
                        aioo_worker.last_name);
  -- get the existing row
  begin
    o_worker := get_row(aioo_worker);
  exception
    when NO_DATA_FOUND then
      o_worker := NULL;
  end;
  -- if a row exists, update it if needed
  if o_worker is not NULL then
    aioo_worker.id := o_worker.id;
    if nvl(o_worker.worker_type_id, n_null) <>
         nvl(aioo_worker.worker_type_id, n_null) or
       nvl(o_worker.external_id,    n_null) <>
         nvl(aioo_worker.external_id,    n_null) or
       nvl(o_worker.first_name,     v_null) <>
         nvl(aioo_worker.first_name,     v_null) or
       nvl(o_worker.middle_name,    v_null) <>
         nvl(aioo_worker.middle_name,    v_null) or
       nvl(o_worker.last_name,      v_null) <>
         nvl(aioo_worker.last_name,      v_null) or
       nvl(o_worker.birth_date,     d_null) <>
         nvl(aioo_worker.birth_date,     d_null) or
       nvl(o_worker.gender_type_id,      n_null) <>
         nvl(aioo_worker.gender_type_id,      n_null) then
      begin
        update WORKERS
        set    worker_type_id = aioo_worker.worker_type_id,
               external_id    = aioo_worker.external_id,
               first_name     = aioo_worker.first_name,
               middle_name    = aioo_worker.middle_name,
               last_name      = aioo_worker.last_name,
               name           = aioo_worker.name,
               birth_date     = aioo_worker.birth_date,
               gender_type_id = aioo_worker.gender_type_id
        where  id             = aioo_worker.id;

--        n_updated := nvl(n_updated, 0) + nvl(sql%rowcount, 0);
      exception
        when OTHERS then
          raise_application_error( -20002, SQLERRM||
            ' on update WORKERS'||
            ' in WORKER.set_row()' );
      end;
    end if;
  else
  -- add the row if it does not exist
    begin
      aioo_worker.id := get_id();
      insert into WORKERS
      values ( aioo_worker );

--      n_inserted := nvl(n_inserted, 0) + nvl(sql%rowcount, 0);
    exception
      when OTHERS then
        raise_application_error( -20003, SQLERRM||
          ' on insert WORKERS'||
          ' in WORKER.set_row()' );
    end;
  end if;
end set_row;


MEMBER PROCEDURE test(
self                           in out nocopy worker) is

begin
  pl('================================== PACKAGE ===================================');
  pl(chr(9));
  pl('WORKER');
  pl(chr(9));
  pl(chr(9)||'No tests for WORKER at this time');
end test;


MAP MEMBER FUNCTION to_varchar2
return                                varchar2 is

begin
  return rtrim(name||to_char(birth_date, 'YYYYMMDDHH24MISS'));
end to_varchar2;


CONSTRUCTOR FUNCTION worker(
self                           in out worker,
ain_worker_type_id             in     number,
aiv_first_name                 in     varchar2,
aiv_middle_name                in     varchar2,
aiv_last_name                  in     varchar2,
aid_birth_date                 in     date,
ain_gender_type_id             in     number)
return                                self as result is

```

```
begin
  id             := WORKER.get_id();
  worker_type_id := ain_worker_type_id;
  external_id    := WORKER.get_external_id();
  first_name     := aiv_first_name;
  middle_name    := aiv_middle_name;
  last_name      := aiv_last_name;
  name           := WORKER.get_formatted_name(
    first_name, middle_name, last_name);
  birth_date     := aid_birth_date;
  gender_type_id := ain_gender_type_id;
  return;
end worker;


CONSTRUCTOR FUNCTION worker(
self                           in out worker)
return                                self as result is

begin
  id             := NULL;
  worker_type_id := NULL;
  external_id    := NULL;
  first_name     := NULL;
  middle_name    := NULL;
  last_name      := NULL;
  name           := NULL;
  birth_date     := NULL;
  gender_type_id := NULL;
  return;
end worker;


end; --WORKER;
/
@be.sql WORKER
```

■ **Note** Make sure you execute scripts `gender_types.ins` and `worker_types.ins` before executing `workers.ins` (Listing 6-13); otherwise, the script will be missing required code values.

Listing 6-13. The Populate Table Script for Object Table WORKERS, workers.ins

```
rem workers.ins
rem by Donald J. Bales on 2014-10-20
rem Seed the Worker table with the top 100 names
rem 100 last x 100 first x 26 middle = 260,000 entries

set serveroutput on size 1000000;

```

```
declare

-- This is the number of seconds since midnight
-- I'll use it to profile my code's performance.
n_start                               number :=
  to_number(to_char(SYSDATE, 'SSSSS'));

-- Here, I declare four psuedo-constants to hold the
-- ID values from the code tables, rather `than look
-- them up repeatedly during the insert process.
n_G_FEMALE                            GENDER_TYPES.id%TYPE;
n_G_MALE                              GENDER_TYPES.id%TYPE;
n_WT_CONTRACTOR                       WORKER_TYPES.id%TYPE;
n_WT_EMPLOYEE                         WORKER_TYPES.id%TYPE;

-- I'll use this to keep track of the number of
-- rows inserted.
n_inserted                            number := 0;

begin
  -- Get the ID values for the codes
  n_G_FEMALE      := GENDER_TYPE.get_id('F');
  n_G_MALE        := GENDER_TYPE.get_id('M');
  n_WT_CONTRACTOR := WORKER_TYPE.get_id('C');
  n_WT_EMPLOYEE   := WORKER_TYPE.get_id('E');

  -- Use an INSERT INTO SELECT SQL statement
  insert into WORKERS
  select WORKER(
         WORKERS_ID.nextval,
         decode(mod(WORKERS_ID.currval, 2),
           0, n_WT_EMPLOYEE, n_WT_CONTRACTOR),
         lpad(to_char(EXTERNAL_ID_SEQ.nextval), 9, '0'),
         first_name,
         letter||'.',
         last_name,
         WORKER.get_formatted_name(
           first_name, letter||'.', last_name),
         DATE_.random(
           to_number(to_char(SYSDATE, 'YYYY')) - 65,
           to_number(to_char(SYSDATE, 'YYYY')) - 18),
         decode(gender_code, 'F', n_G_FEMALE, n_G_MALE))
  from   RPS.TOP_100_LAST_NAMES,
         RPS.TOP_100_FIRST_NAMES,
         RPS.A_THRU_Z;

  n_inserted := n_inserted + sql%rowcount;

  commit;

  pl(to_char(n_inserted)||' rows inserted in '||
    (to_number(to_char(SYSDATE, 'SSSSS')) - n_start)||
    ' seconds.');
end;
/

execute SYS.DBMS_STATS.gather_table_stats(USER, 'WORKERS');
```

If you compare the three object tables—`GENDER_TYPES`, `WORKER_TYPES`, and `WORKERS`—against the class diagram in Figure 6-1, you'll see that you've fully implemented both the attributes and methods of the classes: `GENDER_TYPE`, `WORKER_TYPE`, and `WORKER` in the database using user-defined `TYPE`s. Congratulations.

Is there a performance penalty for using object-relational technology? Sure there is! You didn't think you could do extra work, that is, instatiating classes (`TYPES`) for free did you? How much of a performance penalty? Well, `workers.ins` inserted 260,000 objects in 126 seconds. That's 2063 objects per second, or about six times slower than its relational counterpart. Is it worth the extra functionality? I think so, but now it's up to you.

Summary

To sum it all up, the real world is made up of things, or objects. Objects have both attributes and behaviors. Using attributes alone, you can answer only the question "What was that?" But with behaviors, you can also answer the question "When did it behave that way?" So you decide which way to go. Try one, then the other!

Table 6-1 is a summary of the SQL and PL/SQL objects that are used in order to fully model a business, scientific, or any real-world problem accurately.

Table 6-1. *A Summary of SQL and PL/SQL Objects Used to Model the Real World*

Item	Data	Behavior
Relational table (SQL)	Columns	
Relational view (SQL)	Columns	
Table package (PL/SQL)		Methods
User-defined type (SQL and PL/SQL)	Attributes	Methods
Object view (SQL)	Columns mapped to attributes	Methods
Object table (SQL)	Attributes	Methods

The single most important point of this chapter is that you can't accurately model anything without attributes and behavior, or data and methods. And as the saying goes, "Those who cannot remember the past are condemned to repeat it." We, the business and technical community, can now accurately model the real world. So we can remember the past and no longer repeat our mistakes. We can profit from our knowledge, the information we have gathered, as we all move through time and space.

Now that you know how to write some PL/SQL, let's look at how you can see what's going on as your PL/SQL program executes.

CHAPTER 7

Troubleshooting

I believe programmers are no better than their knowledge of the debugging and troubleshooting tools available for the programming language they're using. Why? Well, first, all programmers make coding mistakes. I often remark that the day I code something that compiles and runs correctly the first time, I'm going to retire because that would be the peak of my programming career. Second, programmers make logic mistakes. When is the last time you had to write some parsing code? That's one of the toughest types of programming to get right the first, second, third, or nth time around.

To find and solve our mistakes, we need a means to be able to discover exactly what is going on in our programs at that point in time when an error occurs. Sadly enough, when PL/SQL first appeared and for quite some time after, there was virtually no way to debug a stored PL/SQL program unit. The best we could do was to use `SYS.DBMS_OUTPUT.put_line()` to display a bunch of messages on the screen after the stored procedure finished executing.

Then along came the package `SYS.DBMS_PIPE`, where the most adventurous of us could write our own utilities to monitor an executing stored PL/SQL program unit in "real time" from a second session. That was an improvement, but not one that most PL/SQL programmers could use. Next, the `pragma autonomous transaction` showed up, which allowed us to write logging utilities that used a second session in order to monitor a stored PL/SQL program unit, and could permanently save the monitoring messages to a table. That was better, but still not very good.

More recently, the package `SYS.DBMS_DEBUG` became available. It allows us to write our own programs to actually run a remote debugging utility against a stored PL/SQL program unit. And now Oracle has made a PL/SQL debugger freely available to its programming communities with a product (written in Java) called Oracle SQL Developer. Other vendors have followed suit, and now you can remotely debug from graphical user interface (GUI) integrated development environments (IDEs) like TOAD for Oracle and Visual Studio, to name just a few. With a real remote debugger in our hands, we can actually see just what's happening in our PL/SQL programs.

When it comes to SQL, we've had access to `EXPLAIN PLAN` and `TKPROF` for as long as I can remember. Both give us the means to see the plans that the Oracle SQL Optimizer is going to use to access the underlying objects that are part of our SQL statements. Once again, using these tools, we can actually see just what's happening in our SQL.

However, having access to these fine troubleshooting tools is not enough. You also need to prepare for trouble ahead of time. You need to build troubleshooting capabilities into your program units. To that end, I'm going to show you how to do the following:

- Prevent trouble in the first place
- Prepare for trouble so you're ready for troubleshooting when an error does occur
- Use `SYS.DBMS_OUTPUT.put_line()` to provide meaningful troubleshooting information after a program unit finishes executing

- Use a logging utility to provide meaningful troubleshooting information in real time
- Use a remote debugger to walk through a program unit as it executes
- Use EXPLAIN PLAN to troubleshoot the performance of your SQL statements

Let's start out with some prevention techniques.

Prevention

If you want to prevent problems, then assume nothing. A handful of capabilities built into PL/SQL are nothing but an invitation for trouble. They are all centered on data types and implicit conversion. What's implicit conversion? Let's say you have number held in a varchar2 data type variable, v_value. You try assigning n_value, a number data type variable, that value with the following line of code:

```
n_value := v_value;
```

That should work, right? Yes, it should, but when it doesn't, because you don't actually have a numeric literal stored in variable v_value, the implicit data type conversion will raise an "unexpected" exception in your program unit, which will be hard to identify. By "identify," I mean determine which line of code caused the error and why. Before we get to the solution for this problem, let's look at another example.

This time, let's say you want pass a date value to a function that will return the time in seconds since midnight, January 1, 1980. The function requires the date be passed as a varchar2 parameter in the form DD-MON-YY. Hey, no problem. Just pass the date variable like so:

```
...
d_value                             date := SYSDATE;
n_value                             number;

begin
  n_value := date_to_long(d_value);
...
```

Oracle's default date format is DD-MON-YY, so it will work fine, right? Not exactly. If the current NLS_DATE_FORMAT for the session is DD-MON-YY (the default), it will work, but not if it is YYYYMMDD HH24MISS, as I set mine every time I log in to SQL*Plus.

What's the solution? Use a combination of anchors, data type prefixes, and explicit conversions with blocking.

Anchors

I've already discussed anchors in Chapter 3. They are those wacky looking data type declarations that use the %TYPE or %ROWTYPE keyword. For example, here's a list of variables declared in a manner so they match the data types of their corresponding table columns:

```
...
d_birth_date                        WORKER.birth_date%TYPE;
n_gender_type_id                    WORKER.gender_type_id%TYPE;
v_name                              WORKER.name%TYPE;
...
```

How does using anchors help prevent errors? Since each variable is anchored to the data type of the column in a table for which it will be used to temporarily hold a value, SQL and PL/SQL will not need to perform an implicit data type conversion when values are moved between the SQL and PL/SQL. Explicitly anchoring the data types of variables to their database counterparts prevents implicit conversions. Preventing implicit conversions prevents errors.

But if you're going to anchor variables to their corresponding database columns or attributes, why use data type prefixes?

Data Type Prefixes

Data type prefixes help prevent errors in two ways. One is that when you declare a variable with a data type prefix, you're documenting that you understand that the data type is a `date`, `number`, or `varchar2`. You're saying, "Hey, I know what this is!" From that point in your coding forward, you can work with that assertion in place, to make sure that you're not doing any implicit conversions. Preventing implicit conversions prevents errors.

Data type prefixes also make it clear that a data type conversion is necessary. If you find yourself coding away in the far recesses of your stored procedure, and you come to a line where you're going to make an assignment and the data type prefixes are not the same, you know that you need to code an explicit data type conversion. In turn, coding an explicit data type conversion will prevent an implicit conversion. Again, preventing implicit conversions prevents errors.

So let's look at how you code an explicit data type conversion.

Explicit Conversions

When you perform an explicit conversion, you can wrap your PL/SQL statements in their own PL/SQL block, or as I like to say, "block your code." This allows you to catch any exceptions raised during the data type conversion, so you can do something intelligent with your newfound knowledge of the error.

You perform an explicit data type conversion by using one of the following functions:

- `to_char()`: Used to convert a `date` or `number` to a `varchar2` data type
- `to_date()`: Used to convert a `varchar2` to a `date` data type
- `to_number()`: Used to convert a `varchar2` to a `number` data type

For example, to convert the value January 1, 1980 in variable `d_date` to a `varchar2` data type for variable `v_date` in the form `YYYYMMDD`, you could use the following code:

```
v_date := to_char(d_date, 'YYYYMMDD');
```

It's unlikely that converting from a `date` (or `number`) to a `varchar2` is ever going to cause an error as long as the receiving variable is declared large enough to hold the result, but, on the other hand, it's very likely an error will occur if you convert from a `varchar2` to a `date`, as in the following:

```
...
  begin
    d_date := to_date(v_date, 'YYYYMMDD');
  exception
    when OTHERS then
      pl(SQLERRM);
      pl('Converting "'||v_date||'" to a date using format YYYYMMDD');
      raise_application_error(-20001, SQLERRM||
      ' converting v_date to d_date'||
      ' in my_program_unit.method');
  end;
...
```

■ **Note** Way back in Chapter 1 I created a script named `pl.prc` that created a procedure called `pl()` that calls `SYS.DBMS_OUTPUT.put_line()` because I'm a lazy programmer who does not like to type `SYS.DBMS_OUTPUT.put_line()` everywhere I want to post a message.

In this example, if the character representation of the `date` in variable `v_date` is not in the format `YYYYMMDD`, the `to_date()` function will raise an appropriate exception. The enclosing PL/SQL block will echo the details to the screen using `put_line()` via `pl()`, and then raise an application error that will report exactly where the error occurred in the program. This, in turn, will give you details as to why there was an error, so you are armed with good error information when you start troubleshooting, not some time after you are well into troubleshooting.

Just as `to_date()` and `to_char()` have formats they can use to specify the conversion parameters, so does `to_number()`. You can find the details on these formats in the freely available *PL/SQL User's Guide and Reference*. You can find this and the rest of the Oracle documentation set online at `http://otn.oracle.com`.

So the proper use of the combination of anchors, data type prefixes, and explicit conversion functions will prevent many unexpected errors. Next, let's see how you can better prepare for those that will still eventually arrive.

Preparation

Preparing for trouble ahead of time means preparing for troubleshooting ahead of time. How do you prepare for troubleshooting? You can do that by using blocks and bread crumbs.

You can block (wrap code in its own PL/SQL block) risky code ahead of time. When I say "risky code," I mean

- Explicit data type conversions
- Movement of larger character strings to shorter character variables
- Singleton SQL statements

And what about bread crumbs? You know the fairy tale about Hansel and Gretel, right? They dropped bread crumbs on the ground as they walked through the forest so they could find their way back. Well, I want you to drop code on your listings as you type through your program, so you, too, can find your way back—back to the source of a problem.

Let's start our discussion of blocking and bread crumbs with the former.

Blocking

I just showed you an example of blocking—wrapping a small piece of your PL/SQL in its own PL/SQL block in order to catch a raised exception and dealing with it—when I discussed explicit conversions. Now I'll show you another example, where I move a larger character string into a smaller character variable.

It's not uncommon when coding a data migration or data processing program to move a larger `varchar2` variable into a smaller one. In such a situation, you can substring the larger variable in order to blindly truncate the larger string, or you can block the assignment so it raises an exception that you can deal with intelligently. Here's an example of the latter:

```
declare

v_large                            varchar2(80);
v_small                            varchar2(30);

begin
  -- I'm assigning the variable in the executable section because
  -- assignment errors in the declaration section are also very hard
  -- to troubleshoot!
  -- 12345678901234567890123456789012345678901234567890123456789012345678
  v_large :=
    'This is a large string of characters, at least longer than 30 bytes!';

  -- Now let's raise an exception
  begin
    -- This won't work!  68 bytes won't fit in 30 bytes!
    v_small := v_large;
  exception
    when OTHERS then
      pl(SQLERRM);
      pl('Moving v_large, length '||
        to_char(length(v_large))||' into v_small.');
      raise_application_error(-20001, SQLERRM||
       ' on v_small := v_large'||
       ' in my anonymous procedure');
  end;

  pl(v_small);
end;
/
```

Executing this example results in the following output from SQL*Plus:

```
ORA-06502: PL/SQL: numeric or value error: character string buffer too small
Moving v_large, length 68 into v_small.
declare
*
ERROR at line 1:
ORA-20001: ORA-06502: PL/SQL: numeric or value error: character string
buffer too small on v_small := v_large in my anonymous procedure
ORA-06512: at line 23
```

As you can see from the output, the first three lines come from the `pl()` messages, while the last four come from the raised application error. The important point here is that without the "extra" information displayed by `pl()` or the raised application error, you wouldn't know where in the program the assignment error occurred. So by "blocking" the code, you can use `pl()` or `raise_application_error()`, or both, in order to identify the location and reason for an error in your PL/SQL program.

This is invaluable information when troubleshooting. And, by now, you're probably tired of me stating that, but I can't impress on you enough how taking the time to add a few additional lines of PL/SQL code while you're programming can later drastically reduce the amount of time it takes to test and troubleshoot your code.

So how about those bread crumbs?

Bread Crumbs

What do I mean by "bread crumbs?" I mean adding columns to staging tables, adding logging from your PL/SQL programs, and so on, as you initially write your code, in preparation for trouble. I suppose you may think, "That's not a very optimistic way to think about my work." However, programming is highly detailed logical work. Therefore, human beings are bound to make mistakes, since we are, by nature, emotionally "big picture" thinkers.

With that in mind, here are some ideas for leaving behind bread crumbs:

- Never use `WHEN OTHERS THEN NULL` in an exception-handling section. OK, how about almost never use `WHEN OTHERS THEN NULL`. It's a rare occasion when you'll actually want to suppress all errors and do nothing. Think about it. The only example I've ever run into is my errorless `to_number_or_null()` and `to_date_or_null()` functions. If there are errors, you need to know, and you need to fix your program's logic so it deals with the errors intelligently, which means predictably.
- Never handle exceptions in a table package's methods or a type's methods. You want these to show up in the presentation layer so the end user (the programmer) can deal with them appropriately, which means predictably.
- Use `SYS.DBMS_OUTPUT.put_line()` to display success and error messages as the output of any data migration or data processing program unit.
- Use a procedure that utilizes `pragma autonomous transaction` to log your data migration or data processing program's progress to a table so you can see where in the process your program is currently executing or later review the program's execution.
- If you're involved in building interfaces that migrate data from another system into yours, add columns to the interface's staging tables, with the same names as the primary key columns in the destination tables. Then store the mappings used by your PL/SQL program (the primary key values) in the corresponding staging table columns when moving the data. This will allow you to see where your program moved the data.

You'll see some of these ideas in action in Chapter 10, when I talk about the polymorphic use of method names among the various table package methods and type methods.

I'll talk more about the use of `put_line()` and logging next. `put_line()` was the original means of debugging available to PL/SQL programmers, and even though it's not as powerful as a full-blown debugger, it remains useful. Let's see why.

After the Fact

Up to this point, you've seen the stored package procedure `SYS.DBMS_OUTPUT.put_line()` in action time and time again. Do you remember how, back in Chapter 2, I wrapped `SYS.DBMS_OUTPUT.put_line()` with a stored procedure named `pl()` so I wouldn't have to type that long name every time I wanted to display something on the screen?

Just because `put_line()` is the simplest of debugging tools in your arsenal does not by any means make it useless. If fact, because of its simplicity, it will probably be the first tool you use to debug any PL/SQL program unit. However, keep in mind that when you use `put_line()`, you're saying, "I can't wait to find out what's going on. OK, maybe I can." Why? Because you don't see any output from `put_line()` until your PL/SQL program unit has finished executing.

All the output from `put_line()` is stored in a temporary buffer until your PL/SQL program unit completes its execution, successfully or not. Then whatever tool you are using to execute your PL/SQL must query the `DBMS_OUTPUT` buffer and display your buffered messages on its screen. SQL*Plus does this for you automatically. However, if you were to write your own PL/SQL execution tool, you would need to program it to pull the messages from the `DBMS_OUTPUT` buffer after your PL/SQL program completed executing. The point is that `put_line()` messages appear after the fact.

In addition, you may be limited to the amount of message text you can output during any PL/SQL program unit's execution. You set this value in SQL*Plus using this command:

```
set serveroutput on size 1000000;
```

The size you specify is the maximum amount of memory to use for the `DBMS_OUTPUT` buffer. It used to be that you could specify 1,000,000 bytes at most, as in the preceding line. However, now you can use an unlimited amount, but is that a good idea?

And then there's the third limitation to `put_line()`. No single message can be more that 32,767 bytes in length. While that's not much of limitation, large messages can easily use up the buffer, so you must be careful about how you specify your messages.

In the end, the value of the information you get from `put_line()` is going to be equal to the quality of the messages you add to your PL/SQL code. So let's discuss that next.

Success Messages

It's just as important to display messages of successful operation as it is those related to failure. If you're writing a data processing or data migration program, it's likely that you'll leave your `put_line()` message in place. The thoughtful placement of success messages will narrow down the number of lines to investigate if an error does occur. For example, in Listing 7-1, I have five success messages. When an application error is raised on line 14, these messages will narrow the location of where the error actually took place.

Listing 7-1. An Example of Success Messages Narrowing the Scope of an Error, success.sql

```
01  rem success.sql
02  rem by Donald J. Bales on 2014-10-20
03  rem a script with success messages
04
05  declare
06
07  n_number                              number;
08
09  begin
10    pl('begin');
11
```

```
12    n_number := -1;
13
14    pl('No error here!');
15
16    n_number := 0;
17
18    pl('Still no error here!');
19
20    n_number := 'one';
21
22    pl('After the error.');
23
24    pl('end');
25  exception
26    when OTHERS then
27      raise_application_error(-20000, SQLERRM||
28        ' on assigning a value to n_number'||
29        ' in success.sql');
30  end;
31  /
```

When the script `success.sql` is executed, SQL*Plus outputs the following:

```
SQL> @success.sql
```

```
begin
No error here!
Still no error here!
declare
*
ERROR at line 1:
ORA-20000: ORA-06502: PL/SQL: numeric or value error: character to number
conversion error on assigning a value to n_number in success.sql
ORA-06512: at line 23
```

So, PL/SQL is reporting an `ERROR at line 1:`? That doesn't make much sense. Yet, further down it reports an error at line 23. Hey, that doesn't help much either. It's just a line number by the exception, but it can't be the error—it's a blank line! Where did the error occur? It took place somewhere in the block of PL/SQL code in scope for the exception-handling section.

Regardless, if we rely on our success messages, we can see that the error took place some time after the message `Still no error here!` and before `After the error`, and thus narrow down our search to lines 19 through 21. That helps.

In addition to using success messages to narrow the scope of an error, I like to keep track of the number of inserts, updates, deletes, and selects, and then display them at the end of the procedure to verify that something has actually happened.

If, on the other hand, you're writing table package or type service methods, you may use `put_line()` messages during the development process, and then manually comment them out before going into production. Why just comment them out and not delete them altogether? By leaving them commented out, you give support programmers a clue about a hard-to-understand or an error-prone section of code, and give them an opportunity to comment the `put_line()` back into play to help them debug your code in the future.

So how can you use failure messages?

Failure Messages

In practice, I rely on method `raise_application_error()` to send a meaningful error number and message to the presentation layer. I simply number application error messages from -20000 to -20199, from top down in my package body. The messages include the variable `SQLERRM`, a very brief note about what I was doing in the section of code, and the package and/or function or procedure name as a location of the error. The description in the message needs to be brief because `raise_application_error()` allows a maximum message size of only 2,048 bytes (255 bytes in earlier versions).

Since my message size is limited by `raise_application_error()`, I supplement the error message with extra lines of output using `put_line()` before the call to `raise_application_error()`. With the "extra" lines of output, I list the values of variables. By including the extra lines of error information, I can call the PL/SQL program unit that raised an error message with the same values as the presentation layer in order to re-create and then correct my code defect.

Now that you have some idea how to go about using `put_line()`, let's see you put it to use.

It's Your Turn to Use put_line( )

It's your turn to put your knowledge of `put_line()` and `raise_application_error()` to work by following these steps.

1. Write an anonymous PL/SQL procedure that adds a number in a `number` variable to a "number" in a `varchar2` variable together. Here's the hitch: you should spell out the second number in the `varchar2` variable so it will raise an exception when added.
2. "Block" the line of code where you do your addition and then catch the error, list the contents of the variables with `pl()`, and then raise an application error.
3. Save your script as `failure.sql`.
4. Execute your script, `@failure.sql`.

Did your script and results turn out similar to mine? Listing 7-2 is my solution to this exercise.

■ **Note** You won't get any output if you haven't executed the SQL*Plus command `set serveroutput on size 1000000;`, which I have already placed in the script `login.sql` that SQL*Plus executes every time it starts.

Listing 7-2. An Example of Using put_line( ) to List Variable Values, failure.sql

```
rem failure.sql
rem by Donald J. Bales on 2014-10-20
rem a script that fails on purpose

declare

n_number                              number;
v_number                              varchar2(30);

```

```
10  begin
11    pl('begin');
12
13    pl('before n_number assignment');
14
15    n_number := 1;
16
17    pl('after n_number assignment');
18
19    pl('before v_number assignment');
20
21    v_number := 'two';
22
23    pl('after v_number assignment');
24
25    pl('before addition');
26    begin
27      pl('n_number + v_number = '||to_char(n_number + to_number(v_number)));
28    exception
29      when OTHERS then
30        pl('n_number = '||to_char(n_number));
31        pl('v_number = '||v_number);
32        raise_application_error(-20000, SQLERRM||
33          ' on n_number + v_number'||
34          ' in failure.sql');
35    end;
36    pl('after addition');
37
38    pl('end');
39  end;
40  /
```

And here are the results from executing the `failure.sql` script:

```
SQL> @failure.sql
```

```
begin
before n_number assignment
after n_number assignment
before v_number assignment
after v_number assignment
before addition
n_number = 1
v_number = two
declare
*
ERROR at line 1:
ORA-20000: ORA-06502: PL/SQL: numeric or value error: character to
number conversion error on n_number + v_number in failure.sql
ORA-06512: at line 28
```

This time, since I blocked the one line where I'm performing the addition, the line number for the error reported by PL/SQL is fairly accurate. Still, the success messages do more to narrow the location of the error than does the error message from PL/SQL's `raise_application_error()`. In addition, since I use `pl()` to display the variable values, it's fairly easy to discern the reason for the program's error.

But what happens if you have a long-running procedure, and you want to get some ongoing feedback about its success? Then it's time to take advantage of logging from another session.

As It Happens

By utilizing the PL/SQL `pragma autonomous transaction`, you can build your own logging utility that can do the following:

- Insert and commit messages into a logging table from your PL/SQL program unit without committing your PL/SQL program's own transaction context
- Select the committed messages from a log table immediately after they are written from any other session

In essence, it's as if you're saying, "No, I've changed my mind. I can't wait after all." This technique of logging from another transaction context using an autonomous transaction allows you to see what's happening in your PL/SQL program unit almost in real time. You'll start by building your own logging utility, and then putting it to work in an example. First, you need a table to store messages.

A DEBUG Table

Should I build a relational example or an object-relational example? This time I'll build an object-relational example, and then you'll build its relational equivalent. So what do I need to store about a message? How about the list of attributes in Table 7-1?

Table 7-1. *Attributes for a Debugging Message Table*

Attribute	Description
`id`	A primary key column for the object table
`text`	The message to log from the calling PL/SQL program unit
`unique_session_id`	The unique session ID from the calling PL/SQL program unit
`insert_user`	The user from the calling PL/SQL program unit
`insert_date`	The date and time (`SYSDATE`) from the calling PL/SQL program unit

And don't forget about the behavior! What will my debug `TYPE` or package need to do for me? How about the list of behaviors in Table 7-2?

Table 7-2. Behaviors for a Debugging Message Table

Behavior	Description
`get_id()`	Allocate a primary key from the corresponding sequence
Null constructor	Return an object initialized to `NULL` values
Convenience constructor	Return an object initialized and ready for `INSERT`
Map method	Return a value to sort an object by
`enable()`	Enable `set_text()` for the specified program unit
`disable()`	Disable `set_text()` for the specified program unit
`set_text()`	Log the text to the debug table

Since I'm building the object-relational version, I need to create the `TYPE` first, the table second, and then the `TYPE BODY` last. Listing 7-3 is my source code for the object `TYPE DEBUG_O`.

Listing 7-3. Type DEBUG's Specification, ops.debug.tps

```
01  create type  DEBUG as object (
02  /*
03  debug.tps
04  by Donald Bales on 2014-10-20
05  Type DEBUG's specification:
06  A type for logging debug information
07  */
08  id                                    number(38),
09  text                                  varchar2(256),
10  unique_session_id                     varchar2(24),
11  insert_user                           varchar2(30),
12  insert_date                           date,
13  -- Get the next primary key value
14  STATIC FUNCTION get_id
15  return                                number,
16  -- A NULL values constructor
17  CONSTRUCTOR FUNCTION debug(
18  self                           in out nocopy debug)
19  return                                self as result,
20  -- A convenience constructor
21  CONSTRUCTOR FUNCTION debug(
22  self                           in out nocopy debug,
23  ain_id                         in     number,
24  aiv_text                       in     varchar2)
25  return                                self as result,
26  -- Override the default constructor
27  CONSTRUCTOR FUNCTION debug(
28  self                           in out nocopy debug,
29  id                             in     number,
30  text                           in     varchar2,
31  unique_session_id              in     varchar2,
32  insert_user                    in     varchar2,
33  insert_date                    in     date)
34  return                                self as result,
35  -- Write to the debug object table
36  STATIC PROCEDURE set_text(
37  aiv_program_unit               in     varchar2,
38  aiv_text                       in     varchar2),
39  -- A map function
40  MAP MEMBER FUNCTION to_map
41  return                                number
42  ) not final;
43  /
44  @se.sql
```

Let's take a close look at Listing 7-3.

- Lines 8 through 12 declare the five attributes for the TYPE.
- Lines 14 and 15 declare a static function `get_id()` to allocate the next primary key value. Since it's a static method, the function is executed using the TYPE rather than an instance of the TYPE.
- Lines 17 and 18 declare a constructor that returns an instance of the TYPE initialized to NULL values.
- Lines 21 through 25 declare a convenience constructor that will return a fully initialized instance of the TYPE, ready to be inserted into the DEBUGS table.
- Lines 27 through 34 declare a constructor that will override the default constructor definition provided by SQL.
- Lines 36 through 38 declare static procedure `set_text()`, which will insert an entry into the DEBUGS table using an autonomous transaction. This will allow me to commit the log entry without committing anything in the session where I'm using this method to log debug information.
- Lines 40 and 41 declare a MAP method used by SQL to compare and sort objects of this TYPE.

The next step in the development process is to create an object table based on the TYPE. You may have thought that I needed to code the TYPE's implementation first. In this case, I'm going to reference the object table in the TYPE BODY, so I must create the table first. Listing 7-4 is the DDL for creating an object table based on TYPE DEBUG.

Listing 7-4. DDL for Creating an Object Table Based on Type DEBUG, ops.debugs.tab

```
01  rem debugs.tab
02  rem by Donald Bales on 2014-10-20
03  rem Create debugging message table
04
05  -- drop table DEBUGS;
06  create table DEBUGS of DEBUG;
07
08  alter  table DEBUGS add
09  constraint   DEBUGS_PK
```

```
10  primary key (
11  id )
12  using index;
13
14  -- drop sequence DEBUGS_ID;
15  create sequence DEBUGS_ID
16  start with 1 order;
17
18  execute SYS.DBMS_STATS.gather_table_stats(USER, 'DEBUGS');
19
20  grant all on DEBUGS to PUBLIC;
```

Let's look at Listing 7-4 line by line:

- Line 6 creates object table `DEBUGS` based on `TYPE DEBUG`.
- Lines 8 through 12 create a primary key on the object table `DEBUGS`.
- Lines 15 through 16 declare a sequence to be used to allocate primary key values for table `DEBUGS`.
- On line 18, I analyze table `DEBUGS` to give the Optimizer some initial statistics to work with.
- On line 20, I grant all privileges to `PUBLIC` so anyone on the database can use the debug table facility I'm creating.

Now that the table exists, I can compile the `TYPE BODY` without dependency errors. Listing 7-5 is the `TYPE BODY` for `TYPE DEBUG`.

Listing 7-5. Type DEBUG's Implementation, debug.tpb

```
001  create or replace type body DEBUG as
002  /*
003  debug.tpb
004  by Donald Bales on 2014-10-20
005  Type DEBUG's implementation
006  A type for logging debug information
007  */
008
009  STATIC FUNCTION get_id
010  return                                number is
011
012  n_id                                  number;
013
014  begin
015    select DEBUGS_ID.nextval
016    into   n_id
017    from   SYS.DUAL;
018
019    return n_id;
020  end get_id;
021
022
```

```
CONSTRUCTOR FUNCTION debug(
self                           in out nocopy debug)
return                                self as result is

begin
  pl('debug(zero param)');
  self.id                := NULL;
  self.text              := NULL;
  self.unique_session_id := NULL;
  self.insert_user       := NULL;
  self.insert_date       := NULL;

  return;
end debug;


CONSTRUCTOR FUNCTION debug(
self                           in out nocopy debug,
ain_id                         in     number,
aiv_text                       in     varchar2)
return                                self as result is

begin
  pl('debug(two params)');
  self.id                := ain_id;
  self.text              := aiv_text;
  self.unique_session_id := SYS.DBMS_SESSION.unique_session_id;
  self.insert_user       := USER;
  self.insert_date       := SYSDATE;

  return;
end debug;


-- Override the default constructor.  To do so, you must
-- use the same attributes names for the parameter names
-- and use them in the order specified in the type spec.
CONSTRUCTOR FUNCTION debug(
self                           in out nocopy debug,
id                             in     number,
text                           in     varchar2,
unique_session_id              in     varchar2,
insert_user                    in     varchar2,
insert_date                    in     date)
return                                self as result is

begin
  pl('debug(five params)');
  self.id                := id;
  self.text              := text;
  self.unique_session_id := unique_session_id;
```

```
074   self.insert_user       := insert_user;
075   self.insert_date       := insert_date;
076
077   return;
078 end debug;
079
080
081 STATIC PROCEDURE set_text(
082 aiv_program_unit               in     varchar2,
083 aiv_text                       in     varchar2) is
084
085 pragma autonomous_transaction;
086
087 v_text                                varchar2(256);
088
089 begin
090   v_text := substrb(aiv_program_unit||': '||aiv_text, 1, 256);
091
092   insert into DEBUGS
093   values (DEBUG(DEBUGS_ID.nextval, aiv_text));
094 -- A defect in SQL prevented me from using the
095 -- function get_id() as follows:
096 --  values (DEBUG(DEBUG.get_id(), aiv_text));
097   commit;
098 end set_text;
099
100
101 MAP MEMBER FUNCTION to_map
102 return                                number is
103
104 begin
105   return id;
106 end to_map;
107
108
109 end;
110 /
111 @be.sql DEBUG
```

Listing 7-5 doesn't have any new code, so I'll just point out two details. The first centers around the second constructor found on lines 39 through 51. In this constructor, I should be able to code line 47 to read as follows:

```
self.id                 := DEBUG.get_id();
```

However, in SQL the constructor is called repeatedly, seemingly the number of times that there are attributes in the TYPE. Accordingly, SQL calls the constructor for this TYPE five times. I consider this a defect. It causes extra CPU and memory consumption, along with the wasted allocation of sequence values that will not be used if implemented in a reasonably object-oriented fashion. I've left in some troubleshooting pl() statements to prove that the constructors are called multiple times. To work around this defect, I've added parameter ain_id on line 41, and used the sequence directly in the SQL—for example, on line 93.

How long it will take Oracle to get around to fixing this problem is anyone's guess. I first pointed out this error in 2006, and it's still not fixed, so for the time being, I'm coding the convenience constructor for two parameters instead of one. So, I've just shown you an example of using `pl()` to help troubleshoot a problem.

The second item to notice is the use of the following on line 85:

```
pragma autonomous_transaction;
```

This effectively executes method `set_text()` in its own session, so committing the inserted debugging information will not affect the transaction state in the calling program unit.

My next step is to test what I've coded. To do that, I actually have three listings. Listing 7-6 is a test unit for `TYPE DEBUG`.

Listing 7-6. Type DEBUG's Test Unit, ops.debug.sql

```
rem debug.sql
rem by Donald J. Bales on 2014-10-20
rem A test unit for type DEBUG

declare

begin
  DEBUG.set_text('DEBUG.SQL', 'before the loop');
  for i in 1..10 loop
    DEBUG.set_text('DEBUG.SQL', 'loop '||to_char(i)||' before sleep');
    SYS.DBMS_LOCK.sleep(3);
    DEBUG.set_text('DEBUG.SQL', 'loop '||to_char(i)||' after sleep');
  end loop;
  DEBUG.set_text('DEBUG.SQL:', 'after the loop');
end;
/
```

When executed, Listing 7-6 will log debug messages to object table `DEBUGS`. But before you execute it, you may want to determine your session's unique ID so you can specify that value from a second session in order to filter the debug messages that appear as your program executes.

Listing 7-7 is a very short anonymous PL/SQL program to get your session's unique ID. Then when you want to see what's going on with the program from which you're debug logging, you can specify your first session's unique session ID on the SQL*Plus command line when you execute the SQL query from Listing 7-8.

Listing 7-7. An Example of How to Get Your Unique Session ID, usi.sql

```
rem usi.sql
rem by Donald J. Bales on 2014-10-20
rem Show me my unique session ID

execute pl('unique_session_id='||SYS.DBMS_SESSION.unique_session_id);
```

For example, if I execute `usi.sql` in SQL*Plus from my first session, session 1, it reports the following:

```
SQL> @usi.sql
```

```
unique_session_id= 000487240001

PL/SQL procedure successfully completed.
```

Next, I open a second session, session 2. I execute the following at the `SQL>` prompt:

```
@debug_a_session.sql 000487240001
```

Of course, I get `no rows selected` because I haven't started my test unit in session 1. So I go back to session 1 and execute the following at the `SQL>` prompt:

```
@debug.sql
```

Then I switch back to session 2 and simply type a forward slash at the `SQL>` prompt to see the PL/SQL program in session 1's progress:

```
SQL> @debug_a_session.sql 000487240001
```

```
old   4: where  unique_session_id = upper('&unique_session_id')
new   4: where  unique_session_id = upper('000487240001')

no rows selected
```

```
SQL> /
```

```
old   4: where  unique_session_id = upper('&unique_session_id')
new   4: where  unique_session_id = upper('000487240001')

        ID TEXT
---------- ----------------------------------------------------
       203 before the loop
       204 loop 1 before sleep
       205 loop 1 after sleep
       206 loop 2 before sleep
```

```
SQL> /
```

```
old   4: where  unique_session_id = upper('&unique_session_id')
new   4: where  unique_session_id = upper('000487240001')
```

```
        ID TEXT
---------- ----------------------------------------------------
       203 before the loop
       204 loop 1 before sleep
       205 loop 1 after sleep
       206 loop 2 before sleep
       207 loop 2 after sleep
       208 loop 3 before sleep
       209 loop 3 after sleep
       210 loop 4 before sleep
       211 loop 4 after sleep
       212 loop 5 before sleep
       213 loop 5 after sleep
       214 loop 6 before sleep

12 rows selected.
```

```
SQL> /
```

```
old   4: where  unique_session_id = upper('&unique_session_id')
new   4: where  unique_session_id = upper('000487240001')

        ID TEXT
---------- ----------------------------------------------------
       203 before the loop
       204 loop 1 before sleep
       205 loop 1 after sleep
       206 loop 2 before sleep
       207 loop 2 after sleep
       208 loop 3 before sleep
       209 loop 3 after sleep
       210 loop 4 before sleep
       211 loop 4 after sleep
       212 loop 5 before sleep
       213 loop 5 after sleep
       214 loop 6 before sleep
       215 loop 6 after sleep
       216 loop 7 before sleep
       217 loop 7 after sleep
       218 loop 8 before sleep
       219 loop 8 after sleep
       220 loop 9 before sleep
       221 loop 9 after sleep
       222 loop 10 before sleep
       223 loop 10 after sleep
       224 after the loop

22 rows selected.
```

As you can see from the preceding output, I reexecuted the SQL `SELECT` statement three times (using the forward slash, `/`) during the 33 seconds it took to run the test unit, and I got more debug information as the program unit executed.

If you examine Listing 7-8, which I used to query the table DEBUGS, you can see that I am limiting the information to a specified unique session ID and for the last ten minutes (the expression (10/(24*60)) means ten minutes).

Listing 7-8. An Example of How to Check on Progress in Real Time, ops.debug_a_session.sql

```
rem debug_a_sesion.sql
rem by Donald J. Bales on 2014-10-20
rem Query DEBUGS using the specified unique session ID

define unique_session_id=&1;

select id,
       text
from   DEBUGS
where  unique_session_id = upper('&unique_session_id')
and    insert_date       > SYSDATE - (10/(24*60))
order by id;
```

A debug table can be very handy. It gives you the kind of information you get from put_line(), but as it happens. Now you can just add the following command to your code as needed:

```
DEBUG.set_text(<aiv_program_unit>, <aiv_text>);
```

However, you'll need to wrap set_text() in an IF statement if you want to turn it on or off as needed. I have a better solution. How about a debug package?

A DEBUGGER Package

I'm going to create a DEBUGGER package in order to extend the table DEBUGS and its underlying TYPE DEBUG's functionality. I have two methods that I wasn't able to add to TYPE DEBUG because there's no way to maintain temporary state in a TYPE's BODY. That's not the case for a package, so I'm going to create a "role" package DEBUGGER for table DEBUGS, which will implement methods disable(), enable(), and a conditional set_text().

Method enable() will add a specified program unit to a list of program units for which to log debug information to table DEBUGS. If a program calls DEBUGGER.enable(), passing its name, then any calls to DEBUGGER.set_text() will be logged to table DEBUGS. If a program doesn't enable debug logging, nothing will happen when it calls DEBUGGER.set_text(). Conversely, method DEBUGGER.disable() will remove a specified program unit from the "debug logging enabled" list. Listing 7-9 is the package specification, and Listing 7-10 is its corresponding package body.

Listing 7-9. A Role Package Specification for Object Table DEBUGS, ops.debugger.pks

```
create or replace package DEBUGGER as
/*
debugger.pks
by Donald J. Bales on 2014-10-20
Object Table DEBUGS's package
*/

```

```
-- Disable debug logging for the specified program unit
PROCEDURE disable(
aiv_program_unit               in     varchar2);

-- Enable debug logging for the specified program unit
PROCEDURE enable(
aiv_program_unit               in     varchar2);

-- Conditionally log the debug information for the specified
-- program unit, if it is enabled
PROCEDURE set_text(
aiv_program_unit               in     varchar2,
aiv_text                       in     DEBUGS.text%TYPE);


end DEBUGGER;
/
@se.sql DEBUGGER;
```

Listing 7-10. A Role Package Body for Object Table DEBUGS, ops.debugger.pkb

```
create or replace package body DEBUGGER as
/*
debugger.pkb
by Donald J. Bales on 2014-10-20
Object Table DEBUGS' package
*/

-- Declare a table type and then table to hold the
-- enabled program units
TYPE program_unit_table is table of varchar2(1)
index by varchar2(30);

t_program_unit                        program_unit_table;


PROCEDURE disable(
aiv_program_unit               in     varchar2) is

v_program_unit                        varchar2(30);

begin
  v_program_unit := upper(aiv_program_unit);

  if t_program_unit.exists(v_program_unit) then
    t_program_unit.delete(v_program_unit);
  end if;
end disable;


PROCEDURE enable(
aiv_program_unit               in     varchar2) is

```

```
33 v_program_unit                        varchar2(30);
34
35 begin
36   v_program_unit := upper(aiv_program_unit);
37
38   if not t_program_unit.exists(v_program_unit) then
39     t_program_unit(v_program_unit) := NULL;
40   end if;
41 end enable;
42
43
44 PROCEDURE set_text(
45 aiv_program_unit               in     varchar2,
46 aiv_text                       in     DEBUGS.text%TYPE) is
47
48 v_program_unit                        varchar2(30);
49
50 begin
51   v_program_unit := upper(aiv_program_unit);
52
53   if t_program_unit.exists(v_program_unit) then
54     DEBUG.set_text(v_program_unit, aiv_text);
55   end if;
56 end set_text;
57
58
59 end DEBUGGER;
60 /
61 @be.sql DEBUGGER;
```

Let's take a detailed look at Listing 7-10:

- Lines 10 and 11 declare a PL/SQL table TYPE indexed by a `varchar2`. You can't do this with older versions of Oracle, but you can now. I'm taking advantage of that fact, so PL/SQL can do the work instead of me writing a lot more code.
- Line 13 declares an "enabled program unit list" table, which will temporarily hold a list of program units for which to log debug information to table DEBUGS.
- Lines 16 through 27 implement method `disable()`. This method looks to see if an entry exists in the "enabled program unit" PL/SQL table for the specified program unit. If it does exist, it deletes the PL/SQL table entry, effectively disabling debug logging for the specified program unit.
- Lines 30 through 41 implement the `enable()` method. This method looks to see if an entry exists in the "enabled program unit" PL/SQL table for the specified program unit. If it does not exist, the method adds an entry to the PL/SQL table, effectively enabling debug logging for the specified program unit.
- Lines 44 through 56 implement the `set_text()` method. This method simply calls the autonomous procedure `set_text()` in the underlying TYPE DEBUG if the program unit in question is enabled.

"Big deal—so what?" you say. The implications are staggering. You can add `DEBUGGER.set_text()` calls to your long-running or complicated PL/SQL programs and leave them there to be enabled as needed when trouble rears its ugly head!

Listing 7-11 is a test unit for package DEBUG_OTS that turns debug logging on then off, repeating the same test twice.

Listing 7-11. A Test Unit for Package DEBUGGER, ops.debugger.sql

```
rem debugger.sql
rem by Donald J. Bales on 2014-10-20
rem A test unit for package DEBUGGER

declare

begin
  -- Enable debug output
  DEBUGGER.enable('DEBUGGER.SQL');
  -- Test
  DEBUGGER.set_text('DEBUGGER.SQL', 'before the loop ');
  for i in 1..10 loop
    DEBUGGER.set_text('DEBUGGER.SQL', 'loop '||to_char(i)||' before sleep');
    SYS.DBMS_LOCK.sleep(3);
    DEBUGGER.set_text('DEBUGGER.SQL', 'loop '||to_char(i)||' after sleep');
  end loop;
  DEBUGGER.set_text('DEBUGGER.SQL', 'after the loop ');

  -- Disable debug output
  DEBUGGER.disable('DEBUGGER.SQL');
  -- Test
  DEBUGGER.set_text('DEBUGGER.SQL', 'before the loop ');
  for i in 1..10 loop
    DEBUGGER.set_text('DEBUGGER.SQL', 'loop '||to_char(i)||' before sleep');
    -- SYS.DBMS_LOCK.sleep(3);
    DEBUGGER.set_text('DEBUGGER.SQL', 'loop '||to_char(i)||' after sleep');
  end loop;
  DEBUGGER.set_text('DEBUGGER.SQL', 'after the loop ');
end;
/
```

Given that you have your unique session ID and start `debugger.sql` in session 1, and then switch to session 2 and query table DEBUGS with `debug_a_session.sql`, you'll see output like this:

```
SQL> @debug_a_session.sql 000487240001
```

```
old   4: where  unique_session_id = upper('&unique_session_id')
new   4: where  unique_session_id = upper('000487240001')

        ID TEXT
---------- ----------------------------------------------------
       225 before the loop
       226 loop 1 before sleep
       227 loop 1 after sleep
       228 loop 2 before sleep

4 rows selected.
```

```
SQL> /
```

```
old   4: where  unique_session_id = upper('&unique_session_id')
new   4: where  unique_session_id = upper('000487240001')

        ID TEXT
---------- ---------------------------------------------------
       225 before the loop
       226 loop 1 before sleep
       227 loop 1 after sleep
       228 loop 2 before sleep
       229 loop 2 after sleep
       230 loop 3 before sleep
       231 loop 3 after sleep
       232 loop 4 before sleep
       233 loop 4 after sleep
       234 loop 5 before sleep
       235 loop 5 after sleep
       236 loop 6 before sleep
       237 loop 6 after sleep
       238 loop 7 before sleep
       239 loop 7 after sleep
       240 loop 8 before sleep
       241 loop 8 after sleep
       242 loop 9 before sleep
       243 loop 9 after sleep
       244 loop 10 before sleep
       245 loop 10 after sleep
       246 after the loop

22 rows selected.
```

In the preceding output, you see the first half of the test unit where the program unit was enabled, but not the second half of the program unit where it was disabled. This means you can turn debug logging on and off programmatically as needed. That's a powerful troubleshooting tool!

Now that you've seen me do the object-relational version, it's your turn to do the relational version.

It's Your Turn to Use Debug Logging

Your assignment is to create a relational debug table and table package that incorporate the same functionality as the object-relational example I just showed you. Yes, you should also include the test unit. Follow these steps.

1. Write a DDL script to create a relational table called `DEBUGS` with the same columns as the attributes found in `TYPE DEBUG`.
2. Save your script as rps.`debugs.tab`.
3. Create your table `DEBUGS` by executing script `@rps.debugs.tab`.
4. Write a DDL script to create a table package specification for `DEBUG`. You should have three methods: `disable()`, `enable()`, and `set_text()`.

5. Save your script as rps.debug.pks.

6. Create your package specification by executing script @rps.debug.pks.

7. Write a DDL script to create a table package body for DEBUG. Remember to use the pragma autonomous_transaction; in set_text()!

8. Save your script as rps.debug.pkb.

9. Create your package body by executing script @rps.debug.pkb.

10. Write a test unit for package DEBUG, saving your script as rps.debug.sql.

11. Open two SQL*Plus sessions. Get the unique session ID from the first session by executing script usi.sql. Then start your test unit in the first session by executing script @rps.debug.sql.

12. Quickly switch to session 2, and then execute a SELECT statement against table DEBUGS so you can see the output of your test unit as it executes.

Listings 7-12 through 7-15 are my solution to this exercise. Listing 7-12 is a script to create a relational table for debug logging output.

Listing 7-12. A DDL Script to Create Table DEBUGS, rps.debugs.tab

```
rem debugs.tab
rem by Donald Bales on 2014-10-20
rem Create debugging message table

--drop   table DEBUGS;
create table DEBUGS (
id                             number                         not null,
text                           varchar2(256),
unique_session_id              varchar2(24)                   not null,
insert_user                    varchar2(30)  default USER     not null,
insert_date                    date          default SYSDATE  not null );

alter  table DEBUGS add
constraint   DEBUGS_PK
primary key (
id )
using index;

--drop   sequence DEBUGS_ID;
create sequence DEBUGS_ID
start with 1 order;

execute SYS.DBMS_STATS.gather_table_stats(USER, 'DEBUGS');

grant all on DEBUGS to PUBLIC;
```

Listing 7-13 is the specification for the table package for table DEBUG. I've declared three methods: disable(), enable(), and conditional set_text().

Listing 7-13. A DDL Script to Create Table Package Spec DEBUG, rps.debug.pks

```
create or replace package DEBUG as
/*
debug.pks
by Donald J. Bales on 2014-10-20
Table DEBUGS's package
*/

n_id                                 number := 0;

-- Get the next primary key value for the table
FUNCTION get_id
return                               DEBUGS.id%TYPE;

-- Enable debug output for the specified program unit
PROCEDURE enable(
aiv_program_unit               in     varchar2);

-- Disable debug output for the specified program unit
PROCEDURE disable(
aiv_program_unit               in     varchar2);

-- Log debug output if enabled for the specified program unit
PROCEDURE set_text(
aiv_program_unit               in     varchar2,
aiv_text                       in     DEBUGS.text%TYPE);


end DEBUG;
/
@se.sql DEBUG
```

Listing 7-14 is the body for table package `DEBUG`. In it, I've declared a PL/SQL table `TYPE` and PL/SQL table to hold the "enabled program units," and then implemented methods `disable()`, `enable()`, and `set_text()`.

Listing 7-14. A DDL Script to Create Table Package Body DEBUG, rps.debug.pkb

```
create or replace package body DEBUG as
/*
debug.pkb
by Donald J. Bales on 2014-10-20
Table DEBUGS's package
*/

-- A table to hold the list of program units for which
-- to store debug information
TYPE program_unit_table is table of varchar2(1)
index by varchar2(30);

```

```
t_program_unit                        program_unit_table;


FUNCTION get_id
return                                DEBUGS.id%TYPE is

n_id                                  DEBUGS.id%TYPE;

begin
  select DEBUGS_ID.nextval
  into   n_id
  from   SYS.DUAL;

  return n_id;
end get_id;


PROCEDURE disable(
aiv_program_unit               in     varchar2) is

v_program_unit                        varchar2(30);

begin
  v_program_unit := upper(aiv_program_unit);

  if t_program_unit.exists(v_program_unit) then
    t_program_unit.delete(v_program_unit);
  end if;
end disable;


PROCEDURE enable(
aiv_program_unit               in     varchar2) is

v_program_unit                        varchar2(30);

begin
  v_program_unit := upper(aiv_program_unit);

  if not t_program_unit.exists(v_program_unit) then
    t_program_unit(v_program_unit) := NULL;
  end if;
end enable;


PROCEDURE set_text(
aiv_program_unit               in     varchar2,
aiv_text                       in     DEBUGS.text%TYPE) is

pragma autonomous_transaction;

```

```
v_program_unit                        varchar2(30);

begin
  v_program_unit := upper(aiv_program_unit);

  if t_program_unit.exists(v_program_unit) then
    insert into DEBUGS (
           id,
           text,
           unique_session_id )
    values (
           DEBUG.get_id(),
           substrb(v_program_unit||': '||aiv_text, 1, 256),
           SYS.DBMS_SESSION.unique_session_id);
  end if;
  commit;
end set_text;


end DEBUG;
/
@be.sql DEBUG
```

In Listing 7-14, method `set_text()` logs information to table DEBUGS only if the specified program unit is "enabled." Listing 7-15 is a test unit for table package DEBUG.

Listing 7-15. An Anonymous PL/SQL Script to Test Table Package DEBUG, rps.debug.sql

```
rem debug.sql
rem by Donald J. Bales on 2014-10-20
rem Test unit for package DEBUG

declare

v_program_unit                        varchar2(30) :=
  'debug.sql';

begin
  DEBUG.enable(v_program_unit);
  DEBUG.set_text(v_program_unit, 'before the loop ');
  for i in 1..1000 loop
    DEBUG.set_text(v_program_unit, 'loop '||to_char(i)||' before sleep');
    SYS.DBMS_LOCK.sleep(3);
    DEBUG.set_text(v_program_unit, 'loop '||to_char(i)||' after sleep');
  end loop;
  DEBUG.set_text(v_program_unit, 'after the loop ');
  DEBUG.disable(v_program_unit);
  DEBUG.set_text(v_program_unit, 'before the loop ');
  for i in 1..1000 loop
```

```
      DEBUG.set_text(v_program_unit, 'loop '||to_char(i)||' before sleep');
      -- SYS.DBMS_LOCK.sleep(3);
      DEBUG.set_text(v_program_unit, 'loop '||to_char(i)||' after sleep');
    end loop;
    DEBUG.set_text(v_program_unit, 'after the loop ');
  end;
  /
```

The following is the output from a query against the debug table DEBUGS:

```
SQL> select * from debugs;
```

```
        ID TEXT
---------- -------------------------------------------------
       313 debug.sql: before the loop
       314 debug.sql: loop 1 before sleep
       315 debug.sql: loop 1 after sleep
       316 debug.sql: loop 2 before sleep
```

```
SQL> /
```

```
        ID TEXT
---------- -------------------------------------------------
       313 debug.sql: before the loop
       314 debug.sql: loop 1 before sleep
       315 debug.sql: loop 1 after sleep
       316 debug.sql: loop 2 before sleep
```

```
SQL> /
```

```
        ID TEXT
---------- -------------------------------------------------
       313 debug.sql: before the loop
       314 debug.sql: loop 1 before sleep
       315 debug.sql: loop 1 after sleep
       316 debug.sql: loop 2 before sleep
       317 debug.sql: loop 2 after sleep
       318 debug.sql: loop 3 before sleep
       319 debug.sql: loop 3 after sleep
       320 debug.sql: loop 4 before sleep
       321 debug.sql: loop 4 after sleep
       322 debug.sql: loop 5 before sleep
       323 debug.sql: loop 5 after sleep
       324 debug.sql: loop 6 before sleep

12 rows selected.
```

```
SQL> /

        ID TEXT
---------- ------------------------------------------------
       313 debug.sql: before the loop
       314 debug.sql: loop 1 before sleep
       315 debug.sql: loop 1 after sleep
       316 debug.sql: loop 2 before sleep
       317 debug.sql: loop 2 after sleep
       318 debug.sql: loop 3 before sleep
       319 debug.sql: loop 3 after sleep
       320 debug.sql: loop 4 before sleep
       321 debug.sql: loop 4 after sleep
       322 debug.sql: loop 5 before sleep
       323 debug.sql: loop 5 after sleep
       324 debug.sql: loop 6 before sleep
       325 debug.sql: loop 6 after sleep
       326 debug.sql: loop 7 before sleep
       327 debug.sql: loop 7 after sleep
       328 debug.sql: loop 8 before sleep
       329 debug.sql: loop 8 after sleep
       330 debug.sql: loop 9 before sleep
       331 debug.sql: loop 9 after sleep
       332 debug.sql: loop 10 before sleep
       333 debug.sql: loop 10 after sleep
       334 debug.sql: after the loop

22 rows selected.
```

As you can see from this output, you are able to view the progress of the test unit as it executes. Armed with this troubleshooting tool, you can monitor your long-running or short-running data processing or data migration programs.

In practice, I've even found this technique useful in some table package or TYPE methods that are called by the presentation layer. One example is when I worked with a table package that built SQL statements dynamically using information from the database, and then passed them back to the presentation layer. If a user got an error, I could see what SQL was passed back to his web page by looking in the debug table in the database. It didn't take long for me to figure out that I had some data-entry errors in the tables used to build the dynamic queries, but it would have been next to impossible to identify the problem in the presentation layer.

As an alternative to debug logging, you may decide to use package SYS.DBMS_TRACE to trace the execution of a session to a file that you can later examine, line by line, or using a utility like TKPROF. However, I've found that DBMS_TRACE creates too much information to be useful. With it, you have limited control of the volume of information collected. In contrast, with a debug logging utility, you determine what information is logged and when.

Another alternative package you may want to investigate is SYS.DBMS_ERRLOG. With this package, you can write debug information to a table anytime an exception occurs in your PL/SQL program unit. I still find the use of my "homegrown" debug logging to be more useful.

Debug logging is a good tool, but in some situations, a real debugging tool is more appropriate. Let's look at Oracle's debugger next.

One Step at a Time

After what seemed an eternity, PL/SQL programmers now have a real, honest-to-goodness debugger. What's a debugger? It allows you to step through your PL/SQL code as it executes, one step at a time, line by line, inspecting the value of variables, and seeing how your program executes your logic. It's a remote debugger—remote in the fact that your PL/SQL program unit must be stored in the database, and it must be executable. By "executable," I mean it must be a stored function, procedure, or packaged function or procedure.

So how did this revolution come about? It started with a PL/SQL package called `SYS.DBMS_DEBUG`. Oracle database PL/SQL package `DBMS_DEBUG` provides communication hooks into the PL/SQL debugger layer in the database. Using this package, you can build your own remote debugger, but it's much easier to use Oracle SQL Developer.

Debugging with Oracle SQL Developer

Oracle SQL Developer is an SQL and PL/SQL development tool for the Oracle database. You can download a free copy from the Oracle Technology Network site, `http://otn.oracle.com`.

I'm not going to give you a lesson on how to use Oracle SQL Developer here, because that would be a book in itself, but I will show you some highlights to debugging with it.

Your first step in using a remote debugger with Oracle is to grant debugging rights to the username for which you intend to debug a stored program unit. That's done by the system administrator or DBA using the following syntax:

```
grant debug connect session to <username>;
grant debug any procedure to <username>;
```

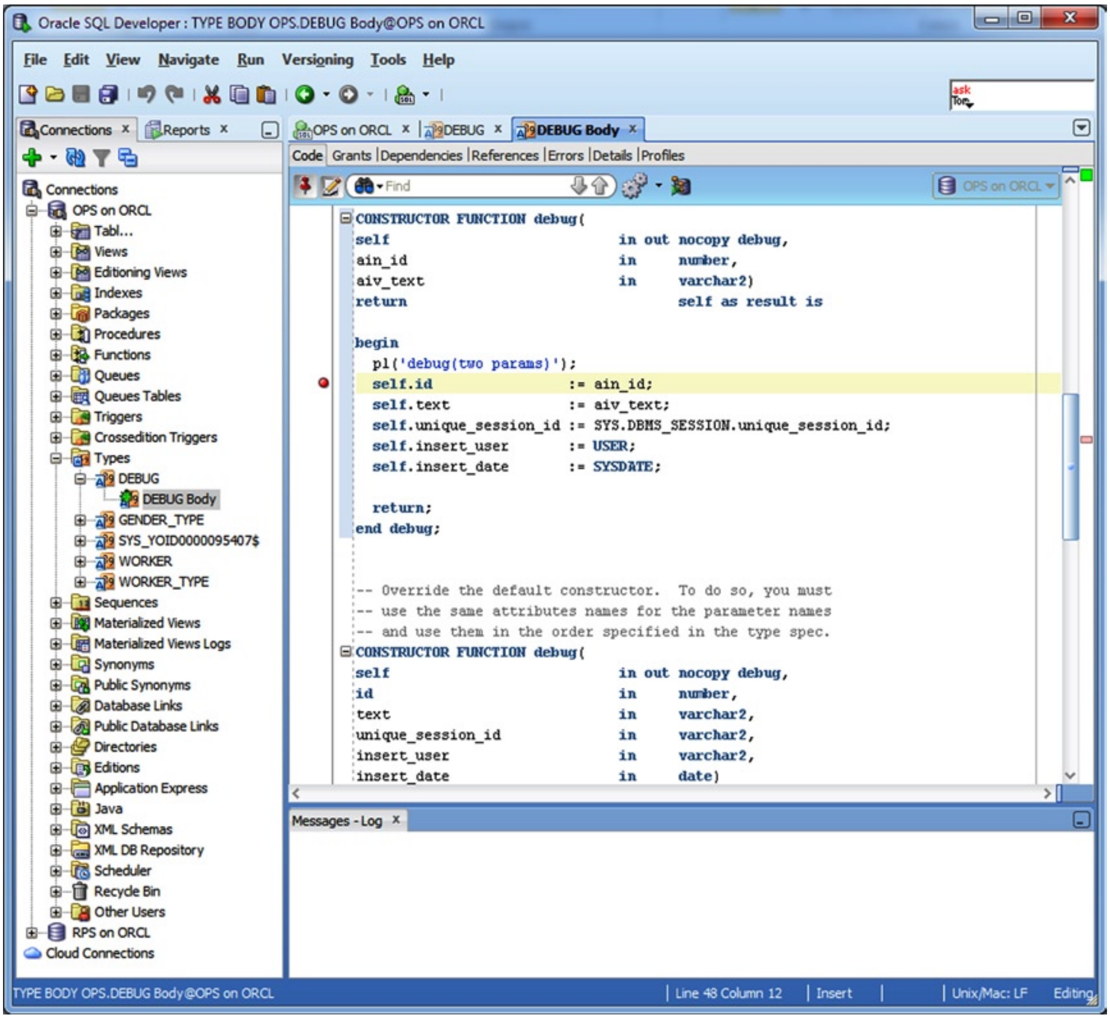
where `<username>` is the name of the user for which to grant the debug privileges.

Your next step is to recompile the stored program units in question with the `DEBUG` option, using the appropriate syntax for the object type from the following list:

```
alter function  <name> compile debug;
alter package   <name> compile debug package;
alter package   <name> compile debug specification;
alter package   <name> compile debug body;
alter procedure <name> compile debug;
alter trigger   <name> compile debug;
alter type      <name> compile debug specification;
alter type      <name> compile debug body;
```

Alternatively, you can recompile the code from Oracle SQL Developer! Let me show you an example of debugging (of all things) the `DEBUG TYPE` and the `DEBUGGER` package. In this example, I've already started Oracle SQL Developer and logged in to database ORCL, where, incidentally, I have already granted debug connect session and debug any procedure rights to the username.

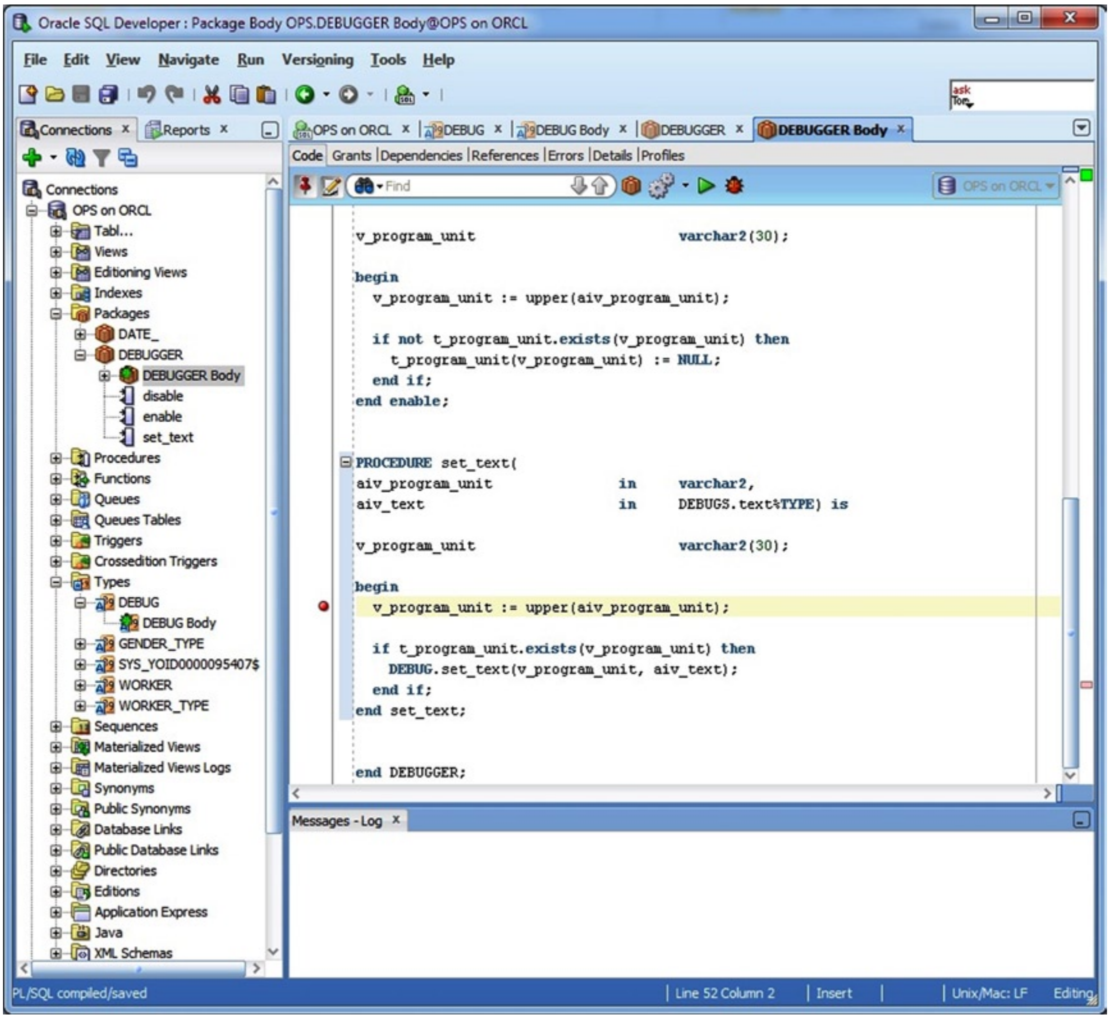
In Figure 7-1, I used the tree view on the left side of the screen to drill down and select the `BODY` for `TYPE DEBUG`. From there, I right-clicked and chose Edit. That action displayed the tab DEBUG Body, where I subsequently added a breakpoint to the constructor.



```
CONSTRUCTOR FUNCTION debug(
self                          in out nocopy debug,
ain_id                        in     number,
aiv_text                      in     varchar2)
return                               self as result is

begin
  pl('debug(two params)');
  self.id                := ain_id;
  self.text              := aiv_text;
  self.unique_session_id := SYS.DBMS_SESSION.unique_session_id;
  self.insert_user       := USER;
  self.insert_date       := SYSDATE;

  return;
end debug;


-- Override the default constructor.  To do so, you must
-- use the same attributes names for the parameter names
-- and use them in the order specified in the type spec.
CONSTRUCTOR FUNCTION debug(
self                          in out nocopy debug,
id                            in     number,
text                          in     varchar2,
unique_session_id             in     varchar2,
insert_user                   in     varchar2,
insert_date                   in     date)
```

Figure 7-1. *Setting a breakpoint in TYPE DEBUG's constructor*

In Figure 7-2, I used the tree view to find the package body for DEBUGGER. Next, I right-clicked and selected Edit. That action displayed the tab DEBUGGER Body, where I added a breakpoint for procedure `set_text()`. Then I clicked the icon to recompile the item with debug.

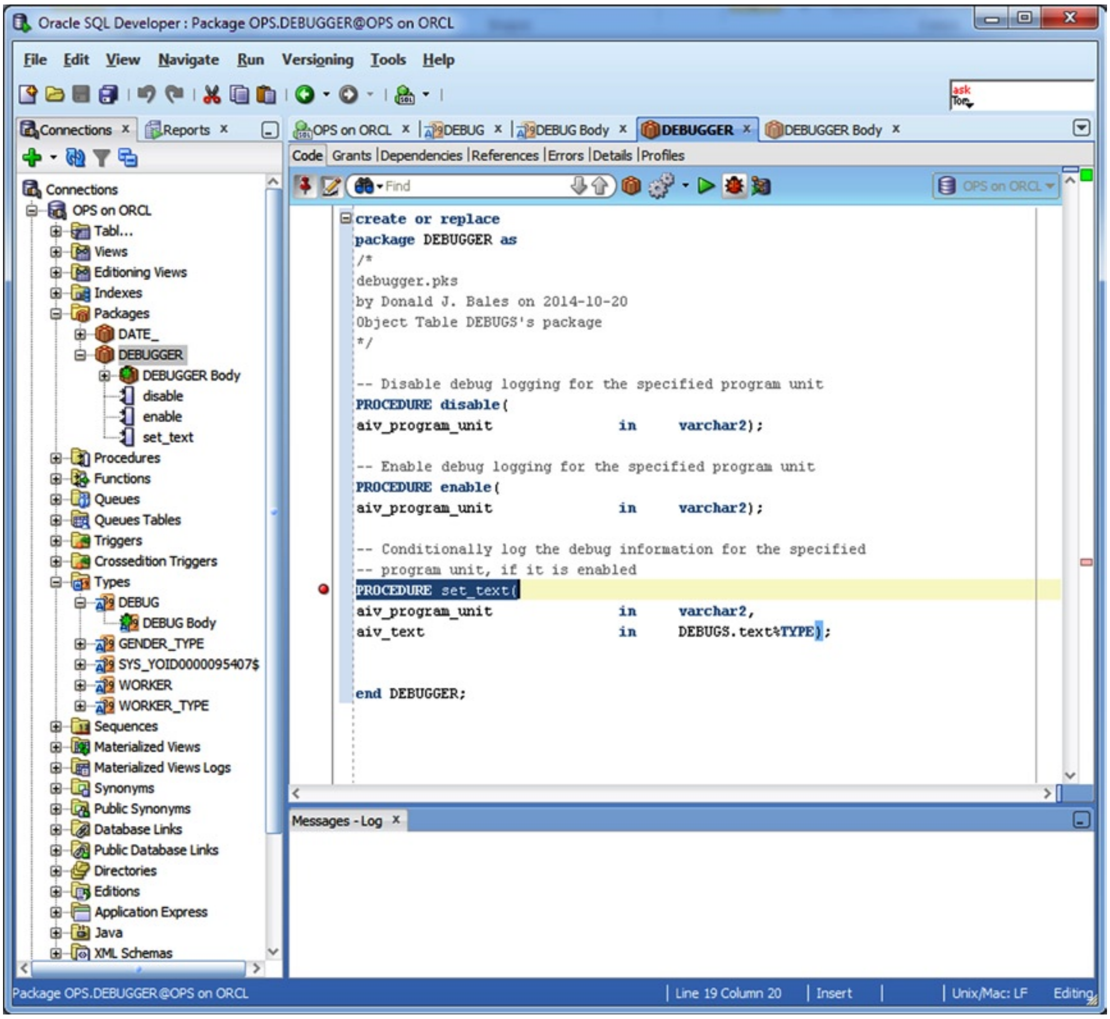


```
v_program_unit                    varchar2(30);

begin
  v_program_unit := upper(aiv_program_unit);

  if not t_program_unit.exists(v_program_unit) then
    t_program_unit(v_program_unit) := NULL;
  end if;
end enable;


PROCEDURE set_text(
aiv_program_unit              in      varchar2,
aiv_text                      in      DEBUGS.text%TYPE) is

v_program_unit                    varchar2(30);

begin
  v_program_unit := upper(aiv_program_unit);

  if t_program_unit.exists(v_program_unit) then
    DEBUG.set_text(v_program_unit, aiv_text);
  end if;
end set_text;


end DEBUGGER;
```

Figure 7-2. *Setting a breakpoint in package body method DEBUGGER.set_text( )*

At this point, I've set two breakpoints: one in TYPE DEBUG's constructor and a second in package body DEBUGGER's `set_text()` method. Now when I execute a program unit that calls either DEBUG's constructor or DEBUGGER`.set_text()`, the debugger will stop execution so I can inspect variable values or single-step through each line of code.

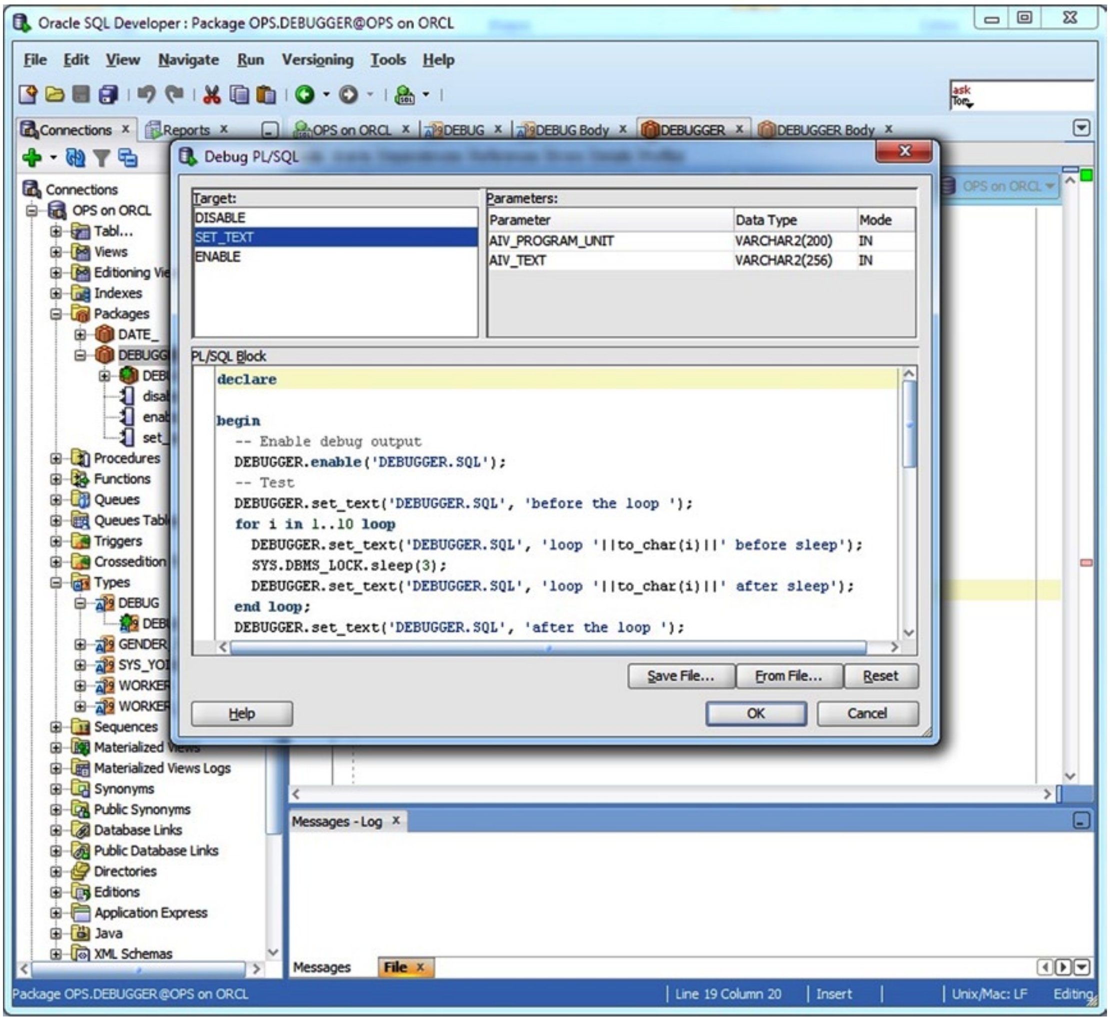
My next task is to select an executable target and then debug it. That's what I did in Figure 7-3. Once again, I used the tree view to select the package specification for DEBUGGER. Then I right-clicked and selected Edit. That action displayed the tab DEBUGGER. From there, I clicked the debug icon. Since I'm in a package specification, the target is runnable, so Oracle SQL Developer prompts me for an anonymous procedure that I can use to execute the target.



```
create or replace
package DEBUGGER as
/*
debugger.pks
by Donald J. Bales on 2014-10-20
Object Table DEBUGS's package
*/

-- Disable debug logging for the specified program unit
PROCEDURE disable(
aiv_program_unit                in      varchar2);

-- Enable debug logging for the specified program unit
PROCEDURE enable(
aiv_program_unit                in      varchar2);

-- Conditionally log the debug information for the specified
-- program unit, if it is enabled
PROCEDURE set_text(
aiv_program_unit                in      varchar2,
aiv_text                        in      DEBUGS.text%TYPE);


end DEBUGGER;
```

Figure 7-3. *Editing the package specification for DEBUGGER in order to debug it*

When I clicked the debug icon in Figure 7-3, the Debug PL/SQL dialog box appeared, as shown in Figure 7-4. Here, I selected the target method to debug—in this case, `set_text`. Next, I needed to modify the anonymous PL/SQL procedure stub presented by Oracle SQL Developer or select one from the file system by clicking the From File button. Since I already had a test unit script written, `ops.debug.sql`, I selected it from the file system, deleted the remark lines and the trailing compile slash, and then clicked the OK button to start the procedure, thus starting the debugging session.



Target:

DISABLE
SET_TEXT
ENABLE

Parameters:

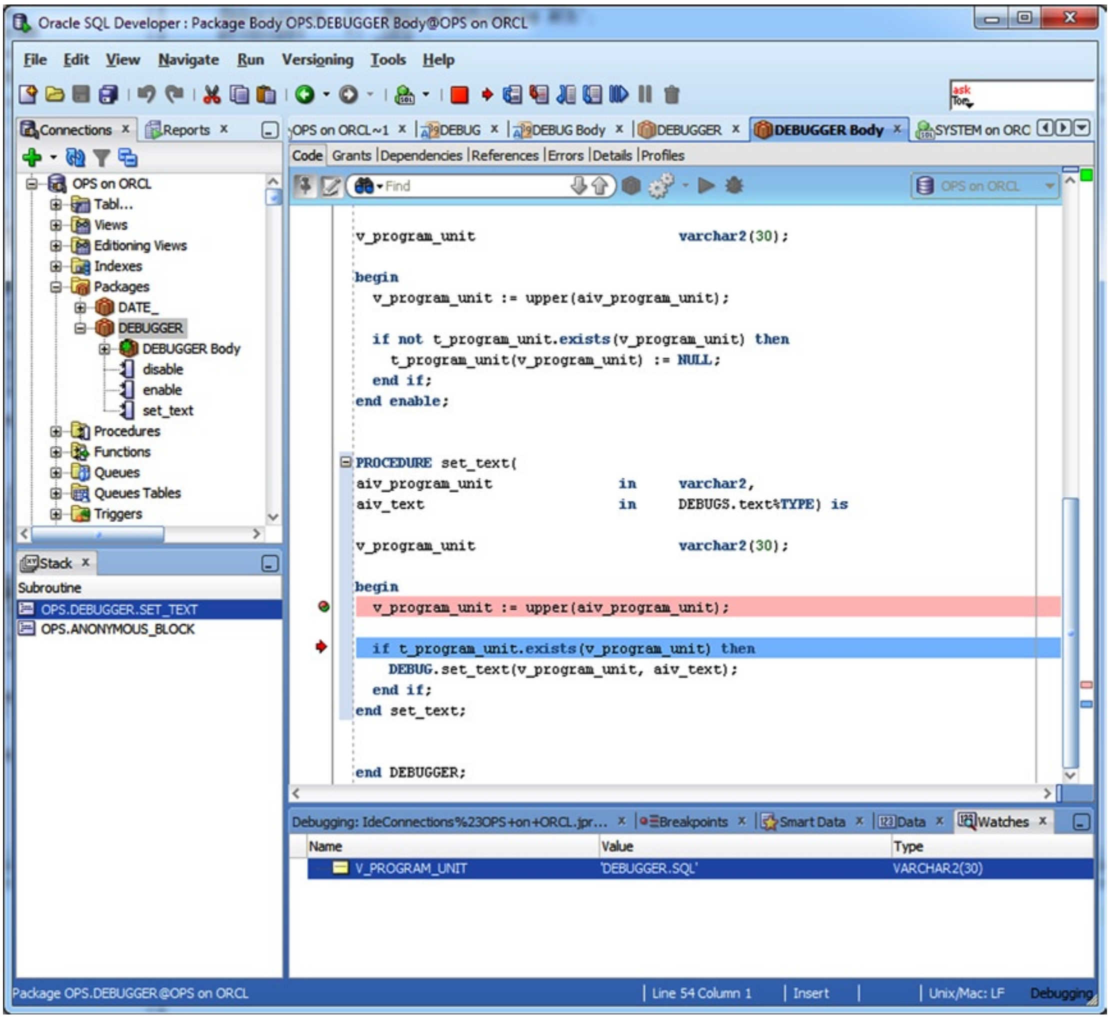
Parameter	Data Type	Mode
AIV_PROGRAM_UNIT	VARCHAR2(200)	IN
AIV_TEXT	VARCHAR2(256)	IN

PL/SQL Block

```
declare

begin
  -- Enable debug output
  DEBUGGER.enable('DEBUGGER.SQL');
  -- Test
  DEBUGGER.set_text('DEBUGGER.SQL', 'before the loop ');
  for i in 1..10 loop
    DEBUGGER.set_text('DEBUGGER.SQL', 'loop '||to_char(i)||' before sleep');
    SYS.DBMS_LOCK.sleep(3);
    DEBUGGER.set_text('DEBUGGER.SQL', 'loop '||to_char(i)||' after sleep');
  end loop;
  DEBUGGER.set_text('DEBUGGER.SQL', 'after the loop ');
```

Figure 7-4. *Specifying the anonymous PL/SQL script to execute the runnable target*

In Figure 7-5, the debugger stopped the execution of the program when it encountered the breakpoint set on method `set_text()`. From there, I clicked the Step Into icon in order to execute the code line by line. In the lower-right corner of the screen, you can see the value of variable `v_program_unit` because I set up a watch on that variable.



```
v_program_unit                    varchar2(30);

begin
  v_program_unit := upper(aiv_program_unit);

  if not t_program_unit.exists(v_program_unit) then
    t_program_unit(v_program_unit) := NULL;
  end if;
end enable;


PROCEDURE set_text(
aiv_program_unit            in     varchar2,
aiv_text                    in     DEBUGS.text%TYPE) is

v_program_unit                     varchar2(30);

begin
  v_program_unit := upper(aiv_program_unit);

  if t_program_unit.exists(v_program_unit) then
    DEBUG.set_text(v_program_unit, aiv_text);
  end if;
end set_text;


end DEBUGGER;
```

Subroutine
OPS.DEBUGGER.SET_TEXT
OPS.ANONYMOUS_BLOCK

Name	Value	Type
V_PROGRAM_UNIT	'DEBUGGER.SQL'	VARCHAR2(30)

```
Package OPS.DEBUGGER@OPS on ORCL    | Line 54 Column 1 | Insert |    | Unix/Mac: LF    Debugging
```

Figure 7-5. *Stepping into code after a breakpoint has been encountered*

As you can see from this short example, you have total access to both the values of variables and how program logic is being executed when you're in a debugger. This is the ultimate troubleshooting tool. Or is it?

For a simple troubleshooting task, you are probably better off using `put_line()`. For a long-running program unit, you're probably better off using debug logging. Then once you've narrowed down the problem, if you haven't already solved it, you may want to use a debugger. Why?

Using a debugger requires a great deal of setup, arranging access to the username of the stored program unit, grants for debugging, and the creation of an access control list. And it can take a lot of time to use for the simple fact that stepping through a program line by line can be extremely time-consuming. It's up to you to use the appropriate tool at the appropriate time.

Debugging Anonymous PL/SQL

So far, I've been talking only about debugging stored program units. What about anonymous PL/SQL procedures? Sorry, you cannot debug anonymous PL/SQL program units. And that should not be a big deal. If you have an anonymous PL/SQL program that's so big that it needs debugging, it probably needs to be permanently stored in the database. Once you store it in the database, you can use Oracle SQL Developer to debug it.

Debugging with TOAD for Oracle

TOAD for Oracle is a very popular SQL and PL/SQL development tool by Quest Software. There's a freeware version available for download from Dell (formerly Quest Software) at `http://software.dell.com/products/toad-for-oracle/`. However, the free version does not include debugging capability. To get a copy of TOAD with a debugger, you must download the trial version. The TOAD debugger has almost the same set of debugging features as Oracle SQL Developer, but I prefer Oracle SQL Developer.

Debugging with Visual Studio

Oracle has a plug-in module that allows you to use the remote debugger from Microsoft's Visual Studio. Once again, you can download this plug-in from Oracle's Technology Network web site at `http://otn.oracle.com`.

It's Your Turn to Use a Debugger

I know I haven't taken the time to show you how to use the PL/SQL debugger; I've only walked through an example. As a professional, it will be invaluable for you to know how to use the PL/SQL debugger. So, follow these somewhat loosely defined steps to install the PL/SQL debugger and get some experience using it.

1. Go to `http://otn.oracle.com` and search for "Oracle SQL Developer download." This should bring you to the Oracle SQL Developer page, where you can download a copy of the software, get its installation instructions, and access tutorials for using the product.
2. Download Oracle SQL Developer.
3. Print a copy of the tutorials "Creating a database connection" and "Loading, executing and debugging PL/SQL."
4. Install Oracle SQL Developer.
5. Run Oracle SQL Developer and create a connection to the database you're using for username RPS for working on your exercises.
6. Using the "Loading, executing and debugging PL/SQL" tutorial as your guide, find table package `DEBUG` in the tree view.
7. Edit the package body by right-clicking its name in the tree view, and then recompile it with debug.
8. Create breakpoints in `DEBUG`'s three methods: `disable()`, `enable()`, and `set_text()`.
9. Edit the package specification, and click the ladybug icon to run the debugger.

10. When the Debug PL/SQL dialog box appears, click the From File button, and then load your test unit script, `rps.debug.sql`.
11. Remove the comment lines at the top of the test unit script and the trailing compile slash at the end of the script, and then click OK to start your debug session.
12. After the first breakpoint is triggered, click the Step Into icon to walk through the code line by line.
13. Add some watches so you can see the variable's values change as the program executes.
14. Sit back and think how helpful this tool can be in your future.

At this point, you should now have three tools in your troubleshooting arsenal: `put_line()`, table package `DEBUG`, and a real live debugger! With these tools, you should be able to troubleshoot any logic problem, but what about performance?

If you have a long-running or large stored procedure, how do you know where in its code it's slow? You can get this information with runtime profiling, our next topic.

Profiling PL/SQL

Profiling in this context is about collecting runtime statistics from your PL/SQL program units in order to determine which lines of code are consuming the most resources, usually in a unit of time. Armed with these statistics, you can quickly see what part of your PL/SQL program is taking the most time to execute, so you can concentrate your efforts on improving performance on those lines of code that are poor performers.

In days of yore, you had to write your own profiling package in order to collect runtime statistics. Then you had to sprinkle your code with calls to your profiling package in order to collect the statistics. In fact, I did just that, creating a profiling package with architecture similar to the debug logging package.

Nowadays, you have access to a built-in profiling package, `SYS.DBMS_PROFILER`, which can hook itself into you session and profile your PL/SQL code line by line, without you needing to add many lines of code to your listings. Here, you'll look at the three tables where `DBMS_PROFILER` stores its collected statistics, the package's methods, and an example of its use. Then you'll finish up this section by profiling your own code.

Profiler's Tables

The profiling package `DBMS_PROFILER` stores the statistics it collects during its use in memory, until you call its `flush_data()` method, at which point it moves the statistics to three tables:

- `PLSQL_PROFILER_RUNS`: Holds information about a particular run
- `PLSQL_PROFILER_UNITS`: Holds the names of program units for a particular run
- `PLSQL_PROFILE_DATA`: Holds the profiling statistics for every line of each program unit accessed in a particular run

Your Oracle system administrator or DBA must create these tables globally using the profload.sql script, or in the schema you're logged in to using the proftab.sql script, before you try to use the profiler. In addition, you must have the same rights granted to your username as you need for debugging.

You can find detailed information about the `DBMS_PROFILER` package and these three tables in Oracle's *PL/SQL Packages and Types Reference*. Let's look at the package's methods next.

Profiler's Methods

The DBMS_PROFILER package has seven methods, of which you must use at least three to profile an application. Here are the three I am referring to:

- `start_profiler()`: Initializes and starts a profiling "run" in order to collect statistics. You can specify a description for the run so you can identify the run number after the run, or you can use an overloaded version of the method that returns the run number when you start the run.
- `stop_profile()`: Stops a previously started run.
- `flush_data()`: Stores the statistics for the current run into three tables: PLSQL_PROFILER_RUNS, PLSQL_PROFILER_UNITS, and PLSQL_PROFILER_DATA.

To start a profiling session, you need to execute procedure `start_profiler()` in your PL/SQL program unit where you want to start collecting performance statistics. To stop collecting statistics, you need to execute `stop_profile()`, usually followed by `flush_data()`, in order to permanently store the statistics in the profiler's tables.

Listing 7-16 is a SQL*Plus script that can run any anonymous PL/SQL script with profiling turned on.

Listing 7-16. A Script to Execute Another Script with Profiling, run_profile.sql

```
rem run_profile.sql
rem by Donald J. Bales on 2014-10-20
rem Capture DBMS_PROFILER information for the specified script

define script="&1";

set verify off;

declare

n_run_number                          number;

begin
  DBMS_PROFILER.start_profiler(
    '&script'||' on '||to_char(SYSDATE, 'YYYYMMDD HH24MISS'),
    ' ',
    n_run_number);

  pl('DBMS_PROFILER run_number = '||to_char(n_run_number));
end;
/

@&script

execute DBMS_PROFILER.stop_profiler;
execute DBMS_PROFILER.flush_data;

set verify on;
```

To execute the script, type the name of the script in Listing 7-16 followed by the name of the script you wish to execute after the SQL*Plus prompt, as follows:

```
SQL> @run_profile.sql <script_name>
```

For example, to profile TYPE DEBUG and role package DEBUGGER, I first log in with username OPS, create the profiler tables by executing script C:\oracle12c\product\12.1.0\dbhome_1\RDBMS\ADMIN\proftab.sql, and then execute the script run_profile.sql, passing in the name of my test unit script, ops.debugger.sql:

```
SQL> @run_profile.sql ops.debugger.sql
```

Here's the output from executing the script in SQL*Plus:

```
SQL> @run_profile ops.debugger.sql
```

```
DBMS_PROFILER run_number = 4

PL/SQL procedure successfully completed.

PL/SQL procedure successfully completed.

PL/SQL procedure successfully completed.

PL/SQL procedure successfully completed.
```

run_profile.sql displays the run number for a profile run on the screen, so you can then run a report to view the profiling data.

Profiling Reports

I find two profiling reports helpful: one to display the average percent of processing time in descending order, and another to order average time consumption by program unit and line number. The SQL*Plus script avg_profile.sql, shown in Listing 7-17, displays what percent of processing time was consumed by each program unit and line of code, in the descending order of time consumption.

Listing 7-17. A Script to Create an Average Percent Profiling Report, avg_profile.sql

```
rem avg_profile.sql
rem by Donald J. Bales on 2014-10-20
rem Create a DBMS_PROFILER report by avg desc

define runid="&1";

column avg_pct   format 990.99;
column line#     format 9999;
column occur     format 9999
column text      format a42 trunc;
column unit_name format a11;

set linesize  1000;
set newpage   1;
set pagesize  32767;
set trimspool on;
set verify    off;

spool avg_profile_&runid..txt;

select v.unit_name,
       round(v.avg_time/t.avg_time*100, 2) avg_pct,
       v.occur,
       v.line#,
       ltrim(s.text) text
from   SYS.ALL_SOURCE s,
     ( select u.runid,
              u.unit_owner,
              u.unit_type,
              u.unit_name,
              d.min_time,
              to_number(decode(d.total_occur,
                NULL, NULL,
                0,    0,
                round(d.total_time/d.total_occur))) avg_time,
              d.max_time,
              d.total_time,
              d.total_occur occur,
              d.line#
       from   PLSQL_PROFILER_UNITS u,
              PLSQL_PROFILER_DATA d
       where  u.runid       = d.runid
       and    u.unit_number = d.unit_number
       and    d.runid       = &runid ) v,
     ( select sum(to_number(decode(d.total_occur,
                NULL, NULL,
                0,    0,
                round(d.total_time/d.total_occur)))) avg_time
       from   PLSQL_PROFILER_UNITS u,
              PLSQL_PROFILER_DATA d
       where  u.runid       = d.runid
       and    u.unit_number = d.unit_number
       and    d.runid       = &runid ) t
where  v.unit_owner  = s.owner(+)
and    v.unit_type   = s.type(+)
and    v.unit_name   = s.name(+)
and    v.line#       = s.line(+)
and    v.avg_time    > 0
order by v.avg_time desc,
       v.unit_name,
       v.line#;

spool off;

set verify on;
```

The avg_profile.sql script produces a report that shows the following information:

- The program unit's name
- Its average consumption of time
- How many times the line was executed during the run
- The line number and text from the PL/SQL program unit in question

Listing 7-18 is an example of a report created by avg_profile.sql from Listing 7-17.

Listing 7-18. An Average Percent Time Consumption Report for Test Unit ops.debugger.sql

```
UNIT_NAME   AVG_PCT OCCUR LINE# TEXT
----------- ------- ----- ----- ------------------------------------------
DEBUG         39.72    22    92 insert into DEBUGS
DEBUG         15.28    22    97 commit;
<anonymous>    9.53     2     1
<anonymous>    6.57     1     5
<anonymous>    6.11    18     1
<anonymous>    5.06     1    11
<anonymous>    1.56     2     1
<anonymous>    1.28    10    11
DEBUGGER       0.97     1    36 v_program_unit := upper(aiv_program_unit);
DEBUG          0.86   132    46 pl('debug(two params)');
<anonymous>    0.83    10     9
DEBUG          0.82   132    49 self.unique_session_id := SYS.DBMS_SESSION
DEBUG          0.80   132    50 self.insert_user       := USER;
<anonymous>    0.75    10    10
PL             0.75   133    11 SYS.DBMS_OUTPUT.put_line(aiv_text);
DEBUG          0.65   132    53 return;
DEBUG          0.62    22    89 begin
DEBUG          0.59    22    90 v_text := substrb(aiv_program_unit||': '||
DEBUGGER       0.54     1    25 t_program_unit.delete(v_program_unit);
DEBUG          0.46    22    98 end set_text;
DEBUGGER       0.43     1    30 PROCEDURE enable(
DEBUGGER       0.43     1    39 t_program_unit(v_program_unit) := NULL;
DEBUGGER       0.40    22    54 DEBUG.set_text(v_program_unit, aiv_text);
DEBUG          0.34   132    39 CONSTRUCTOR FUNCTION debug(
DEBUGGER       0.32     1    22 v_program_unit := upper(aiv_program_unit);
DEBUGGER       0.32     1    38 if not t_program_unit.exists(v_program_uni
DEBUGGER       0.32    44    51 v_program_unit := upper(aiv_program_unit);
DEBUG          0.28    22    81 STATIC PROCEDURE set_text(
DEBUGGER       0.28    44    44 PROCEDURE set_text(
DEBUGGER       0.25    44    53 if t_program_unit.exists(v_program_unit) t
DEBUG          0.24   132    51 self.insert_date       := SYSDATE;
<anonymous>    0.23    10    20
<anonymous>    0.22     1    16
<anonymous>    0.22     1    18
<anonymous>    0.22     1    25
DEBUGGER       0.22     1    16 PROCEDURE disable(
DEBUGGER       0.22     1    24 if t_program_unit.exists(v_program_unit) t
DEBUG          0.20   132    54 end debug;
DEBUG           0.16   132    47 self.id                 := ain_id;
<anonymous>     0.13    10    22
<anonymous>     0.11     1     7
<anonymous>     0.11     1    12
<anonymous>     0.11     1    13
DEBUGGER        0.11     1    27 end disable;
DEBUGGER        0.11     1    41 end enable;
<anonymous>     0.09    11     8
PL              0.08   133    12 end pl;
DEBUGGER        0.05    44    56 end set_text;
DEBUG           0.05   132    48 self.text               := aiv_text;
<anonymous>     0.04    11    19

50 rows selected.
```

Looking at Listing 7-18, it's easy to see that the bulk of time consumption is taken by the INSERT statement. This is typical. The slowest portion of any PL/SQL procedure is usually one or more SQL statements. That's why it's important to always maximize the efficiency of your SQL statements. You'll learn about one of the tools you can use to do that shortly, in the section about EXPLAIN PLAN. For now, it's important for you to understand just how valuable this report is when considering how to approach performance enhancements to your PL/SQL program units. With data like this, you can significantly narrow down the lines of code for which you need to improve performance, and not waste a lot of time guessing which ones are the poor performers.

A second report I like to use orders the average time consumption by program unit and line number. The script I execute for this report is named `ord_profile.sql` (you can find the listing for this report in the downloadable source code for the book). Just as with `avg_profile.sql`, you execute the script at the SQL*Plus prompt, passing in the run number as a parameter. Here's an example:

```
SQL> @ord_profile.sql 4
```

This command produced the report example shown in Listing 7-19. This report is helpful because it shows which lines in your program were actually executed. And even more interesting, you can add up the statistics for a function or procedure call by totaling the statistics from the line where the method is defined down to the line where it ends. For example, doing this for the constructor debug in Listing 7-19, you can calculate that it consumed 38,265 nanoseconds of processing time.

Listing 7-19. An Average Time Consumption Report by Program Unit and Line Number for Test Unit ops.debugger.sql

```
UNIT_NAME     AVG_TIME OCCUR LINE# TEXT
------------- -------- ----- ----- ----------------------------------------
<anonymous>      14497     2     1
<anonymous>      56766    18     1
<anonymous>          0     0     1
<anonymous>      88482     2     1
<anonymous>          0     0     1
<anonymous>      60987     1     5
<anonymous>          0     0     6
<anonymous>        999     1     7
<anonymous>        818    11     8
<anonymous>       7698    10     9
<anonymous>       6999    10    10
```

```
<anonymous>      11898    10    11
<anonymous>      46990     1    11
<anonymous>        999     1    12
<anonymous>        999     1    13
<anonymous>       1999     1    16
<anonymous>       1999     1    18
<anonymous>        364    11    19
<anonymous>       2100    10    20
<anonymous>       1200    10    22
<anonymous>          0     1    24
<anonymous>       1999     1    25
DEBUG                0     0     9 STATIC FUNCTION get_id
DEBUG                0     0    14 begin
DEBUG                0     0    15 select DEBUGS_ID.nextval
DEBUG                0     0    19 return n_id;
DEBUG                0     0    20 end get_id;
DEBUG                0     0    23 CONSTRUCTOR FUNCTION debug(
DEBUG                0     0    27 begin
DEBUG                0     0    28 pl('debug(zero param)');
DEBUG                0     0    29 self.id                := NULL;
DEBUG                0     0    30 self.text              := NULL;
DEBUG                0     0    31 self.unique_session_id := NULL;
DEBUG                0     0    32 self.insert_user       := NULL;
DEBUG                0     0    33 self.insert_date       := NULL;
DEBUG                0     0    35 return;
DEBUG                0     0    36 end debug;
DEBUG             3174   132    39 CONSTRUCTOR FUNCTION debug(
DEBUG                0   132    45 begin
DEBUG             8029   132    46 pl('debug(two params)');
DEBUG             1469   132    47 self.id                := ain_id;
DEBUG              477   132    48 self.text              := aiv_text;
DEBUG             7604   132    49 self.unique_session_id := SYS.DBMS_SESSI
DEBUG             7445   132    50 self.insert_user       := USER;
DEBUG             2197   132    51 self.insert_date       := SYSDATE;
DEBUG             6037   132    53 return;
DEBUG             1833   132    54 end debug;
DEBUG                0     0    60 CONSTRUCTOR FUNCTION debug(
DEBUG                0     0    69 begin
DEBUG                0     0    70 pl('debug(five params)');
DEBUG                0     0    71 self.id                := id;
DEBUG                0     0    72 self.text              := text;
DEBUG                0     0    73 self.unique_session_id := unique_session
DEBUG                0     0    74 self.insert_user       := insert_user;
DEBUG                0     0    75 self.insert_date       := insert_date;
DEBUG                0     0    77 return;
DEBUG                0     0    78 end debug;
DEBUG             2636    22    81 STATIC PROCEDURE set_text(
DEBUG             5726    22    89 begin
DEBUG             5453    22    90 v_text := substrb(aiv_program_unit||': '
DEBUG           368832    22    92 insert into DEBUGS
DEBUG           141880    22    97 commit;
DEBUG             4226    22    98 end set_text;
DEBUG                0     0   101 MAP MEMBER FUNCTION to_map
DEBUG                0     0   104 begin
DEBUG                0     0   105 return id;
DEBUG                0     0   106 end to_map;
DEBUGGER             0     0     1 package body DEBUGGER as
DEBUGGER          1999     1    16 PROCEDURE disable(
DEBUGGER             0     1    21 begin
DEBUGGER          2999     1    22 v_program_unit := upper(aiv_program_unit
DEBUGGER          1999     1    24 if t_program_unit.exists(v_program_unit)
DEBUGGER          4998     1    25 t_program_unit.delete(v_program_unit);
DEBUGGER             0     1    26 end if;
DEBUGGER           999     1    27 end disable;
DEBUGGER          3999     1    30 PROCEDURE enable(
DEBUGGER             0     1    35 begin
DEBUGGER          8998     1    36 v_program_unit := upper(aiv_program_unit
DEBUGGER          2999     1    38 if not t_program_unit.exists(v_program_u
DEBUGGER          3999     1    39 t_program_unit(v_program_unit) := NULL;
DEBUGGER             0     1    40 end if;
DEBUGGER           999     1    41 end enable;
DEBUGGER          2636    44    44 PROCEDURE set_text(
DEBUGGER             0    44    50 begin
DEBUGGER          2931    44    51 v_program_unit := upper(aiv_program_unit
DEBUGGER          2363    44    53 if t_program_unit.exists(v_program_unit)
DEBUGGER          3726    22    54 DEBUG.set_text(v_program_unit, aiv_text)
DEBUGGER             0    44    55 end if;
DEBUGGER           500    44    56 end set_text;
DEBUGGER             0     0    59 end DEBUGGER;
PL                   0     0     1 PROCEDURE pl(
PL                6953   133    11 SYS.DBMS_OUTPUT.put_line(aiv_text);
PL                 729   133    12 end pl;

93 rows selected.
```

Utilizing the statistics provided by DBMS_PROFILER, you can easily determine any bottlenecks in your PL/SQL programs and approach performance tuning in an efficient manner. DBMS_PROFILER data can also be used to detect defects in your code, in a fashion similar to debug logging.

Did you notice that, in both reports, the constructor for DEBUG was called 132 times, yet the INSERT statement was executed only 22 times? That means that SQL executed the constructor six times during each insert, clearly a defect in the SQL layer of the database, and subsequently a performance problem.

Now that I've profiled the object-relational version of the debug logger, it's your turn to profile the relational version.

It's Your Turn to Profile

The value of profiling code grows with the number of lines of code you're profiling. Still, you'll start out small by using DBMS_PROFILER on a smaller set of program units: your own code.

Before you begin, it's a good idea to see if DBMS_PROFILER is installed and if there are tables that it can store its data into when method flush_data() is called. To that end, execute a script like is_profiler.sql, as shown in Listing 7-20.

Listing 7-20. A Script to Detemine If SYS.DBMS_PROFILER Is Installed Properly, is_profiler.sql

```
rem is_profiler.sql
rem by Donaled J. Bales on 2014-10-20
rem Check to see if the profiler is installed and accessible

declare

n_major                                number;
n_minor                                number;
n_package                              number;
n_local                                number;
n_global                               number;

begin
  select count(1)
  into   n_package
  from   SYS.ALL_OBJECTS
  where  object_type = 'PACKAGE'
  and    object_name = 'DBMS_PROFILER'
  and    owner       = 'SYS';

  if n_package > 0 then
    SYS.DBMS_PROFILER.get_version(n_major, n_minor);

    pl('DBMS_PROFILER Version '||
      to_char(n_major)||'.'||
      to_char(n_minor));

    pl('DBMS_PROFILER.internal_version_check = '||
      to_char(SYS.DBMS_PROFILER.internal_version_check));
  else
    pl('Sorry, either the profile does not exist, or you'||
       'don''t have access to it.  Contact your DBA!');
  end if;

  select count(1)
  into   n_local
  from   SYS.ALL_OBJECTS
  where  object_type = 'TABLE'
  and    object_name in (
    'PLSQL_PROFILER_RUNS',
    'PLSQL_PROFILER_UNITS',
    'PLSQL_PROFILER_DATA')
  and    owner = USER;

  if n_local = 3 then
    pl('You have access to locally defined profiler tables '||
      'for your current username: '||USER);
  end if;

  select count(1)
  into   n_global
  from   SYS.ALL_OBJECTS
  where  object_type = 'TABLE'
  and    object_name in (
    'PLSQL_PROFILER_RUNS',
    'PLSQL_PROFILER_UNITS',
    'PLSQL_PROFILER_DATA')
  and    owner = 'SYS';

  if n_global = 3 then
    pl('You have access to gloablly defined profiler tables '||
      'under username SYS');
  end if;

  if n_local  <> 3 and
     n_global <> 3 then
    pl('Sorry, either the profile tables do not exist, or you'||
       'don''t have access to them.  Contact your DBA!');
  end if;

end;
/
```

You should see SQL*Plus output like this:

```
SQL> @is_profiler.sql
```

```
DBMS_PROFILER Version 2.0
DBMS_PROFILER.internal_version_check = 0
You have access to locally defined profiler tables for your current username: RPS

PL/SQL procedure successfully completed.
```

Given that you have access to the profiler, profile your relational version of the debug logger by following these steps.

1. Profile your debug logger by executing the following at the SQL*Plus prompt:

   ```
   SQL> @run_profile.sql rps.debug.sql
   ```

   This profiles your debug logging table package by executing your test unit for said package. The `run_profiler.sql` script should have displayed the run number on the screen. Jot down this number because you'll need it to run the two profiling reports next.

2. Create an "average percent consumption" report by executing the following at the SQL*Plus prompt:

   ```
   SQL> @avg_profile.sql <run_number>
   ```

   where `<run_number>` is the run number you got from executing script `run_profile.sql`.

3. Examine the file `avg_profile_<run_number>.txt`. Ask yourself, "What's the biggest consumer of resources?"
4. Create an "order by program unit and line number" report by executing the following at the SQL*Plus prompt:

   ```
   SQL> @ord_profile.sql <run_number>
   ```

5. Examine the file `ord_profile_<run_number>.txt`. Scan down the report. Find where your methods start and stop. Add up the average time consumption in nanoseconds. Ask yourself, "What's the biggest consumer of resources?"

Interestingly enough, in both cases, when you ask yourself to identify the biggest consumer of resources, you'll see that the answer is your SQL statements. Yes, we're back to dealing with SQL again. It's important to verify that your PL/SQL program logic is sound and it performs well, but it's even more important to make sure that your SQL is efficient. So let's see how you can determine just what's going on in a SQL statement next.

Profiling SQL

It's undeniable. You must make sure your SQL statements are as efficient as possible and that they are doing as much of the data manipulation work as is possible because SQL is more efficient at manipulating data than PL/SQL. So how do you see what's going on when it comes to a SQL statement?

Oracle provides two tools that you can use to examine the underlying access plan generated by the Oracle SQL Optimizer:

- `EXPLAIN PLAN`: Shows the execution plan generated by the Optimizer for a SQL statement you execute under the Oracle keywords `EXPLAIN PLAN`
- `TKPROF`: A utility program that can produce execution plans for all SQL statements executed again a database

Let's start out by looking at `EXPLAIN PLAN`.

Explain Plan

"Why does this take so long to run?" `EXPLAIN PLAN` will tell you, in just a bit more time than it takes you wrap your SQL statement in the keywords `EXPLAIN PLAN FOR`, exactly how the database intends to execute your SQL statement. Armed with this information, you can quickly determine if you need to do any of the following:

- Add an index to a table (or remove it)
- Rewrite your SQL statement
- Break your data processing into smaller chunks of work
- Just live with what you have

Given what you just learned in the section on profiling about performance in a PL/SQL program, your first step should always be to use `EXPLAIN PLAN` on every SQL statement in your PL/SQL program unit. So how do you do that?

1. Execute your SQL statement prefixed with the keywords `EXPLAIN PLAN FOR`.
2. Query the table `PLAN_TABLE` to extract the statistics.

In the olden days, you had to write your own SQL statements to query the PLAN_TABLE, but now you have access to package SYS.DBMS_XPLAN, which will do all the work of formatting the statistics for you.

Listing 7-21 is a SQL*Plus script named xp.sql that will explain the Optimizer's plan for a SQL statement stored in a file, with the filename passed to the script as the first parameter.

Listing 7-21. A Script to Explain the Optimizer Plan for SQL Statements, xp.sql

```
rem xp.sql
rem by Donald J. Bales on 2014-10-20
rem Display the execution plan for the last executed cursor

define script="&1";

set linesize  1000;
set newpage   1;
set pagesize  0;
set trimspool on;
set verify    off;

EXPLAIN PLAN FOR
select 1 from DUAL;

spool &script..pln;

EXPLAIN PLAN FOR
@&script

set echo off;

select * from table(SYS.DBMS_XPLAN.DISPLAY);

spool off;

set pagesize  32767;
set verify    on;
```

For example, first I save the following simple query in file select_workers_equlato.sql:

```
select *
from   WORKERS
where  name = 'DOE, JOHN J.'
order by 1;
```

Next, I execute xp.sql in SQL*Plus, passing it the filename as follows:

```
SQL> @xp.sql select_workers_equalto.sql
```

This produces the following plan:

```
Explained.

Plan hash value: 2276017427

----------------------------------------------------------------------------
| Id  | Operation                             | Name         | Rows  | Bytes |
----------------------------------------------------------------------------
|   0 | SELECT STATEMENT                      |              |     1 |    66 |
|   1 |  SORT ORDER BY                        |              |     1 |    66 |
|   2 |   TABLE ACCESS BY INDEX ROWID BATCHED| WORKERS      |     1 |    66 |
|*  3 |    INDEX RANGE SCAN                   | WORKERS_UK2 |     1 |       |
----------------------------------------------------------------------------

-------------------------
| Cost (%CPU)| Time     |
-------------------------
|     6  (17)| 00:00:01 |
|     6  (17)| 00:00:01 |
|     5   (0)| 00:00:01 |
|     3   (0)| 00:00:01 |
-------------------------

Predicate Information (identified by operation id):
---------------------------------------------------

   3 - access("NAME"='DOE, JOHN J.')

15 rows selected.
```

If you examine the plan, you'll see that the query is retrieving the values from the database by first scanning index WORKERS_UK2. Since I know how the indexes were built, I can be assured by looking at the plan that the Optimizer has chosen the best plan for accessing the WORKERS table. Now let's see what the Optimizer decides to do when I change the query from an "equal to" to a "like literal ending with a wildcard" query.

First, I save the following query in file select_workers_likepct.sql:

```
select *
from   WORKERS
where  name like 'DOE%'
order by 1;
```

Next, I execute xp.sql against that filename as follows:

```
SQL> @xp.sql select_workers_likepct.sql
```

This produces the following plan:

```
Explained.

Plan hash value: 2276017427

----------------------------------------------------------------------------
| Id  | Operation                            | Name         | Rows  | Bytes |
----------------------------------------------------------------------------
|   0 | SELECT STATEMENT                     |              |     1 |    66 |
|   1 |  SORT ORDER BY                       |              |     1 |    66 |
|   2 |   TABLE ACCESS BY INDEX ROWID BATCHED| WORKERS      |     1 |    66 |
|*  3 |    INDEX RANGE SCAN                  | WORKERS_UK2  |     1 |       |
----------------------------------------------------------------------------

-------------------------
| Cost (%CPU)| Time     |
-------------------------
|     6  (17)| 00:00:01 |
|     6  (17)| 00:00:01 |
|     5   (0)| 00:00:01 |
|     3   (0)| 00:00:01 |
-------------------------

Predicate Information (identified by operation id):
---------------------------------------------------

   3 - access("NAME" LIKE 'DOE%')
       filter("NAME" LIKE 'DOE%')

16 rows selected.
```

The Optimizer chose the same plan for this query as it did that last one.

Now let's try a worst-case scenario for any LIKE statement. I'll use the (%) wildcard on both sides of the literal. I would assume that this SQL statement will lead to a *full index scan*, instead of an *index range scan*. Does it?

First, I save the following query in file select_workers_pctlikepct.sql:

```
select *
from   WORKERS
where  name like '%DOE%'
order by 1;
```

Next, I pass the filename to xp.sql as follows:

```
SQL> @xp.sql select_workers_pctlikepct.sql
```

This produces the following plan:

```
Explained.

Plan hash value: 412163233

--------------------------------------------------------------
| Id  | Operation          | Name    | Rows  | Bytes |TempSpc|
--------------------------------------------------------------
|   0 | SELECT STATEMENT   |         | 13000 |   837K|       |
|   1 |  SORT ORDER BY     |         | 13000 |   837K|  1144K|
|*  2 |   TABLE ACCESS FULL| WORKERS | 13000 |   837K|       |
--------------------------------------------------------------

-------------------------
| Cost (%CPU)| Time     |
-------------------------
|  1065   (1)| 00:00:01 |
|  1065   (1)| 00:00:01 |
|   856   (1)| 00:00:01 |
-------------------------

Predicate Information (identified by operation id):
---------------------------------------------------

   2 - filter("NAME" LIKE '%DOE%' AND "NAME" IS NOT NULL)

14 rows selected.
```

No, it doesn't use an index at all. Instead, it resorted to the worst of all options: a *full table scan*. Ouch! The cost went from 6 to 1065. That means it will take about 177 times longer for this query to respond than the first two. It looks like if I want to maintain performance in my application, I'm going to have to devise another solution for allowing my end users to find someone with a name like %<name>%. Is there something I can do in Oracle to improve this situation? Yes, sometimes there is.

Physics vs. Explain Plan

If you have a table that has much larger row sizes than an applicable index, you can use simple physics to improve your query response time. For example, the average row size for the table WORKERS is 87 bytes. The average row size for index WORKERS_UK2 is 17 bytes. If I add a hint to the query forcing it to full scan the index WORKERS_UK2, the database will be able to retrieve five times as many index blocks per retrieval that it can table blocks. What does the Optimizer have to say about this plan? Let's find out.

First, I save the following query as select_workers_pctlikepct2.sql:

```
select /*+ INDEX(WORKERS WORKERS_UK2) */
       *
from   WORKERS
where  name like '%DOE%'
order by 1;
```

In this query, I've added the hint `/*+ INDEX(WORKERS WORKERS_UK2) */`, which tells the Optimizer to use index `WORKERS_UK2`. Next, I use `xp.sql` to do explain the Optimizer's plan as follows:

```
SQL> xp.sql select_workerS_pctlikepct2.sql
```

This produces the following plan:

```
Explained.

Plan hash value: 2470337875

-----------------------------------------------------------------------------
| Id  | Operation                             | Name        | Rows   | Bytes |
-----------------------------------------------------------------------------
|   0 | SELECT STATEMENT                      |             | 13000 |   837K|
|   1 |  SORT ORDER BY                        |             | 13000 |   837K|
|   2 |   TABLE ACCESS BY INDEX ROWID BATCHED| WORKERS     | 13000 |   837K|
|*  3 |    INDEX FULL SCAN                    | WORKERS_UK2 | 13000 |       |
-----------------------------------------------------------------------------

---------------------------------
|TempSpc| Cost (%CPU)| Time     |
---------------------------------
|       | 14787   (1)| 00:00:01 |
|  1144K| 14787   (1)| 00:00:01 |
|       | 14579   (1)| 00:00:01 |
|       |  1576   (1)| 00:00:01 |
---------------------------------

Predicate Information (identified by operation id):
---------------------------------------------------

   3 - filter("NAME" LIKE '%DOE%' AND "NAME" IS NOT NULL)

15 rows selected.
```

Indeed, the Optimizer understands my hint and is prepared to scan the index, but the cost is astronomical! Well guess what—*the Optimizer is wrong*. It doesn't understand the underlying physics involved.

Since there are 260,000 rows of data, with an average length of 87 bytes, if the Oracle database retrieves the data in 4KB blocks, it will require the retrieval of at least 5,500 blocks from the disk drive. On the other hand, it will require the retrieval of only about 1,080 blocks to identify which data rows to retrieve. Since, in this context, searching for part of a name will return a small set of rows, the application's performance can permanently benefit from the use of the hint, regardless of how the Optimizer feels about it. But the proof is in testing. And that is testing a snapshot of a fully loaded production database, not your development database. It's not until there are millions of rows in tables that you will probably need to "out think" Oracle's optimizer.

If I execute the first query `select_worker_ot_pctlikepct.sql`, which does not have the hint, against 260,000 rows, it takes on average three seconds to retrieve the matching rows. If I execute the second query, `select_worker_ot_pctlikepct2.sql`, which does have the hint to scan the index, it takes on average one second to retrieve the matching rows.

What's the moral of this story? The Optimizer doesn't always know the best way to retrieve data. It works with what it knows—basically statistics gathered when you analyze a table. On the other hand, you're an intelligent programmer who is much more knowledgeable and can therefore consider things like physics.

It's Your Turn to Use Explain Plan

Do you remember the section on FORALL in Chapter 5? That's where I nailed down the value of using the power of SQL instead of writing a whole lot of PL/SQL code to do the same work. The following SQL statement comes from Listing 5-14:

```
insert into WORKERS (
       worker_id,
       worker_type_id,
       external_id,
       first_name,
       middle_name,
       last_name,
       name,
       birth_date,
       gender_id)
select WORKERS_ID.nextval,
       decode(mod(WORKER_ID_SEQ.currval, 2),
         0, n_WT_EMPLOYEE, n_WT_CONTRACTOR),
       lpad(to_char(EXTERNAL_ID_SEQ.nextval), 9, '0'),
       first_name,
       letter||'.',
       last_name,
       WORKER.get_formatted_name(
         first_name, letter||'.', last_name),
       DATE_.random(
         to_number(to_char(SYSDATE, 'YYYY')) - 65,
         to_number(to_char(SYSDATE, 'YYYY')) - 18),
       decode(gender_code, 'F', n_G_FEMALE, n_G_MALE)
from   TOP_100_LAST_NAMES,
       TOP_100_FIRST_NAMES,
       A_THRU_Z;
```

In this code, I use pseudo-constants n_WT_EMPLOYEE, n_WT_CONTRACTOR, n_G_FEMALE, and n_G_MALE, which were preselected from the database, instead of selecting those values from the database in the SQL INSERT statement. Why?

It's another one of those tricks I've learned along the way. After years of using EXPLAIN PLAN on every SQL statement I've written, I noticed that I can improve the performance of a SQL statement if I reduce the number of tables accessed in the statement. If a SQL statement has three or less tables being selected, it performs pretty well. Add more tables, and its performance goes downhill fast.

So, if I have fairly limited number of constant values, I select them into pseudo-constant variables ahead of time, and then use those pseudo-constants in my SQL statement. Here's the Optimizer's plan for the preceding SQL `INSERT` statement:

```
Explained.

Plan hash value: 3139420850

----------------------------------------------------------------------------
| Id  | Operation                 | Name                    | Rows  | Bytes |
----------------------------------------------------------------------------
|   0 | INSERT STATEMENT          |                         |   260K|  4570K|
|   1 |  LOAD TABLE CONVENTIONAL  | WORKERS                 |       |       |
|   2 |   SEQUENCE                | WORKERS_ID              |       |       |
|   3 |    MERGE JOIN CARTESIAN   |                         |   260K|  4570K|
|   4 |     MERGE JOIN CARTESIAN  |                         |  2600 | 23400 |
|   5 |      INDEX FULL SCAN      | A_THRU_Z_PK             |    26 |    52 |
|   6 |      BUFFER SORT          |                         |   100 |   700 |
|   7 |       INDEX FAST FULL SCAN| TOP_100_LAST_NAMES_PK   |   100 |   700 |
|   8 |     BUFFER SORT           |                         |   100 |   900 |
|   9 |      INDEX FAST FULL SCAN | TOP_100_FIRST_NAMES_PK |   100 |   900 |
----------------------------------------------------------------------------

-------------------------
| Cost (%CPU)| Time     |
-------------------------
|   717   (1)| 00:00:01 |
|            |          |
|            |          |
|   717   (1)| 00:00:01 |
|    10   (0)| 00:00:01 |
|     1   (0)| 00:00:01 |
|     9   (0)| 00:00:01 |
|     0   (0)| 00:00:01 |
|   717   (1)| 00:00:01 |
|     0   (0)| 00:00:01 |
-------------------------

16 rows selected.
```

So here's your assignment. Rewrite the preceding SQL `INSERT` statement, which takes 47 seconds on average to execute on my machine, so the ID values for `EMPLOYEE`, `CONTRACTOR`, `FEMALE`, and `MALE` come from tables in the SQL `INSERT` statement's `SELECT` statement. Figure out if my working assumption about the number of tables in a SQL statement was true for this case, too. Follow these steps in order to find out for yourself.

1. Rewrite the SQL `INSERT` statement from Listing 5-14, adding two more tables to the `SELECT` statement, so you can get the ID values for corresponding codes from the database in the SQL statement.
2. Do an `EXPLAIN PLAN` on your SQL `INSERT` statement to determine what the Optimizer is planning. Is your plan better than the one for the SQL `INSERT` statement from Listing 5-14?

3. Look up the ID values for EMPLOYEE, CONTRACTOR, FEMALE, and MALE, and then substitute these values into the SQL INSERT statement from Listing 5-14.

4. Delete the contents of table WORKERS, and then execute the SQL INSERT statement from Listing 5-14 that you just modified, keeping track of how long it takes to execute. I suggest you do this at least three times, and then calculate the average value for how long it takes for the INSERT statement to execute.

5. Delete the contents of table WORKERS, and then execute your SQL INSERT statement where you include the GENDER_TYPES and WORKER_TYPES tables in its SELECT statement. Once again, I suggest you do this three times, and then calculate the average response time.

6. Compare the results of your timings between the two SQL INSERT statements. Which one was faster? Which SQL INSERT would you choose?

I'll show you my solution to this exercise. First, here's the SQL INSERT statement from Listing 5-14, modified to include tables GENDER_TYPES and WORKER_TYPES in its SELECT statement:

```
insert into WORKERS (
       id,
       worker_type_id,
       external_id,
       first_name,
       middle_name,
       last_name,
       name,
       birth_date,
       gender_type_id)
select WORKERS_ID.nextval,
       decode(mod(WORKERS_ID.currval, 2),
         0, c1.id, c2.id),
       lpad(to_char(EXTERNAL_ID_SEQ.nextval), 9, '0'),
       first_name,
       letter||'.',
       last_name,
       WORKER.get_formatted_name(
         first_name, letter||'.', last_name),
       DATE_.random(
         to_number(to_char(SYSDATE, 'YYYY')) - 65,
         to_number(to_char(SYSDATE, 'YYYY')) - 18),
       decode(gender_code, 'F', c3.id, c4.id)
from   TOP_100_LAST_NAMES,
       TOP_100_FIRST_NAMES,
       A_THRU_Z,
       WORKER_TYPES c1,
       WORKER_TYPES c2,
       GENDER_TYPES c3,
       GENDER_TYPES c4
where  c1.code = 'E'
and    c2.code = 'C'
and    c3.code = 'F'
and    c4.code = 'M';
```

And here's the Optimizer's plan for this SQL INSERT statement:

```
Explained.

Plan hash value: 599918850

-----------------------------------------------------------------------------
| Id  | Operation                                  | Name                  |
-----------------------------------------------------------------------------
|   0 | INSERT STATEMENT                           |                       |
|   1 |  LOAD TABLE CONVENTIONAL                   | WORKERS               |
|   2 |   SEQUENCE                                 | WORKERS_ID            |
|   3 |    MERGE JOIN CARTESIAN                    |                       |
|   4 |     MERGE JOIN CARTESIAN                   |                       |
|   5 |      MERGE JOIN CARTESIAN                  |                       |
|   6 |       MERGE JOIN CARTESIAN                 |                       |
|   7 |        NESTED LOOPS                        |                       |
|   8 |         NESTED LOOPS                       |                       |
|   9 |          TABLE ACCESS BY INDEX ROWID       | GENDER_TYPES          |
|* 10 |           INDEX UNIQUE SCAN                | GENDER_TYPES_UK       |
|  11 |          TABLE ACCESS BY INDEX ROWID       | GENDER_TYPES          |
|* 12 |           INDEX UNIQUE SCAN                | GENDER_TYPES_UK       |
|  13 |         TABLE ACCESS BY INDEX ROWID        | WORKER_TYPES          |
|* 14 |          INDEX RANGE SCAN                  | WORKER_TYPES_UK       |
|  15 |        BUFFER SORT                         |                       |
|  16 |         TABLE ACCESS BY INDEX ROWID BATCHED| WORKER_TYPES          |
|* 17 |          INDEX RANGE SCAN                  | WORKER_TYPES_UK       |
|  18 |       BUFFER SORT                          |                       |
|  19 |        INDEX FULL SCAN                     | A_THRU_Z_PK           |
|  20 |      BUFFER SORT                           |                       |
|  21 |       INDEX FAST FULL SCAN                 | TOP_100_LAST_NAMES_PK |
|  22 |     BUFFER SORT                            |                       |
|  23 |      INDEX FAST FULL SCAN                  | TOP_100_FIRST_NAMES_PK |
-----------------------------------------------------------------------------
```

```
------ ----------------------------------------
| Id   | Rows  | Bytes | Cost (%CPU)| Time     |
------ ----------------------------------------
|   0  |  260K|  9648K|   723   (1)| 00:00:01 |
|   1  |      |       |            |          |
|   2  |      |       |            |          |
|   3  |  260K|  9648K|   723   (1)| 00:00:01 |
|   4  | 2600 | 75400 |    16   (0)| 00:00:01 |
|   5  |   26 |   572 |     7   (0)| 00:00:01 |
|   6  |    1 |    20 |     6   (0)| 00:00:01 |
|   7  |    1 |    15 |     4   (0)| 00:00:01 |
|   8  |    1 |    10 |     2   (0)| 00:00:01 |
|   9  |    1 |     5 |     1   (0)| 00:00:01 |
|* 10  |    1 |       |     0   (0)| 00:00:01 |
|  11  |    1 |     5 |     1   (0)| 00:00:01 |
|* 12  |    1 |       |     0   (0)| 00:00:01 |
|  13  |    1 |     5 |     2   (0)| 00:00:01 |
|* 14  |    1 |       |     1   (0)| 00:00:01 |
|  15  |    1 |     5 |     4   (0)| 00:00:01 |
|  16  |    1 |     5 |     2   (0)| 00:00:01 |
|* 17  |    1 |       |     1   (0)| 00:00:01 |
|  18  |   26 |    52 |     5   (0)| 00:00:01 |
|  19  |   26 |    52 |     1   (0)| 00:00:01 |
|  20  |  100 |   700 |    15   (0)| 00:00:01 |
|  21  |  100 |   700 |     0   (0)| 00:00:01 |
|  22  |  100 |   900 |   723   (1)| 00:00:01 |
|  23  |  100 |   900 |     0   (0)| 00:00:01 |
------ ----------------------------------------

Predicate Information (identified by operation id):
---------------------------------------------------

  10 - access("C4"."CODE"='M')
  12 - access("C3"."CODE"='F')
  14 - access("C1"."CODE"='E')
  17 - access("C2"."CODE"='C')

38 rows selected.
```

The SQL INSERT statement with the GENDER_TYPES and WORKER_TYPES tables in its SQL SELECT statement is less efficient (cost equal to 723 vs. 717) according to EXPLAIN PLAN. What about how long it actually takes to execute? On my machine, it's actually three seconds faster than the SQL INSERT statement from Listing 5-14! So much for my experience!

The moral of this story is that you can't assume anything. You must always test the actual performance of your SQL statements before and after you've made modifications to the database, or to your SQL statements, in order to improve performance.

If you want a larger view of SQL statement performance, then perhaps you should use TKPROF.

TKPROF

TKPROF is a tool that's normally available only to your DBA. You're nice to your DBA, aren't you? So asking for his or her help in accessing trace files won't be a problem, right?

TKPROF is a utility that you can use in conjunction with session or system tracing to format the output of tracing into plans similar to those generated by EXPLAIN PLAN. The big difference is that you can gather statistics using package SYS.DBMS_MONITOR, which in turn will create trace files. Then you can use the trcsess utility to format the trace information into a format for TKPROF, and use TKPROF to format the output of the trace files into information you can use to examine the efficiency of an application's SQL statements as they were actually executed in a database.

To use TKPROF, follow these steps.

1. Utilize package DBMS_MONITOR to trace your application's use of SQL.
2. Use the trcsess utility to consolidate trace information into a file that can be analyzed using TKPROF.
3. Examine the consolidated trace file using TKPROF, in order to determine high-cost SQL statements in your application.

Using TKPROF, you'll be able to see the following for each SQL statement executed while you're monitoring the database:

- Resources consumed
- Number of times it was called
- Number of rows processed
- Optimizer's execution plan

Once you're armed with this information, you can use EXPLAIN PLAN to determine if there is a better alternative SQL statement, or if you need to come up with an entirely new solution. You may also want to investigate using package SYS.DBMS_SQLTUNE to help you decide how to properly tune a SQL statement.

You can find more information about performance tuning and EXPLAIN PLAN in the *Oracle Database Performance Tuning Guide*. You can find more information about the SYS.DBMS_* PL/SQL packages mentioned in this chapter in the *PL/SQL Packages and Types Reference*.

So what have you learned?

Summary

This chapter was all about troubleshooting. First, I discussed how to reduce the amount of troubleshooting you may have to do by simply preventing trouble in the first place. Second, I talked about adding troubleshooting-enabling code into your PL/SQL program units as you go, in anticipation of and preparation for trouble. Next, I covered four different troubleshooting tools:

- put_line()
- Debug logging
- Remote debugging
- EXPLAIN PLAN

Armed with these tools, you'll be able to handle any PL/SQL problem that comes your way. Now that you know how to fix any defect, how do you go about finding them all? By testing! And that's what I'm going to cover next.

CHAPTER 8

Testing

After 30 plus years of enterprise application development, I've found that the actual application development process for programmers consists of three high-level tasks:

- Coding
- Testing
- Documenting

The graph in Figure 8-1 is what I consider the ideal distribution of time for those three tasks. Yes, that's 60% of the development time spent on testing. The first response I get from most developers and project managers is, "Wow, that's an awful lot of time for testing, isn't it?" Not really. All the time you spend testing is time you won't have to spend supporting the application. And it costs a lot more to fix a defect in production than it does to take care of the problem earlier. It's as simple as that.

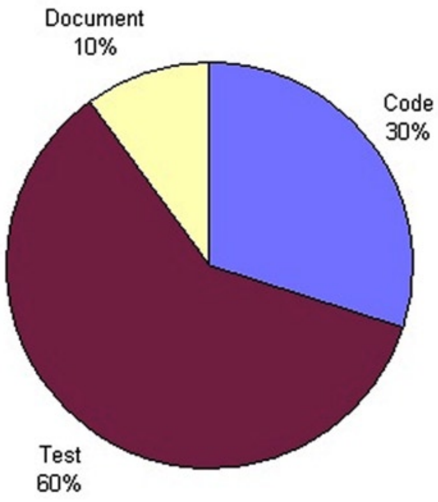


Figure 8-1. *An ideal distribution of development work*

Professional PL/SQL programmers write test units for their PL/SQL program units as they write their program units. I've been having you write them all along, haven't I? These are the only proper ways to reduce the amount of time spent testing:

- Develop with modularity (object orientation) because once a well-encapsulated software component is tested, it's unlikely it will break or need testing if a different unrelated module is modified.
- Automate testing by writing automated test units for every program unit (within reason) and/or by using a testing application suite.
- Write rerunnable test units. You should be able to run test units over and over again until there are no errors, without having to do any extra work to run them again.
- Update test units with additional tests if a defect not caught by the current test unit rears its ugly head.
- Don't lose your test units.
- Document your test units.

In contrast, nowadays it seems that everyone's favorite way to reduce the amount of time spent testing is to not test at all, which means passing testing on to the end user (not a good idea), which in turn means passing it on to support personnel (even worse). Why is passing testing on to support personnel even worse? At least the end users have a good idea how things should work. Support personnel usually know even less. It becomes a case of the proverbial "blind leading the blind."

So just whose responsibility is testing?

1. You are primarily responsible for testing your own code. You need to write test plans and test units to execute those test plans.
2. Your peers on your programming team are also responsible if they run into an error when using one of your components. Their responsibility is to inform you that there is a defect in your code, to ask you to update your test plans, update your test units, and then to test your code again.
3. Your supervisor, whether a technical lead, project manager, or in another position, is responsible for verifying that you have executed your test plans and that there are no errors. Your supervisor is also responsible for verifying that your test plans are updated if someone encounters an error.
4. An application's support personnel are responsible for reporting errors to the development team so defects can be fixed, and then test plans and test units can be updated and rerun.
5. An application's end users are responsible for reporting errors to the support team so defects can be fixed, and then test plans and test units can be updated and rerun.

I used a numbered list for these responsibilities to emphasize that *you are the one most responsible for testing.*

So just what do I mean by “test plan” and “test unit”? A test plan is a document that outlines how an application is to be tested. It should at least answer the following questions:

- How will the persistence layer (database) be tested?
- How will the application layer (middle tier) be tested?
- How will the presentation layer (the various presentation layers: data entry, reporting, interfaces, and so on) be tested?
- What technique will be used to keep track of what needs to be tested?
- What technique will be used to record that something has been tested?
- Who will sign off that the testing has been completed successfully and that there are no errors?
- How many rounds of testing will there be, and who will perform each round of testing?

A test unit is a list of tests to be executed by a tester (a person who tests) or executed by a program, written or scripted, which executes the test steps in an automated fashion. This chapter is about writing test units:

- The commonly executed steps in a PL/SQL test unit for SQL
- The commonly executed steps in a PL/SQL test unit for PL/SQL
- A table to store the tests performed and their results
- A package to aid in writing PL/SQL test units
- A framework for keeping track of what needs to be tested in a persistence layer (database/objectbase)

Let’s start by looking at the common tasks involved in testing SQL.

SQL Test Patterns

If you have a PL/SQL method that uses SQL, then you must devise some method to test that the SQL in that program unit works correctly. From an abstract point of view, that boils down to executing some or all of these steps in the following order:

1. `DELETE`
2. `INSERT`
3. `SELECT`
4. `UPDATE`
5. `DELETE`

If you’re going to test a program unit’s ability to `INSERT` a new entry into a table, you first need to decide on an acceptable set of values to use during the `INSERT`, and then you must clean up after yourself by removing what you’ve just added so the test unit can be run again. Since it’s entirely possible that an error may have occurred before your `INSERT` operation, you need to `DELETE` first. Otherwise, when you rerun your test on `INSERT`, you may get an error due to a row that was not properly cleaned up or removed during a prior test. That’s why I have `DELETE` as the number one high-level operation for testing any PL/SQL program unit that automates SQL testing.

Next, if you're going to test a PL/SQL program unit's ability to retrieve values from a table, you first need to INSERT those values so they are available. That means you must INSERT before you SELECT, which, in turn, means you need to DELETE, INSERT, SELECT, and then DELETE in your test unit.

Now if you're going to test a program unit's ability to UPDATE, it follows that you must first SELECT to verify that there is something to UPDATE, which requires you to INSERT before you SELECT and DELETE before you INSERT. Then you need to DELETE in order to clean up after yourself.

Last, if you're going to test a program unit's ability to DELETE, you need to perform a DELETE, then an INSERT, followed by a SELECT, (yes, you can skip UPDATE) and then a DELETE. I like to call this abstract pattern *the SQL Circle of Life,* as illustrated in Figure 8-2.

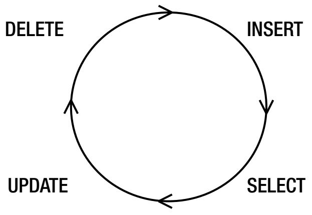


Figure 8-2. *The SQL Circle of Life*

At this moment, this discussion may seem quite silly. But you'll see soon enough, when you start writing test units, you will need to keep the SQL Circle of Life in mind when writing rerunnable SQL test units in PL/SQL.

Let's look at patterns found when testing PL/SQL methods next.

PL/SQL Test Patterns

Just as there is an abstract pattern to testing SQL in PL/SQL, there is also a pattern you'll need to follow to test PL/SQL program units themselves. The PL/SQL testing pattern is "blocking" your test code.

You need to wrap each of your PL/SQL tests in a PL/SQL block so you can programmatically maintain control in your test unit. If you can't maintain control in your test unit, it may end abruptly without performing all your tests. Here's an example:

```
...
begin
  -- Perform your test by calling a method with test data here

  -- Then check to ensure test success here
exception
  when OTHERS then
    -- Catch any PL/SQL exception and report the error here
end;
-- Go on to the next test
...
```

You'll end up testing your PL/SQL methods by calling them with test values in your test unit, and then inspecting the results of the operation to verify it worked correctly. In order to maintain control, you'll need to catch any raised exceptions, hence the when OTHERS then clause in the exception-handling section of the PL/SQL block surrounding your code. From the exception-handling section, you'll report any errors that take place, therefore handling the exception, not raising the exception to the outer (enclosing) PL/SQL block. Then you'll go on to perform your next method test.

How will you report and keep track of success or failure in your test units? You'll do that with a testing tool. Let's look at that next.

A Testing Tool

Humans are very good at creating their own tools. To that end, I've created a "testing tool" that helps me code my PL/SQL test units.

I have two high-level requirements for this testing tool. It needs to

- Provide a set of constants that I can use for column values when testing.
- Provide a set of methods that I can use to save tests and results for later analysis.

Do you recall that in the "SQL Test Patterns" section, I stated that you first need to decide on an acceptable set of values to use during the INSERT? How do you go about that?

Well here's how I do it: I ask the database! Listing 8-1 is a SQL*Plus query I run to determine the varchar2 lengths that are in common use. For the most part, there should only be a few. While in the past, the lengths of a character field may have had some meaning, they no longer do. With the advent of globalization, the lengths of character fields only amount to specifying an upper limit on the amount of storage you're willing to use for a given string value.

Listing 8-1. A Query to Determine Commonly Used Lengths for Varchar2 Columns, data_length_histogram.sql

```
rem data_length_histogram.sql
rem by Donald J. Bales on 2014-10-20
rem Create a histogram of VARCHAR2 data lengths in use

column column_name format a30;

set linesize  1000;
set newpage   1;
set pagesize  32767;
set trimspool on;

spool data_length_histogram.txt;

select column_name,
       min(data_length) min,
       avg(data_length) avg,
       max(data_length) max,
       count(1) occurs
from   SYS.ALL_TAB_COLUMNS
where  owner = USER
and    data_type like 'VARCHAR%'
and    table_name not in (
       'AUTHORS',
       'AUTHOR_PUBLICATIONS',
       'A_THRU_Z',
       'DEBUGS',
       'PLAN_TABLE',
       'PLSQL_PROFILER_RUNS',
       'PLSQL_PROFILER_UNITS',
       'PLSQL_PROFILER_DATA',
       'TOP_100_FIRST_NAMES',
       'TOP_100_LAST_NAMES' )
group by column_name
order by max(data_length),
       column_name
/

spool off;
```

And here's the output from the query in Listing 8-1:

```
COLUMN_NAME                           MIN        AVG        MAX     OCCURS
------------------------------ ---------- ---------- ---------- ----------
LOGICAL_INDICATOR                       1          1          1          1
PHYSICAL_INDICATOR                      1          1          1          1
CAS_NUMBER                             30         30         30          1
CODE                                   30         30         30          7
EXTERNAL_ID                            30         30         30          1
FIRST_NAME                             30         30         30          1
LAST_NAME                              30         30         30          1
MIDDLE_NAME                            30         30         30          1
DESCRIPTION                            80         80         80          4
ID_CONTEXT                            100        100        100          2
NAME                                   80 85.7142857        100          7
TITLE                                 100        100        100          1
NARRATIVE                            2000       2000       2000          1

13 rows selected.
```

Analyzing this output, I have concluded that I will need the following constants for testing:

- A TRUE value for the indicator variables
- A FALSE value for the indicator variables
- A 30-character code value that I can specify any time I test inserting a new code or partial name value into a code or content table
- An 80-character description value that I can specify any time I test inserting a new description into a code or content table
- A 100-character value that I can specify any time I test inserting a new ID context or title into a content or intersection table
- A 2,000-character value that I can specify any time I test inserting a new comment or narrative into a content table

I'll keep this list of requirements in mind when I code my testing tool's package specification, so the constants will be accessible to all other program units, and therefore available when writing their test units.

WHY ARE WE SPECIFYING CHARACTER COLUMN LENGTHS ANYWAY?

After having internationalized a number of enterprise applications, I began to wonder why we have to specify a maximum column length for character columns at all. In the future, I don't think we'll need to do this; the database will handle the length automatically, and why not?

One programmer I know argued that was important and gave me what he thought was a valid example: "It's important to constrain a number column for money. It should be `NUMBER(11,2)`, because dollars have hundredths values (dimes and pennies)." But that's only valid for dollars; other currencies have thousandths.

Consider that characters used in the English language use one byte of storage. Other languages use characters that require two to four bytes of storage. In addition, sentences, even words, in English are quite compact when compared with other languages. For example, an idea expressed in 30 *characters* in English may take four to five times as many words and/or *characters* in German.

So just what are we specifying when we constrain a `varchar2`'s length? I think it's just our expectation that nothing entered into the column will ever need to be larger than what we've specified. So until Oracle gets with my line of thinking, we might as well decide on a standard set of character column lengths and stick to it. Here are the lengths I commonly use for character fields in applications:

- *Code*: 30 English only; 60 internationalized
- *Code context*: 500 English only; 1,000 internationalized
- *Comments*: 2,000 English only; 4,000 internationalized
- *Description*: 80 English only; 160
- *ID context*: 100 English only; 200 internationalized
- *Name*: 80 English only; 160 internationalized
- *Name context*: 1,000 English only; 2,000 internationalized
- *Title*: 80 English only; 160 internationalized

I would like to hear your thoughts: `don@donaldbales.com`. Now back to testing.

How about some behavior? What will I call the methods that aid me with writing test units? Here's a preliminary set of requirements:

- `clear()`: To erase the results of a previous test run from table `TESTS`
- `get_id()`: To allocate a new primary key value for the table `TESTS`
- `test()`: To test the testing tool
- `set_test()`: To start a new test
- `set_result()`: To store the results of a test

However, before I write a testing tool package, I need to create a table to permanently store the results of my tests.

A TEST Table

Why store my test results in a table? Because then I can use SQL to query the table to analyze the results of my testing. No tool is more powerful at manipulating data than SQL, so a table is the ideal place to save the results of testing.

What do I need to store? Here's my short list of data to store:

- The name of the package or user-defined TYPE (object name) that contains the method being tested
- The name of the method being tested
- An external identifier for the test being performed on a given method so I can identify a given test if it fails
- A short but meaningful description of the test
- The result of the test

In order to store this data, I've written the DDL script in Listing 8-2. It creates a test table named TESTS. I've also added an ID column for a primary key. This will be a unique session ID, so testing in one session does not collide with testing going on in another session. I've also included insert user and insert date columns, which are standard columns I add to all tables (to add those bread crumbs I talked about in Chapter 7).

Listing 8-2. A DDL Script to Create a Testing Results Table, rps.tests.tab

```
rem tests.tab
rem by Donald Bales on 2014-10-20
rem Create test results

create table TESTS (
id                             number                        not null,
object_name                    varchar2(30),
method_name                    varchar2(30),
test_number                    number,
description                    varchar2(80),
result                         varchar2(256),
unique_session_id              varchar2(24)                  not null,
insert_user                    varchar2(30)  default USER     not null,
insert_date                    date          default SYSDATE  not null );

alter  table TESTS add
constraint   TESTS_PK
primary key (
id )
using index
tablespace USERS pctfree 0
storage (initial 1M next 1M pctincrease 0);

create sequence TESTS_ID
start with 1 order;

execute SYS.DBMS_STATS.gather_table_stats(USER, 'TESTS');

grant all on TESTS to PUBLIC;
grant all on TESTS to PUBLIC;
```

Now that I have a table to store results, let's get to writing a testing tool package.

A TEST Package Specification

In my testing tool's package, I define a set of variables or constants that are suitable as insert values for SQL statements. I can then use these predefined values when writing test units. This approach has several advantages. First, global use of these testing values will create an environment where testing is done with consistency. In turn, because of that consistency, everyone involved in testing will know what these predefined values are, and then know that they are looking at test data if they encounter these values while testing.

Listing 8-3 is the package specification for my testing tool. On the top half of the specification, I've added globally accessible constants to be utilized by all programmers when writing their test units. These are followed by methods designed to aid programmers when writing their test units. By using these methods, the test data is consistently formatted and stored for easy analysis.

Listing 8-3. A Testing Tool Package Spec, rps.test.pks

```
001 create or replace package TEST as
002 /*
003 test.pks
004 by Donald J. Bales on 2014-10-20
005 A Testing package
006 */
007
008 -- Result constants
009 v_TEST_ERROR                constant  varchar2(5) := 'ERROR';
010 v_TEST_OK                   constant  varchar2(2) := 'OK';
011 v_TEST_SUCCESS              constant  varchar2(7) := 'SUCCESS';
012
013 -- Testing constants
014 d_TEST_19000101             constant  date        :=
015   to_date('19000101', 'YYYYMMDD');
016 d_TEST_99991231             constant  date        :=
017   to_date('99991231', 'YYYYMMDD');
018
019 v_TEST_N                    constant  varchar2(1) := 'N';
020
021 v_TEST_Y                    constant  varchar2(1) := 'Y';
022
023 v_TEST_30                   constant  varchar2(30) :=
024   'TEST TEST TEST TEST TEST TESTx';
025
026 v_TEST_30_1                 constant  varchar2(30) :=
027   'TEST1 TEST1 TEST1 TEST1 TEST1x';
028
029 v_TEST_30_2                 constant  varchar2(30) :=
030   'TEST2 TEST2 TEST2 TEST2 TEST2x';
031
032 v_TEST_80                   constant  varchar2(80) :=
033   'Test Test Test Test Test Test Test Test '||
034   'Test Test Test Test Test Test Test Testx';
035
```

```
v_TEST_100                  constant  varchar2(100) :=
  'Test Test Test Test Test Test Test Test Test Test '||
  'Test Test Test Test Test Test Test Test Test Testx';

v_TEST_2000                 constant  varchar2(2000) :=
  'Test Test Test Test Test Test Test Test Test Test '||
  'Test Test Test Test Test Test Test Test Test Test '||
  'Test Test Test Test Test Test Test Test Test Test '||
  'Test Test Test Test Test Test Test Test Test Test '||
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  'Test Test Test Test Test Test Test Test Test Test '||
  'Test Test Test Test Test Test Test Test Test Test '||
  'Test Test Test Test Test Test Test Test Test Test '||
  'Test Test Test Test Test Test Test Test Test Testx';

--          1         2         3         4         5
-- 12345678901234567890123456789012345678901234567890

-- Clear the results of the last test
PROCEDURE clear(
aiv_object_name                         TESTS.object_name%TYPE);


-- Set the result of the last test to v_TEST_ERROR
PROCEDURE error;


-- Set the result of the last test to the passed Oracle error
PROCEDURE error(
aiv_result                    in        TESTS.result%TYPE);


-- Display help text
PROCEDURE help;


-- Instantiate the package
PROCEDURE initialize;


-- Set the result of the last test to v_TEST_OK
PROCEDURE ok;


-- Update the test with its results
PROCEDURE set_result(
aiv_result                    in        TESTS.result%TYPE);


-- Add a test
PROCEDURE set_test(
aiv_object_name               in        TESTS.object_name%TYPE,
aiv_method_name               in        TESTS.method_name%TYPE,
ain_test_number               in        TESTS.test_number%TYPE,
aiv_description               in        TESTS.description%TYPE);


-- Set the result of the last test to v_TEST_SUCCESS
PROCEDURE success;


-- Test unit
PROCEDURE test;


end TEST;
/
@se.sql TEST
```

Let's examine Listing 8-3, line by line:

- Lines 9 through 11 add three character constants, `ERROR`, `OK`, and `SUCCESS`, to be used as values for parameter `aiv_result`, when calling method `result()`. `OK` means the test completed successfully, and `ERROR` means the test did not complete successfully. Constant `SUCCESS` is called only at the end of a program unit's test unit after recording a test for the package or user-defined `TYPE` in question, in order to flag that the package or `TYPE`'s test unit completely successfully, without raising any uncaught exceptions. If an uncaught exception does occur, the programmer should pass the value of `SQLERRM` as the result.
- Lines 14 through 80 add constants to be used globally for testing inserts into SQL tables. These "testing" values not only self-document their values as test values, but also exercise the maximum column size constraints on the columns for tables for which they are used to test.
- Lines 86 and 87 declare method `clear()`, which a program should call at the beginning of a test unit in order to clear any previous test results before starting a new round of tests.
- Line 91 declares method `error()`, which a program should call to record that the test resulted in an error.
- Lines 95 and 96 declare an overridden version of method `error()`, which takes one argument. A program should call this method if it needs to record an Oracle exception error message.
- Lines 107 and 108 declare method `ok()`, which a program should call to record that an individual test completed without errors.
- Lines 112 and 113 declare the method `set_result()`. Methods `error()`, `ok()`, and `success()` call this method to record testing results. This method uses `pragma autonomous_transaction` so entries are not lost if the test fails in the program unit in question because of an uncaught exception.
- Lines 117 through 121 declare the method `set_test()`, which a programmer should use to record a test that is about to be executed inside a test unit. This method also uses `pragma autonomous_transaction` so entries are not lost if the test fails in the program unit in question because of an uncaught exception.
- Line 125 declares method `success()`, which a program should call at the end of a test unit to flag that the entire test unit completed successfully. That doesn't mean that there weren't errors during the individual tests; it means that the method `test()` itself was completely executed.
- Line 129 declares the standard test unit method to be used by every package and user-defined `TYPE`: `test()`. This is where a programmer codes the test units for every associated PL/SQL program unit. You'll see an example in the testing tool's package body shortly.

The test result constants `OK`, `ERROR`, and `SUCCESS` make it easy to identify errors after tests are run. If you want to know which test unit methods failed, just write a query where you list every object in the table `TESTS` that doesn't have a row where the `object_name` can also be found with a result value of `SUCCESS`. If you want to know which individual tests failed, write a query to list the rows where column `result` starts with `ERR` or `ORA`. I'll show you a couple of sample queries like these in the "Automating Testing" section later in this chapter.

Now let's look at the implementation.

A TEST Package Body

Now that you've seen the specification for my testing tool, let's look at its implementation, including an example of its use. Listing 8-4 is the DDL to create the package body for package TEST.

Listing 8-4. A Testing Tool Package Body, rps.test.pkb

```
create or replace package body TEST as
/*
test.pkb
by Donald J. Bales on 2014-10-20
A Testing package
*/

-- Hold this value across calls to test() and result()
n_id                                  TESTS.id%TYPE;


PROCEDURE clear(
aiv_object_name                       TESTS.object_name%TYPE) is

pragma autonomous_transaction;

begin
  delete TESTS
  where  object_name       = aiv_object_name
  and    unique_session_id = SYS.DBMS_SESSION.unique_session_id;

  commit;
end clear;


PROCEDURE error is

begin
  set_result(v_TEST_ERROR);
end error;


PROCEDURE error(
aiv_result                     in     TESTS.result%TYPE) is

begin
  set_result(aiv_result);
end error;


FUNCTION get_id
return                                TESTS.id%TYPE is

n_id                                  TESTS.id%TYPE;

```

```
begin
  select TESTS_ID.nextval
  into   n_id
  from   SYS.DUAL;

  return n_id;
end get_id;


PROCEDURE help is
begin
  pl('You''re on your own buddy.');
end help;


PROCEDURE initialize is
begin
  null;
end;


PROCEDURE ok is

begin
  set_result(v_TEST_OK);
end ok;


PROCEDURE set_result(
aiv_result                     in     TESTS.result%TYPE) is

pragma autonomous_transaction;

begin
  update TESTS
  set    result = aiv_result
  where  id     = n_id;

  if nvl(sql%rowcount, 0) = 0 then
    raise_application_error(-20000, 'Can''t find test'||
      to_char(n_id)||
      ' on update TEST'||
      ' in TEST.test');
  end if;

  n_id := NULL;

  commit;
end set_result;


```

```
PROCEDURE set_test(
aiv_object_name                in     TESTS.object_name%TYPE,
aiv_method_name                in     TESTS.method_name%TYPE,
ain_test_number                in     TESTS.test_number%TYPE,
aiv_description                in     TESTS.description%TYPE) is

pragma autonomous_transaction;

begin
  n_id := get_id();

  begin
    insert into TESTS (
           id,
           object_name,
           method_name,
           test_number,
           description,
           result,
           unique_session_id,
           insert_user,
           insert_date )
    values (
           n_id,
           upper(aiv_object_name),
           upper(aiv_method_name),
           ain_test_number,
           aiv_description,
           NULL,
           SYS.DBMS_SESSION.unique_session_id,
           USER,
           SYSDATE );
  exception
    when OTHERS then
      raise_application_error(-20000, SQLERRM||
        ' on insert TEST'||
        ' in TEST.test');
  end;
  commit;
end set_test;


PROCEDURE success is

begin
  set_result(v_TEST_SUCCESS);
end success;


PROCEDURE test is

```

```
n_number                              number;

begin
  pl('TESTS.test()');
  clear('TEST');

  set_test('TEST', NULL, 1,
    'Is v_TEST_N equal to N?');
  if v_TEST_N = 'N' then
    ok();
  else
    error();
  end if;

  set_test('TEST', NULL, 2,
    'Is the length of v_TEST_N equal to 1?');
  if nvl(length(v_TEST_N), 0) = 1 then
    ok();
  else
    error();
  end if;

  set_test('TEST', NULL, 3,
    'Is v_TEST_Y equal to Y?');
  if v_TEST_Y = 'Y' then
    ok();
  else
    error();
  end if;

  set_test('TEST', NULL, 4,
    'Is the length of v_TEST_Y equal to 1?');
  if nvl(length(v_TEST_Y), 0) = 1 then
    ok();
  else
    error();
  end if;

  set_test('TEST', NULL, 5,
    'Is the length of v_TEST_30 equal to 30?');
  if nvl(length(v_TEST_30), 0) = 30 then
    ok();
  else
    error();
  end if;

  set_test('TEST', NULL, 6,
    'Is the length of v_TEST_30_1 equal to 30?');
  if nvl(length(v_TEST_30_1), 0) = 30 then
    ok();
  else
```

```
    error();
  end if;

  set_test('TEST', NULL, 7,
    'Is the length of v_TEST_30_2 equal to 30?');
  if nvl(length(v_TEST_30_2), 0) = 30 then
    ok();
  else
    error();
  end if;

  set_test('TEST', NULL, 8,
    'Is the length of v_TEST_80 equal to 80?');
  if nvl(length(v_TEST_80), 0) = 80 then
    ok();
  else
    error();
  end if;

  set_test('TEST', NULL, 9,
    'Is the length of v_TEST_100 equal to 100?');
  if nvl(length(v_TEST_100), 0) = 100 then
    ok();
  else
    error();
  end if;

  set_test('TEST', NULL, 10,
    'Is the length of v_TEST_2000 equal to 2000?');
  if nvl(length(v_TEST_2000), 0) = 2000 then
    ok();
  else
    error();
  end if;

  set_test('TEST', 'get_id', 11,
    'Does get_id() work?');
  begin
    n_number := get_id();
    if n_number > 0 then
      ok();
    else
      error();
    end if;
  exception
    when OTHERS then
      error(SQLERRM);
  end;

  set_test('TEST', 'help', 12,
    'Does help() work?');
```

```
250    begin
251      help();
252  --    raise_application_error(-20999, 'Testing test unit report');
253      ok();
254    exception
255      when OTHERS then
256        error(SQLERRM);
257    end;
258
259    set_test('TEST', NULL, NULL, NULL);
260    success();
261  end test;
262
263
264  end TEST;
265  /
266  @be.sql TESTS
```

Let's look at Listing 8-4 in detail:

- Lines 12 through 23 implement procedure `clear()`, which is called by method `test()` to remove any previous test for the same unique session ID.
- Lines 26 through 30 implement procedure `error()`, which is called by method `test()` to record a generic error.
- Lines 33 through 38 implement procedure `error()`, which is called by method `test()` inside an exception handler in order to record an Oracle exception's error message.

■ **Note** Do you find the use of the same method names for more than one purpose disturbing? This is called *overloading* the method names. One `error()` method is used to record a generic error, while the second is used to record an Oracle error message.

- Lines 41 through 52 implement function `get_id()`, which returns the next primary key value to be used when inserting a row into table `TESTS`.
- Lines 67 through 71 implement procedure `ok()`, which is called by method `test()` to record the success of an individual test.
- Lines 74 through 94 implement procedure `set_result()`, which updates the last recorded test with the passed result value. This method uses an instance-level variable, `n_id`, in coordination with procedure `test()`. `test()` saves the last `id` it allocates to variable `n_id` in the package's memory, and then `set_result()` uses that value when saving the result. I do this to reduce the amount of coding required by the test unit writer.
- Lines 97 through 136 implement procedure `set_test()`, which is used by test unit writers to record that a test is about to take place.

- Lines 139 through 143 implement procedure `success()`, which is called by method `test()` to indicate the successful execution of the test unit itself.
- Lines 146 through 260 implement procedure `test()`, which is the actual test unit for package `TEST`. Yes, I've used the testing tool to test the testing tool. Neat, huh?
- Line 148, inside the test unit method `test()`, declares a number variable to temporarily hold the result of one of the tests.
- Line 151 calls `pl()` to give feedback to the tester that the test has been started.
- Line 152 calls procedure `TEST.clear()`, passing the name of the object in order to remove any previous test results.
- Lines 154 and 155 call procedure `TEST.test()`, passing it the information about the test I'm about to perform.
- Line 156 performs my first test, to see if the constant `TEST.v_TEST_N` has the correct value. Since I'm certain that this test cannot cause an exception, I have not blocked the code for the test.
- Line 157 sets the result for the test to constant `TEST.v_TEST_OK` by calling procedure `ok()` if `v_TEST_N` is indeed the character `N`; otherwise, on line 159, I set the result to `TEST.v_TEST_ERROR` by calling procedure `error()`.
- Lines 162 through 232 perform tests on the remaining constants in a similar fashion. With all these tests, I'm confident that an exception cannot possibly be raised, so I don't block the test code. This is not so for the next test.
- Lines 234 and 235 call procedure `TEST.test()` in order to record that I'm about to perform a test of function `get_id()`.
- Lines 236 through 246 block the call to method `get_id()` in order to catch any unexpected exception. Next, I execute my actual test, a call to `get_id()`. If there is no unexpected exception, the next line, 238, tests to see if the ID value was greater than zero. If so, I call method `ok()`; otherwise, I call `error()`. If an exception does occur, I call `error()`, passing the value of `SQLERRM`.
- Lines 250 through 256 block a call to `help()` and then test it in a fashion similar to the previous test.
- Line 258 calls `test()` for the package, therefore passing only the object's name.
- Line 259 calls procedure `success()`. These last two calls will indicate that the test procedure `test()` itself completed successfully, instead of possibly aborting somewhere in the midst of the test from an unhandled exception.

Now that I've shown you my relational testing tool, it's your turn to create an object-relational version.

It's Your Turn to Create a Testing Tool

Your assignment is to recreate the testing tool I've just shown you as an object-relational `TYPE` instead of a package. There's one twist, though. You can't declare constants, pseudo-constants, or variables in a `TYPE`, as I did in the `TEST` package specification, so you'll need to declare additional parameterless functions that return the constant values.

To create an object-relational testing tool, follow these steps.

1. Write a DDL script to create a TYPE specification named TEST. This type should have an attribute for every column name in table TESTS. It should also have corresponding methods for each method found in package TEST. In addition, you'll add parameterless functions in the place of the constants in package TEST. Include the method signature for, but skip coding the methods `help()` and `test()`. We'll work on coding `test()` in the next section, and `help()` in the next chapter.
2. Save your script as `ops.test.tps`.
3. Log in as username OPS.
4. Compile your script: `SQL> @ops.test.tps`.
5. Write a DDL script to create the object table TESTS of TEST.
6. Save your script as `ops.tests.tab`.
7. Compile your script: `SQL> @ops.tests.tab`.
8. Write a DDL script to create the TYPE BODY for TEST.
9. Save your script as `ops.test.tpb`.
10. Compile your script: `SQL> @ops.test.tpb`.

But what about testing your new test tool? I'll devote the entire next section to that task. Do you want to see my solution for this exercise? Listings 8-5, 8-6, and 8-7 are the DDL for the TYPE specification, table, and body, respectively, for my version of TYPE TEST.

Listing 8-5. A DDL Script for TYPE TEST's Spec, ops.test.tps

```
drop   type TEST;
create type TEST as object (
/*
test.tps
by Donald J. Bales on 2014-10-20
A Type for logging test results
*/
-- Type TEST's attributes
id                                    number,
object_name                           varchar2(30),
method_name                           varchar2(30),
test_number                           number,
description                           varchar2(80),
result                                varchar2(256),
unique_session_id                     varchar2(24),
insert_user                           varchar2(30),
insert_date                           date,

-- Allocate the next primary key value fir id
STATIC FUNCTION get_id
return                                number,

-- Get the test value for January 1, 1900
```

```
STATIC FUNCTION get_test_19000101
return                                date,

-- Get the test value for December 31, 1999
STATIC FUNCTION get_test_19991231
return                                date,

-- Get the test value N for any indicators
STATIC FUNCTION get_test_n
return                                varchar2,

-- Get the test value Y for any indicators
STATIC FUNCTION get_test_y
return                                varchar2,

-- Get the 30 character test value
STATIC FUNCTION get_test_30
return                                varchar2,

-- Get the first 30 character test value duplicate for LIKE
STATIC FUNCTION get_test_30_1
return                                varchar2,

-- Get the second 30 character test value duplicate for LIKE
STATIC FUNCTION get_test_30_2
return                                varchar2,

-- Get the 80 character test value
STATIC FUNCTION get_test_80
return                                varchar2,

-- Get the 100 character test value
STATIC FUNCTION get_test_100
return                                varchar2,

-- Get the 2000 character test value
STATIC FUNCTION get_test_2000
return                                varchar2,

-- Clear any previous test run for the specified object name
STATIC PROCEDURE clear(
aiv_object_name                       varchar2),

-- Set the result to ERROR
MEMBER PROCEDURE error,

-- Set the result to Oracle ERROR
MEMBER PROCEDURE error(
aiv_result                    in      varchar2),

074 -- Set the result to the specified result value
075 MEMBER PROCEDURE set_result(
076 aiv_result                    in     varchar2),
077
078 -- Show the help text for this object
079 STATIC PROCEDURE help,
080
081 -- Set the result to OK
082 MEMBER PROCEDURE ok,
083
084 -- Set the result of the execution of test() to SUCCESS
085 MEMBER PROCEDURE success,
086
087 -- Test this object
088 STATIC PROCEDURE "test",
089
090 -- Set the test about to be performed
091 MEMBER PROCEDURE set_test(
092 aiv_object_name               in     varchar2,
093 aiv_method_name               in     varchar2,
094 ain_test_number               in     number,
095 aiv_description               in     varchar2),
096
097 -- Get the map value
098 MAP MEMBER FUNCTION to_map
099 return                               number,
100
101 -- Parameter-less constructor
102 CONSTRUCTOR FUNCTION test(
103 self                          in out nocopy test)
104 return                        self as result,
105
106 -- Convenience constructor
107 CONSTRUCTOR FUNCTION test(
108 self                          in out nocopy test,
109 ain_id                        in     number,
110 aiv_object_name               in     varchar2,
111 aiv_method_name               in     varchar2,
112 ain_test_number               in     number,
113 aiv_description               in     varchar2)
114 return                               self as result
115 );
116 /
117 @se.sql
118
119 grant execute on TEST to public;
```

In Listing 8-5, the TYPE specification for TEST, I added the static functions get_test_19000101() through get_test_2000() to act as and replace the constants d_TEST_19000101 through v_TEST_2000 from the package TEST specification on lines 14 through 80.

Listing 8-6. The DDL Script for Table TESTS, ops.tests.tab

```
rem tests.tab
rem by Donald Bales on 2014-10-20
rem Create test results

--drop   table TESTS;
create table TESTS of TEST
tablespace USERS pctfree 0
storage (initial 1M next 1M pctincrease 0);

alter  table TESTS add
constraint   TESTS_PK
primary key (
id )
using index
tablespace USERS pctfree 0
storage (initial 1M next 1M pctincrease 0);

--drop   sequence TESTS_ID;
create sequence TESTS_ID
start with 1 order;

execute SYS.DBMS_STATS.gather_table_stats(USER, 'TESTS');

grant all on TESTS to PUBLIC;
```

There's nothing really new in Listing 8-6, the script to create a table based on TYPE TEST.

Listing 8-7. A DDL Script for TYPE TEST's BODY, ops.test.tpb

```
create or replace type body TEST as
/*
test.tpb
by Donald J. Bales on 2014-10-20
A Type for logging test results
*/

STATIC PROCEDURE clear(
aiv_object_name                       varchar2) is

pragma autonomous_transaction;

begin
  delete TESTS
  where  object_name       = aiv_object_name
  and    unique_session_id = SYS.DBMS_SESSION.unique_session_id;

  commit;
end clear;


```

```
STATIC FUNCTION get_id
return                                number is

n_id                                  number;

begin
  select TESTS_ID.nextval
  into   n_id
  from   SYS.DUAL;

  return n_id;
end get_id;


STATIC FUNCTION get_test_19000101
return                                date is

begin
  return to_date('19000101', 'YYYYMMDD');
end get_test_19000101;


STATIC FUNCTION get_test_19991231
return                                date is

begin
  return to_date('19991231', 'YYYYMMDD');
end get_test_19991231;


STATIC FUNCTION get_test_n
return                                varchar2 is

begin
  return 'N';
end get_test_n;


STATIC FUNCTION get_test_y
return                                varchar2 is

begin
  return 'Y';
end get_test_y;


STATIC FUNCTION get_test_30
return                                varchar2 is

begin
  return 'TEST TEST TEST TEST TEST TESTx';
end get_test_30;
```

```


STATIC FUNCTION get_test_30_1
return                                varchar2 is

begin
  return 'TEST1 TEST1 TEST1 TEST1 TEST1x';
end get_test_30_1;


STATIC FUNCTION get_test_30_2
return                                varchar2 is

begin
  return 'TEST2 TEST2 TEST2 TEST2 TEST2x';
end get_test_30_2;


STATIC FUNCTION get_test_80
return                                varchar2 is

begin
  return 'Test Test Test Test Test Test Test Test '||
         'Test Test Test Test Test Test Test Testx';
end get_test_80;


STATIC FUNCTION get_test_100
return                                varchar2 is

begin
  return 'Test Test Test Test Test Test Test Test Test Test '||
         'Test Test Test Test Test Test Test Test Test Testx';
end get_test_100;


STATIC FUNCTION get_test_2000
return                                varchar2 is
--                 1         2         3         4         5
--        12345678901234567890123456789012345678901234567890
begin
  return 'Test Test Test Test Test Test Test Test Test Test '||
         'Test Test Test Test Test Test Test Test Test Test '||
         'Test Test Test Test Test Test Test Test Test Test '||
         'Test Test Test Test Test Test Test Test Test Test '||
         'Test Test Test Test Test Test Test Test Test Test '||
         'Test Test Test Test Test Test Test Test Test Test '||
         'Test Test Test Test Test Test Test Test Test Test '||
         'Test Test Test Test Test Test Test Test Test Test '||
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         'Test Test Test Test Test Test Test Test Test Test '||
         'Test Test Test Test Test Test Test Test Test Test '||
         'Test Test Test Test Test Test Test Test Test Test '||
         'Test Test Test Test Test Test Test Test Test Test '||
         'Test Test Test Test Test Test Test Test Test Test '||
         'Test Test Test Test Test Test Test Test Test Test '||
         'Test Test Test Test Test Test Test Test Test Testx';
end get_test_2000;


STATIC PROCEDURE help is
begin
  pl('You''re on your own buddy.');
end help;


MEMBER PROCEDURE error is

begin
  set_result('ERROR');
end error;


MEMBER PROCEDURE error(
aiv_result                     in     varchar2) is

```

```
begin
  set_result(aiv_result);
end error;


MEMBER PROCEDURE ok is

begin
  set_result('OK');
end ok;


MEMBER PROCEDURE set_result(
aiv_result                     in     varchar2) is

pragma autonomous_transaction;

begin
  result := aiv_result;

  update TESTS
  set    result = self.result
  where  id     = self.id;

  if nvl(sql%rowcount, 0) = 0 then
    raise_application_error(-20000, 'Can''t find test'||
      to_char(self.id)||
      ' on update TEST'||
      ' in TEST_TS.test');
  end if;

  self := new test();

  commit;
end set_result;


MEMBER PROCEDURE set_test(
aiv_object_name                in     varchar2,
aiv_method_name                in     varchar2,
ain_test_number                in     number,
aiv_description                in     varchar2) is

pragma autonomous_transaction;

begin
  self.id                 := TEST.get_id();
  self.object_name        := upper(aiv_object_name);
  self.method_name        := upper(aiv_method_name);
  self.test_number        := ain_test_number;
  self.description        := aiv_description;
  self.result             := NULL;
  self.unique_session_id := SYS.DBMS_SESSION.unique_session_id;
  self.insert_user       := USER;
  self.insert_date       := SYSDATE;

  begin
    insert into TESTS values (self);
  exception
    when OTHERS then
      raise_application_error(-20000, SQLERRM||
        ' on insert TESTS'||
        ' in TEST.set_test');
  end;
  commit;
end set_test;


MEMBER PROCEDURE success is

begin
  set_result('SUCCESS');
end success;


STATIC PROCEDURE "test" is

n_number                              number;
o_test                                TEST;

begin
  pl('TEST.test()');

  -- A defect requires the schema owner
  &_USER..TEST.clear('TEST');

  o_test := new TEST();
  o_test.set_test('TEST', NULL, 1,
    'Is get_test_N equal to N?');
  if TEST.get_test_N = 'N' then
    o_test.success();
  else
    o_test.error();
  end if;

  o_test.set_test('TEST', NULL, 2,
    'Is the length of get_test_N equal to 1?');
  if nvl(length(TEST.get_test_N), 0) = 1 then
    o_test.success();
  else
    o_test.error();
  end if;

```

```
o_test.set_test('TEST', NULL, 3,
  'Is get_test_Y equal to Y?');
if TEST.get_test_Y = 'Y' then
  o_test.success();
else
  o_test.error();
end if;

o_test.set_test('TEST', NULL, 4,
  'Is the length of get_test_Y equal to 1?');
if nvl(length(TEST.get_test_Y), 0) = 1 then
  o_test.success();
else
  o_test.error();
end if;

o_test.set_test('TEST', NULL, 5,
  'Is the length of get_test_30 equal to 30?');
if nvl(length(TEST.get_test_30), 0) = 30 then
  o_test.success();
else
  o_test.error();
end if;

o_test.set_test('TEST', NULL, 6,
  'Is the length of get_test_30_1 equal to 30?');
if nvl(length(TEST.get_test_30_1), 0) = 30 then
  o_test.success();
else
  o_test.error();
end if;

o_test.set_test('TEST', NULL, 7,
  'Is the length of get_test_30_2 equal to 30?');
if nvl(length(TEST.get_test_30_2), 0) = 30 then
  o_test.success();
else
  o_test.error();
end if;

o_test.set_test('TEST', NULL, 8,
  'Is the length of get_test_80 equal to 80?');
if nvl(length(TEST.get_test_80), 0) = 80 then
  o_test.success();
else
  o_test.error();
end if;

o_test.set_test('TEST', NULL, 9,
  'Is the length of get_test_100 equal to 100?');
if nvl(length(TEST.get_test_100), 0) = 100 then
```

```
    o_test.success();
  else
    o_test.error();
  end if;

  o_test.set_test('TEST', NULL, 10,
    'Is the length of get_test_2000 equal to 2000?');
  if nvl(length(TEST.get_test_2000), 0) = 2000 then
    o_test.success();
  else
    o_test.error();
  end if;

  o_test.set_test('TEST', 'get_id', 11,
    'Does get_id() work?');
  begin
    n_number := TEST.get_id();
    if n_number > 0 then
      o_test.success();
    else
      o_test.error();
    end if;
  exception
    when OTHERS then
      o_test.error(SQLERRM);
  end;

  o_test.set_test('TEST', 'help', 12,
    'Does help() work?');
  begin
    &_USER..TEST.help();
    raise_application_error(-20999, 'Testing the error routine');
    o_test.success();
  exception
    when OTHERS then
      o_test.error(SQLERRM);
  end;

  o_test.set_test('TEST', NULL, NULL, NULL);
  o_test.success();
end "test";


MAP MEMBER FUNCTION to_map
return                                number is

begin
  return self.id;
end to_map;


```

```
CONSTRUCTOR FUNCTION test(
self                           in out nocopy test)
return                                self as result is

begin
  self.id                := NULL;
  self.object_name       := NULL;
  self.method_name       := NULL;
  self.test_number       := NULL;
  self.description       := NULL;
  self.result            := NULL;
  self.unique_session_id := NULL;
  self.insert_user       := NULL;
  self.insert_date       := NULL;

  return;
end test;


CONSTRUCTOR FUNCTION test(
self                           in out nocopy test,
ain_id                         in     number,
aiv_object_name                in     varchar2,
aiv_method_name                in     varchar2,
ain_test_number                in     number,
aiv_description                in     varchar2)
return                                self as result is

begin
  self.id                := ain_id;
  self.object_name       := aiv_object_name;
  self.method_name       := aiv_method_name;
  self.test_number       := ain_test_number;
  self.description       := aiv_description;
  self.result            := NULL;
  self.unique_session_id := SYS.DBMS_SESSION.unique_session_id;
  self.insert_user       := USER;
  self.insert_date       := SYSDATE;

  return;
end test;


end;
/
@be.sql TEST
```

Did you notice in Listing 8-6 that I used the SQL*Plus defined variable `&USER` in the source listing? This is a work-around to a defect in the Oracle compiler when trying to resolve the name of a method that is part of the same `TYPE BODY`.

In the sections that follow, I'll use the relational testing tool to test packages and the object-relational tool I just created to test TYPEs. So let's move on to a discussion of testing with these new testing tools.

Testing

Do you recall the discussion about table types early in Chapter 1, where I said that tables fall into one of three categories: content, codes, or intersections? The types of methods and method names used by each of these three categories will follow a pattern. Content table packages (or TYPEs) will all have a similar set of methods and method names. Code table packages (or TYPEs) will also have a similar set of methods and method names. And so will intersection table packages (or TYPEs).

Accordingly, these three categories will have a pattern of tests that follows the set of methods and method names used by each category. Content table packages will generally have methods to insert, update, delete, and select a specified row from a table. In contrast, a code table will have only a method to get the ID value for a specified code, or code and description for a specified ID. Intersection table packages will have methods like content table packages, and additional methods suitable only for intersections.

So the SQL Circle of Life I talked about earlier in this chapter will be fully employed for content and intersection table packages but not for code table packages. Since content tables are usually dependent on one or more code tables, and intersection tables are dependent on two content tables, let's start with a code table package. I'll cover the testing of the WORKER_TYPE table package now, and you'll code and test the GENDER_TYPE table package later in this section.

Testing a Code Table Package

As usual, let's dive right into a code listing. Listings 8-8 and 8-9 are the full-blown, production-ready packages for the WORKER_TYPE table.

The package specification lists methods that are specific to a code table.

- `get_code_descr()`: Used to retrieve the code and description values for a specified ID.
- `get_code_id_descr()`: Used to retrieve the code, ID, and description values for a fully or partially specified code. For a partially specified code, the method may return a single matching set of values or raise exception TOO_MANY_ROWS if more than one matching entry exists in the table.
- `get_id()`: Returns the ID that corresponds to the specified code.

The package specification also lists some methods that are universal to all table packages.

- `get_id()`: Returns a newly allocated primary key value for the table.
- `help()`: Displays help text for the package.
- `test()`: Tests the package.

Listing 8-8. The Specification for Table Package WORKER_TYPE,rps.worker_type.pks

```
create or replace PACKAGE WORKER_TYPE as
/*
worker_type.pks
by Don Bales on 2014-10-20
Code Table WORKER_TYPES's methods.
*/

```

```

-- Gets the code and decription values for the specified ain_id.
PROCEDURE get_code_descr(
ain_id                         in     WORKER_TYPES.id%TYPE,
aov_code                          out WORKER_TYPES.code%TYPE,
aov_description                   out WORKER_TYPES.description%TYPE );


-- Verifies the passed aiov_code value is an exact or like match on
-- the date specified.
PROCEDURE get_code_id_descr(
aiov_code                      in out WORKER_TYPES.code%TYPE,
aon_id                            out WORKER_TYPES.id%TYPE,
aov_description                   out WORKER_TYPES.description%TYPE,
aid_on                         in     WORKER_TYPES.active_date%TYPE );


-- Verifies the passed aiov_code value is currently an exact or like
-- match.
PROCEDURE get_code_id_descr(
aiov_code                      in out WORKER_TYPES.code%TYPE,
aon_id                            out WORKER_TYPES.id%TYPE,
aov_description                   out WORKER_TYPES.description%TYPE );


-- Returns a newly allocated id value.
FUNCTION get_id
return                                WORKER_TYPES.id%TYPE;


-- Returns the id for the specified code value.
FUNCTION get_id(
aiv_code                       in     WORKER_TYPES.code%TYPE )
return                                WORKER_TYPES.id%TYPE;


-- Test-based help for this package. "set serveroutput on" in
-- SQL*Plus.
PROCEDURE help;


-- Test units for this package.
PROCEDURE test;


end WORKER_TYPE;
/
@se.sql WORKER_TYPE
```

Listing 8-9. The Body for Table Package WORKER_TYPE ,rps. worker_type.pkb

```
create or replace PACKAGE BODY WORKER_TYPE as
/*
worker_type.pkb
by Don Bales on 2014-10-20
Table WORKER_TYPES's methods
*/


PROCEDURE get_code_descr(
ain_id                          in     WORKER_TYPES.id%TYPE,
aov_code                           out WORKER_TYPES.code%TYPE,
aov_description                    out WORKER_TYPES.description%TYPE ) is

begin
  select code,
         description
  into   aov_code,
         aov_description
  from   WORKER_TYPES
  where  id = ain_id;
end get_code_descr;


PROCEDURE get_code_id_descr(
aiov_code                       in out WORKER_TYPES.code%TYPE,
aon_id                             out WORKER_TYPES.id%TYPE,
aov_description                    out WORKER_TYPES.description%TYPE,
aid_on                          in     WORKER_TYPES.active_date%TYPE ) is

v_code                                 WORKER_TYPES.code%TYPE;

begin
  select id,
         description
  into   aon_id,
         aov_description
  from   WORKER_TYPES
  where  code = aiov_code
  and    aid_on between active_date and nvl(inactive_date, DATE_.d_MAX);
exception
  when NO_DATA_FOUND then
    select id,
           code,
           description
    into   aon_id,
           v_code,
           aov_description
    from   WORKER_TYPES
    where  code like aiov_code||'%'
    and    aid_on between active_date and nvl(inactive_date, DATE_.d_MAX);

    aiov_code := v_code;
end get_code_id_descr;


PROCEDURE get_code_id_descr(
aiov_code                       in out WORKER_TYPES.code%TYPE,
aon_id                             out WORKER_TYPES.id%TYPE,
aov_description                    out WORKER_TYPES.description%TYPE ) is

begin
 get_code_id_descr(
  aiov_code,
  aon_id,
  aov_description,
  SYSDATE );
end get_code_id_descr;


FUNCTION get_id
return                                 WORKER_TYPES.id%TYPE is

n_id                                   WORKER_TYPES.id%TYPE;

begin
  select WORKER_TYPES_ID.nextval
  into   n_id
  from   SYS.DUAL;

  return n_id;
end get_id;


FUNCTION get_id(
aiv_code                        in     WORKER_TYPES.code%TYPE )
return                                 WORKER_TYPES.id%TYPE is

n_id                                   WORKER_TYPES.id%TYPE;

begin
  select id
  into   n_id
  from   WORKER_TYPES
  where  code = aiv_code;

  return n_id;
end get_id;


PROCEDURE help is

```

```
begin
--   12345678901234567890123456789012345678901234567890123456789012345678901234567890
 pl('================================= PACKAGE ===================================');
 pl(chr(9));
 pl('WORKER_TYPE');
 pl(chr(9));
 pl('---------------------------------- FUNCTIONS ---------------------------------');
 pl(chr(9));
 pl('WORKER_TYPE.get_id');
 pl('return                                WORKER_TYPES.id%TYPE;');
 pl(chr(9)||'Returns a newly allocated sequence value for id.');
 pl(chr(9));
 pl('WORKER_TYPE.get_id(');
 pl('aiv_code                       in     WORKER_TYPES.code%TYPE )');
 pl('return                                WORKER_TYPES.id%TYPE;');
 pl(chr(9)||'Returns the corresponding id for the specified code.');
 pl(chr(9));
 pl('---------------------------------- PROCEDURES --------------------------------');
 pl(chr(9));
 pl('WORKER_TYPE.get_code_descr(');
 pl('ain_id                         in     WORKER_TYPES.id%TYPE,');
 pl('aov_code                          out WORKER_TYPES.code%TYPE,');
 pl('aov_description                   out WORKER_TYPES.description%TYPE );');
 pl(chr(9)||'Gets the corresponding code and description for the specified');
 pl(chr(9)||'id.');
 pl(chr(9));
 pl('WORKER_TYPE.get_code_id_descr(');
 pl('aiov_code                      in out WORKER_TYPES.code%TYPE,');
 pl('aon_id                            out WORKER_TYPES.id%TYPE,');
 pl('aov_description                   out WORKER_TYPES.description%TYPE,');
 pl('aid_on                         in     WORKER_TYPES.active_date%TYPE );');
 pl(chr(9)||'Gets the corresponding code, id, and description for');
 pl(chr(9)||'the specified code.  First it trys to find an exact match.  If one');
 pl(chr(9)||'cannot be found, it trys to find a like match.  It may throw a');
 pl(chr(9)||'NO_DATA_FOUND or a TOO_MANY_ROWS exception if a match cannot be');
 pl(chr(9)||'found for the specified code and point in time.');
 pl(chr(9));
 pl('WORKER_TYPE.get_code_id_descr(');
 pl('aiov_code                      in out WORKER_TYPES.code%TYPE,');
 pl('aon_id                            out WORKER_TYPES.id%TYPE,');
 pl('aov_description                   out WORKER_TYPES.description%TYPE );');
 pl(chr(9)||'Gets the corresponding code, id, and description for');
 pl(chr(9)||'the specified code.  First it trys to find an exact match.  If one');
 pl(chr(9)||'cannot be found, it trys to find a like match.  It may throw a');
 pl(chr(9)||'NO_DATA_FOUND or a TOO_MANY_ROWS exception if a match cannot be');
 pl(chr(9)||'found for the specified code at the current point in time.');
 pl(chr(9));
 pl('WORKER_TYPE.help( );');
 pl(chr(9)||'Displays this help text if set serveroutput is on.');
 pl(chr(9));
 pl('WORKER_TYPE.test( );');
 pl(chr(9)||'Built-in test unit.  It will report success or error for each test if set');
 pl(chr(9)||'serveroutput is on.');
 pl(chr(9));
end help;


PROCEDURE test is

n_id                                  WORKER_TYPES.id%TYPE;
v_code                                WORKER_TYPES.code%TYPE;
v_description                         WORKER_TYPES.description%TYPE;

begin
  -- Send feedback that the test ran
  pl('WORKER_TYPE.test()');

  -- Clear the last set of test results
  &_USER..TEST.clear('WORKER_TYPE');

  -- First, we need some test values

  -- Let's make sure they don't already exist: DELETE
  &_USER..TEST.set_test('WORKER_TYPE', 'DELETE', 0,
    'Delete test entries');
  begin
    delete WORKER_TYPES
    where  code in (
      &_USER..TEST.v_TEST_30,
      &_USER..TEST.v_TEST_30_1,
      &_USER..TEST.v_TEST_30_2);
    &_USER..TEST.ok();
  exception
    when OTHERS then
      &_USER..TEST.error(SQLERRM);
  end;

  -- Now let's add three test codes: INSERT
  &_USER..TEST.set_test('WORKER_TYPE', 'INSERT', 1,
    'Insert 3 test entries');
  begin
    insert into WORKER_TYPES (
           id,
           code,
           description,
           active_date,
           inactive_date )
    values (
           get_id(),
           &_USER..TEST.v_TEST_30,
           &_USER..TEST.v_TEST_80,
           &_USER..TEST.d_TEST_19000101,
           &_USER..TEST.d_TEST_99991231 );

    insert into WORKER_TYPES (
           id,
           code,
           description,
           active_date,
           inactive_date )
    values (
           get_id(),
           &_USER..TEST.v_TEST_30_1,
           &_USER..TEST.v_TEST_80,
           &_USER..TEST.d_TEST_19000101,
           &_USER..TEST.d_TEST_99991231 );

    insert into WORKER_TYPES (
           id,
           code,
           description,
           active_date,
           inactive_date )
    values (
           get_id(),
           &_USER..TEST.v_TEST_30_2,
           &_USER..TEST.v_TEST_80,
           &_USER..TEST.d_TEST_19000101,
           &_USER..TEST.d_TEST_99991231 );

    &_USER..TEST.ok();
  exception
    when OTHERS then
      &_USER..TEST.error(SQLERRM);
  end;

  -- Now that we have test entries,
  -- let's test the package methods
  &_USER..TEST.set_test('WORKER_TYPE', 'get_id()', 2,
    'Get the ID for the specified code');
  begin
    n_id := get_id(&_USER..TEST.v_TEST_30);

    if n_id > 0 then
      &_USER..TEST.ok();
    else
      &_USER..TEST.error();
    end if;
```

```
exception
  when OTHERS then
    &_USER..TEST.error(SQLERRM);
end;

&_USER..TEST.set_test('WORKER_TYPE', 'get_code_descr()', 3,
  'Get the code and description for the specified ID');
begin
  get_code_descr(
    n_id,
    v_code,
    v_description);
  if v_code        = &_USER..TEST.v_TEST_30 and
     v_description = &_USER..TEST.v_TEST_80 then
    &_USER..TEST.ok();
  else
    &_USER..TEST.error();
  end if;
exception
  when OTHERS then
    &_USER..TEST.error(SQLERRM);
end;

&_USER..TEST.set_test('WORKER_TYPE', 'get_code_id_descr()', 4,
  'Get the code, ID, and description for the specified code');
begin
  v_code := &_USER..TEST.v_TEST_30;
  get_code_id_descr(
    v_code,
    n_id,
    v_description);
  if v_code           = &_USER..TEST.v_TEST_30 and
     n_id             > 0                      and
     v_description    = &_USER..TEST.v_TEST_80 then
    &_USER..TEST.ok();
  else
    &_USER..TEST.error();
  end if;
exception
  when OTHERS then
    &_USER..TEST.error(SQLERRM);
end;

&_USER..TEST.set_test('WORKER_TYPE', 'get_code_id_descr()', 5,
  'Get the code, ID, and description for the specified date');
begin
  v_code := 'TEST';
  -- This test should raise a TOO_MANY_ROWS exception
  -- because at least three duplicate values will
  -- on the date specified
  get_code_id_descr(
          v_code,
          n_id,
          v_description,
          &_USER..TEST.d_TEST_99991231);
        if v_code           = &_USER..TEST.v_TEST_30 and
           n_id > 0                  and
           v_description    = &_USER..TEST.v_TEST_80 then
          &_USER..TEST.ok();
        else
          &_USER..TEST.error();
        end if;
      exception
        when TOO_MANY_ROWS then
          &_USER..TEST.ok();
        when OTHERS then
          &_USER..TEST.error(SQLERRM);
      end;

      &_USER..TEST.set_test('WORKER_TYPE', 'help()', 6,
        'Display help');
      begin
        help();
        &_USER..TEST.ok();
      exception
        when OTHERS then
          &_USER..TEST.error(SQLERRM);
      end;

      -- Let's make sure they don't already exist: DELETE
      &_USER..TEST.set_test('WORKER_TYPE', 'DELETE', 7,
        'Delete test entries');
      begin
        delete WORKER_TYPES
        where  code in (
          &_USER..TEST.v_TEST_30,
          &_USER..TEST.v_TEST_30_1,
          &_USER..TEST.v_TEST_30_2);
        &_USER..TEST.ok();
      exception
        when OTHERS then
          &_USER..TEST.error(SQLERRM);
      end;

      &_USER..TEST.set_test('WORKER_TYPE', NULL, NULL, NULL);
      &_USER..TEST.success();
    end test;


    end WORKER_TYPE;
    /
    @be.sql WORKER_TYPE
```

I'll explain only the test unit method `test()` in Listing 8-9 this time around.

- Lines 161 through 163 declare a handful of variables that I will need while testing the package's methods.
- Line 167 uses `pl()` to output some feedback to the tester that the test method did indeed execute.
- Line 170 clears any previous test results for this package.
- Lines 175 through 187 delete any existing "test" entries so they don't cause a problem with the current test. I do this with a SQL `DELETE` statement because the code table package pattern of methods has no ongoing use for a routine that deletes code values.
- Lines 190 through 236 insert three "test" entries into the code table. The first entry uses the standard 30-character value for the code. I'll try to find an exact match for this value later in testing. The second and third entries exist to cause a `TOO_MANY_ROWS` exception later in testing. Without explicitly testing the method, `get_id()`, the method that returns a new primary key value is also tested during the insertion of the three "test" entries.
- Lines 240 through 253 test the second `get_id()` method, the code table package pattern method, which returns a code's ID value.
- Lines 255 through 271 test method `get_code_descr()`.
- Lines 273 through 291 test the method `get_code_id_descr()` for an exact match on today's date.
- Lines 293 through 317 test the method `get_code_id_descr()` to verify it will raise exception `TOO_MANY_ROWS` when there is no exact match.
- Lines 319 through 327 test method `help()`.
- Lines 330 through 342 delete the "test" entries I added at the beginning of the test. This means I've used `DELETE`, `INSERT`, and then `DELETE` as the SQL Circle of Life for testing this code table package.
- Lines 344 and 345 add the entry to the testing table that indicates the test method itself ran successfully.

I can now query the table `TESTS` to find the results of the test. Listing 8-10 is a SQL*Plus script to list the results of the last performed test.

Listing 8-10. A Report to Show the Results of the Last Test, rps.last_test_results.sql

```
rem last_test_results.sql
rem by Donald J. Bales on 2014-10-20
rem Display the last test results

set linesize 1000;
set newpage  1;
set pagesize 32767;
set trimspool on;

column test         format a34;
column t#           format 99;
column description  format a27;
column result       format a7;

spool last_test_results.txt;

select t.object_name||
       decode(substr(t.method_name, -1, 1), ')', '.', ' ')||
       t.method_name test,
       t.test_number t#,
       t.description,
       t.result
from   TESTS t
where  t.unique_session_id = SYS.DBMS_SESSION.unique_session_id
and    t.object_name       = (
select e.object_name
from   TESTS e
where  e.unique_session_id = SYS.DBMS_SESSION.unique_session_id
and    e.id                = (
select max(x.id)
from   TESTS x
where  x.unique_session_id = SYS.DBMS_SESSION.unique_session_id))
order by t.id;

spool off;
```

When I run script `last_test_results.sql` after testing `WORKER_TYPE` I get the following output from SQL*Plus:

```
TEST                               T# DESCRIPTION                     RESULT
---------------------------------- --- ------------------------------- -------
WORKER_TYPE DELETE                   0 Delete test entries             OK
WORKER_TYPE INSERT                   1 Insert 3 test entries           OK
WORKER_TYPE.GET_ID()                 2 Get the ID for the specified code    OK

WORKER_TYPE.GET_CODE_DESCR()         3 Get the code and description    OK
                                       for the specified ID

WORKER_TYPE.GET_CODE_ID_DESCR()      4 Get the code, ID, and           OK
                                       description for the specified code

WORKER_TYPE.GET_CODE_ID_DESCR()      5 Get the code, ID, and descr     OK
                                       iption for the specified date

WORKER_TYPE.HELP()                   6 Display help                    OK
WORKER_TYPE DELETE                   7 Delete test entries             OK
WORKER_TYPE                                                            SUCCESS

9 rows selected.
```

If any of the tests failed, the enclosing PL/SQL block caught any raised exception, then the column `result` would list the word `ERROR` or the reported Oracle error message from any raised exception. If the enclosing PL/SQL block around a test failed to catch a raised exception, then the test unit itself would not complete, and the last entry in the report, `SUCCESS`, would not exist. Now that you've seen me do it, it's your turn.

It's Your Turn to Test a Code Table Package

I tested the `WORKER_TYPE` code table package, and you'll test the `GENDER_TYPE` code table package. The two tests should be very similar. You can find a full-blown, production-ready version of package `GENDER_TYPE` in the downloaded code directory for Chapter 8. I suggest you proceed as follows.

1. Copy the method `WORKER_TYPE.test()` and paste it into package body `GENDER_TYPE`.
2. Modify the method for any column name and other changes.
3. Save and compile the package body.
4. Execute the test against `GENDER_TYPE` by executing method `test()`.
5. Use report `last_test_results.sql` to see the results of your test.

No, I'm not going to show you my solution because it follows the same pattern as any other code table package's `test()` method. Instead, let's move on to testing a content table's package.

Testing a Content Table Package

This time, for an example of a content table test unit, I'm going to show you only a partial code listing. Listing 8-11 is the test unit from the full-blown, production-ready package for the `LOGICAL_WORKPLACES` table. Its package specification (not shown) lists the following methods that are specific to a content table package (or `TYPE`):

- `get_name()` or `get_name_context()`: Actually, in this case, since table `LOGICAL_WORKPLACES` has a hierarchal relationship with itself, the method is `get_name_context()`, which shows all the names in the hierarchy separated by periods (`.`).
- `get_external_id()` or `get_code_context()`: Once again, since table `LOGICAL_WORKPLACES` has a hierarchal relationship with itself, the method is named `get_code_context()`, which shows all the external IDs in the hierarchy separated by periods (`.`).
- `get_row()`: Returns a matching row depending on primary key column or unique key column value(s) set in the record passed to the method.
- `set_row()`: Updates an existing matching row, using the same rules implemented by `get_row()` to find a matching row, or inserts a new row if a match is not found.

The package specification has one method that is unique to a hierarchal table:

- `create_id_context()`: Creates a hierarchal unique key that represents the hierarchal relationship between rows in the same table as a character value separated by periods (`.`)

And it also has some methods that are universal to all table packages:

- `get_id()`Returns a newly allocated primary key value for the table
- `help()`help text for the package
- `test()`package

Listing 8-11. The test( ) Method from Table Package Body LOGICAL_WORKPLACE, rps.logical_workplace.pkb

```
PROCEDURE test is

/*
LOGICAL_WORKPLACES
 Name                                      Null?    Type
 ----------------------------------------- -------- -------------
 LOGICAL_WORKPLACE_ID                      NOT NULL NUMBER
 PARENT_ID                                          NUMBER
 ID_CONTEXT                                NOT NULL VARCHAR2(100)
 WORKPLACE_TYPE_ID                         NOT NULL NUMBER
 CODE                                      NOT NULL VARCHAR2(30)
 NAME                                      NOT NULL VARCHAR2(80)
 ACTIVE_DATE                               NOT NULL DATE
 INACTIVE_DATE                                      DATE
*/

v_id_context
  LOGICAL_WORKPLACES.id_context%TYPE;
r_logical_workplace                    LOGICAL_WORKPLACES%ROWTYPE;

begin
  pl('LOGICAL_WORKPLACE.test()');

  &_USER..TEST.clear('LOGICAL_WORKPLACE');

  &_USER..TEST.set_test('LOGICAL_WORKPLACE', 'DELETE', 0,
    'Delete existing test entries');
  begin
    delete LOGICAL_WORKPLACES
    where  code in (
      &_USER..TEST.v_TEST_30_1,
      &_USER..TEST.v_TEST_30_2);

    delete LOGICAL_WORKPLACES
    where  code = &_USER..TEST.v_TEST_30;

    &_USER..TEST.ok();
  exception
    when OTHERS then
      &_USER..TEST.error(SQLERRM);
  end;

```

```
&_USER..TEST.set_test('LOGICAL_WORKPLACE', 'get_id()', 1,
  'Allocate the next primary key value');
begin
  r_logical_workplace.id := get_id();

  if r_logical_workplace.id > 0 then
    &_USER..TEST.ok();
  else
    &_USER..TEST.error();
  end if;
exception
  when OTHERS then
    &_USER..TEST.error(SQLERRM);
end;

&_USER..TEST.set_test('LOGICAL_WORKPLACE',
  'create_id_context()', 2, 'Create an ID context value');
begin
  r_logical_workplace.parent_id            := NULL;
  r_logical_workplace.id_context           :=
    create_id_context(
      r_logical_workplace.parent_id,
      r_logical_workplace.id);

  if r_logical_workplace.id_context =
    to_char(r_logical_workplace.id) then
    &_USER..TEST.ok();
  else
    &_USER..TEST.error();
  end if;
exception
  when OTHERS then
    &_USER..TEST.error(SQLERRM);
end;

&_USER..TEST.set_test('LOGICAL_WORKPLACE', 'set_row()', 3,
  'Insert parent test entry');
begin
  r_logical_workplace.workplace_type_id    :=
    WORKPLACE_TYPE.get_id('C');
  r_logical_workplace.code                 :=
    &_USER..TEST.v_TEST_30;
  r_logical_workplace.name                 :=
    &_USER..TEST.v_TEST_80;
  r_logical_workplace.active_date          :=
    &_USER..TEST.d_TEST_19000101;
  r_logical_workplace.inactive_date        :=
    &_USER..TEST.d_TEST_99991231;
  set_row(r_logical_workplace);

  &_USER..TEST.ok();
exception
```

```
  when OTHERS then
    &_USER..TEST.error(SQLERRM);
end;

&_USER..TEST.set_test('LOGICAL_WORKPLACE', 'set_row()', 4,
  'Insert child entries');
begin
  r_logical_workplace.parent_id             :=
    r_logical_workplace.id;
  r_logical_workplace.id                    := get_id();
  r_logical_workplace.id_context            :=
    create_id_context(
      r_logical_workplace.parent_id,
      r_logical_workplace.id);
  -- save this value for testing get_row()
  v_id_context                              :=
    r_logical_workplace.id_context;
  r_logical_workplace.workplace_type_id     :=
    WORKPLACE_TYPE.get_id('B');
  r_logical_workplace.code                  :=
    &_USER..TEST.v_TEST_30_1;
  r_logical_workplace.name                  :=
    &_USER..TEST.v_TEST_80;
  set_row(r_logical_workplace);

  r_logical_workplace.id                    := get_id();
  r_logical_workplace.id_context            :=
    create_id_context(
      r_logical_workplace.parent_id,
      r_logical_workplace.id);
  r_logical_workplace.code                  :=
    &_USER..TEST.v_TEST_30_2;
  set_row(r_logical_workplace);

  &_USER..TEST.ok();
exception
  when OTHERS then
    &_USER..TEST.error(SQLERRM);
end;

&_USER..TEST.set_test('LOGICAL_WORKPLACE', 'get_code_context()', 5,
  'Get the code context for v_TEST_30_2');
begin
  pl(get_code_context(
    r_logical_workplace.id));

  &_USER..TEST.ok();
exception
  when OTHERS then
    &_USER..TEST.error(SQLERRM);
end;

```

```
  &_USER..TEST.set_test('LOGICAL_WORKPLACE', 'get_name_context()', 6,
    'Get the name context for v_TEST_30_2');
  begin
    pl(get_name_context(
      r_logical_workplace.id));

    &_USER..TEST.ok();
  exception
    when OTHERS then
      &_USER..TEST.error(SQLERRM);
  end;

  &_USER..TEST.set_test('LOGICAL_WORKPLACE', 'get_row()', 7,
    'Get the row using the id for v_TEST_30_2');
  begin
--  r_logical_workplace.id                   := NULL;
    r_logical_workplace.parent_id            := NULL;
    r_logical_workplace.id_context           := NULL;
    r_logical_workplace.workplace_type_id    := NULL;
    r_logical_workplace.code                 := NULL;
    r_logical_workplace.name                 := NULL;
    r_logical_workplace.active_date          := NULL;
    r_logical_workplace.inactive_date        := NULL;

    r_logical_workplace := get_row(r_logical_workplace);

    if r_logical_workplace.id_context is not NULL then
      &_USER..TEST.ok();
    else
      &_USER..TEST.error();
    end if;
  exception
    when OTHERS then
      &_USER..TEST.error(SQLERRM);
  end;

  &_USER..TEST.set_test('LOGICAL_WORKPLACE', 'get_row()', 8,
    'Get the row using the id_context for v_TEST_30_1');
  begin
    r_logical_workplace.id                   := NULL;
    r_logical_workplace.parent_id            := NULL;
    r_logical_workplace.id_context           :=
      v_id_context;
    r_logical_workplace.workplace_type_id    := NULL;
    r_logical_workplace.code                 := NULL;
    r_logical_workplace.name                 := NULL;
    r_logical_workplace.active_date          := NULL;
    r_logical_workplace.inactive_date        := NULL;

    r_logical_workplace := get_row(r_logical_workplace);

    if r_logical_workplace.id is not NULL then
      &_USER..TEST.ok();
    else
      &_USER..TEST.error();
    end if;
  exception
    when OTHERS then
      pl('v_id_context="'||v_id_context||'"');
      &_USER..TEST.error(SQLERRM);
  end;

  &_USER..TEST.set_test('LOGICAL_WORKPLACE', 'get_row()', 9,
    'Get the row using the code for v_TEST_30');
  begin
    r_logical_workplace.id                   := NULL;
    r_logical_workplace.parent_id            := NULL;
    r_logical_workplace.id_context           := NULL;
    r_logical_workplace.workplace_type_id    := NULL;
    r_logical_workplace.code                 :=
      &_USER..TEST.v_TEST_30;
    r_logical_workplace.name                 :=
      &_USER..TEST.v_TEST_80;
    r_logical_workplace.active_date          :=
      &_USER..TEST.d_TEST_19000101;
    r_logical_workplace.inactive_date        := NULL;

    r_logical_workplace := get_row(r_logical_workplace);

    if r_logical_workplace.id is not NULL then
      &_USER..TEST.ok();
    else
      &_USER..TEST.error();
    end if;
  exception
    when OTHERS then
      &_USER..TEST.error(SQLERRM);
  end;

  &_USER..TEST.set_test('LOGICAL_WORKPLACE', 'help()', 10,
    'Display the help text');
  begin
    help();

    &_USER..TEST.ok();
  exception
    when OTHERS then
      &_USER..TEST.error(SQLERRM);
  end;

  &_USER..TEST.set_test('LOGICAL_WORKPLACE', 'DELETE', 11,
    'Delete test entries');
```

```
512    begin
513      delete LOGICAL_WORKPLACES
514      where  code in (
515        &_USER..TEST.v_TEST_30_1,
516        &_USER..TEST.v_TEST_30_2);
517
518      delete LOGICAL_WORKPLACES
519      where  code = &_USER..TEST.v_TEST_30;
520
521      &_USER..TEST.ok();
522    exception
523      when OTHERS then
524        &_USER..TEST.error(SQLERRM);
525    end;
526
527    commit;
528    &_USER..TEST.set_test('LOGICAL_WORKPLACE', NULL, NULL, NULL);
529    &_USER..TEST.success();
530  end test;
```

The test unit for package `LOGICAL_WORKPLACE` is quite lengthy, so that's why I'm using a partial listing in Listing 8-11. You can find the entire listing in the download directory for Chapter 8.

Let's examine this content table package's test unit line by line:

- Lines 280 through 282 declare two variables that I use during the test.
- Line 285 outputs some feedback so the tester knows the test has actually executed.
- Line 287 clears any previous test data.
- Lines 287 through 304 start the SQL Circle of Life for my test entries by pre-deleting any that may still exist.
- Lines 306 through 319 test method `get_id()`.
- Lines 321 through 339 test method `create_id_context()`.
- Lines 341 through 360 test method `set_row()` by inserting a parent company row based on `TEST.v_TEST_30`. This begins the `INSERT` portion of the SQL Circle of Life.
- Lines 362 through 396 test method `set_row()` again, this time inserting two child rows, business units, based on `TEST.v_TEST_30_1` and `TEST.v_TEST_30_2`. This begins the `INSERT` or `UPDATE` portion of the SQL Circle of Life.
- Lines 398 through 408 test method `get_code_context()`. This starts the `SELECT` portion of the SQL Circle of Life.
- Lines 410 through 420 test method `get_name_context()`.
- Lines 422 through 444 test method `get_row()` using the primary key column.
- Lines 446 through 470 test method `get_row()` a second time, using the unique `id_context` column.
- Lines 472 through 497 test method `get_row()` a third time, this time using unique columns `code`, `name`, and `active_date`.

- Lines 499 through 508 test method `help()`.
- Lines 510 through 525 delete my test entries from the table. This brings me full circle on my SQL Circle of Life, from `DELETE` to `INSERT` to `UPDATE` to `SELECT`, and then back to `DELETE`.
- Finally, on lines 528 through 529, I record that the test unit executed successfully.

Did you notice that in this example, a content table package's test unit used the full SQL Circle of Life, whereas the code table package used only a portion of it? And did you see that every test was blocked—executed in its own PL/SQL block in order to catch any raised exceptions, rather than abort the test unit? Now it's your turn.

It's Your Turn to Test a Content Table Package

Now you will create a test unit for content table package `PHYSICAL_WORKPLACE`. In case you haven't noticed yet, table `PHYSICAL_WORKPLACES` is extremely similar to table `LOGICAL_WORKPLACES`, so you should be able to do some "code borrowing" to create a table package for `PHYSICAL_WORKPLACES`, including its test unit method `test()`. Please follow these steps.

1. Write the DDL scripts to create a table package for table `PHYSICAL_WORKPLACES` by borrowing the code from `LOGICAL_WORKPLACE`. This means you'll need to do some thinking about the differences between the two tables, and the resulting differences between the two packages, and then make the appropriate changes.
2. Save your specification script as `rps.physical_workplace.pks`, and your body script as `rp.physical_workplace.pkb`.
3. Compile the WORKER package because your solution may require it as a dependency: `rps.worker.pks` and `rps.worker.pkb.`
4. Compile your package.
5. Execute the test unit: `SQL> execute physical_workplace.test();`.
6. Use script `last_test_results.sql` to view the outcome of your test unit.
7. Add a test to your test unit to change the inactive date for business unit `TEST_TS.v_TEST_CODE_30_2` to `TEST_TS.d_TEST_19991231`.
8. Execute the test unit again: `SQL> execute physical_workplace.test();`.
9. Use script `last_test_results.sql` to view the outcome of your test unit.

Once again, I'm not going to show you my solution. But you can find it in the solutions download directory for Chapter 8.

Next, let's test an intersection table package.

Testing an Intersection Table Package

It's time to test the third category of the dynamic trio: an intersection table package. As in the previous example, Listing 8-12 is a partial code listing, showing the test unit from the full-blown, production-ready package for the `LOGICAL_ASSIGNMENTS` table. In case you've forgotten, `LOGICAL_ASSIGNMENTS` holds a list (a history) of logical assignments for a worker, such as which department the person worked for from one point in time to another. Its package specification lists the following methods that are specific to an intersection table package (or TYPE):

- get_logical_workplace(): Returns the LOGICAL_WORKPLACES assigned at the specified point in time
- is_active(): Returns TRUE if the specified worker has a logical assignment at the specified point in time

The package specification contains several methods in common with a content table package:

- get_row(): Returns a matching row depending on primary key column or unique key column value(s) set in the record passed to the method
- set_row(): Updates an existing matching row, using the same rules implemented by get_row() to find a matching row, or inserts a new row if a match is not found

And the package specification also has some methods that are universal to all table packages:

- get_id()Returns a newly allocated primary key value for the table
- help()Display help text for the package
- test()the package

Listing 8-12. The test( ) Method from Table Package Body LOGICAL_ASSIGNMENT,rps.logical_assignment.pkb

```
PROCEDURE test is

n_logical_workplace_id              LOGICAL_WORKPLACES.id%TYPE;
n_logical_workplace_id_1            LOGICAL_WORKPLACES.id%TYPE;
n_logical_workplace_id_2            LOGICAL_WORKPLACES.id%TYPE;
n_worker_id                         WORKERS.id%TYPE;
n_worker_id_1                       WORKERS.id%TYPE;
n_worker_id_2                       WORKERS.id%TYPE;
r_worker                            WORKERS%ROWTYPE;
r_logical_workplace                 LOGICAL_WORKPLACES%ROWTYPE;
r_logical_assignment                LOGICAL_ASSIGNMENTS%ROWTYPE;

begin
  pl('LOGICAL_ASSIGNMENT.test()');

  &_USER..TEST.clear('LOGICAL_ASSIGNMENT');

  -- In order to make entries into an Intersection table
  -- you first have to have entries in the two tables
  -- for which an entry will create an intersection
  &_USER..TEST.set_test('LOGICAL_ASSIGNMENT', 'DELETE', 0,
    'Delete existing test entries from LOGICAL_ASSIGNMENTS');
  begin
    delete LOGICAL_ASSIGNMENTS
    where  logical_workplace_id in (
    select logical_workplace_id
    from   LOGICAL_WORKPLACES
    where  code in (
      &_USER..TEST.v_TEST_30,
      &_USER..TEST.v_TEST_30_1,
      &_USER..TEST.v_TEST_30_2 ) );

    delete LOGICAL_ASSIGNMENTS
    where  worker_id in (
    select worker_id
    from   WORKERS
    where  external_id in (
      &_USER..TEST.v_TEST_30,
      &_USER..TEST.v_TEST_30_1,
      &_USER..TEST.v_TEST_30_2 ) );

    &_USER..TEST.ok();
  exception
    when OTHERS then
      &_USER..TEST.error(SQLERRM);
  end;

  &_USER..TEST.set_test('LOGICAL_ASSIGNMENT', 'DELETE', 1,
    'Delete existing test entries from LOGICAL_WORKPLACES');
  begin
    delete LOGICAL_WORKPLACES
    where  code in (
      &_USER..TEST.v_TEST_30_1,
      &_USER..TEST.v_TEST_30_2 );

    delete LOGICAL_WORKPLACES
    where  code in (
      &_USER..TEST.v_TEST_30 );

    &_USER..TEST.ok;
  exception
    when OTHERS then
      &_USER..TEST.error(SQLERRM);
  end;

  &_USER..TEST.set_test('LOGICAL_ASSIGNMENT', 'DELETE', 2,
    'Delete existing test entries from WORKERS');
  begin
    delete WORKERS
    where  external_id in (
      &_USER..TEST.v_TEST_30,
      &_USER..TEST.v_TEST_30_1,
      &_USER..TEST.v_TEST_30_2 );

    &_USER..TEST.ok();
  exception
    when OTHERS then
      &_USER..TEST.error(SQLERRM);
  end;

```

```
&_USER..TEST.set_test('LOGICAL_ASSIGNMENT', 'INSERT', 3,
  'Insert WORKERS test entries using set_row()');
begin
  r_worker.id               := WORKER.get_id();
  r_worker.worker_type_id := WORKER_TYPE.get_id('E');
  r_worker.external_id    := &_USER..TEST.v_TEST_30;
  r_worker.first_name     := &_USER..TEST.v_TEST_30;
  r_worker.middle_name    := &_USER..TEST.v_TEST_30;
  r_worker.last_name      := &_USER..TEST.v_TEST_30;
  r_worker.name           := WORKER.get_formatted_name(
    r_worker.first_name,
    r_worker.middle_name,
    r_worker.last_name);
  r_worker.birth_date     := to_date('19800101', 'YYYYMMDD');
  r_worker.gender_type_id := GENDER_TYPE.get_id('M');
  WORKER.set_row(r_worker);
  n_worker_id             := r_worker.id;

  r_worker.id               := WORKER.get_id();
  r_worker.worker_type_id := WORKER_TYPE.get_id('E');
  r_worker.external_id    := &_USER..TEST.v_TEST_30_1;
  r_worker.first_name     := &_USER..TEST.v_TEST_30_1;
  r_worker.middle_name    := &_USER..TEST.v_TEST_30_1;
  r_worker.last_name      := &_USER..TEST.v_TEST_30_1;
  r_worker.name           := WORKER.get_formatted_name(
    r_worker.first_name,
    r_worker.middle_name,
    r_worker.last_name);
  r_worker.birth_date     := to_date('19700101', 'YYYYMMDD');
  r_worker.gender_type_id := GENDER_TYPE.get_id('F');
  WORKER.set_row(r_worker);
  n_worker_id_1           := r_worker.id;

  r_worker.id               := WORKER.get_id();
  r_worker.worker_type_id := WORKER_TYPE.get_id('C');
  r_worker.external_id    := &_USER..TEST.v_TEST_30_2;
  r_worker.first_name     := &_USER..TEST.v_TEST_30_2;
  r_worker.middle_name    := &_USER..TEST.v_TEST_30_2;
  r_worker.last_name      := &_USER..TEST.v_TEST_30_2;
  r_worker.name           := WORKER.get_formatted_name(
    r_worker.first_name,
    r_worker.middle_name,
    r_worker.last_name);
  r_worker.birth_date     := to_date('19600101', 'YYYYMMDD');
  r_worker.gender_type_id := GENDER_TYPE.get_id('M');
  WORKER.set_row(r_worker);
  n_worker_id_2           := r_worker.id;

```

```
    &_USER..TEST.ok();
  exception
    when OTHERS then
      &_USER..TEST.error(SQLERRM);
  end;

  &_USER..TEST.set_test('LOGICAL_ASSIGNMENT', 'INSERT', 4,
    'Insert LOGICAL_WORKPLACES test entries using set_row()');
  begin
    r_logical_workplace.id                   :=
      LOGICAL_WORKPLACESS.get_id();
    r_logical_workplace.parent_id            := NULL;
    r_logical_workplace.id_context           :=
      LOGICAL_WORKPLACESS.create_id_context(
        r_logical_workplace.parent_id,
        r_logical_workplace.id);
    r_logical_workplace.workplace_type_id    :=
      WORKPLACE_TYPE_TS.get_id('C');
    r_logical_workplace.code                 := &_USER..TEST.v_TEST_30;
    r_logical_workplace.name                 := &_USER..TEST.v_TEST_80;
    r_logical_workplace.active_date          := &_USER..TEST.d_TEST_19000101;
    r_logical_workplace.inactive_date        := &_USER..TEST.d_TEST_99991231;
    LOGICAL_WORKPLACESS.set_row(r_logical_workplace);
    n_logical_workplace_id                   :=
      r_logical_workplace.id;

    r_logical_workplace.id                   :=
      LOGICAL_WORKPLACESS.get_id();
    r_logical_workplace.parent_id            :=
      n_logical_workplace_id;
    r_logical_workplace.id_context           :=
      LOGICAL_WORKPLACESS.create_id_context(
        r_logical_workplace.parent_id,
        r_logical_workplace.id);
    r_logical_workplace.workplace_type_id    :=
      WORKPLACE_TYPE_TS.get_id('B');
    r_logical_workplace.code                 := &_USER..TEST.v_TEST_30_1;
    r_logical_workplace.name                 := &_USER..TEST.v_TEST_80;
    r_logical_workplace.active_date          := &_USER..TEST.d_TEST_19000101;
    r_logical_workplace.inactive_date        := &_USER..TEST.d_TEST_99991231;
    LOGICAL_WORKPLACESS.set_row(r_logical_workplace);
    n_logical_workplace_id_1                 :=
      r_logical_workplace.id;

    r_logical_workplace.id :=
      LOGICAL_WORKPLACESS.get_id();
    r_logical_workplace.parent_id            :=
      n_logical_workplace_id;
    r_logical_workplace.id_context           :=
      LOGICAL_WORKPLACESS.create_id_context(
        r_logical_workplace.parent_id,
        r_logical_workplace.id);
    r_logical_workplace.workplace_type_id    :=
      WORKPLACE_TYPE_TS.get_id('B');
    r_logical_workplace.code                 := &_USER..TEST.v_TEST_30_2;
    r_logical_workplace.name                 := &_USER..TEST.v_TEST_80;
    r_logical_workplace.active_date          := &_USER..TEST.d_TEST_19000101;
    r_logical_workplace.inactive_date        := &_USER..TEST.d_TEST_99991231;
    LOGICAL_WORKPLACESS.set_row(r_logical_workplace);
    n_logical_workplace_id_2                 :=
      r_logical_workplace.id;

    &_USER..TEST.ok();
  exception
    when OTHERS then
      &_USER..TEST.error(SQLERRM);
  end;

  -- Now that I have entries in the two tables being intersected
  -- I can now start testing this package...
  &_USER..TEST.set_test('LOGICAL_ASSIGNMENT', 'get_id()', 5,
    'Allocate the next primary key value using get_id()');
  begin
    r_logical_assignment.id :=
      LOGICAL_ASSIGNMENT.get_id();

    if nvl(r_logical_assignment.id, 0) > 0 then
      &_USER..TEST.ok();
    else
      &_USER..TEST.error();
    end if;
  exception
    when OTHERS then
      &_USER..TEST.error(SQLERRM);
  end;

  &_USER..TEST.set_test('LOGICAL_ASSIGNMENT', 'set_row()', 6,
    'Insert history for v_TEST_30 using set_row()');
  begin
    r_logical_assignment.worker_id            := n_worker_id;
    r_logical_assignment.logical_workplace_id :=
      n_logical_workplace_id_2;
    r_logical_assignment.active_date          :=
      to_date('20000101', 'YYYYMMDD');
    r_logical_assignment.inactive_date        := NULL;
    LOGICAL_ASSIGNMENT.set_row(r_logical_assignment);

    &_USER..TEST.ok;
  exception
    when OTHERS then
      &_USER..TEST.error(SQLERRM);
  end;

```

```
&_USER..TEST.set_test('LOGICAL_ASSIGNMENT', 'set_row()', 7,
  'Insert history for V_TEST_30_1 using set_row()');
begin
  r_logical_assignment.id :=
    LOGICAL_ASSIGNMENT.get_id();
  r_logical_assignment.worker_id            := n_worker_id_1;
  r_logical_assignment.logical_workplace_id :=
    n_logical_workplace_id_1;
  r_logical_assignment.active_date          :=
    to_date('19900101', 'YYYYMMDD');
  r_logical_assignment.inactive_date        :=
    to_date('19991231', 'YYYYMMDD');
  LOGICAL_ASSIGNMENT.set_row(r_logical_assignment);

  r_logical_assignment.id :=
    LOGICAL_ASSIGNMENT.get_id();
  r_logical_assignment.worker_id            := n_worker_id_1;
  r_logical_assignment.logical_workplace_id :=
    n_logical_workplace_id_2;
  r_logical_assignment.active_date          :=
    to_date('20000101', 'YYYYMMDD');
  r_logical_assignment.inactive_date        := NULL;
  LOGICAL_ASSIGNMENT.set_row(r_logical_assignment);

  &_USER..TEST.ok;
exception
  when OTHERS then
    &_USER..TEST.error(SQLERRM);
end;

&_USER..TEST.set_test('LOGICAL_ASSIGNMENT', 'set_row()', 8,
  'Insert history for V_TEST_30_2 using set_row()');
begin
  r_logical_assignment.id :=
    LOGICAL_ASSIGNMENT.get_id();
  r_logical_assignment.worker_id            := n_worker_id_2;
  r_logical_assignment.logical_workplace_id :=
    n_logical_workplace_id_1;
  r_logical_assignment.active_date          :=
    to_date('19800101', 'YYYYMMDD');
  r_logical_assignment.inactive_date        :=
    to_date('19891231', 'YYYYMMDD');
  LOGICAL_ASSIGNMENT.set_row(r_logical_assignment);

  r_logical_assignment.id :=
    LOGICAL_ASSIGNMENT.get_id();
  r_logical_assignment.worker_id            := n_worker_id_2;
  r_logical_assignment.logical_workplace_id :=
    n_logical_workplace_id_2;
  r_logical_assignment.active_date          :=
    to_date('19900101', 'YYYYMMDD');
    r_logical_assignment.inactive_date        :=
      to_date('19901231', 'YYYYMMDD');
    LOGICAL_ASSIGNMENT.set_row(r_logical_assignment);

    &_USER..TEST.ok;
  exception
    when OTHERS then
      &_USER..TEST.error(SQLERRM);
  end;

  -- Commit the deletes and inserts
  commit;

  &_USER..TEST.set_test('LOGICAL_ASSIGNMENT',
    'get_logical_workplace()', 9,
    'Get the current logical workplace for v_TEST_30');
  begin
    r_logical_workplace := NULL;
    r_logical_workplace := get_logical_workplace(n_worker_id);

    if nvl(r_logical_workplace.id, 0) > 0 then
      &_USER..TEST.ok();
    else
      &_USER..TEST.error();
    end if;
  exception
    when OTHERS then
      &_USER..TEST.error(SQLERRM);
  end;

  &_USER..TEST.set_test('LOGICAL_ASSIGNMENT',
    'get_logical_workplace()', 10,
    'Get the logical workplace on 6/30/1995 for v_TEST_30_1');
  begin
    r_logical_workplace := NULL;
    r_logical_workplace := get_logical_workplace(
      n_worker_id_1,
      to_date('19950630', 'YYYYMMDD'));

    if nvl(r_logical_workplace.id, 0) > 0 then
      &_USER..TEST.ok();
    else
      &_USER..TEST.error();
    end if;
  exception
    when OTHERS then
      &_USER..TEST.error(SQLERRM);
  end;

  &_USER..TEST.set_test('LOGICAL_ASSIGNMENT',
    'get_logical_workplace()', 11,
    'Get the logical workplace on 6/30/1995 for v_TEST_30_2');
  begin
    -- this should fail
    r_logical_workplace := NULL;
    r_logical_workplace := get_logical_workplace(
      n_worker_id_2,
      to_date('19950630', 'YYYYMMDD'));

    if nvl(r_logical_workplace.id, 0) > 0 then
      &_USER..TEST.error();
    else
      &_USER..TEST.ok();
    end if;
  exception
    when NO_DATA_FOUND then
      &_USER..TEST.ok();
    when OTHERS then
      &_USER..TEST.error(SQLERRM);
  end;

  &_USER..TEST.set_test('LOGICAL_ASSIGNMENT', 'help()', 12,
    'Test help()');
  begin
    help();

    &_USER..TEST.ok;
  exception
    when OTHERS then
      &_USER..TEST.error(SQLERRM);
  end;

  &_USER..TEST.set_test('LOGICAL_ASSIGNMENT', 'is_active()', 13,
    'Is there an active assignment on 6/30/1995 for v_TEST_30?');
    -- No
  begin
    if is_active(n_worker_id, to_date('19950630', 'YYYYMMDD')) then
      &_USER..TEST.error();
    else
      &_USER..TEST.ok();
    end if;
  exception
    when OTHERS then
      &_USER..TEST.error(SQLERRM);
  end;

  &_USER..TEST.set_test('LOGICAL_ASSIGNMENT', 'is_active()', 14,
    'Is there an active assignment on 6/30/1995 for v_TEST_30_1?');
    -- Yes
  begin
    if is_active(n_worker_id_1, to_date('19950630', 'YYYYMMDD')) then
      &_USER..TEST.ok();
  else
    &_USER..TEST.error();
  end if;
exception
  when OTHERS then
    &_USER..TEST.error(SQLERRM);
end;

&_USER..TEST.set_test('LOGICAL_ASSIGNMENT', 'is_active()', 15,
  'Is there currently an active assignment for v_TEST_30_2?');
  -- No
begin
  if is_active(n_worker_id_2) then
    &_USER..TEST.error();
  else
    &_USER..TEST.ok();
  end if;
exception
  when OTHERS then
    &_USER..TEST.error(SQLERRM);
end;

-- Now clean up after the tests by deleting the test entries
&_USER..TEST.set_test('LOGICAL_ASSIGNMENT', 'DELETE', 16,
  'Delete existing test entries from LOGICAL_ASSIGNMENTS');
begin
  delete LOGICAL_ASSIGNMENTS
  where  logical_workplace_id in (
  select logical_workplace_id
  from   LOGICAL_WORKPLACES
  where  code in (
    &_USER..TEST.v_TEST_30,
    &_USER..TEST.v_TEST_30_1,
    &_USER..TEST.v_TEST_30_2 ) );

  delete LOGICAL_ASSIGNMENTS
  where  worker_id in (
  select worker_id
  from   WORKER_T
  where  external_id in (
    &_USER..TEST.v_TEST_30,
    &_USER..TEST.v_TEST_30_1,
    &_USER..TEST.v_TEST_30_2 ) );

  &_USER..TEST.ok();
exception
  when OTHERS then
    &_USER..TEST.error(SQLERRM);
end;

```

```
629    &_USER..TEST.set_test('LOGICAL_ASSIGNMENT', 'DELETE', 17,
630      'Delete existing test entries from LOGICAL_WORKPLACES');
631    begin
632      delete LOGICAL_WORKPLACES
633      where  code in (
634        &_USER..TEST.v_TEST_30_1,
635        &_USER..TEST.v_TEST_30_2 );
636
637      delete LOGICAL_WORKPLACES
638      where  code in (
639        &_USER..TEST.v_TEST_30 );
640
641      &_USER..TEST.ok;
642    exception
643      when OTHERS then
644        &_USER..TEST.error(SQLERRM);
645    end;
646
647    &_USER..TEST.set_test('LOGICAL_ASSIGNMENT', 'DELETE', 18,
648      'Delete existing test entries from WORKERS');
649    begin
650      delete WORKERS
651      where  external_id in (
652        &_USER..TEST.v_TEST_30,
653        &_USER..TEST.v_TEST_30_1,
654        &_USER..TEST.v_TEST_30_2 );
655
656      &_USER..TEST.ok();
657    exception
658      when OTHERS then
659        &_USER..TEST.error(SQLERRM);
660    end;
661
662    commit;
663    &_USER..TEST.set_test('LOGICAL_ASSIGNMENT', NULL, NULL, NULL);
664    &_USER..TEST.success();
665  end test;
```

The important point about an intersection table package is that it is dependent on test entries in the two tables it intersects. So you'll see that on lines 215 through 392, I must start out by deleting any test entries in the "intersected" tables, `WORKERS` and `LOGICAL_WORKPLACES`, and then I must add entries to these tables in order to have entries from which to establish an intersection entry. So every intersection table package must also insert and delete entries from the tables on which it is depends. Now it's your turn to work on an intersection table package.

It's Your Turn to Test an Intersection Table Package

You will now create a test unit for intersection table package `PHYSICAL_ASSIGNMENT`. Just as in the last exercise, the corresponding table for this exercise, `PHYSICAL_ASSIGNMENTS`, is extremely similar to table `LOGICAL_ASSIGNMENTS`, so you should once again be able to do some "code borrowing" to create a table package for `PHYSICAL_ASSIGNMENTS`, including its test unit method `test()`. Follow these steps.

1. Write the DDL scripts to create a table package for table `PHYSICAL_ASSIGNMENTS` by borrowing the code from `LOGICAL_ASSIGNMENT`.
2. Save your specification script as `rps.physical_assignment.pks`, and your body script as `rps.physical_assignment.pkb`.
3. Compile your package.
4. Execute the test unit: `SQL> execute physical_assignment.test();`.
5. Use script `last_test_results.sql` to view the outcome of your test unit.

Once again, I'm not going to show you my solution. But you can find it in the solutions download directory for Chapter 8.

So just how different can it be to test a TYPE instead of a package? Let's find out.

Testing a Type

Testing a TYPE is not all that different from testing a package. The only significant difference is that when you declare the `test()` method in a TYPE, it must be declared as a STATIC method. And when you code the method, you must remember that you'll need to work with a variable of that TYPE, and instance, as well as the TYPE when performing your testing. If you don't have an instance of the TYPE, you won't be able to access and test all its methods.

Listing 8-13 is a partial listing of the TYPE TEST, an object-relational testing tool. This listing shows only the test unit for the TYPE itself.

Listing 8-13. The Test Unit from TYPE TEST, ops.test.tpb

```
STATIC PROCEDURE "test" is

n_number                              number;
o_test                                TEST;

begin
  pl('TEST.test()');

  -- A defect requires the schema owner
  &_USER..TEST.clear('TEST');

  o_test := new TEST();
  o_test.set_test('TEST', NULL, 1,
    'Is get_test_N equal to N?');
  if TEST.get_test_N = 'N' then
    o_test.success();
  else
    o_test.error();
  end if;

  o_test.set_test('TEST', NULL, 2,
    'Is the length of get_test_N equal to 1?');
  if nvl(length(TEST.get_test_N), 0) = 1 then
    o_test.success();
  else
    o_test.error();
  end if;

  o_test.set_test('TEST', NULL, 3,
    'Is get_test_Y equal to Y?');
  if TEST.get_test_Y = 'Y' then
    o_test.success();
  else
    o_test.error();
  end if;

  o_test.set_test('TEST', NULL, 4,
    'Is the length of get_test_Y equal to 1?');
  if nvl(length(TEST.get_test_Y), 0) = 1 then
    o_test.success();
  else
    o_test.error();
  end if;

  o_test.set_test('TEST', NULL, 5,
    'Is the length of get_test_30 equal to 30?');
  if nvl(length(TEST.get_test_30), 0) = 30 then
    o_test.success();
  else
    o_test.error();
  end if;

  o_test.set_test('TEST', NULL, 6,
    'Is the length of get_test_30_1 equal to 30?');
  if nvl(length(TEST.get_test_30_1), 0) = 30 then
    o_test.success();
  else
    o_test.error();
  end if;

  o_test.set_test('TEST', NULL, 7,
    'Is the length of get_test_30_2 equal to 30?');
  if nvl(length(TEST.get_test_30_2), 0) = 30 then
    o_test.success();
  else
    o_test.error();
  end if;

  o_test.set_test('TEST', NULL, 8,
    'Is the length of get_test_80 equal to 80?');
  if nvl(length(TEST.get_test_80), 0) = 80 then
    o_test.success();
  else
    o_test.error();
  end if;

```

```
    o_test.set_test('TEST', NULL, 9,
      'Is the length of get_test_100 equal to 100?');
    if nvl(length(TEST.get_test_100), 0) = 100 then
      o_test.success();
    else
      o_test.error();
    end if;

    o_test.set_test('TEST', NULL, 10,
      'Is the length of get_test_2000 equal to 2000?');
    if nvl(length(TEST.get_test_2000), 0) = 2000 then
      o_test.success();
    else
      o_test.error();
    end if;

    o_test.set_test('TEST', 'get_id', 11,
      'Does get_id() work?');
    begin
      n_number := TEST.get_id();
      if n_number > 0 then
        o_test.success();
      else
        o_test.error();
      end if;
    exception
      when OTHERS then
        o_test.error(SQLERRM);
    end;

    o_test.set_test('TEST', 'help', 12,
      'Does help() work?');
    begin
      &_USER..TEST.help();
      raise_application_error(-20999, 'Testing the error routine');
      o_test.success();
    exception
      when OTHERS then
        o_test.error(SQLERRM);
    end;

    o_test.set_test('TEST', NULL, NULL, NULL);
    o_test.success();
  end "test";...
```

First, notice that I've declared the method as a STATIC procedure. This means it will be accessible from the TYPE itself, not through an instance of the type.

Second, on line 419, I declare a variable of the TYPE and then on line 427, I set the variable to a new instance of the TYPE. Then I use this instance when calling MEMBER methods in the test unit. Beyond those two major changes, the differences in methods test() in package TEST and TYPE TEST are only semantic (as in the variations in the programmer-created language). One last detail! I had to test the method "test" in order to get around a name space error. I could have named it test_ or TEST_ or anything other than the name of the TYPE itself, but I like to keep things obvious, so I forced Oracle to name it test in lower case.

Now that you have seen an example of testing a TYPE, it's your turn.

It's Your Turn to Test a Type

Now you'll select any TYPE that you've created so far, and code its test unit method test(). However, you'll use your object-relational testing tool. This means you'll also need to modify the SQL*Plus report last_test_results.sql so it queries your testing tool's object table TESTS. This time, I'm not even going to give you any steps. You've seen enough examples that you should be able to list the steps you need to complete in order to do this exercise. Good skill!

Now, it's time we move on to the automation of testing.

Automating Testing

Do you remember that in the beginning of this chapter I promised you a framework for automating your testing? Well, by utilizing information from Oracle's data dictionary and writing another program unit that calls all your test units, you can execute one PL/SQL method that will in turn execute every test() method you've written, and then report on the test results.

There are several data dictionary views that have information about packages, TYPEs, and their methods. The three best suited to my needs of identifying every package and TYPE that does and does not have a test() method are SYS.ALL_ARGUMENTS, SYS.USER_PROCDURES, and SYS.USER_TYPE_METHODS. The following are SQL*Plus descriptions of the views:

```
SYS.USER_ARGUMENTS
 Name                                      Null?    Type
 ----------------------------------------- -------- ---------------------------
 OBJECT_NAME                                        VARCHAR2(128)
 PACKAGE_NAME                                       VARCHAR2(128)
 OBJECT_ID                                 NOT NULL NUMBER
 OVERLOAD                                           VARCHAR2(40)
 SUBPROGRAM_ID                                      NUMBER
 ARGUMENT_NAME                                      VARCHAR2(128)
 ...
SYS.USER_TYPE_METHODS
 Name                                      Null?    Type
 ----------------------------------------- -------- ---------------------------
 TYPE_NAME                                 NOT NULL VARCHAR2(128)
 METHOD_NAME                               NOT NULL VARCHAR2(128)
 METHOD_NO                                 NOT NULL NUMBER
 METHOD_TYPE                                        VARCHAR2(6)
 PARAMETERS                                NOT NULL NUMBER
 ...
```

```
SYS.USER_PROCEDURES
 Name                                      Null?    Type
 ----------------------------------------- -------- -------------
 OBJECT_NAME                                        VARCHAR2(128)
 PROCEDURE_NAME                                     VARCHAR2(128)
 OBJECT_ID                                          NUMBER
 SUBPROGRAM_ID                                      NUMBER
 OVERLOAD                                           VARCHAR2(40)
 OBJECT_TYPE                                        VARCHAR2(13)
 ...
```

Using the information provided by these views, I can write a query that does the following:

- Lists the name of every package and TYPE that has a `test()` method
- Lists the name of every package and TYPE that does not have a `test()` method

If I couple that information with the output of the test units that is stored in table TESTS, I can write a query that does the following:

- Lists information about every test that failed
- Lists the name of every package or TYPE where its test method failed

So the information provided by the data dictionary views and the testing tool's table TESTS arms me with all the information I need to automate the testing of the PL/SQL program units and to report on the test results. Therefore, to automate the testing of the PL/SQL program units, all I need to do is follow these two simple steps.

1. Add a test unit method `test()` to every PL/SQL package or TYPE definition.
2. Execute a process to execute each test unit method and report the results.

You already know how to do the first step, so let's see an example of how to do the second step.

Automate Test Processing

Listing 8-14 is an example of a PL/SQL program unit that executes all coded `test()` methods for the current schema, and then reports on the results. It queries view SYS.ALL_ARGUMENTS to get a list of packages and TYPEs that do and do not have `test()` methods. It executes each `test()` method, recording the results of execution, as the test method itself records the results of each of its tests. Finally, it reports the results of the tests.

Listing 8-14. An Example of a Test Unit Processing, test.sql

```
rem test.sql
rem by Donald J. Bales on 2014-10-20
rem An anonymous PL/SQL procedure to execute all test units
rem and to report on the results of each test.

declare

-- Get the names of all packages and types that have a test unit
cursor c_test is
select p.object_name package_name
from   SYS.USER_PROCEDURES p
```

```
where  p.object_type           = 'PACKAGE'
and    upper(p.procedure_name) = 'TEST'
and not exists (
select 1
from   SYS.USER_ARGUMENTS x
where  x.package_name          = p.object_name
and    x.object_name           = p.procedure_name)
UNION
select m.type_name package_name
from   SYS.USER_TYPE_METHODS m
where  upper(m.method_name)    = 'TEST'
and    m.parameters            = 0
order by 1;

-- Get the names of all packages and types that don't have a test unit
cursor c_missing is
(select p.object_name package_name
from   SYS.USER_PROCEDURES p
where  p.object_type           = 'PACKAGE'
UNION
select m.type_name package_name
from   SYS.USER_TYPE_METHODS m )
MINUS
(select p.object_name package_name
from   SYS.USER_PROCEDURES p
where  upper(p.procedure_name) = 'TEST'
and not exists (
select 1
from   SYS.USER_ARGUMENTS x
where  x.package_name          = p.object_name
and    x.object_name           = p.procedure_name)
UNION
select m.type_name package_name
from   SYS.USER_TYPE_METHODS m
where  upper(m.method_name)    = 'TEST'
and    m.parameters            = 0)
order by 1;

-- Get the names of all packages and types that have test unit errors
cursor c_error is
select object_name||
         decode(substr(method_name, -1, 1), ')', '.', ' ')||
         method_name object_method,
       test_number,
       result
from   TESTS
where  result <> 'OK'
and    result <> 'SUCCESS'
order by 1;

```

```
TYPE error_message_table is table of varchar2(32767)
index by binary_integer;

n_error_message                       number := 0;
n_object_method_width                 number := 39;
n_result_width                        number := 29;
n_status                              number;
n_test_number_width                   number := 5;

t_error_message                       error_message_table;

v_line                                varchar2(32767);

begin
  -- execute the test units
  for r_test in c_test loop
    begin
      execute immediate 'begin '||r_test.package_name||'.test(); end;';
    exception
      when OTHERS then
        n_error_message := n_error_message + 1;
        t_error_message(n_error_message) :=
          r_test.package_name||'.test() '||SQLERRM;
    end;
  end loop;
  -- Empty the output buffer
  loop
    SYS.DBMS_OUTPUT.get_line(v_line, n_status);
    if nvl(n_status, 0) < 1 then
      exit;
    end if;
  end loop;
  -- Show the test units that had errors
  for r_error in c_error loop
    if c_error%rowcount = 1 then
      pl(chr(9));
      pl('THE FOLLOWING OBJECT''S TEST UNITS HAD ERRORS:');
      pl(chr(9));
      pl(
        rpad(
          substr('OBJECT/METHOD',
            1, n_object_method_width),
          n_object_method_width, ' ')||
        ' '||
        lpad(
          substr('TEST#',
            1, n_test_number_width),
          n_test_number_width, ' ')||
        ' '||
        rpad(
          substr('ERROR',
            1, n_result_width),
          n_result_width, ' ')
        );
      pl(
        rpad(
          substr('-------------',
            1, n_object_method_width),
          n_object_method_width, '-')||
        ' '||
        lpad(
          substr('-----',
            1, n_test_number_width),
          n_test_number_width, '-')||
        ' '||
        rpad(
          substr('-----',
            1, n_result_width),
          n_result_width, '-')
        );
    end if;
    pl(
      rpad(
        substr(r_error.object_method,
          1, n_object_method_width),
        n_object_method_width, ' ')||
      ' '||
      lpad(
        substr(ltrim(to_char(r_error.test_number)),
          1, n_test_number_width),
        n_test_number_width, ' ')||
      ' '||
      rpad(
        substr(r_error.result,
          1, n_result_width),
        n_result_width, ' ')
      );
  end loop;
  -- Show the test units that failed to run
  if t_error_message.count > 0 then
    for i in t_error_message.first..t_error_message.last loop
      if i = t_error_message.first then
        pl(chr(9));
        pl('THE FOLLOWING OBJECT''S TEST UNITS FAILED:');
      end if;
      pl(chr(9));
      pl(t_error_message(i));
    end loop;
  end if;
  -- Show the object that missing test units
  for r_missing in c_missing loop
    if c_missing%rowcount = 1 then
      pl(chr(9));
```

```
165        pl('THE FOLLOWING OBJECTS ARE MISSING TEST UNITS:');
166        pl(chr(9));
167      end if;
168      pl(r_missing.package_name);
169    end loop;
170  end;
171  /
```

Let’s break this listing down line by line:

- Lines 9 through 24 declare a cursor, `c_test`, against data dictionary views `SYS.USER_ARGUMENTS`, `SYS.USER_PROCEDURES`, and `SYS.USER_TYPE_METHODS`, which gives me a list of packages and `TYPE`s that have a method `test()`.
- Lines 27 through 48 declare second cursor, `c_missing`, against `SYS.USER_ARGUMENTS`, `SYS.USER_PROCEDURES`, and `SYS.USER_TYPE_METHODS`which gives me a list of packages and `TYPE`s that do not have a `test()` method.
- Lines 51 through 60 declare a cursor, `c_error`, against table `TESTS` that lists all the individual tests that failed during the current test run.
- Lines 62 and 63 declare a PL/SQL table `TYPE`, `error_message_table`, which I will use to declare an array of exceptions raised during the execution of each `test()` method.
- Lines 77 through 86 execute a cursor for loop, where I call each package and `TYPE`’s `test()` method. I’ve blocked the dynamic call to each method, so I can capture and later report on any raised exceptions (`test()` method failures).
- Lines 88 through 93 use a manual for loop to empty the `SYS.DBMS_OUTPUT.put_line()` buffer after having executed every test unit method. I do this to throw out any `put_line()` messages generated by each test unit.
- Lines 95 through 149 report, using `put_line()`, about any test failures during the test run.
- Lines 151 through 160 report any `test()` method failures during the test run. I could have created a fourth cursor to show me the `test()` methods that failed during execution, but I’m already getting this information from the blocked dynamic PL/SQL call to each method on lines 77 through 86.
- Lines 162 through 169 list any packages or `TYPE`s that do not have a test unit method `test()`.

The only thing this procedure cannot do is determine whether or not a programmer has actually taken the time to code the test unit. The following is sample output from this procedure while I was coding in my environment:

```
SQL> @test.sql

THE FOLLOWING OBJECT'S TEST UNITS HAD ERRORS:

OBJECT/METHOD                          TEST# ERROR
-------------------------------------- ----- ----------------------------
LOGICAL_WORKPLACE.GET_ROW()                7 ORA-01403: no data found
LOGICAL_WORKPLACE.GET_ROW()                8 ORA-01403: no data found
LOGICAL_WORKPLACE.GET_ROW()                9 ORA-01403: no data found
LOGICAL_WORKPLACE.SET_ROW()                4 ORA-01403: no data found
LOGICAL_WORKPLACE.SET_ROW()                3 ORA-20003: ORA-01400: cannot
```

```
THE FOLLOWING OBJECTS ARE MISSING TEST UNITS:

DEBUG
PARAMETER
SCOPE

PL/SQL procedure successfully completed.
```

The first part of the report, test unit errors, shows that exception ORA-20003 was raised while testing method LOGICAL_WORKPLACE.SET_ROW(). This information tells me to go directly to package LOGICAL_WORKPLACE to examine what might be wrong with the test or the method set_row().

The second part of the report, missing test units, lists the packages and TYPEs that are missing a test unit method. With this information, I can add the task of coding test units for these to my to-do list. Don't ignore this list. Anything not tested is something that can and probably will produce errors.

In practice, on an enterprise application, I've seen a test unit process like this take two to three hours to execute. In addition, it always finds one to three errors in each newly coded package. As time goes by, and new defects are detected by end users and others, it's your responsibility to go back and update the test unit method to test for any newly reported defect. Using this kind of automated testing, combined with consistently adding any new test cases, you can make your persistence layer statistically error-free.

I don't think that the "processing" procedure just described should be external (losable) to the database/objectbase. Instead, it should be added to package TEST as method process(). That way, you will be able to test any package or procedure by calling its test() method, and you can test the entire persistence layer by calling TEST.process(). Now that's a powerful testing tool!

It's Your Turn to Automate Test Processing

For your final assignment in this chapter, modify your object-relational testing tool to add STATIC procedure process(), which will execute a program unit similar to test.sql using your testing tool's result table TESTS. Then execute TEST.process() to see the results of testing your object-relational persistence layer.

Summary

My hope is that you now realize how important, and easy, it is to properly test your PL/SQL program units. A couple of hours of extra coding up front for each program unit can save your hundreds of hours of troubleshooting later on. More important, it will save your end users from hundreds of hours of lost productivity and frustration.

I've shown you the coding patterns involved when coding test units for SQL and PL/SQL. I've shown you how to create a relational and object-relational testing tool that can automatically test every program unit and access to their associated tables in your database by executing one procedure: process().

My final suggestion is that you decide on the use of a relational or an object-relation testing tool and then add the required test units that access that tool to each and every program unit you write.
As a developer of enterprise applications, I have historically had low error rates. I've achieved them by incorporating testing into the process of developing. Assume nothing. Test everything.

Just how important is it to test everything? During the coding of the examples for this book, this testing framework found an average of two errors for each package or TYPE. And I've been coding in PL/SQL for more than 20 years!

There's one last tactic you can employ to help prevent errors: provide access to good documentation to your developers. And that's what I'm going to cover in the next chapter.

CHAPTER 9

Documenting

Once, when I was a young executive, I reported to the chief financial officer (CFO). Upon arriving at the new organization, I formulated a strategy to bring the company's computer technology up to date. Part of that plan was to provide each computer user in the organization with a computer that best suited that user's needs. This meant that executive administrators got high-powered desktop computers, while executives and consultants were armed with top-of-the-line notebooks. Not only did we make sure everyone was using the latest office automation software and groupware, we also built a state-of-the-art Executive Information System (EIS) that was tightly integrated with the accounting system.

The management team had no issues with authorizing capital expenditures for the computer hardware. Nor did the team balk about the investment in software. But when it came to spending money to provide personnel with training so they could take advantage of the new hardware and software, I could not get approval from the CFO. Why? He explained to me that any time you train people, they just move on to a better-paying job, so training was counterproductive.

To say the least, I was amazed and dismayed at the same time. I thought to myself, and further argued with the management team, "Why did you invest in hardware and software if you never had any intention of training people how to use it?" No amount of arguing could move them on this issue. So from my perspective, they attained minimal gains from their investment in hardware and software. Do you find this attitude as strange as I do?

If you do, then you'll logically also have to agree with me that the development of any reusable software component has no value if you don't inform your programming staff members that the reusable component exists, and then educate them on how to use the component. At the very least, you should have some documentation they can refer to in order to find out what is available and how to use it!

Here's a second story. I once worked on a project for a major retailer to package some of its software for distribution to regional offices in the company. As part of that work, I wrote the (missing) technical reference and end-user tutorial documentation so the support staff could figure out how to support the software, and the end users would know how to use the software. A novel idea, don't you think? When it came time to send the software to each regional office, I was told that I first had to remove the documentation from the distribution. Why? Because the documentation held trade secrets that the personnel of the firm could not be trusted with. Argh!

If I ran a tool and die company that made nuts and bolts, created a catalog of available parts, but then never distributed it to perspective customers, I would be out of business in no time at all. If I ran an integrated circuit manufacturing firm, but didn't let anyone know that the firm existed and what electronic components it manufactured, once again, I would be filing for bankruptcy in less than a month.

What's my point? The day and age of software components has been here for more than 30 years, but reuse depends on the distribution of documentation. Since the first machine language subroutine was written, that subroutine has been available as a reusable component. Since the first procedure programming language library was created, that library has been available as a reusable component. Since object-oriented languages first appeared on the scene, the creation of software components was made simple.

If you've created a web application using PHP, Python Django, or Ruby on Rails, you know how important API documentation is in order to use those programming languages or frameworks. If you've programmed in Java, you've used the Java Foundation Classes (JFC) or Java Enterprise Edition (JEE) framework. If you've programmed in PL/SQL, you've at least used the standard library. I could go on and on. These are all reusable software components.

If you're developing a solution to a business problem, you should have use-case narratives, use-case diagrams, process-flow diagrams, and so on to use a set of requirements for doing your programming work. During the creation of these documents, it should have become obvious what higher-level abstractions and patterns could be discerned from the end user's requirements. Using these abstractions and patterns, you can create components that are reusable through inheritance.

Furthermore, while developing, if you find yourself writing the same SQL statement or PL/SQL routine more than once, it's time to abstract that repeated pattern into a reusable component that can then be used by other components in your solution. If you do this, great! But if you don't document the existence of each and every component, what it does, and how to use it, it doesn't exist outside the realm of your own mind. So you must—I mean *must*—document as you go. And second, you must provide other possible users a means to know that reusable (even non-reusable) components exist, what they can do, and how to use them. And that is what this chapter is all about.

In this chapter, I'll cover the following:

- Documentation that cannot be lost or thrown away
- Documentation that is available on demand
- Distributable documentation

Let's start with documentation that cannot be lost or thrown away.

Indestructible Documentation

What a silly notion—indestructible documentation. Or perhaps not? You know of Murphy's Law, don't you? "Anything that can go wrong will go wrong." It's easy to lose your documentation if it's stored on a file system that is not part of the ongoing application.

One beautiful thing about PL/SQL is that the source code is permanently stored in the database. The only way to lose it is to lose the database, and at that point, who needs the source code?

Another beautiful thing about PL/SQL is that most executable code resides in either a package or TYPE specification. And these specifications allow you to comment the code. So the easiest way to document your packages and TYPEs is to put meaningful and properly formatted comments in each object's specification. At the very least, the text of the specification will then be available via the SYS.USER_SOURCE view.

But before you make up your mind on what to document, how to document it, and where to put any documentation you do create, let's look at what SQL*Plus provides for package and TYPE documentation.

SQL*Plus Documentation Tools

In SQL*Plus, you can use the describe command to determine the format of a table or the call specifications of a function, procedure, package, or TYPE. Here's an example of using describe on the table WORKER_TYPE_T:

```
SQL> desc WORKER_TYPES

WORKER_TYPES
```

```
 Name                                      Null?    Type
 ----------------------------------------- -------- ------------
 ID                                        NOT NULL NUMBER(38)
 CODE                                      NOT NULL VARCHAR2(30)
 DESCRIPTION                               NOT NULL VARCHAR2(80)
 ACTIVE_DATE                               NOT NULL DATE
 INACTIVE_DATE                             NOT NULL DATE
```

And here's an example of using the describe command on the package WORKER_TYPE:

```
SQL> desc WORKER_TYPES
```

```
WORKER_TYPES
 Name                                      Null?    Type
 ----------------------------------------- -------- --------------------
 ID                                        NOT NULL NUMBER(38)
 CODE                                      NOT NULL VARCHAR2(30)
 DESCRIPTION                               NOT NULL VARCHAR2(80)
 ACTIVE_DATE                               NOT NULL DATE
 INACTIVE_DATE                             NOT NULL DATE

SQL> @desc WORKER_TYPE
WORKER_TYPE
PROCEDURE GET_CODE_DESCR
 Argument Name                  Type                    In/Out Default?
 ------------------------------ ----------------------- ------ --------
 AIN_ID                         NUMBER(38)              IN
 AOV_CODE                       VARCHAR2(30)            OUT
 AOV_DESCRIPTION                VARCHAR2(80)            OUT
PROCEDURE GET_CODE_ID_DESCR
 Argument Name                  Type                    In/Out Default?
 ------------------------------ ----------------------- ------ --------
 AIOV_CODE                      VARCHAR2(30)            IN/OUT
 AON_ID                         NUMBER(38)              OUT
 AOV_DESCRIPTION                VARCHAR2(80)            OUT
 AID_ON                         DATE                    IN
PROCEDURE GET_CODE_ID_DESCR
 Argument Name                  Type                    In/Out Default?
 ------------------------------ ----------------------- ------ --------
 AIOV_CODE                      VARCHAR2(30)            IN/OUT
 AON_ID                         NUMBER(38)              OUT
 AOV_DESCRIPTION                VARCHAR2(80)            OUT
FUNCTION GET_ID RETURNS NUMBER(38)
FUNCTION GET_ID RETURNS NUMBER(38)
 Argument Name                  Type                    In/Out Default?
 ------------------------------ ----------------------- ------ --------
 AIV_CODE                       VARCHAR2(30)            IN
PROCEDURE HELP
PROCEDURE TEST
```

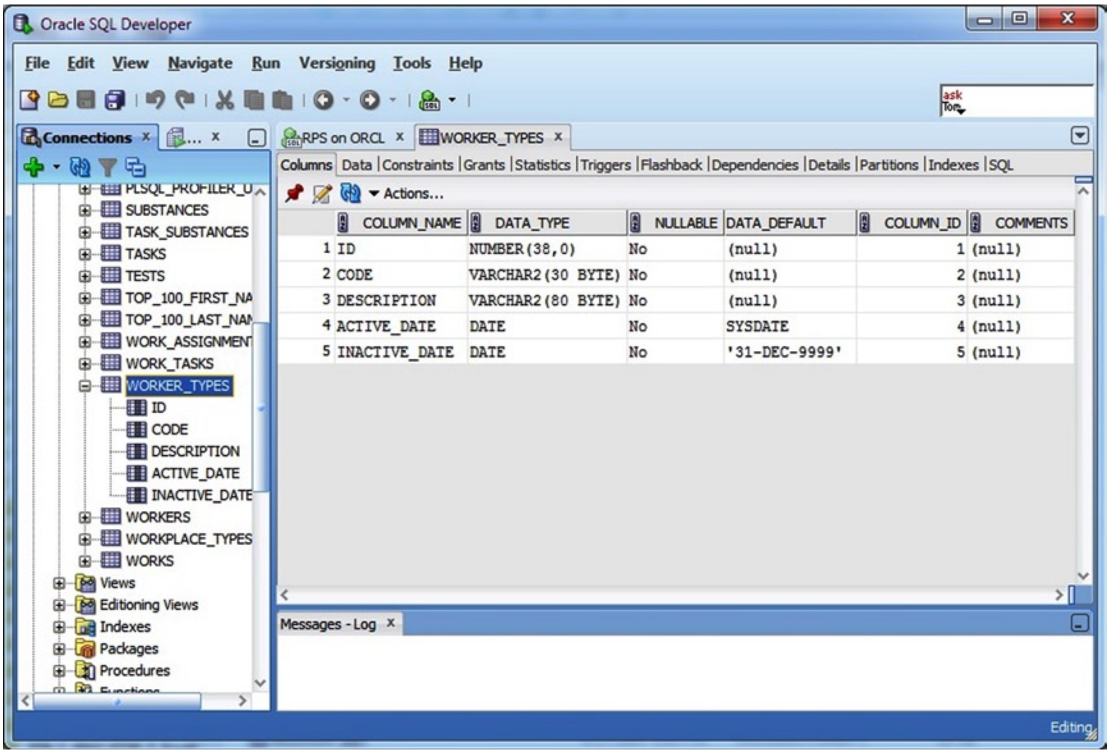
The describe command shows the format of the table, or the signature of the methods, but nothing else. It doesn't provide an explanation as to what the column names in the table are supposed to store, nor what the methods may actually do.

Sometimes, you'll already know what a method can do, and you're just looking for its method signature. In that case, describe will suit your purpose. But describe will never be a suitable means of looking up documentation on how something works.

Let's see what GUI development environment tools can provide.

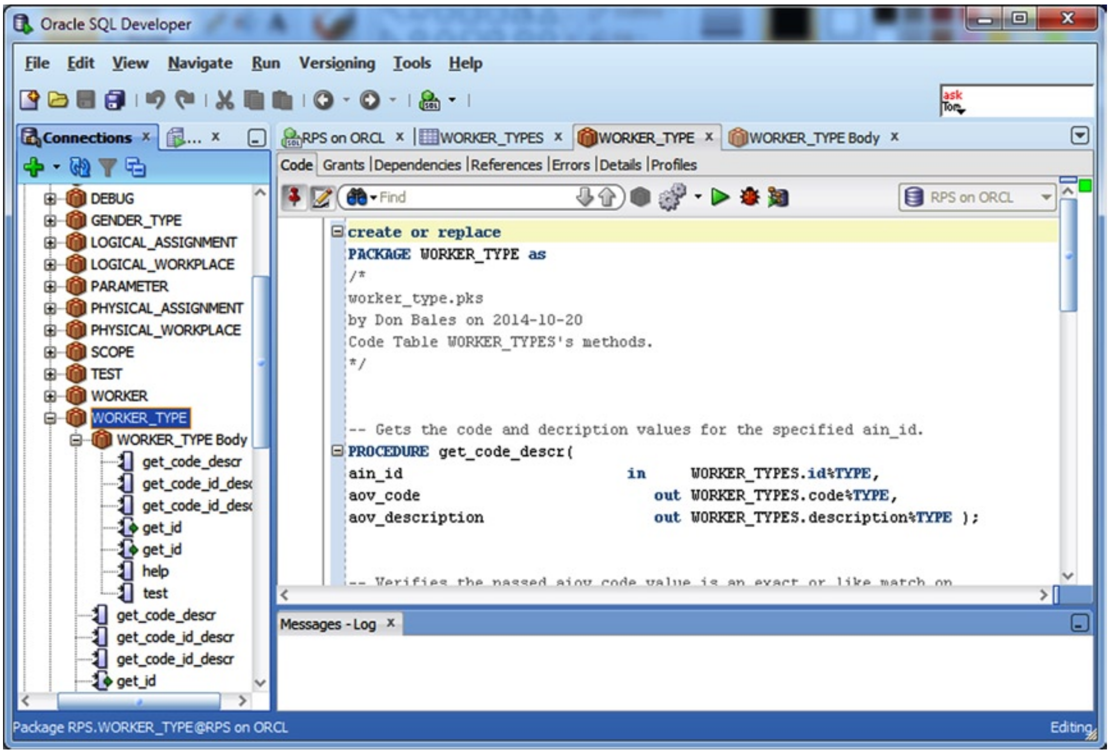
GUI Development Environment Tools

Tools like Oracle SQL Developer and TOAD for Oracle also show table formats and method signatures in much the same manner as SQL*Plus does. In Figures 9-1 and 9-2, you can see how Oracle SQL Developer presents information about table and package methods. When it comes to help with a package or TYPE definition, Oracle SQL Developer simply displays the source for the package specification.



	COLUMN_NAME	DATA_TYPE	NULLABLE	DATA_DEFAULT	COLUMN_ID	COMMENTS
1	ID	NUMBER(38,0)	No	(null)	1	(null)
2	CODE	VARCHAR2(30 BYTE)	No	(null)	2	(null)
3	DESCRIPTION	VARCHAR2(80 BYTE)	No	(null)	3	(null)
4	ACTIVE_DATE	DATE	No	SYSDATE	4	(null)
5	INACTIVE_DATE	DATE	No	'31-DEC-9999'	5	(null)

Figure 9-1. *A table definition as presented in Oracle SQL Developer*



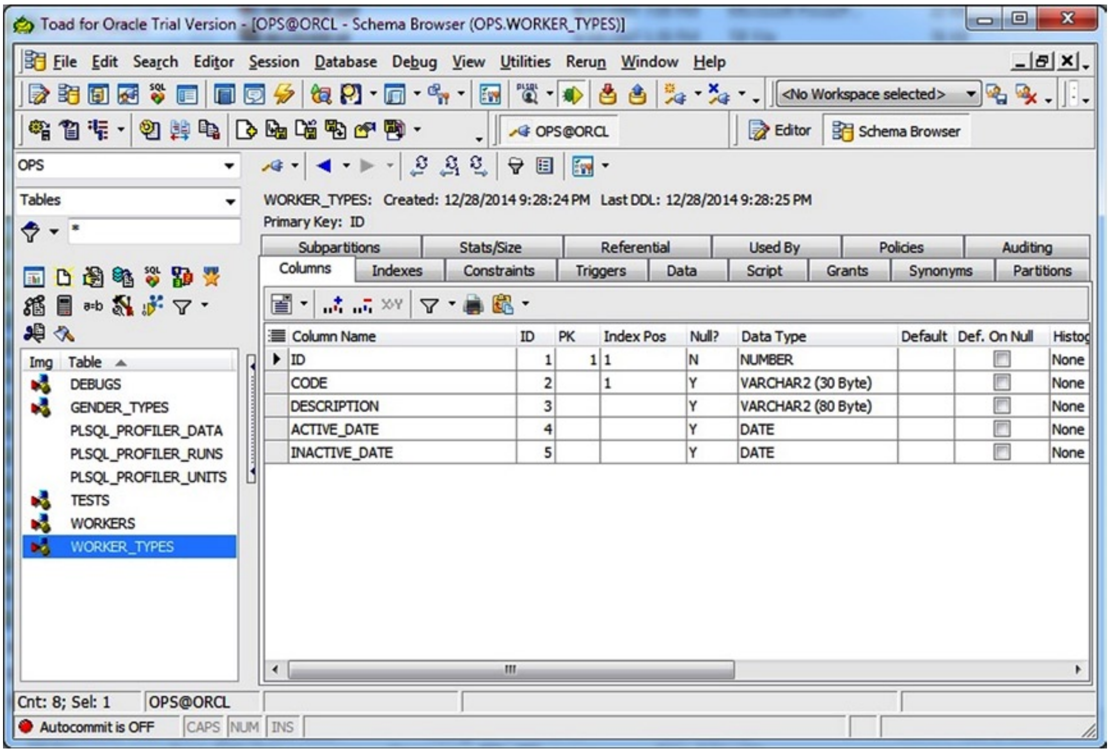
```
create or replace
PACKAGE WORKER_TYPE as
/*
worker_type.pks
by Don Bales on 2014-10-20
Code Table WORKER_TYPES's methods.
*/


-- Gets the code and decription values for the specified ain_id.
PROCEDURE get_code_descr(
ain_id                          in      WORKER_TYPES.id%TYPE,
aov_code                           out  WORKER_TYPES.code%TYPE,
aov_description                    out  WORKER_TYPES.description%TYPE );


-- Verifies the passed aiov_code value is an exact or like match on
```

Figure 9-2. *A package definition as presented in Oracle SQL Developer*

So how does TOAD present the same information? Look in Figures 9-3 and 9-4 for the answer. When it comes to package or TYPE information, TOAD also presents the source code of the package specification, just as Oracle SQL Developer does.

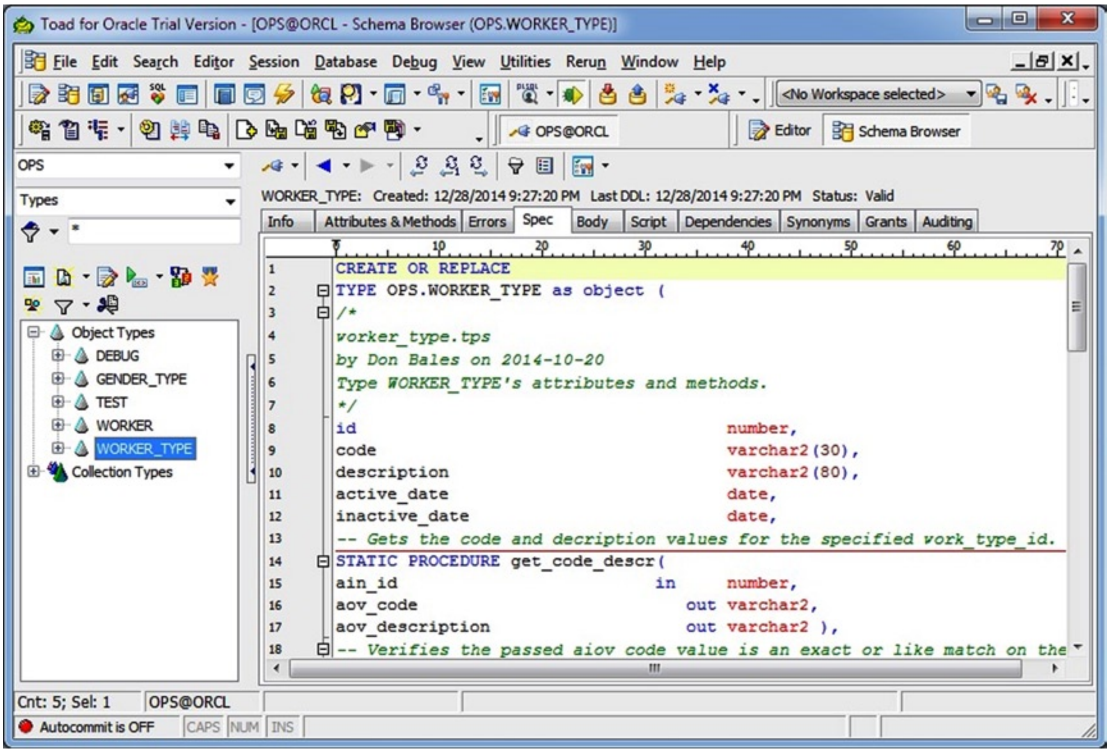

Toad for Oracle Trial Version - [OPS@ORCL - Schema Browser (OPS.WORKER_TYPES)]
File Edit Search Editor Session Database Debug View Utilities Rerun Window Help
<No Workspace selected>
OPS@ORCL
Editor
Schema Browser
OPS
Tables
Subpartitions Stats/Size Referential Used By Policies Auditing
Columns Indexes Constraints Triggers Data Script Grants Synonyms Partitions
Cnt: 8; Sel: 1
OPS@ORCL
Autocommit is OFF
CAPS NUM INS

WORKER_TYPES: Created: 12/28/2014 9:28:24 PM Last DDL: 12/28/2014 9:28:25 PM
Primary Key: ID

Img	Table
	DEBUGS
	GENDER_TYPES
	PLSQL_PROFILER_DATA
	PLSQL_PROFILER_RUNS
	PLSQL_PROFILER_UNITS
	TESTS
	WORKERS
	WORKER_TYPES

Column Name	ID	PK	Index Pos	Null?	Data Type	Default	Def. On Null	Histog
ID	1	1	1	N	NUMBER		☐	None
CODE	2		1	Y	VARCHAR2 (30 Byte)		☐	None
DESCRIPTION	3			Y	VARCHAR2 (80 Byte)		☐	None
ACTIVE_DATE	4			Y	DATE		☐	None
INACTIVE_DATE	5			Y	DATE		☐	None

Figure 9-3. *A table definition as presented in TOAD*


Toad for Oracle Trial Version - [OPS@ORCL - Schema Browser (OPS.WORKER_TYPE)]
File Edit Search Editor Session Database Debug View Utilities Rerun Window Help
<No Workspace selected>
OPS@ORCL
Editor
Schema Browser
OPS
Types
Object Types
DEBUG
GENDER_TYPE
TEST
WORKER
WORKER_TYPE
Collection Types
Info Attributes & Methods Errors Spec Body Script Dependencies Synonyms Grants Auditing
Cnt: 5; Sel: 1
OPS@ORCL
Autocommit is OFF
CAPS NUM INS

WORKER_TYPE: Created: 12/28/2014 9:27:20 PM Last DDL: 12/28/2014 9:27:20 PM Status: Valid

```
CREATE OR REPLACE
TYPE OPS.WORKER_TYPE as object (
/*
worker_type.tps
by Don Bales on 2014-10-20
Type WORKER_TYPE's attributes and methods.
*/
id                                    number,
code                                  varchar2(30),
description                           varchar2(80),
active_date                           date,
inactive_date                         date,
-- Gets the code and decription values for the specified work_type_id.
STATIC PROCEDURE get_code_descr(
ain_id                         in     number,
aov_code                          out varchar2,
aov_description                   out varchar2 ),
-- Verifies the passed aiov code value is an exact or like match on the
```

Figure 9-4. *A type specification as presented in TOAD*

Looking at the examples from these two IDEs, it occurs to me, once again, that the best place for documentation on what methods are for and how they actually work is right there in the specification source code itself, as properly formatted comments.

So if you properly format comments in a package or TYPE specification, you should be able to create a tool to display those comments, along with method call specifications as text or in any format. But first, you'll need to follow some commenting rules.

Rules for Documentation Comments

In order to be able to do any level of manipulation with the comments placed in the specifications for a package or TYPE, the use of the comments needs to be consistent from one specification to the next. To that end, following a minimal set of rules for adding comments to a specification will enable you to later display that information in various formats. The rules consist of the following:

- Place a multiline descriptive comment at the very beginning of each package and TYPE specification. This comment includes the object name, author, date written, and modification history.
- Place a single or multiline comment before every

- Package constant
- Package variable
- List of TYPE attributes
- Method signature

If you follow these two simple rules, you can next provide developers with documentation on demand.

Documentation on Demand

You can provide developers with documentation on demand by adding procedure `help()` to every package and `TYPE` specification. Then anytime they want to know what an executable object is for and what it can do, all they need to is execute its `help()` method. Here's an example:

```
SQL> WORKER_TYPE.help();
```

But first, you need to code those `help()` methods so they do something when executed! Let's build a text-based documentation formatting tool for package and `TYPE` specifications—and then add it as a command in each `help()` method.

A Text-Based Documentation Formatting Tool

So what tasks should this text-based formatting tool perform? How about the following?

- Read a specification and format the output.
- Remove any single-line or multiline comment delimiters.
- Preserve any hard carriage returns in order to maintain vertical spacing.
- Preserve any space or tab indentation in order to maintain horizontal spacing.

Using PL/SQL, I can accomplish the following tasks:

- Read through the source code of a specification by accessing view `SYS.USER_SOURCE`.
- Parse out and replace any single-line or multiline comment delimiters.
- Identify a hard carriage return and forward it to `put_line()`.

But the last requirement will be difficult. `put_line()`, the only means of displaying text from PL/SQL, will just truncate any leading spaces, so the best I can do is provide a hack where I send `put_line()` a tab character any time I have a source line that starts with a space character.

Now that I have some requirements to work with, I can build the text-based help tool. Listing 9-1 is the package specification for a text-based documentation formatting tool, or "text-help" tool appropriately named `TEXT_HELP`.

Listing 9-1. A Package Spec to Create Text-Based Help, text_help.pks

```
create or replace PACKAGE TEXT_HELP as
/*
test_help.pkb
by Donald J. Bales on 2014-10-20
A package to produce text based help
```

```
*/

/*
The help text for this package.
*/
PROCEDURE help;


/*
Generate help text for the specified object using its specification.
*/
PROCEDURE process(
aiv_object_name               in     varchar2);


/*
The test unit for this package.
*/
PROCEDURE test;


end text_help;
/
@se.sql
```

TEXT_HELP has three methods:

- help() displays on-demand help for this package by utilizing its second method process().
- process() retrieves the specified specification from view SYS.USER_SOURCE, and then displays the specification as nicely formatted text.
- test() is the test unit for this package.

Also notice that in Listing 9-1, I followed the commenting rules outlined earlier. Do as I say, *and* as I do!

Listing 9-2 is the implementation for TEXT_HELP. The only "new" method is process(). It's an ugly combination of parsing with substr() and an if-then-elsif-then-else tree that implements the requirements outlined earlier in this section.

Listing 9-2. A Package Body to Create Text-Based Help, text_help.pkb

```
create or replace PACKAGE BODY TEXT_HELP as
/*
test_help.pkb
by Donald J. Bales on 2014-10-20
A package to produce text based help
*/

PROCEDURE help is

begin
  TEXT_HELP.process('TEXT_HELP');
end help;
```

```


/*
A procedure to output formatted package or TYPE text
*/
PROCEDURE out(
aiv_text                       in    varchar2) is

v_text                               varchar(255);
n_text                               number := 1;

begin
  if nvl(length(aiv_text), 0) < 256 then
    v_text := aiv_text;
  else
    v_text := substr(aiv_text, 1, 252)||'...';
  end if;
  if nvl(substr(v_text, 1, 1), chr(32)) = chr(32) then
    if length(v_text) > 0 then
      for i in 1..length(v_text) loop
        if nvl(substr(v_text, i, 1), chr(32)) <> chr(32) then
          n_text := i;
          exit;
        end if;
      end loop;
    end if;
    SYS.DBMS_OUTPUT.put_line(chr(9)||substr(v_text, n_text));
  else
    SYS.DBMS_OUTPUT.put_line(v_text);
  end if;
end out;


PROCEDURE process(
aiv_object_name               in     varchar2) is

cursor c1(
aiv_object_name               in     varchar2) is
select text
from   SYS.USER_SOURCE
where  name = upper(aiv_object_name)
and    type in ('PACKAGE', 'TYPE')
order by line;

b_method                              boolean := FALSE;
b_comment                             boolean := FALSE;
v_text                                SYS.USER_SOURCE.text%TYPE;

begin
  for r1 in c1(aiv_object_name) loop
    v_text := replace(replace(r1.text, chr(13), NULL), chr(10), NULL);
    if    substr(ltrim(v_text), 1, 3) = '/* '                      then
      if nvl(instr(v_text, '*/'), 0) = 0 then
        b_comment := TRUE;
      end if;
      out(substr(ltrim(v_text), 4));
    elsif substr(ltrim(v_text), 1, 2) = '/*'                       then
      if nvl(instr(v_text, '*/'), 0) = 0 then
        b_comment := TRUE;
      end if;
      out(substr(ltrim(v_text), 3));
    elsif b_comment                                                and
          substr(rtrim(v_text), -2, 2) = '*/'                      then
      b_comment := FALSE;
      out(substr(rtrim(v_text), 1, length(rtrim(v_text)) - 2));
    elsif b_comment                                                then
      out(v_text);
    elsif substr(ltrim(v_text), 1, 3) = '-- '                      then
      out(substr(ltrim(v_text), 4));
    elsif substr(ltrim(v_text), 1, 2) = '--'                       then
      out(substr(ltrim(v_text), 3));
    elsif upper(substr(ltrim(v_text), 1,  8)) = 'FUNCTION'         or
          upper(substr(ltrim(v_text), 1,  9)) = 'PROCEDURE'        or
          upper(substr(ltrim(v_text), 1, 15)) = 'MEMBER FUNCTION'  or
          upper(substr(ltrim(v_text), 1, 16)) = 'MEMBER PROCEDURE' or
          upper(substr(ltrim(v_text), 1, 16)) = 'STATIC FUNCTION'  or
          upper(substr(ltrim(v_text), 1, 16)) = 'STATIC PROCEDURE' then
      if nvl(instr(v_text, ';'), 0) = 0 then
        b_method := TRUE;
      end if;
      out(v_text);
    elsif b_method                                                 and
          substr(rtrim(v_text), -1, 1) = ';'                       then
      b_method := FALSE;
      out(v_text);
    elsif b_method                                                 then
      out(v_text);
    elsif c1%rowcount = 1                                          then
      out(v_text);
    elsif upper(substr(ltrim(v_text), 1, 3)) = 'END'               then
      out(chr(12)); -- form feed
      exit;
    else
      out(v_text);
    end if;
  end loop;
  SYS.DBMS_OUTPUT.new_line();
end process;


PROCEDURE test is

```

```
115  begin
116    pl('TEXT_HELP.test()');
117
118    &_USER..TEST.clear('TEXT_HELP');
119
120    &_USER..TEST.set_test('TEXT_HELP', 'help()', 1,
121      'Test method help()' );
122    begin
123      help();
124
125      &_USER..TEST.ok();
126    exception
127      when OTHERS then
128        &_USER..TEST.error(SQLERRM);
129    end;
130
131    &_USER..TEST.set_test('TEXT_HELP', 'process()', 2,
132      'Test method help()' );
133    begin
134      process('TEXT_HELP');
135
136      &_USER..TEST.ok();
137    exception
138      when OTHERS then
139        &_USER..TEST.error(SQLERRM);
140    end;
141
142    &_USER..TEST.set_test('TEXT_HELP', NULL, NULL, NULL);
143    &_USER..TEST.success();
144  end test;
145
146
147  end text_help;
148  /
149  @be.sql
```

The code in this package body is not all that impressive, nor important. It's its use that is important, so let's see how to use it.

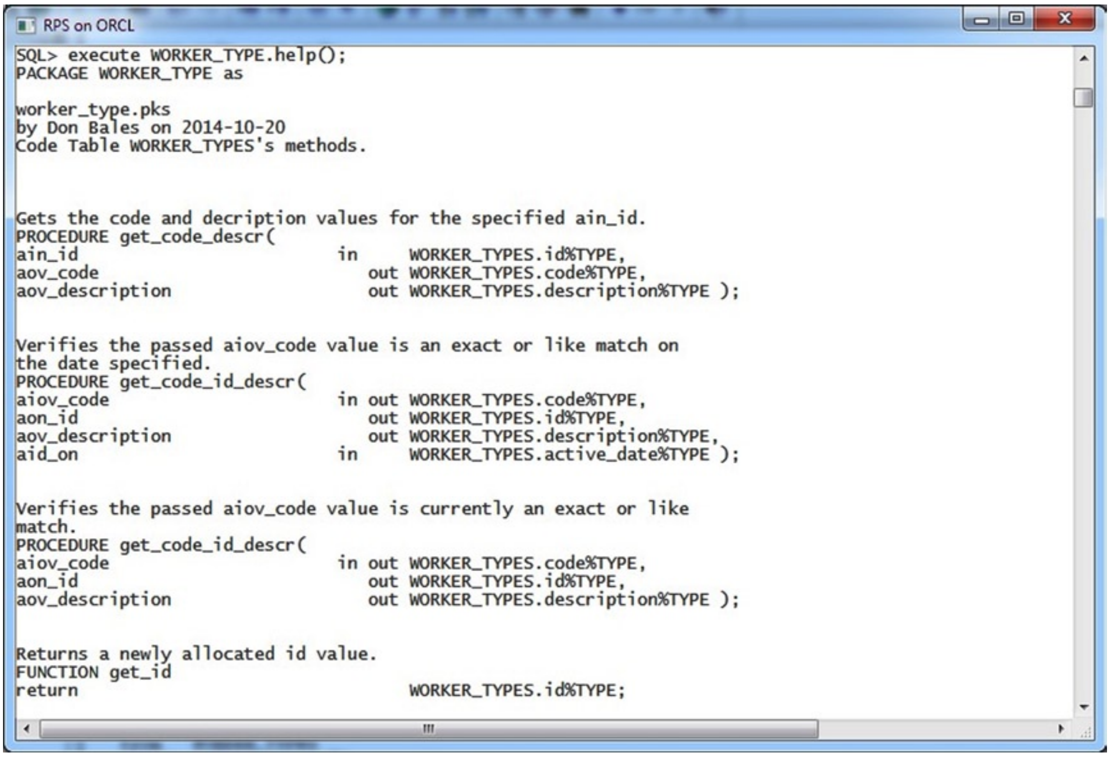
On lines 8 through 12 in Listing 9-2, I've coded the `help()` method for `TEXT_HELP`. In order to produce the text-based help for the package, all I need to do is pass the name of the package or `TYPE` to method `TEXT_HELP.process()`.

Now, let's see what it produces.

Accessing Documentation on Demand

As I mentioned earlier, now all I need do to get documentation on demand is to execute a package or `TYPE`'s `help()` method, assuming that the `help()` method in turn calls `TEXT_HELP.process()` to produce the output.

Figure 9-5 is an example of executing the `help()` method for package `WORKER_TYPE`. As you can see in Figure 9-5, the output is much more significant than the result from using `describe` in SQL*Plus or what the IDEs had to offer.



```
SQL> execute WORKER_TYPE.help();
PACKAGE WORKER_TYPE as

worker_type.pks
by Don Bales on 2014-10-20
Code Table WORKER_TYPES's methods.



Gets the code and decription values for the specified ain_id.
PROCEDURE get_code_descr(
ain_id                         in     WORKER_TYPES.id%TYPE,
aov_code                          out WORKER_TYPES.code%TYPE,
aov_description                   out WORKER_TYPES.description%TYPE );


Verifies the passed aiov_code value is an exact or like match on
the date specified.
PROCEDURE get_code_id_descr(
aiov_code                      in out WORKER_TYPES.code%TYPE,
aon_id                            out WORKER_TYPES.id%TYPE,
aov_description                   out WORKER_TYPES.description%TYPE,
aid_on                         in     WORKER_TYPES.active_date%TYPE );


Verifies the passed aiov_code value is currently an exact or like
match.
PROCEDURE get_code_id_descr(
aiov_code                      in out WORKER_TYPES.code%TYPE,
aon_id                            out WORKER_TYPES.id%TYPE,
aov_description                   out WORKER_TYPES.description%TYPE );


Returns a newly allocated id value.
FUNCTION get_id
return                                WORKER_TYPES.id%TYPE;
```

Figure 9-5. *Sample output from TEXT_HELP.process()*

The only limit to the depth of the documentation is the amount of time you're willing to spend writing it as you code each specification. Yes, once again, *you* are responsible for the quality of the outcome of *your* activities. But that's what it means to be a "professional." You're responsible, you know it, and you live up to that responsibility.

Now that you have access to `TEXT_HELP`, it's your turn to put it to work.

It's Your Turn to Access Documentation on Demand

Here are your tasks for this assignment.

1. Go back to every package and `TYPE` specification you've written, and add properly formatted comments (come on, at least do a couple).
2. Add the specification for procedure `help()` to each of those specifications, if you haven't already.
3. Access your help text by executing the `help()` command on each of your PL/SQL executables.

What do you think? Wouldn't you find immediate and easy access to documentation on what an object is for and how to use it invaluable? In practice, I've found that programmers are twice as likely to reuse a component if they have easy access to its documentation. But you can do even better.

Programmers are four times as likely to use a component if they know it exists beforehand and they also know how to use it. That sounds like training, doesn't it? Will your CFO or project manager tell you that you may not provide training; in other words, that you may not reuse your components? If not, then you'll need documentation you can distribute freely. To that end, let's look at the ability to create distributable documentation from a package or TYPE specification next.

Distributable Documentation

All that's necessary to create a set of distributable documentation for every specification in the database is to query the database's data dictionary for a list of those specifications, and then save each document to an operating system file. And that can be done by calling the help() method for each executable object. But let's do better than that. Text-based documentation can look quite boring and be quite unfriendly.

I know, let's use HTML instead! Let's create an HTML-based documentation formatting tool, or "HTML-help" tool. I'll even go so far as to call it HTML_HELP!

An HTML-Based Documentation Formatting Tool

Listing 9-3 is the package specification for an HTML-based help tool. Working with the capabilities of SQL*Plus, I can use it to produce an HTML help file for each executable object, and then an index to all those documents.

Listing 9-3. A Package Spec to Create HTML-Based Help, html_help.pks

```
01  create or replace PACKAGE HTML_HELP as
02  /*
03  html_help.pks
04  by Donald J. Bales on 2014-10-20
05  Package to create HTML-based help files for packages.
06  */
07
08  -- Creates a "object_index" html file for the current USER.
09
10  PROCEDURE create_index;
11
12
13  -- Creates a "<object_name>" html for each package for the current USER.
14
15  PROCEDURE create_help(
16  aiv_object_name                in     varchar2);
17
18
19  -- Text-based help for this package.  "set serveroutput on" in SQL*Plus.
20
21  PROCEDURE help;
22
23
24  PROCEDURE test;
25
26
```

```
end HTML_HELP;
/
@se.sql HTML_HELP
```

HTML_HELP has four methods:

- create_index() creates an index to all the documents created using the next method, create_help().
- create_help() creates an HTML-based document from the comments and method signatures in a specification.
- help() produces on-demand help for this package.
- test() is the test unit for this package.

Methods create_index() and create_help() require the use of a SQL*Plus script in order to write the output to operating system files.

Listing 9-4 is the implementation for HTML_HELP. In this case, I'm showing only a partial listing; you will find the full listing in the chapter's download directory. What's important here is the outcome of this package: documentation. And that outcome can be distributable if I save it as individual files on a file system.

Listing 9-4. A Package Body to Create HTML-Based Help, html_help.pkb

```
create or replace PACKAGE BODY HTML_HELP as
/*
html_help.pkb
by Donald J. Bales on 2014-10-20
Package to create HTML-based help files for packages
*/

-- TYPES

TYPE spec_record is record (
line_type                              varchar2(1),
line_number                            number,
line_text                              varchar2(2000),
method_name                            varchar2(2000),
first_sentence                         varchar2(2000));

TYPE spec_table is table of spec_record index by binary_integer;

TYPE buffer_table is table of varchar2(2000) index by binary_integer;

-- CONSTANTS

v_LT_COMMENT                 constant  varchar2(1) := 'C';
v_LT_METHOD                  constant  varchar2(1) := 'M';
v_LT_OTHER                   constant  varchar2(1) := 'O';

-- FORWARD DECLARATIONS

```

```
FUNCTION get_comment_start(
aiv_text                        in      varchar2)
return                                  number;


FUNCTION get_comment_end(
aiv_text                        in      varchar2)
return                                  number;


FUNCTION get_method_end(
aiv_text                        in      varchar2)
return                                  number;


FUNCTION get_method_name_start(
aiv_text                        in      varchar2)
return                                  number;


FUNCTION get_method_name_end(
aiv_text                        in      varchar2)
return                                  number;


FUNCTION is_comment_start(
aiv_text                        in      varchar2)
return                                  boolean;


FUNCTION is_comment_end(
aiv_text                        in      varchar2)
return                                  boolean;


FUNCTION is_method_end(
aiv_text                        in      varchar2)
return                                  boolean;


PROCEDURE out(
aiv_text                        in      varchar2);


PROCEDURE open_html(
aiv_title                       in      varchar2);


PROCEDURE close_html;


```

```
-- FUNCTIONS

FUNCTION get_comment_line_text(
aiv_text                       in     varchar2)
return                                varchar2 is

n_start                               number := 1;
n_end                                 number;

begin
  if is_comment_start(aiv_text) then
    n_start := get_comment_start(aiv_text);
  end if;
  if is_comment_end(aiv_text) then
    n_end := get_comment_end(aiv_text);
  else
    n_end := nvl(length(aiv_text), 0);
  end if;
  if n_end > n_start then
    return substr(aiv_text, n_start, (n_end + 1) - n_start);
  else
    return NULL;
  end if;
end get_comment_line_text;


FUNCTION get_comment_end(
aiv_text                       in     varchar2)
return                                number is

n_position                            number;

begin
  n_position := nvl(instr(upper(aiv_text), '*/'), 0);
  if n_position > 0 then
    return n_position - 1;
  else
    n_position := nvl(instr(upper(aiv_text), '--'), 0);
    if n_position > 0 then
      return nvl(length(aiv_text), 0);
    else
      return -1;
    end if;
  end if;
end get_comment_end;


FUNCTION get_comment_start(
aiv_text                       in     varchar2)
return                                number is

```

```
n_position                           number;

begin
  n_position := nvl(instr(upper(aiv_text), '/*'), 0);
  if n_position > 0 then
    return n_position + 2;
  else
    n_position := nvl(instr(upper(aiv_text), '--'), 0);
    if n_position > 0 then
      return n_position + 2;
    else
      return -1;
    end if;
  end if;
end get_comment_start;


FUNCTION get_first_sentence(
aiv_text                      in     varchar2)
return                               varchar2 is

n_start                              number := 1;
n_end                                number;

begin
  if is_comment_start(aiv_text) then
    n_start := get_comment_start(aiv_text);
  end if;
  n_end := nvl(instr(aiv_text, '.') - 1, -1);
  if n_end = -1 then
    n_end := nvl(length(aiv_text), 0);
  end if;
  if n_end > n_start then
    return substr(aiv_text, n_start, (n_end + 1) - n_start);
  else
    return NULL;
  end if;
end get_first_sentence;


FUNCTION get_method_end(
aiv_text                      in     varchar2)
return                               number is

n_position                           number;

begin
  n_position := nvl(instr(upper(aiv_text), ';'), 0);
  if n_position > 0 then
    return n_position - 1;
  else
```

```
    return length(aiv_text);
  end if;
end get_method_end;


FUNCTION get_method_line_text(
aiv_text                        in     varchar2)
return                                 varchar2 is

n_start                                number := 1;
n_end                                  number;

begin
  if is_method_end(aiv_text) then
    n_end := get_method_end(aiv_text);
  else
    n_end := nvl(length(aiv_text), 0);
  end if;
  if n_end > 0 then
    return substr(aiv_text, n_start, (n_end + 1) - n_start);
  else
    return NULL;
  end if;
end get_method_line_text;


FUNCTION get_method_name(
aiv_text                        in     varchar2)
return                                 varchar2 is

n_first                                number;
n_end                                  number;

begin
  n_first := get_method_name_start(aiv_text);
  n_end   := get_method_name_end(aiv_text);
  if n_end > n_first then
    return substr(aiv_text, n_first, (n_end + 1) - n_first);
  else
    return NULL;
  end if;
end get_method_name;


FUNCTION get_method_name_start(
aiv_text                        in     varchar2)
return                                 number is

n_position                             number;

```

```
begin
  n_position := nvl(instr(upper(aiv_text), 'FUNCTION '), 0);
  if n_position > 0 then
    return n_position + 9;
  else
    n_position := nvl(instr(upper(aiv_text), 'PROCEDURE '), 0);
    if n_position > 0 then
      return n_position + 10;
    else
      return 0;
    end if;
  end if;
end get_method_name_start;


FUNCTION get_method_name_end(
aiv_text                       in     varchar2)
return                                number is

n_position                            number;

begin
  n_position := nvl(instr(upper(aiv_text), '('), 0);
  if n_position > 0 then
    return n_position - 1;
  else
    n_position := get_method_end(aiv_text);
    if n_position > 0 then
      return n_position;
    else
      return nvl(length(aiv_text), 0);
    end if;
  end if;
end get_method_name_end;


FUNCTION is_comment_end(
aiv_text                       in     varchar2)
return                                boolean is

n_position                            number;

begin
  if get_comment_end(aiv_text) >= 0 then
    return TRUE;
  else
    return FALSE;
  end if;
end is_comment_end;


```

```
FUNCTION is_comment_start(
aiv_text                       in     varchar2)
return                                boolean is

n_position                            number;

begin
  if get_comment_start(aiv_text) >= 0 then
    return TRUE;
  else
    return FALSE;
  end if;
end is_comment_start;


FUNCTION is_method_end(
aiv_text                       in     varchar2)
return                                boolean is

n_position                            number;

begin
  if nvl(instr(aiv_text, ';'), 0) > 0 then
    return TRUE;
  else
    return FALSE;
  end if;
end is_method_end;


FUNCTION is_method_start(
aiv_text                       in     varchar2)
return                                boolean is

n_position                            number;

begin
  if get_method_name_start(aiv_text) > 0 then
    return TRUE;
  else
    return FALSE;
  end if;
end is_method_start;


FUNCTION comments_span(
aiv_text                       in     varchar2)
return                                varchar2 is
begin
  return '<span class="comments_span">'||aiv_text||'</span>';
end comments_span;


```

```
FUNCTION first_sentence_span(
aiv_text                       in     varchar2)
return                                varchar2 is
begin
  return '<span class="first_sentence_span">'||aiv_text||'</span>';
end first_sentence_span;


FUNCTION method_span(
aiv_text                       in     varchar2)
return                                varchar2 is
begin
  return '<span class="method_span">'||aiv_text||'</span>';
end method_span;


FUNCTION method_name_span(
aiv_text                       in     varchar2)
return                                varchar2 is
begin
  return '<span class="method_name_span">'||aiv_text||'</span>';
end method_name_span;


FUNCTION package_name_span(
aiv_text                       in     varchar2)
return                                varchar2 is
begin
  return '<span class="package_name_span">'||aiv_text||'</span>';
end package_name_span;


PROCEDURE create_index is

cursor c1 is
select distinct name
from   SYS.USER_SOURCE
where  type in ('PACKAGE', 'TYPE')
order by 1;

cursor c2(
aiv_name                       in     varchar2) is
select text
from   SYS.USER_SOURCE
where  type in ('PACKAGE', 'TYPE')
and    name = aiv_name
order by line;

b_comment                             boolean;
n_period                              number;

```

```
begin
  open_html('Package/Type index');
  out('<h2>Owner '||user||'</h2>');
  out('<table>');
  for r1 in c1 loop
    if c1%rowcount = 1 then
      out('<tr><th colspan="2">Packages/Types</th></tr>');
    end if;
    b_comment := FALSE;
    for r2 in c2(r1.name) loop
      if nvl(instr(r2.text, '/*'), 0) > 0 or
         nvl(instr(r2.text, '--'), 0) > 0 then
        b_comment := TRUE;
      end if;
      if b_comment                                               and
         nvl(instr(upper(r2.text), '.PKS'), 0) = 0               and
         substr(upper(ltrim(r2.text)), 1, 3)  <> 'BY '           and
         substr(upper(ltrim(r2.text)), 1, 13) <> 'COPYRIGHT BY ' then
        n_period := nvl(instr(ltrim(r2.text), '.'), 0);
        if n_period > 0 then
          out('<tr><td class="package_name_td"><a href="'||lower(r1.name)||
          '.html">'||package_name_span(r1.name)||'</a></td><td class="comments_
          td">'||comments_span(substr(ltrim(r2.text), 1, n_period))||'</td></tr>');
          exit;
        end if;
      end if;
    end loop;
  end loop;
  out('</table>');
  close_html();
end create_index;


PROCEDURE create_help(
aiv_object_name                in     varchar2) is

cursor c1(
aiv_object_name                in     varchar2) is
select text,
       type
from   SYS.USER_SOURCE
where  name = upper(aiv_object_name)
and    type in ('PACKAGE', 'TYPE')
and    line > 1
order by line;

b_comment                             boolean := FALSE;
b_first_sentence                      boolean := FALSE;
b_method                              boolean := FALSE;
b_method_name                         boolean := FALSE;
b_other                               boolean := FALSE;
```

```
n_backward                            number;
n_line_number                         number;
n_spec                                number := 0;
t_spec                                spec_table;
v_comment                             varchar2(2000);
v_first_sentence                      varchar2(2000);
v_method                              varchar2(2000);
v_method_name                         varchar2(2000);
v_text                                varchar2(2000);
v_type                                varchar2(30);

begin
  for r1 in c1(aiv_object_name) loop
    if c1%rowcount = 1 then
      v_type := r1.type;
    end if;

    -- strip away any carriage-returns and line-feeds
    v_text := replace(replace(r1.text, chr(13), NULL), chr(10), NULL);
    -- detect comments and methods
    if    is_comment_start(v_text) then
      b_comment                         := TRUE;
      b_first_sentence                  := FALSE;
      if not b_first_sentence then
        v_first_sentence                := get_first_sentence(v_text);
        if v_first_sentence is not NULL then
          b_first_sentence              := TRUE;
          n_line_number                 := 1;
          n_spec                        := n_spec + 1;
          t_spec(n_spec).line_type      := v_LT_COMMENT;
          t_spec(n_spec).line_number    := n_line_number;
          t_spec(n_spec).line_text      := get_comment_line_text(v_text);
          t_spec(n_spec).first_sentence := v_first_sentence;
        end if;
      else
        v_comment                       := get_comment_line_text(v_text);
        if v_comment is not NULL then
          n_line_number                 := 1;
          n_spec                        := n_spec + 1;
          t_spec(n_spec).line_type      := v_LT_COMMENT;
          t_spec(n_spec).line_number    := n_line_number;
          t_spec(n_spec).line_text      := get_comment_line_text(v_text);
          t_spec(n_spec).first_sentence := NULL;
        end if;
      end if;
      if is_comment_end(v_text) then
        b_comment                       := FALSE;
        b_first_sentence                := FALSE;
      end if;
    elsif b_comment              and
          is_comment_end(v_text) then
      if not b_first_sentence then
        v_first_sentence                := get_first_sentence(v_text);
        if v_first_sentence is not NULL then
          b_first_sentence              := TRUE;
          n_line_number                 := 1;
          n_spec                        := n_spec + 1;
          t_spec(n_spec).line_type      := v_LT_COMMENT;
          t_spec(n_spec).line_number    := n_line_number;
          t_spec(n_spec).line_text      := get_comment_line_text(v_text);
          t_spec(n_spec).first_sentence := v_first_sentence;
        end if;
      else
        v_comment                     := get_comment_line_text(v_text);
        if v_comment is not NULL then
          n_line_number                 := n_line_number + 1;
          n_spec                        := n_spec + 1;
          t_spec(n_spec).line_type      := v_LT_COMMENT;
          t_spec(n_spec).line_number    := n_line_number;
          t_spec(n_spec).line_text      := get_comment_line_text(v_text);
          t_spec(n_spec).first_sentence := NULL;
        end if;
      end if;
      b_comment                         := FALSE;
      b_first_sentence                  := FALSE;
    elsif b_comment                                        then
      if not b_first_sentence then
        v_first_sentence                := get_first_sentence(v_text);
        if v_first_sentence is not NULL then
          b_first_sentence              := TRUE;
          n_line_number                 := 1;
          n_spec                        := n_spec + 1;
          t_spec(n_spec).line_type      := v_LT_COMMENT;
          t_spec(n_spec).line_number    := n_line_number;
          t_spec(n_spec).line_text      := get_comment_line_text(v_text);
          t_spec(n_spec).first_sentence := v_first_sentence;
        end if;
      else
        v_comment                     := get_comment_line_text(v_text);
        if v_comment is not NULL then
          n_line_number                 := n_line_number + 1;
          n_spec                        := n_spec + 1;
          t_spec(n_spec).line_type      := v_LT_COMMENT;
          t_spec(n_spec).line_number    := n_line_number;
          t_spec(n_spec).line_text      := get_comment_line_text(v_text);
          t_spec(n_spec).first_sentence := NULL;
        end if;
      end if;
    elsif is_method_start(v_text) then
      b_method                          := TRUE;
      b_method_name                     := FALSE;
      if not b_method_name then
```

```
          v_method_name                   := get_method_name(v_text);
          if v_method_name is not NULL then
            b_method_name                 := TRUE;
            n_line_number                 := 1;
            n_spec                        := n_spec + 1;
            t_spec(n_spec).line_type      := v_LT_METHOD;
            t_spec(n_spec).line_number    := n_line_number;
            t_spec(n_spec).line_text      := get_method_line_text(v_text);
            t_spec(n_spec).method_name    := v_method_name;
          else
            n_line_number                 := 1;
            n_spec                        := n_spec + 1;
            t_spec(n_spec).line_type      := v_LT_METHOD;
            t_spec(n_spec).line_number    := n_line_number;
            t_spec(n_spec).line_text      := get_method_line_text(v_text);
            t_spec(n_spec).method_name    := NULL;
          end if;
        else
          v_method                        := get_method_line_text(v_text);
          if v_method is not NULL then
            n_line_number                 := n_line_number + 1;
            n_spec                        := n_spec + 1;
            t_spec(n_spec).line_type      := v_LT_METHOD;
            t_spec(n_spec).line_number    := n_line_number;
            t_spec(n_spec).line_text      := v_method;
            t_spec(n_spec).method_name    := NULL;
          end if;
        end if;
        if is_method_end(v_text) then
          b_method                        := FALSE;
          b_method_name                   := FALSE;
        end if;
      elsif b_method              and
            is_method_end(v_text) then
        if not b_method_name then
          v_method_name                   := get_method_name(v_text);
          if v_method_name is not NULL then
            b_method_name                 := TRUE;
            n_line_number                 := 1;
            n_spec                        := n_spec + 1;
            t_spec(n_spec).line_type      := v_LT_METHOD;
            t_spec(n_spec).line_number    := n_line_number;
            t_spec(n_spec).line_text      := get_method_line_text(v_text);
            t_spec(n_spec).method_name    := v_method_name;
          else
            n_line_number                 := 1;
            n_spec                        := n_spec + 1;
            t_spec(n_spec).line_type      := v_LT_METHOD;
            t_spec(n_spec).line_number    := n_line_number;
            t_spec(n_spec).line_text      := get_method_line_text(v_text);
            t_spec(n_spec).method_name    := NULL;
      end if;
    else
      v_method                        := get_method_line_text(v_text);
      if v_method is not NULL then
        n_line_number                 := n_line_number + 1;
        n_spec                        := n_spec + 1;
        t_spec(n_spec).line_type      := v_LT_METHOD;
        t_spec(n_spec).line_number    := n_line_number;
        t_spec(n_spec).line_text      := v_method;
        t_spec(n_spec).method_name    := NULL;
      end if;
    end if;
    b_method                          := FALSE;
    b_method_name                     := FALSE;
  elsif b_method                                         then
    v_method                          := get_method_line_text(v_text);
    if v_method is not NULL then
      n_line_number                   := n_line_number + 1;
      n_spec                          := n_spec + 1;
      t_spec(n_spec).line_type        := v_LT_METHOD;
      t_spec(n_spec).line_number      := n_line_number;
      t_spec(n_spec).line_text        := v_method;
      t_spec(n_spec).method_name      := NULL;
    end if;
  elsif upper(substr(ltrim(v_text), 1, 3)) = 'END'       then
    exit;
  elsif nvl(length(rtrim(v_text)), 0) > 0 then
    n_line_number                     := 1;
    n_spec                            := n_spec + 1;
    t_spec(n_spec).line_type          := v_LT_OTHER;
    t_spec(n_spec).line_number        := n_line_number;
    t_spec(n_spec).line_text          := v_text;
  end if;
end loop;

-- Now create the HTML
open_html(aiv_object_name);
-- Package name and comments
if v_type = 'PACKAGE' then
  out('<h2>Package '||upper(aiv_object_name)||'</h2>');
else
  out('<h2>Type '||upper(aiv_object_name)||'</h2>');
end if;
if n_spec > 0 then
  for i in 1..n_spec loop
    if t_spec(i).first_sentence is not NULL then
      out('<p class="comments_p">');
      n_line_number := t_spec(i).line_number;
      for j in i..n_spec loop
        if j                      > 1             and
           t_spec(j).line_number <= n_line_number then
```

```
            exit;
          end if;
          out(t_spec(j).line_text);
        end loop;
        out('</p>');
        exit;
      end if;
    end loop;
    out('<hr/><br/>');
    -- Other
    for i in 1..n_spec loop
      if t_spec(i).line_type = v_LT_OTHER then
        if not b_other then
          out('<table>');
          if v_type = 'PACKAGE' then
            out('<tr><th colspan="2">Global Constants and Variables</th></tr>');
          else
            out('<tr><th colspan="2">Attributes</th></tr>');
          end if;
          out('</table>');
          out('<pre class="other_pre">');
          b_other := TRUE;
        end if;
        if i > 1                                  and
          t_spec(i - 1).line_type = v_LT_COMMENT then
          n_backward := i - t_spec(i - 1).line_number;
          if n_backward > 0 then
            out('</pre><p class="comments_p">');
            for j in n_backward..(i - 1) loop
              out(t_spec(j).line_text);
            end loop;
            out('</p><pre class="other_pre">');
          end if;
        end if;
        out(t_spec(i).line_text);
      end if;
    end loop;
    if b_other then
      out('</pre>');
      out('<hr/><br/>');
    end if;
/*    -- Debug Output
    out('<!--');
    out('<h2>Debug Output</h2>');
    for i in 1..n_spec loop
      if i = 1 then
        out('<table>');
        out('<tr><th>line_type</th><th>line_number</th><th>line_text</th>
        <th>first_sentence</th><th>method_name</th></tr>');
      end if;
      out('<tr><td>'||t_spec(i).line_type||'</td><td>'||t_spec(i).line_number||
      '</td><td>'||t_spec(i).line_text||'</td><td>'||t_spec(i).first_sentence||
      '</td><td>'||t_spec(i).method_name||'</td></tr>');
      if i = n_spec then
        out('</table>');
        out('<hr/>');
      end if;
    end loop;
    out('<hr/><br/>');
    out('-->');  */
    -- Method Summary
    out('<table>');
    out('<tr><th colspan="2">Method Summary</th></tr>');
    for i in 1..n_spec loop
      if t_spec(i).method_name is not NULL then
        v_first_sentence := '<br/>';
        n_backward := i - 1;
        if n_backward > 0 then
          loop
            if t_spec(n_backward).method_name is not NULL then
              exit;
            end if;
            if t_spec(n_backward).first_sentence is not NULL then
              v_first_sentence := t_spec(n_backward).first_sentence;
              exit;
            end if;
            n_backward := n_backward - 1;
            if n_backward < 1 then
              exit;
            end if;
          end loop;
        end if;
        out('<tr><td class="method_name_td"><a href="#'||t_spec(i).method_name||'_'
        ||to_char(i)||'">'||method_name_span(t_spec(i).method_name)||'</a></td>');
        out(' <td class="first_sentence_td">'||first_sentence_span(nvl(v_first_
        sentence, '<br/>'))||'</td></tr>');
      end if;
    end loop;
    out('</table>');
    out('<br/><hr/><br/>');
    -- Method Details
    out('<table>');
    out('<tr><th colspan="2">Method Detail</th></tr>');
    out('</table>');
    for i in 1..n_spec loop
      if t_spec(i).method_name is not NULL then
        out('<h3><a name="#'||t_spec(i).method_name||'_'||to_char(i)||'">'||
        t_spec(i).method_name||'</a></h3>');
        out('<pre class="method_pre">');
        for j in i..n_spec loop
          if t_spec(j).line_type <> v_LT_METHOD or
            (j > i                              and
              t_spec(j).method_name is not NULL) then
            exit;
          end if;
          out(t_spec(j).line_text);
        end loop;
        out('</pre>');
        if i > 1                                and
          t_spec(i - 1).line_type = v_LT_COMMENT then
          n_backward := i - t_spec(i - 1).line_number;
          if n_backward > 0 then
            out('<p class="comments_p">');
            for j in n_backward..(i - 1) loop
              out(t_spec(j).line_text);
            end loop;
            out('</p>');
          end if;
        end if;
        out('<hr/>');
      end if;
    end loop;
  end if;
  close_html();
end create_help;


PROCEDURE help is

begin
  TEXT_HELP.process('HTML_HELP');
end help;


PROCEDURE out(
aiv_text                       in     varchar2) is

TYPE split_table is table of varchar2(255)
index by binary_integer;

n_length                              number;
n_split                               number := 255;
n_start                               number := 1;
n_stop                                number;
n_text                                number := 0;

t_text                                split_table;

n_limit_1                             number := 0;
n_limit_2                             number := 0;

begin
  n_length := nvl(length(aiv_text), 0);

  if n_length > 255 then
    loop
      n_limit_1 := n_limit_1 + 1;
      n_stop := least(n_start + n_split, n_length);
      loop
        n_limit_2 := n_limit_2 + 1;

        if    n_stop = n_start then
          n_stop := n_length;
          exit;
        elsif substr(aiv_text, n_stop, 1) = chr(32) then
          exit;
        else
          n_stop := n_stop - 1;
        end if;
      end loop;
      n_text := n_text + 1;
      t_text(n_text) := substr(aiv_text, n_start, n_stop - n_start);
      n_start := n_stop;
      if n_start >= n_length then
        exit;
      end if;
    end loop;
    for i in t_text.first..t_text.last loop
      SYS.DBMS_OUTPUT.put_line(t_text(i));
    end loop;
  else
    SYS.DBMS_OUTPUT.put_line(aiv_text);
  end if;
end out;


PROCEDURE open_html(
aiv_title                      in     varchar2) is

begin
  out('<html>
<head>
<title>'||aiv_title||'</title>
<link rel="stylesheet" type="text/css" href="stylesheet.css"/>
</head>
<body>');
end open_html;


PROCEDURE close_html is

begin
  out('</body>
</html>');
end close_html;
```

```


PROCEDURE test is

begin
  pl('HTML_HELP.test()');

  &_USER..TEST.clear('HTML_HELP');

  &_USER..TEST.set_test('HTML_HELP', 'create_package_index()', 1,
    'Test method create_package_index()' );
  begin
    create_index();

    &_USER..TEST.ok();
  exception
    when OTHERS then
      &_USER..TEST.error(SQLERRM);
  end;

  &_USER..TEST.set_test('HTML_HELP', 'create_package_help()', 2,
    'Test method create_package_help()' );
  begin
    create_help('HTML_HELP');

    &_USER..TEST.ok();
  exception
    when OTHERS then
      &_USER..TEST.error(SQLERRM);
  end;

  &_USER..TEST.set_test('HTML_HELP', 'help()', 3,
    'Test method help()' );
  begin
    help();

    &_USER..TEST.ok();
  exception
    when OTHERS then
      &_USER..TEST.error(SQLERRM);
  end;

  &_USER..TEST.set_test('HTML_HELP', NULL, NULL, NULL);
  &_USER..TEST.success();
end test;


end HTML_HELP;
/
@be.sql HTML_HELP
```

Listing 9-5 is a SQL*Plus script, `create_html_help.sql`, which in turn writes and executes a SQL*Plus script, `html_help.sql`, in order to generate distributable HTML-based documentation for the executable objects in a schema, as files in a file system.

Listing 9-5. A SQL*Plus Script to Create HTML-Based Help, create_html_help.sql

```
rem create_html_help.sql
rem by Don Bales on 2014-10-20
rem SQL*Plus script to create a SQL*Plus script to create html help for
rem the current user.

set feedback off;
set linesize 1000;
set newpage  1;
set pagesize 0;
set trimspool on;
set serveroutput on size 1000000;

spool html_help.sql;

prompt rem html_help.sql
prompt rem by Don Bales on 2014-10-20
prompt rem Created by SQL*Plus script create_html_help.sql
prompt;
prompt set feedback off;;
prompt set linesize 1000;;
prompt set newpage  1;;
prompt set pagesize 32767;;
prompt set trimspool on;;
prompt;
select 'spool '||lower(name)||'.html;'||
  chr(10)||'execute HTML_HELP.create_help('''||name||''');'||
  chr(10)||'spool off;'||chr(10)
from   SYS.USER_SOURCE
where  type in ('PACKAGE', 'TYPE')
group by name
order by name;

prompt spool object_index.html;;
prompt execute HTML_HELP.create_index();;
prompt spool off;;
prompt;
prompt set feedback on;;
prompt set linesize 1000;;
prompt set newpage  1;;
prompt set pagesize 32767;;
prompt set trimspool on;;

spool off;

@html_help.sql
```

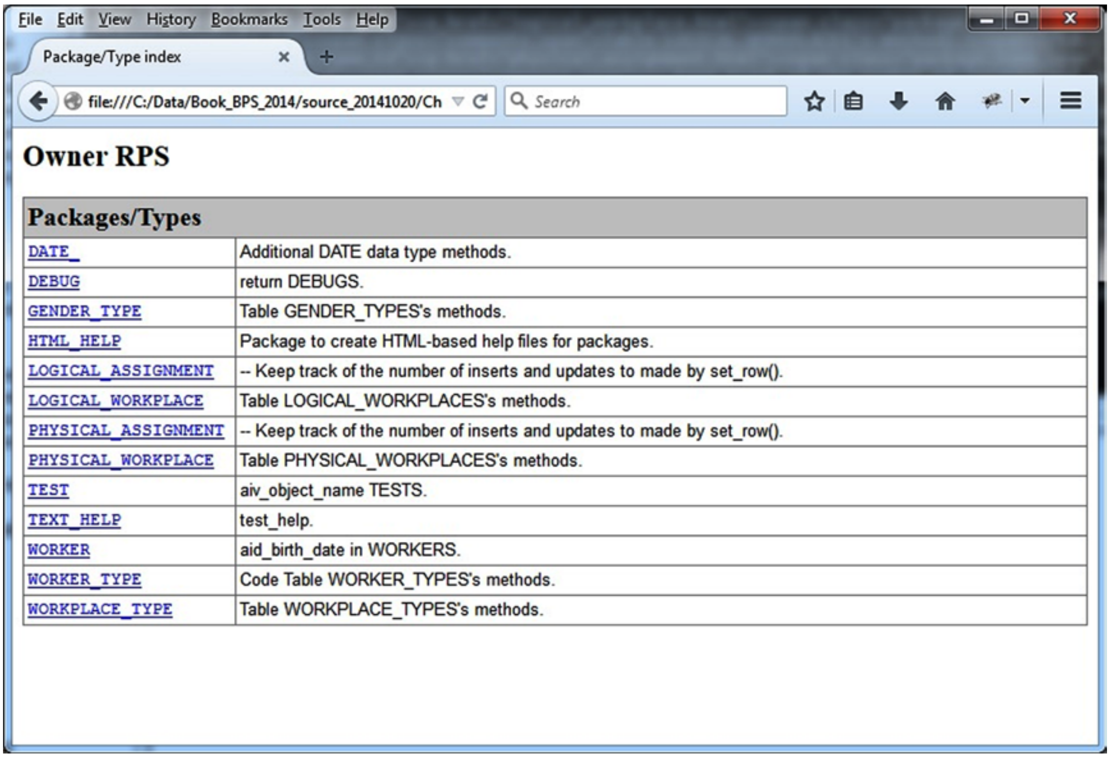
Now that the HTML-help tool has been built, let's see how easy it is to generate distributable documentation.

Generating Distributable Documentation

All I need to do to generate distributable documentation is compile package `HTML_HELP`, and then execute SQL*Plus script `create_html_help.sql`, as in the following example:

```
SQL> @create_html_help.sql
```

Doing so will create an HTML file with the same name as the executable PL/SQL object, but with an `.html` suffix. It will also create an index named `index.html`, which you can open from your browser. Figure 9-6 is an example of what `index.html` looks like in a browser. The format of this, as well as the rest of the documentation files, is controlled by a CSS style sheet named `stylesheet.css`, which is placed in the same directory as the HTML files.

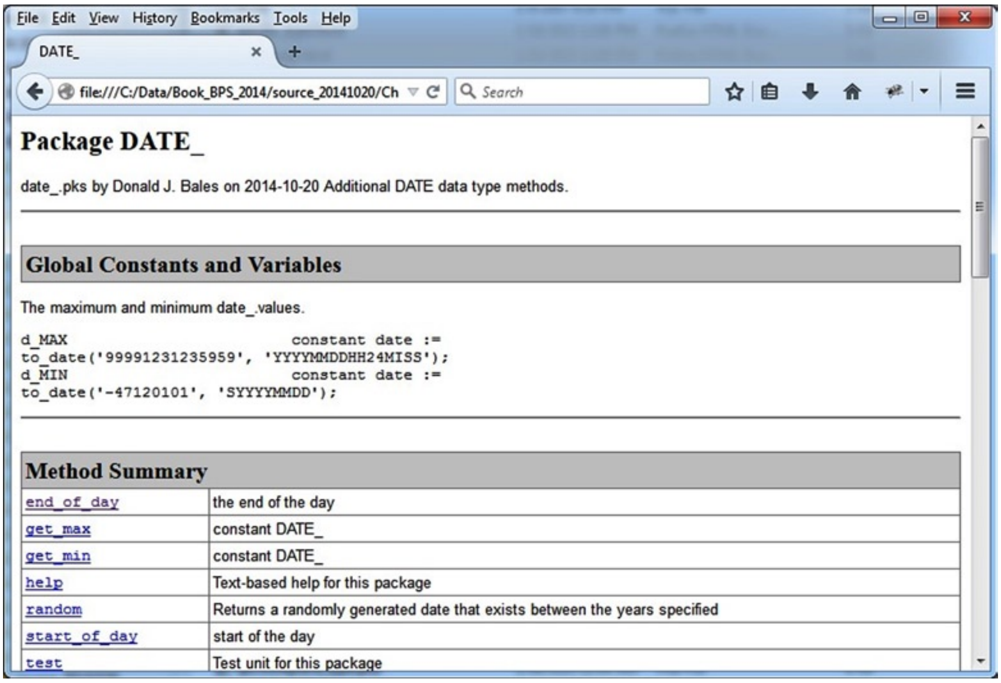

File Edit View History Bookmarks Tools Help
Package/Type index
file:///C:/Data/Book_BPS_2014/source_20141020/Ch
Search

Owner RPS

Packages/Types	
DATE_	Additional DATE data type methods.
DEBUG	return DEBUGS.
GENDER_TYPE	Table GENDER_TYPES's methods.
HTML_HELP	Package to create HTML-based help files for packages.
LOGICAL_ASSIGNMENT	-- Keep track of the number of inserts and updates to made by set_row().
LOGICAL_WORKPLACE	Table LOGICAL_WORKPLACES's methods.
PHYSICAL_ASSIGNMENT	-- Keep track of the number of inserts and updates to made by set_row().
PHYSICAL_WORKPLACE	Table PHYSICAL_WORKPLACES's methods.
TEST	aiv_object_name TESTS.
TEXT_HELP	test_help.
WORKER	aid_birth_date in WORKERS.
WORKER_TYPE	Code Table WORKER_TYPES's methods.
WORKPLACE_TYPE	Table WORKPLACE_TYPES's methods.

Figure 9-6. *Sample output from HTML_HELP.create_index()*

When I select the `DATE_` package from the index in Figure 9-6, my browser opens the generated documentation for the `DATE_` specification, as shown in Figure 9-7. When I select method `end_of_day()` from the method summary, my browser forwards me to another location in the same document where the detail about the method is listed, as shown in Figure 9-8.


File Edit View History Bookmarks Tools Help
DATE_
file:///C:/Data/Book_BPS_2014/source_20141020/Ch
Search

Package DATE_

date_.pks by Donald J. Bales on 2014-10-20 Additional DATE data type methods.

Global Constants and Variables

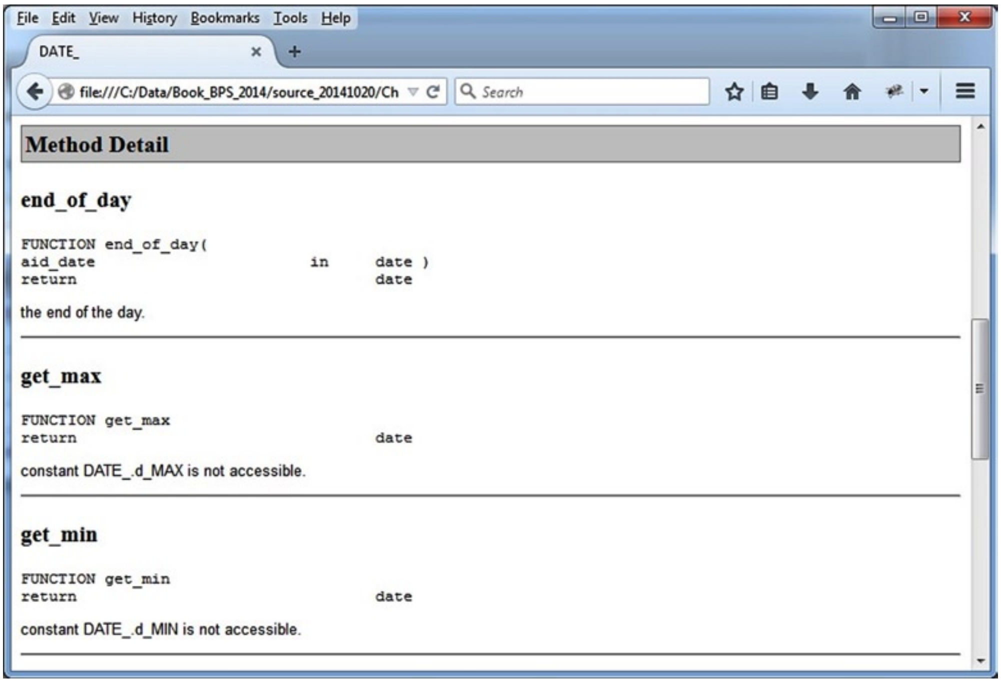
The maximum and minimum date_.values.

```
d_MAX                        constant date :=
to_date('99991231235959', 'YYYYMMDDHH24MISS');
d_MIN                        constant date :=
to_date('-47120101', 'SYYYYMMDD');
```

Method Summary

end_of_day	the end of the day
get_max	constant DATE_
get_min	constant DATE_
help	Text-based help for this package
random	Returns a randomly generated date that exists between the years specified
start_of_day	start of the day
test	Test unit for this package

Figure 9-7. *Page 1 of sample output from HTML_HELP.create_help()*


File Edit View History Bookmarks Tools Help
DATE_
file:///C:/Data/Book_BPS_2014/source_20141020/Ch
Search

Method Detail

end_of_day

```
FUNCTION end_of_day(
aid_date                        in      date )
return                                  date
```

the end of the day.

get_max

```
FUNCTION get_max
return                                  date
```

constant DATE_.d_MAX is not accessible.

get_min

```
FUNCTION get_min
return                                  date
```

constant DATE_.d_MIN is not accessible.

Figure 9-8. *Page 2 of sample output from HTML_HELP.create_help()*

Once again, the depth of the information is bounded only by your imagination and effort. By zipping these HTML files into an archive along with the style sheet, you now have freely distributable, and quite handsome, documentation about your reusable (and non-reusable) components.

Now that you've seen me do it, it's your turn to generate distributable documentation.

It's Your Turn to Generate Distributable Documentation

It's time to generate distributable documentation for your PL/SQL executables. Follow these steps.

1. Find and compile package `HTML_HELP`, files `html_help.pks` and `html_help.pkb`.
2. Create a staging directory where you wish to place the HTML files produced by script `create_html_files.sql`.
3. Copy script `create_html_files.sql` and style sheet `stylesheet.css` to your staging directory.
4. Start a SQL*Plus session from your staging directory.
5. Execute script `create_html_files.sql` from your staging directory.

You should now have as many `.html` files as you have PL/SQL executables, plus one for the `index.html` file in your staging directory. Now you need to take the last step, which is to distribute your documentation.

Documentation Distribution

You're almost finished. You're on the home stretch. But the job is not complete until you actually distribute your documentation. Just how do you do that? Here's how I've done it in the past.

1. Create a list of recipients.
2. Send recipients the `create_html_help.sql` script and style sheet so they can generate their own copy.
3. Package it into an archive like a `.zip` file.
4. Publish it on a web site.

Your first step in the distribution process is creating a list of recipients. Just who needs to know about this software? You should maintain this list in a database. Not only can you then keep track of who you sent the documentation to, but you can also keep a categorized list of the recipients' feedback. With this information, you can determine who is actually using the software, what incremental improvements need to be made, and also who is not using the software. If you find you have recipients that should be, but are not, using your software components, then remedial training is in order. You know, "hands-on" training, where you can not only see how they have tried using it in the past, but also find out what they think is wrong with using it in the first place!

Your next step is deciding how to package it for distribution. Should you let users generate their own? Should you send them an archive? Or should you host the documentation on a web site? I suppose it all depends on how large the audience is, and how often the components are changed.

In a small development group, I like to regenerate the documentation on a daily basis and then have everyone on the team make a copy. In a highly distributed environment and with components that are not modified, it makes more sense to send an archive. If the software changes frequently, it's easier to host the files on a web site.

Regardless of how you distribute the documentation, you should also write some summary documentation about how the components can be used together or about the patterns employed in the use of polymorphic names in the components. I'll talk about the latter in the next chapter.

Keep in mind that just as software development is cyclical and recursive, so is the creation and distribution of any documentation for said software. So you must continually maintain your list of recipients and then redistribute your documentation as needed. Don't stop short of this last step. Otherwise, someone will tell a story about your weird behavior in a book someday.

Summary

I started out this chapter trying to impress upon you how important it is to have documentation for your software components. There is no reuse without proper documentation. Second, I showed you how following a small set of commenting rules can turn your package and TYPE specification source into self-documenting source, which also makes losing the documentation impossible.

Next, I showed you how to build and employ a text-based help tool so programmers have access to text-based documentation for any component on demand. Then I showed you how to build and employ an HTML-based help tool so you can generate a distributable form of the documentation embedded in your package and TYPE specifications.

Finally, I gave you some pointers on distributing your software. One last suggestion is that you consider actually training your programmers on how to create new software components and use existing components.

Next, I'm going to share with you some stories of my successful use of PL/SQL, and why they were successful. So grab a cup of joe and let's go.

CHAPTER 10

Examples

One could argue that polymorphism is the subject of this chapter. Polymorphism is about using the same message (or command) in order to get the same result, but for different kinds of objects. Let's look at a simple example. Figure 10-1 shows the use of the command `draw()` for three different geometric shapes: a square, a triangle, and a circle.

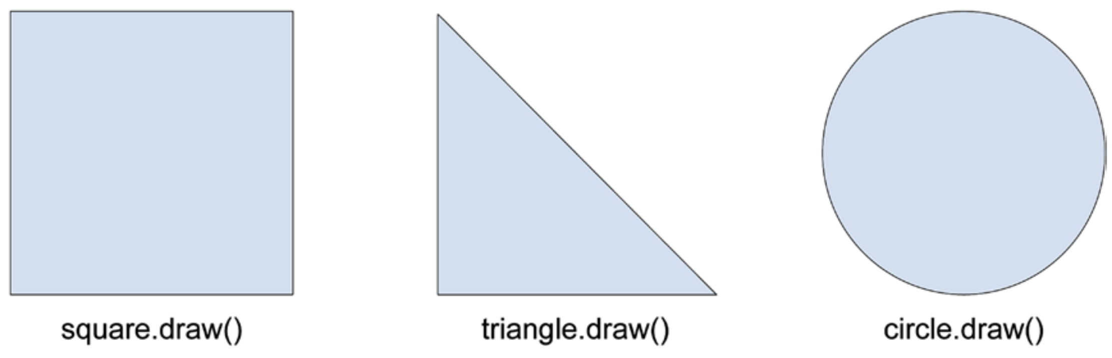


Figure 10-1. *An example of polymorphic command use with different objects*

Although the three geometric shapes in Figure 10-1 are different objects, using the same command, you can communicate what you want each object to do, and the object knows how to do it.

The polymorphic use of commands or messages reduces the use of synonyms in a programming language. If you're a writer, synonyms are wonderful things. They allow you to use words that have similar meanings but sound different, so that your resulting prose can have a somewhat rhythmic cadence. It can sound beautiful.

If you're a programmer, synonyms are awful things. They cause ambiguity because you can't know from "the sound" of the synonym if it means something similar (`LIKE`) or if it means exactly the same thing (`=`). And in programming, ambiguity is a really bad thing. Furthermore, synonyms expand the size of a language and make it harder to learn and use. The harder the language is to use, the more defects will be created when using it, and that too is bad.

Let's go back to Figure 10-1 for a second. I could have named the command to draw each geometric shape in the figure `draw_square()`, `draw_triangle()`, and `draw_circle()`. That's the procedural programming paradigm. But by doing so, I would have made the programming language three times larger than when I simply used the same command, `draw()`, in the context of the object to which it belongs.

Even if you're not using an object-oriented language, you can still use an object-oriented approach by employing modularity and polymorphism. Employing modularity means abstracting large program units into smaller components that can then be reused and assembled to accomplish a larger purpose. Employing polymorphism means abstracting out a set of commands that communicate the same action; however, the action taken will be appropriate for the object executing the command. And that's what I'm going to cover in this chapter, by doing the following:

- Show you a list of polymorphic commands that I have used repeatedly, project after project, always with the same meaning and to take the same action, but an action appropriate to each object.
- Tell you a handful of stories in which I use each polymorphic command, so you'll have some real-world examples to draw from when you employ polymorphism in your next project.
- Leave you with some advice about what you should do next.

I'll get you jump-started with a list of time-tempered polymorphic commands.

Polymorphic Commands

Any time you write or rewrite a program or application, you have an opportunity to abstract out patterns of use that you have experienced beforehand, and employ that experience as the intelligent and wise use of object-orientation. As I've already stated several times, you do not need to be using an object-oriented language in order to employ object-orientation.

Earlier in this book, I introduced you to the idea of creating a "table package" for every table. Each table package contains any executable behavior that "belongs to" the data held in the table in question. Then, in Chapter 6, I showed you how to create an object table, based on a new object `TYPE`, that contains any executable behavior that "belongs to" its associated object attributes.

Creating a table package is an example of employing object-orientation in a procedural language setting, and creating an object table with a `TYPE` is an example of employing object-orientation in an object-oriented language setting. Both examples take advantage of polymorphism.

After more than 20 years of coding in PL/SQL, I've created a list of 50 polymorphic commands that can be employed to name most, if not all, of the methods you will use while developing components (and applications) with PL/SQL. Table 10-1 is a list of the top 20 polymorphic commands I commonly use for table packages and `TYPE`s The first column of the table lists the method name, including whether it is a `FUNCTION` or `PROCEDURE`. If a method name is not followed by parentheses, it means that there is a form of the method that takes no parameters. In columns two through four, I indicate whether a method is used for each "kind" of table: a code table, a content table, or an intersection table. Finally, in column five, I indicate whether the method is used in a hierarchical version of one of the three previous table types.

Table 10-1. *Polymorphic Commands for Package Tables and TYPEs*

Method Name	Code	Content	Intersect	Hierarchical
`FUNCTION create_id_context()`				X
`FUNCTION get_code()`	X			
`FUNCTION get_code_context()`				X
`FUNCTION get_descr()`	X			
`FUNCTION get_id`	X	X	X	
`FUNCTION get_id()`	X			
`FUNCTION get_id_context()`				X
`FUNCTION get_name()`		X	X	
`FUNCTION get_name_context()`				X
`FUNCTION get_row()`		X	X	
`FUNCTION is_active()`	X	X	X	
`FUNCTION is_duplicate()`		X	X	
`FUNCTION is_history()`			X	
`PROCEDURE get_code_descr()`	X			
`PROCEDURE get_code_id_descr()`	X			
`PROCEDURE get_code_id_name()`		X		
`PROCEDURE help`	X	X	X	
`PROCEDURE inactivate()`		X	X	
`PROCEDURE set_row()`		X	X	
`PROCEDURE test`	X	X	X	

Table 10-2 is a list of polymorphic commands employed by packages and TYPEs that play a particular role in a process, rather than act as merely a persistence entity like a table and table package or object table. The first column of Table 10-2 lists method names along with the type of method. Columns two through six indicate the use of the method name by each of the roles listed in the headings:

- *Data migration*: A one-time process where data is moved and/or transformed from one location to another, typically from a "staging table" to an "application table."
- *On-demand data processing*: A process that manipulates data in the database, on demand, for the purpose of completing some ongoing business-related task.
- *Polling data processing*: A process that manipulates data in the database by managing tasks in a queue or simply sleeping between invocations of the process in question, once again for the purpose of completing some ongoing business-related processing.
- *Data entry*: In support of a presentation layer process of entering data into the database for some ongoing business related task.
- *Reporting*: In support of a presentation layer process of viewing data in the database for some ongoing or ad hoc business-related task.

Table 10-2. *Polymorphic Commands for Roles*

Method Name	Data Migration	Demand Process	Polling Process	Data Entry	Report
`FUNCTION calculate()`		X	X	X	X
`FUNCTION get_next()`			X		
`FUNCTION get_report`					X
`FUNCTION get_report()`					X
`FUNCTION get_status`		X	X		
`FUNCTION is_authorized()`				X	
`FUNCTION is_downloaded`		X	X		
`FUNCTION is_uploaded`		X	X		
`FUNCTION process`	X	X	X		
`FUNCTION process()`	X	X	X		
`PROCEDURE calculate()`		X	X	X	X
`PROCEDURE disable`		X	X		
`PROCEDURE download`		X	X		
`PROCEDURE enable`		X	X		
`PROCEDURE help`	X	X	X	X	X
`PROCEDURE initialize`	X	X	X	X	X
`PROCEDURE load`		X	X		
`PROCEDURE post_query()`				X	
`PROCEDURE process`	X	X	X		
`PROCEDURE process()`	X	X	X		
`PROCEDURE quit`		X	X		
`PROCEDURE report`					X
`PROCEDURE report()`					X
`PROCEDURE set_downloaded`		X	X		
`PROCEDURE set_processed`	X	X	X		
`PROCEDURE set_report()`					X
`PROCEDURE set_status()`		X	X		
`PROCEDURE set_uploaded`	X	X	X		
`PROCEDURE start_logging()`		X	X		X
`PROCEDURE status`		X	X		
`PROCEDURE stop_logging()`		X	X		X
`PROCEDURE test`	X	X	X	X	X
`PROCEDURE upload`		X			

There is some overlap between these five role definitions. For example, a service-oriented interface between two systems will employ data migration, data processing, and table package routines. But that's OK. What I'm trying to do is to get you to think in polymorphic terms.

If you learn to think in polymorphic terms, and then employ polymorphism, once you know what a polymorphic command does on one object, you'll already have a good idea of what it does on the next. And that's quite similar to how we think about the real world. If you tell me you ride a bike, I might respond that I ride a horse. We both know what the other means, even if we've never done the other activity, simply because we apply the word *ride* polymorphically to the context—in your case, a bicycle; in my case, a horse.

In the sections that follow, I'm going to tell you how I've used some (it would take another book to explain them all) of these commands in a particular setting.

Let's start with table packages and TYPEs.

Parametric SQL

I could call this story "The Man Who Hated SQL." The programmer in question was unhappy because he had to break the rhythm of his coding from a procedure language (PL/SQL) to a nonprocedural language (SQL) and back again—back and forth, back and forth, PL/SQL and SQL, PL/SQL and SQL.

While our unhappy programmer was complaining about the nonprocedural nature of SQL and how bad SQL is, he should have been more concerned about reducing the number of different SQL statements used against the database, because reducing the number of SQL statements used against an Oracle database can improve the database's overall performance.

I find it surprising, and at the same time somewhat amusing, how many people hate SQL. You would think its creation was the work of the devil. In contrast, my opinion is that SQL is very effective. You can accomplish a lot of data processing work with very little actual programming effort using SQL. OK, I agree, some things don't work consistently from one implementation to the next, but all in all, no viable alternative has taken its place yet, nor does it appear one will any time soon.

It's really amazing how easy data processing is with SQL. Regardless, *one goal during the development of an application should be to write a particular SQL statement once and only once, just as it should be a goal to write the same code routine once and only once, and then use it as a subroutine*. To that end, I create table packages or TYPEs that employ the same set of polymorphic commands to provide a PL/SQL method in place of writing many of the same SQL statements over and over again.

Code Table Methods

As you saw earlier in the book, I use a database architecture where I always store the primary key, which is a sequence-generated ID value that points to a code, into a content or intersection table. I never store the code or description value. Why?

First, modifying the code or description of a given code table entry will require only an UPDATE against the code table. The next time the code and description values are retrieved for a particular ID value, they will then be the "new" values. The primary key, the ID, will always be the same value, but the code and description values can change without impacting the content and intersection tables that have stored the ID value in question.

Second, in an internationalized application, I can transparently switch the code and description values to those with the same meaning in another language, because the only value that is immutable is the ID. With that in mind, think about this. We code programs in English, therefore we should be able to program access to codes in English, and that's why the first method I'm going to talk about exists.

get_id()

Since we code our programs in English, we should be able to specify our code entries as constant values in our programs in English. So any time you need to get the ID value for a particular code value in English, you call FUNCTION get_id(aiv_code), passing it a code value in English, and it returns the corresponding ID value. If the code you specify does not exist, the underlying singleton SQL SELECT statement raises a NO_DATA_FOUND exception, which you must handle in your calling program unit. Here's an example of the method from code table package WORKER_TYPE:

```
FUNCTION get_id(
aiv_code                       in     WORKER_TYPES.code%TYPE )
return                                WORKER_TYPES.id%TYPE is

n_id                                  WORKER_TYPES.id%TYPE;

begin
  select id
  into   n_id
  from   WORKER_TYPES
  where  code = aiv_code;

  return n_id;
end get_id;
```

Once this method is written and in use, one and only one SQL statement need ever be written to retrieve an ID for a specified code value. You will see me use this method quite often in a data migration, data processing, and reporting program units. First, I get the ID values as pseudo-constants in the initialization section of a package whenever there is a small number codes in scope. Next, I reduce the number of tables used in a corresponding cursor's SQL SELECT statement. Instead, I use an IF statement to assign the code entry's code and description values inside the cursor's FOR LOOP. You'll see some examples of this practice later in this chapter, in the "Reporting" section.

get_code_descr()

Once you've decided to use a database architecture where every assigned code value is stored as an ID value, you'll need some way to retrieve the code and description values so they can be displayed in the presentation layer, whether it is for data entry or reporting. And that's the purpose of this method. If you need the code and description values for a specific ID value, you simply call PROCEDURE get_code_descr(ain_id, aov_code, aov_descr), passing it the corresponding ID value. The method returns the code and description values as OUT parameter values If the ID you specify does not exist, the underlying singleton SQL SELECT statement raises a NO_DATA_FOUND exception, which you must handle in your calling program unit. Here's an example of the method from code table package WORKER_TYPE:

```
PROCEDURE get_code_descr(
ain_id                         in     WORKER_TYPES.id%TYPE,
aov_code                          out WORKER_TYPES.code%TYPE,
aov_description                   out WORKER_TYPES.description%TYPE ) is
```

```
begin
  select code,
         description
  into   aov_code,
         aov_description
  from   WORKER_TYPES
  where  id = ain_id;
end get_code_descr;
```

Once again, after this method is written and in use, one and only one SQL statement need ever be written to retrieve a code and description for a specified code ID value. Similar functions can be written to get just the code value or description value, and they would be appropriately named `get_code()` and `get_descr()`.

get_code_id_descr()

If an application is written for a high volume of data entry, the GUI in question will present a field for the entry of a code value and a second field to display the specified code's description value. The users may also have an icon they can click to see a pop-up list of code values from which to select.

The typical end-user action in this design is for the end user to specify all or part of a code value, and then to tab into the next modifiable field, at which point the presentation layer validates the user's code value entry. That's what this method is for: validation.

In order to validate a code value, simply pass the code value to `PROCEDURE get_code_id_descr(aiov_code, aon_id, aov_description, aid_on)`. This procedure first tries to find an exact code value match for the specified point in time. If it does not find a match, the procedure tries to find a single `LIKE` match. If it does not find a single `LIKE` match, it may return a `NO_DATA_FOUND` or `TOO_MANY_ROWS` exception, which the presentation layer will need to handle. Both exceptions mean that the user has specified an invalid code value. Here's an example from code table package `WORKER_TYPE`:

```
PROCEDURE get_code_id_descr(
aiov_code                       in out WORKER_TYPES.code%TYPE,
aon_id                             out WORKER_TYPES.id%TYPE,
aov_description                    out WORKER_TYPES.description%TYPE,
aid_on                          in     WORKER_TYPES.active_date%TYPE ) is

v_code                                 WORKER_TYPES.code%TYPE;

begin
  select id,
         description
  into   aon_id,
         aov_description
  from   WORKER_TYPES
  where  code = aiov_code
  and    aid_on between active_date and nvl(inactive_date, DATE_.d_MAX);
exception
  when NO_DATA_FOUND then
    select id,
           code,
           description
    into   aon_id,
           v_code,
           aov_description
    from   WORKER_TYPES
    where  code like aiov_code||'%'
    and    aid_on between active_date and nvl(inactive_date, DATE_.d_MAX);

    aiov_code := v_code;
end get_code_id_descr;
```

Variable v_code is used in the second half of the method, during the LIKE match, to capture the full-length code value from the database and return it to the presentation layer. You can call this method from the WHEN-VALIDATE-ITEM event in Developer/2000 forms, from the item_changed() event in PowerBuilder, from JavaScript (through a servlet) in the onChange event of an AJAX-based web page, and so on.

Now let's look at methods used with content tables.

Content Table Methods

What's the difference between a code table and a content table? In most cases, code tables have a very limited number of entries—values agreed upon by the consensus of users or dictation of management. These "agreed-upon" values are used to categorize the input of content and sometimes intersection entries. In contrast, content tables have an unlimited number of entries, where end users select or specify code values, enter numeric values, or enter textual values as part of doing business.

In response to the unlimited number of entries possible in content tables, it's not uncommon to take the effort to code methods to eliminate the repeated coding of the SQL singleton SELECT, INSERT, and UPDATE statements with parametric method calls. Let's start out by looking at one such method.

get_row()

Method get_row returns a PL/SQL record (a row) from a relational table or an instance of an object TYPE (a row) from an object table, based on the criteria specified in the record or object passed to the method. As the programmer, it's your responsibility to code the method to retrieve by the primary key and any other unique keys defined for the table in question. Then, to use this method, follow these steps.

1. Set column or attribute values in a corresponding PL/SQL record or object instance for only those columns or attributes that are used in a particular primary or unique key constraint.

2. Pass the PL/SQL record or object instance to the method.

get_row() then returns a matching row from the database if a matching row exists; otherwise, it returns a NULL PL/SQL record or object instance.

This method replaces a singleton SQL SELECT statement with a parametric method call based on a set of primary or unique key values. We never need to code that SQL statement ever again. Where's that unhappy SQL programmer now?

The following is an example of the get_row method from content table package LOGICAL_WORKPLACE:

```
FUNCTION get_row(
air_logical_workplace          in     LOGICAL_WORKPLACES%ROWTYPE)
return                                LOGICAL_WORKPLACES%ROWTYPE is

r_logical_workplace                   LOGICAL_WORKPLACES%ROWTYPE;
```

```
begin
  if    air_logical_workplace.id is not NULL then
    --pl('retrieve the row by the primary key');
    select *
    into   r_logical_workplace
    from   LOGICAL_WORKPLACES
    where  id = air_logical_workplace.id;
  elsif air_logical_workplace.id_context is not NULL then
    --pl('retrieve the row by the id_context unique key');
    select *
    into   r_logical_workplace
    from   LOGICAL_WORKPLACES
    where  id_context = air_logical_workplace.id_context;
  else
    --pl('retrieve the row by the code, name, and active_date');
    select *
    into   r_logical_workplace
    from   LOGICAL_WORKPLACES
    where  code        = air_logical_workplace.code
    and    name        = air_logical_workplace.name
    and    active_date = air_logical_workplace.active_date;
  end if;
  return r_logical_workplace;
exception
  when NO_DATA_FOUND then
    raise;
  when OTHERS then
    raise_application_error(-20001, SQLERRM||
      ' on select LOGICAL_WORKPLACES'||
      ' in LOGICAL_WORKPLACE.get_row()');
end get_row;
```

As you will see shortly, `get_row()` is called by `set_row()` in order to determine whether to insert or update.

get_code_id_name(), get_code(), and get_name()

The methods `get_code_id_name()`, `get_code()`, and `get_name()` serve the same purpose as their counterparts in code table packages. See the section about `get_code_id_descr()` earlier in the chapter for an explanation.

is_duplicate()

In a database design where you use sequence-generated ID values for primary keys, every table will have a primary key that is an ID value, and at least one unique key that acts as a "primary key" made up of real-world values. Method `is_duplicate()` allows the presentation layer to verify that the values specified in fields on a screen are not going to create a row with duplicate values when an entry is saved to the database.

Here's an example of FUNCTION is_duplicate(aiv_code, aiv_name, aid_active_date) from content table package LOGICAL_WORKPLACE:

```
FUNCTION is_duplicate(
aiv_code                      in     LOGICAL_WORKPLACES.code%TYPE,
aiv_name                      in     LOGICAL_WORKPLACES.name%TYPE,
aid_active_date               in     LOGICAL_WORKPLACES.active_date%TYPE)
return                               boolean is

n_count                              number;

begin
  --pl('retrieve the row by the code, name, and active_date');
  select count(1)
  into   n_count
  from   LOGICAL_WORKPLACES
  where  code               = aiv_code
  and    name               = aiv_name
  and    trunc(active_date) = trunc(aid_active_date);

  if nvl(n_count, 0) > 0 then
    return TRUE;
  else
    return FALSE;
  end if;
end is_duplicate;
```

Like its presentation layer counterpart get_code_id_name(), is_duplicate() can be called from any presentation layer This time, however, in order to provide immediate feedback to users that they are specifying duplicate values, before they try to save an entry to the database, because it will return TRUE if the values already exist in the database. If you're working with a programming language in the presentation layer that does not support a Boolean value from SQL, such as Java, you can simply wrap your call to this function in a stand-alone database function like the following:

```
create or replace FUNCTION to_boolean_number(
aib_boolean                   in     boolean )
return                               number is
/*
to_boolean_number.fun
by Donald J. Bales on 2014-10-20
A method to return a numeric value for false (0) and true (1).
This is very handy for calling functions that return boolean
values from JDBC, which can't handle boolean database values.
*/
begin
  if aib_boolean is not null then
    if aib_boolean then
      return 1;
    else
      return 0;
    end if;
  else
    return NULL;
  end if;
end to_boolean_number;
```

FUNCTION `to_boolean_number()` takes a Boolean value as a parameter, and then returns a 1 for TRUE or 0 for FALSE. If you call `is_duplicate()` from a Java program, you'll need to wrap `is_duplicate()` with `to_boolean_number()` so you'll get a numeric value 1 for TRUE and 0 for FALSE. For example, you would code your JDBC stored procedure call as follows:

```
...
int               duplicate = 0;
CallableStatement cstmt     = null;

try {
  // Create the callable statement
  cstmt = conn.prepareCall(
    "{ ? = call to_boolean_number(is_duplicate(?, ?, ?)) }");

  // Register the OUT parameter
  cstmt.registerOutParameter(1, Types.INTEGER);

  // Set the IN parameters
  cstmt.setString(2, code);
  cstmt.setString(3, name);
  cstmt.setTimestamp(4, activeDate);

  // Execute the stored procedure
  cstmt.execute();

  duplicate = cstmt.getInt(1);
}
catch (SQLException e) {
  System.err.println("SQL Error: " + e.getMessage());
}
finally {
  if (cstmt != null)
    try {  cstmt.close(); } catch (SQLException ignore) { }
}
...
```

Enough JDBC, let's get back to PL/SQL.

set_row()

Method `set_row` is the ultimate parametric method replacement for SQL—that is, as far as our unhappy SQL programmer is concerned! To INSERT or UPDATE the database with the row you desire, you simply pass the row in question, a PL/SQL record or object instance, to PROCEDURE `set_row(air_row)`. When you do, here's what `set_row()` does.

1. It calls get_row() to determine if a row with the specified primary or unique key values already exists in the database. If it does, get_row() returns the matching row. Otherwise, get_row() returns a NULL row.
2. If the desired row already exists in the database, set_row() will compare the non-primary key columns. If any non-primary key column values are different, set_row() will UPDATE the database with the modified values.
3. If the desired row doesn't exist in the database, set_row() will allocate a primary key value if necessary, and then INSERT the desired row into the database. The row passed to set_row() is an IN OUT parameter, so the value of any allocated primary key will be updated in the passed row if a new row is inserted into the database.

This is a very handy method when you're coding a data migration program. You can call set_row() as many times as you like with the same values, and it will insert a row only once, and update it only if values have changed. This allows you to code data migration programs that can be rerun as needed until you get the "correct" results.

The following is an example of method set_row() from content table package LOGICAL_WORKPLACE:

```
PROCEDURE set_row(
aior_logical_workplace         in out LOGICAL_WORKPLACES%ROWTYPE) is

d_null                        constant date        := DATES.d_MIN;
n_null                        constant number      := 0;
v_null                        constant varchar2(1) := ' ';
r_logical_workplace                    LOGICAL_WORKPLACES%ROWTYPE;

begin
  -- get the existing row
  begin
    r_logical_workplace := get_row(aior_logical_workplace);
  exception
    when NO_DATA_FOUND then
      r_logical_workplace := NULL;
  end;
  -- if a row exists, update it if needed
  if r_logical_workplace.id is not NULL then
    aior_logical_workplace.id         := r_logical_workplace.id;
    aior_logical_workplace.parent_id  := r_logical_workplace.parent_id;
    aior_logical_workplace.id_context := r_logical_workplace.id_context;
    if nvl(r_logical_workplace.workplace_type_id, n_null) <>
       nvl(aior_logical_workplace.workplace_type_id, n_null) or
       nvl(r_logical_workplace.code,             v_null) <>
       nvl(aior_logical_workplace.code,             v_null) or
       nvl(r_logical_workplace.name,             v_null) <>
       nvl(aior_logical_workplace.name,             v_null) or
       nvl(r_logical_workplace.active_date,      d_null) <>
       nvl(aior_logical_workplace.active_date,      d_null) or
       nvl(r_logical_workplace.inactive_date,    d_null) <>
       nvl(aior_logical_workplace.inactive_date,    d_null) then
    begin
      update LOGICAL_WORKPLACES
      set    workplace_type_id    = aior_logical_workplace.workplace_type_id,
             code                 = aior_logical_workplace.code,
             name                 = aior_logical_workplace.name,
             active_date          = aior_logical_workplace.active_date,
             inactive_date        = aior_logical_workplace.inactive_date
      where  id = aior_logical_workplace.id;

      n_updated := nvl(n_updated, 0) + nvl(sql%rowcount, 0);
    exception
      when OTHERS then
        raise_application_error( -20002, SQLERRM||
          ' on update LOGICAL_WORKPLACES'||
          ' in LOGICAL_WORKPLACE.set_row()' );
    end;
  end if;
else
-- add the row if it does not exist
  begin
    if aior_logical_workplace.id is NULL then
      aior_logical_workplace.id := get_id();
    end if;
    aior_logical_workplace.id_context :=
      create_id_context(
        aior_logical_workplace.parent_id,
        aior_logical_workplace.id );
    insert into LOGICAL_WORKPLACES (
           id,
           parent_id,
           id_context,
           workplace_type_id,
           code,
           name,
           active_date,
           inactive_date )
    values (
           aior_logical_workplace.id,
           aior_logical_workplace.parent_id,
           aior_logical_workplace.id_context,
           aior_logical_workplace.workplace_type_id,
           aior_logical_workplace.code,
           aior_logical_workplace.name,
           aior_logical_workplace.active_date,
           aior_logical_workplace.inactive_date );

    n_inserted := nvl(n_inserted, 0) + nvl(sql%rowcount, 0);
  exception
```

```
      when OTHERS then
        raise_application_error( -20003, SQLERRM||
          ' on insert LOGICAL_WORKPLACES'||
          ' in LOGICAL_WORKPLACE.set_row()' );
    end;
  end if;
end set_row;
```

You have to admit that that is a pretty cool method—that is, if you hate to code SQL.

WHAT? NO METHODS TO REPLACE CURSORS?

Have you noticed that I have all kinds of table package methods that wrap singleton SQL statements with a method, yet I have none to wrap a cursor with a method call? An esteemed peer of mine, Steven Feuerstein, has written about doing just that: wrapping a cursor with a method that returns a collection. A program is then written to loop through the rows of a collection instead of the rows of a cursor.

Used judiciously—that is, with cursors that return a small number of rows—Steven's method can be quite effective. However, in practice, I don't find much use for this technique. Remember that I advocate the use of PL/SQL methods in order to eliminate "duplicate" code. In contrast, I find that most stored procedures that use cursors use a rather unique cursor. So, because of that, I see very little opportunity for reuse.

At the same time, misuse of wrapping cursors with methods that return collections can lead to inordinately large amounts of shared memory use in an Oracle database. This in turn leads to poor performance. Regardless, at some point in time, I suggest you check out Steven's ideas. Every good idea has its place.

Intersection Table Methods

Tables that act as the intersection between two content tables (commonly called a *many-to-many relationship/entity*) use all the same methods as a content tables and a few more. So let's start by listing the methods that an intersection table has in common with a content table:

- `get_row()`: Used to detect and retrieve an existing row based on primary key or unique key data.
- `is_duplicate()`: Used to detect a duplicate entry before a presentation layer program tries to insert the values in question into the database.
- `set_row()`: Used to conditionally insert or update a row in the database, based on use of `get_row()` to detect an existing entry.

An intersection table has two additional methods that are concerned about the existence of intersection history: `is_active()` and `is_history()`. Let's look at `is_active()` first.

is_active()

Method `is_active()` returns a Boolean value based on whether or not an "active" entry exists in an intersection table for the specified "primary" content entity at the specified point in time. By "primary" content entity, I mean the content entity that is the subject of the query.

For example, the three intersection entities in the example's ERD from Chapter 1—LOGICAL_ASSIGNMENTS, PHYSICAL_ASSIGNMENTS, and WORK_ASSIGNMENTS—have a primary content entity, WORKERS, that is the subject of the relationship. And they have a secondary content entity—LOGICAL_WORKPLACES, PHYSICAL_WORKPLACES, and WORKS, respectively—that is the object of the relationship.

By "active," I mean that the specified point in time is between an entry's active date and inactive date. Figure 10-2 illustrates the method's use.

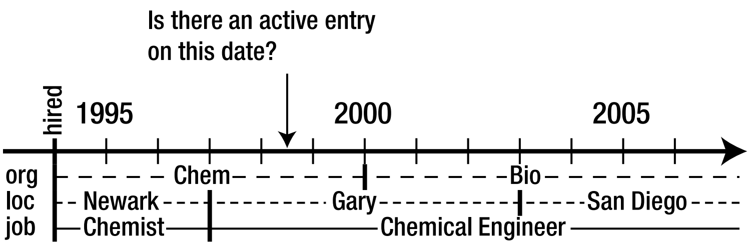


Figure 10-2. An illustration of method is_active()'s use

If an active entry exists, FUNCTION is_active(ain_primary_id, aid_on) returns TRUE; otherwise, it returns FALSE. The following is an example of the method from intersection table package LOGICAL_ASSIGNMENT:

```
FUNCTION is_active(
ain_worker_id                  in     LOGICAL_ASSIGNMENTS.worker_id%TYPE,
aid_on                         in     date)
return                                boolean is

pragma AUTONOMOUS_TRANSACTION;

n_count                               number;

begin
 select count(1)
 into   n_count
 from   LOGICAL_ASSIGNMENTS
 where  worker_id       = ain_worker_id
 and    aid_on    between active_date
                      and nvl(inactive_date, DATE_.d_MAX);

 if nvl(n_count,0) > 0 then
  return TRUE;
 else
  return FALSE;
 end if;

 commit;
end is_active;
```

In the example above and below, for functions is_inactive() and is_history(), I am judiciously using pragma AUTONOMOUS_TRANSACTION so these methods can "see" outside of the current transaction context. That's a bit of an advanced topic. So until you're ready to study up on that topic, make sure you use that pragma extremely carefully, or not at all.

is_history()

The second intersection table package method, `is_history()`, exists for a whole different reason. It determines whether there is any history of an active entry over a specified period of time. `FUNCTION is_history(ain_primary_id, aid_active_date, aid_inactive_date)` is designed to return `TRUE` if history does exist; otherwise, it returns `FALSE`. It also uses `pragma autonomous transaction`, so it can be used in a `before insert for each row` (BIR) trigger on an intersection table, to prevent overlapping historical entries. Figure 10-3 illustrates the use of `is_history()`.

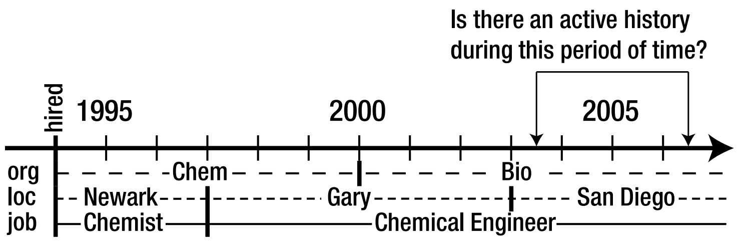


***Figure 10-3.** An illustration of method is_history()'s use*

The following is an example of method `is_history()` from intersection table package `LOGICAL_ASSIGNMENT`:

```
kFUNCTION is_history(
ain_worker_id                   in     LOGICAL_ASSIGNMENTS.worker_id%TYPE,
aid_active_date                 in     LOGICAL_ASSIGNMENTS.active_date%TYPE,
aid_inactive_date               in     LOGICAL_ASSIGNMENTS.inactive_date%TYPE)
return                                 boolean is

pragma AUTONOMOUS_TRANSACTION;

n_count                                number;

begin
  select count(1)
  into   n_count
  from   LOGICAL_ASSIGNMENTS
  where  worker_id                        = ain_worker_id
  and    active_date                     <=
           nvl(aid_inactive_date, DATE_.d_MAX)
  and    nvl(inactive_date, DATE_.d_MAX) >= aid_active_date;
  commit;

  if nvl(n_count,0) > 0 then
    return TRUE;
  else
    return FALSE;
  end if;
end is_history;
```

At first glance, most programmers think I've coded the comparisons between the dates in this method incorrectly, but examine Figure 10-4. What I'm asking the database in the query is, "Are there any entries where the active date takes place before the end of the range (`inactive date`) I'm specifying and at the same time the inactive date takes place after the start of the range (`active_date`) I'm specifying?" If there are, then these entries are active at some point (or points) in time during the range I've specified.

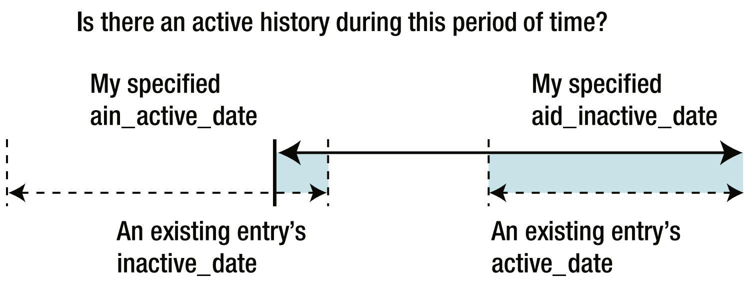

Is there an active history during this period of time?
My specified ain_active_date
My specified aid_inactive_date
An existing entry's inactive_date
An existing entry's active_date

Figure 10-4. *An illustration of overlapping historical entries*

The use of an autonomous transaction in this method allows it to be used to verify that no existing entries overlap the history of the new entry, without generating a mutating table error.

Hierarchical Table Methods

Hierarchical entities—those that have a relationship with themselves—have three additional methods, which are centered on the hierarchy. A common example of a hierarchical entity is one that stores organization information, as the `LOGICAL_WORKPLACE` entity does in the example schema from Chapter 1. From data in this entity, we can build an organization chart, as in Figure 10-5.

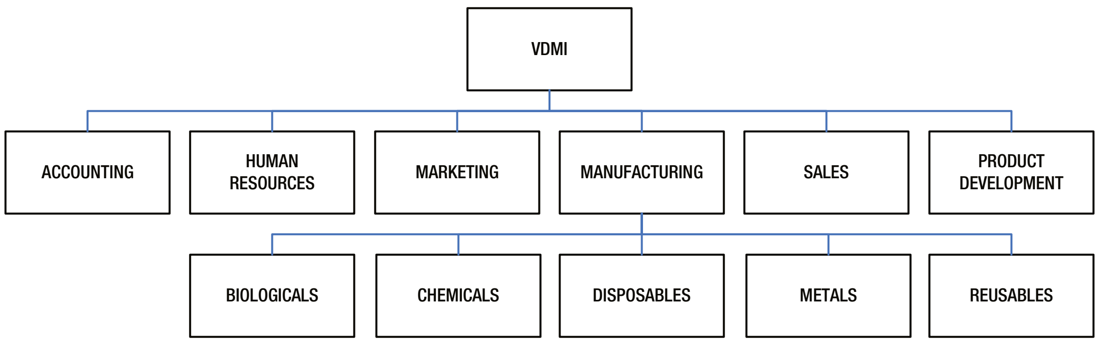


Figure 10-5. *An example of a hierarchical relationship*

Determining who reports to an intermediate organization, like Manufacturing in Figure 10-5, can be quite complex and time-consuming. One option is to use Oracle's `CONNECT BY` clause in a SQL `SELECT` statement, but the retrieval times can be onerous. So as a performance work-around, I create what I call a "contextual primary key string," which is made up of a list of primary keys in the hierarchy separated by some predetermined separator character. I prefer to use a period (`.`).

When I want to identify everyone who works for Manufacturing, I look up the ID context for Manufacturing, and then ask for any entry that is LIKE it. Let's investigate this design further by looking at a method to create the ID context.

create_id_context()

Method create_id_context() returns an ID context string for the specified parent entry and new logical workplace ID. An application programmer must make sure that the associated ID context column in the associated table is set to the return value of FUNCTION create_id_context(ain_parent_id, ain_id) any time a row is inserted into the database. Here's an example of the method for hierarchical content table package LOGICAL_WORKPLACE:

```
FUNCTION create_id_context(
ain_parent_id                in     LOGICAL_WORKPLACES.parent_id%TYPE,
ain_id                       in     LOGICAL_WORKPLACES.id%TYPE)
return                              varchar2 is

v_id_context                        LOGICAL_WORKPLACES.id_context%TYPE;

begin
  v_id_context := get_parent_id_context(ain_parent_id);

  if v_id_context is not NULL then
    return substr(v_id_context||'.'||to_char(ain_id), 1, 2000);
  else
    return to_char(ain_id);
  end if;
end create_id_context;
```

Let's work through an example using the primary key ID values for the organizations represented in Figure 10-5. Table 10-3 lists the primary key values for some of the organizations shown in that figure.

Table 10-3. *Selected LOGICAL WORKPLACE Entries*

Code	Name	logical_workplace_id	id_context
VDMI	Very Dirty Manufacturing, Inc.	1	1
MFG	Manufacturing	5	1.5
CHEM	Chemicals	8	1.5.8
BIO	Biologicals	9	1.5.9
METL	Metals	10	1.5.10
RUSE	Reusables	11	1.5.11
DISP	Disposables	12	1.5.12

The Chemicals department (ID = 8) is part of the Manufacturing business unit (ID = 5). So when FUNCTION create_id_context() is called, its parent's ID value, 5, is passed as ain_parent_id, and its ID value, 8, is passed as ain_logical_workplace_id.

First, the function retrieves the parent's ID context, 1.5. Then the method appends a period and the ID value, 8, to the parent's ID context, to get 1.5.8. This is the value returned by the function.

Once that value is stored in the database, if I want a list of everyone under Manufacturing, all I need to do is add the following SQL to a query:

```
where id_context like aiv_id_context||'%'.
```

get_code_context()

Method `get_code_context()` returns the hierarchical list of code values as a context string for the specified ID. For example, executing `FUNCTION get_code_context(ain_id)` will return the string `VDMI.MFG.CHEM` for the Chemicals department listed in Table 10-3. Here's an example of the method from hierarchical content table package `LOGICAL_WORKPLACE`:

```
FUNCTION get_code_context(
ain_id                         in     LOGICAL_WORKPLACES.id%TYPE)
return                                varchar2 is

cursor c_code_context(
ain_id       in      LOGICAL_WORKPLACES.id%TYPE) is
select upper(code) code
from   LOGICAL_WORKPLACES
connect by prior parent_id = id
start with       id        = ain_id
order by level desc;

v_code_context                        varchar2(2000);

begin
  for r_code_context in c_code_context(ain_id) loop
    v_code_context := substr(v_code_context||'.'||r_code_context.code, 1, 2000);
  end loop;
  return v_code_context;
end get_code_context;
```

In this case, I do use the `CONNECT BY` SQL clause in the method's cursor, `c_code_context`, to get the list of code values for the context string.

get_id_context()

Method `get_id_context()` returns the ID context for the specified ID. For example, calling `FUNCTION get_id_context(ain_id)` for Manufacturing (ID = 5) as in Table 10-3 will return the value 1.5. Here's an example of the method from hierarchical content table package `LOGCAL_WORKPLACE`:

```
FUNCTION get_id_context(
ain_id                         in     LOGICAL_WORKPLACES.id%TYPE)
return                                varchar2 is

v_id_context                          LOGICAL_WORKPLACES.id_context%TYPE;
```

```
begin
  if ain_id is not NULL then
    select id_context
    into   v_id_context
    from   LOGICAL_WORKPLACES
    where  id = ain_id;
  end if;

  return v_id_context;
end get_id_context;
```

This method is used by method `create_id_context()` to get the ID context for a new entry's parent entry.

get_name_context()

Similar to its sibling `get_code_context()`, `get_name_context()` returns the hierarchical list of name values as a context string for the specified ID. For example, executing `FUNCTION get_name_context(ain_id)` will return the string `Very Dirty Manufacturing, Inc..Manufacturing.Chemicals` for the Chemicals department listed in Table 10-3. Here's an example of the method from hierarchical content table package `LOGICAL_WORKPLACE`:

```
FUNCTION get_name_context(
ain_id                         in      LOGICAL_WORKPLACES.id%TYPE)
return                                 varchar2 is

cursor c_name_context(
ain_id                         in      LOGICAL_WORKPLACES.id%TYPE) is
select initcap(name) name
from   LOGICAL_WORKPLACES
connect by prior parent_id = id
start with       id        = ain_id
order by level desc;

v_name_context                         varchar2(2000);

begin
  for r_name_context in c_name_context(ain_id) loop
    v_name_context := substr(v_name_context||'.'||r_name_context.name, 1, 2000);
  end loop;
  return v_name_context;
end get_name_context;
```

As with `get_code_context()`, I use the `CONNECT BY` SQL clause in the method's cursor, `c_name_context`, to get the list of name values for the context string.

That's almost the entire list of table package or object `TYPE` methods. A few more are also used by most executables, so I will discuss them next.

The Black Box

The notion of a “black box” is something that you use but have no idea how it works. A lot of people drive cars, yet they don’t actually know how they work. Even more people use electronic devices, yet they don’t know how they work either. To these users, these are black boxes.

These black boxes have an interface. In the case of a car, the interface consists of an ignition switch, steering wheel, gas pedal, brake pedal, and so on. But beyond the use of the interface, users know little about how gasoline put in the tank turns into mechanical energy that takes them from place to place. And why should they?

In this section, I’m going to introduce you to a handful of methods that are used in almost every table package, object TYPE, or role package. Let’s start with those that are common to all table packages and object TYPEs.

Table Methods

A couple methods are applicable to almost all, if not all, table packages and object TYPEs. They are get_id and inactivate(). The method get_id is shown without parentheses because it takes no arguments. From my point of view, these “black box” methods should exist in every table package and object TYPE. Let’s start with get_id.

get_id

Method get_id allocates and returns a new primary key value from an underlying Oracle sequence. FUNCTION get_id() acts as an abstraction layer between the underlying Oracle sequence and PL/SQL. This abstraction layer allows you to later change the means by which you allocate a primary key value without having to recode any PL/SQL program units that call the method.

The following is an example of the get_id method from code table package WORKER_TYPE:

```
FUNCTION get_id
return                                 WORKER_TYPES.id%TYPE is

n_id                                   WORKER_TYPES.id%TYPE;

begin
  select WORKER_TYPES_ID.nextval
  into   n_id
  from   SYS.DUAL;

  return n_id;
end get_id;
```

inactivate()

Rarely have I encountered an application where I actually delete data from a table. Instead, applications work with the idea of inactivating or invalidating an entry. Method inactivate() handles inactivation.

If you have a code table, you can’t delete a code value that’s in use (one that has any relationships). Yet you may want to stop users from using an “outdated” code value. To do so, you write your code value’s SELECT statement to utilize the code’s inactive date, and then you set a code’s inactive date so users can no longer select it from a list of values.

Along the same line of thinking, if you have a content table, and a particular entry has relationships, but you no longer want users to select the content table entry, you can set its inactive date and prevent it from appearing in the presentation layer. Just as with the code, the content entry has historical significance but is no longer to be used.

With an intersection table, the concept is slightly different. With an intersection, the assignment of a relationship between two tables exists for the period of time defined from its active date through its inactive date. So when you inactivate an intersection entry, you're simply defining the end of a historical relationship.

Regardless of the type of table for which an entry is inactivated, `inactivate()` does the same thing: it sets the inactive date. The following is an example of an `inactivate()` method from content table package `LOGICAL_WORKPLACE`:

```
PROCEDURE inactivate(
ain_id                         in     LOGICAL_WORKPLACES.id%TYPE,
aid_inactive_date              in     LOGICAL_WORKPLACES.inactive_date%TYPE) is

begin
  update LOGICAL_WORKPLACES
  set    inactive_date = aid_inactive_date
  where  id            = ain_id;
end inactivate;
```

That's straightforward enough. Now let's look at methods used by all packages and TYPEs.

Universal Methods

I expect some methods to exist in every package or TYPE. You've already been introduced to methods `help` and `test`. I have one new one here named `initialize`. Let's start with `help`.

help

Method `help` should display help text for the package or TYPE for which it is executed. `PROCEDURE help` was covered extensively in Chapter 9. You should code this method to display help text in whatever manner you find suitable. What I showed you in Chapter 9 was just an example. But, whatever you do, you must be consistent; otherwise, programmers won't consider the help as reliable documentation, and then you'll have defeated the purpose of coding the method altogether.

The following is an example of the method from code table package `WORKER_TYPE`:

```
PROCEDURE help is

begin
  TEXT_HELP.process('WORKER_TYPE');
end help;
```

In this example, `PROCEDURE process` in package `TEXT_HELP` will format and display the contents of the associated specification.

initialize

I know I have not talked about method `initialize` before, but I feel it's an important part of testing and should exist in any package that uses its initialization section. Just in case you don't know what I mean by "initialization section," let me elaborate.

A package body is a PL/SQL block. Because it is a PL/SQL block, it has a declaration section, which is where you code any instance variables, functions, procedures, and so on, and it has an executable section. Really, it does. If, after all the functions and procedures you coded, you add the keyword `BEGIN`, any code from the keyword `BEGIN` to keyword `END` at the end of the package body is executed once, and only once, any time the package is instantiated. By "instantiated," I mean loaded into memory and initialized. There it is, that word: *initialized*.

So for any package where I use the "initialization section," I add a public `PROCEDURE initialize` to the package. Why? So I can test the code in the initialization section.

One of the mysterious errors developers, support personnel, and end users encounter is `NO_DATA_FOUND` the first time they try to use a particular package, and then the error magically goes away. This is almost always caused by a SQL `SELECT` statement executed in the initialization section of a package that can't find a matching row in the database. It happens once, and only once, because the package is initialized once, and only once.

A problem like this can be quite elusive. You can go crazy troubleshooting the problem and then testing that your solution works. How do you fix it? Create a `PROCEDURE initialize` where you put your initialization code, and then execute that procedure in the initialization section of your package. Then, you can execute `PROCEDURE initialize` as many times as you like during testing, without having to log out and in, in order to get the database to initialize the package.

Here's an example of the method:

```
PROCEDURE initialize is

begin
  n_contractor := get_id(v_contractor);
  n_employee   := get_id(v_employee);
  n_unknown    := get_id(v_unknown);
end initialize;
```

Then add a call to `initialize` in the initialization section of your package, like so:

```
...
-- Initialization section
begin
  initialize;

end WORKER_TYPE;
```

Once this code is in place, any time you access the package the first time, the package will execute the code in method `initialize`. And any time you need to test the code from the initialization section of a package, all you need do is execute method `initialize`. Take a look at source file `top_100_names.pkb` for a complete example.

test

The `test` procedure should be coded so it performs all necessary tests on its package or TYPE's methods. I covered this method extensively in Chapter 8. Here's a partial example of the method from code table package `WORKER_TYPE`:

```
PROCEDURE test is

n_id                                    WORKER_TYPES.id%TYPE;
v_code                                  WORKER_TYPES.code%TYPE;
v_description                           WORKER_TYPES.description%TYPE;

begin
  -- Send feedback that the test ran
  pl('WORKER_TYPE.test()');

  -- Clear the last set of test results
  &_USER..TEST.clear('WORKER_TYPE');

  -- First, we need some test values

  -- Let's make sure they don't already exist: DELETE
  &_USER..TEST.set_test('WORKER_TYPE', 'DELETE', 0,
    'Delete test entries');
  begin
    delete WORKER_TYPES
    where  code in (
      &_USER..TEST.v_TEST_30,
      &_USER..TEST.v_TEST_30_1,
      &_USER..TEST.v_TEST_30_2);
    &_USER..TEST.ok();
  exception
    when OTHERS then
      &_USER..TEST.error(SQLERRM);
  end;

  -- Now let's add three test codes: INSERT
  &_USER..TEST.set_test('WORKER_TYPE', 'INSERT', 1,
    'Insert 3 test entries');
  begin
    insert into WORKER_TYPES (
           id,
           code,
           description,
           active_date,
           inactive_date )
    values (
           get_id(),
           &_USER..TEST.v_TEST_30,
           &_USER..TEST.v_TEST_80,
           &_USER..TEST.d_TEST_19000101,
           &_USER..TEST.d_TEST_99991231 );
  insert into WORKER_TYPES (
         id,
         code,
         description,
         active_date,
         inactive_date )
  values (
         get_id(),
         &_USER..TEST.v_TEST_30_1,
         &_USER..TEST.v_TEST_80,
         &_USER..TEST.d_TEST_19000101,
         &_USER..TEST.d_TEST_99991231 );

  insert into WORKER_TYPES (
         id,
         code,
         description,
         active_date,
         inactive_date )
  values (
         get_id(),
         &_USER..TEST.v_TEST_30_2,
         &_USER..TEST.v_TEST_80,
         &_USER..TEST.d_TEST_19000101,
         &_USER..TEST.d_TEST_99991231 );

  &_USER..TEST.ok();
exception
  when OTHERS then
    &_USER..TEST.error(SQLERRM);
end;

-- Now that we have test entries,
-- let's test the package methods
&_USER..TEST.set_test('WORKER_TYPE', 'get_id()', 2,
  'Get the ID for the specified code');
begin
  n_id := get_id(&_USER..TEST.v_TEST_30);

  if n_id > 0 then
    &_USER..TEST.ok();
  else
    &_USER..TEST.error();
  end if;
exception
  when OTHERS then
    &_USER..TEST.error(SQLERRM);
end;
```

```
&_USER..TEST.set_test('WORKER_TYPE', 'get_code_descr()', 3,
  'Get the code and description for the specified ID');
begin
  get_code_descr(
    n_id,
    v_code,
    v_description);
  if v_code        = &_USER..TEST.v_TEST_30 and
     v_description = &_USER..TEST.v_TEST_80 then
    &_USER..TEST.ok();
  else
    &_USER..TEST.error();
  end if;
exception
  when OTHERS then
    &_USER..TEST.error(SQLERRM);
end;

&_USER..TEST.set_test('WORKER_TYPE', 'get_code_id_descr()', 4,
  'Get the code, ID, and description for the specified code');
begin
  v_code := &_USER..TEST.v_TEST_30;
  get_code_id_descr(
    v_code,
    n_id,
    v_description);
  if v_code           = &_USER..TEST.v_TEST_30 and
     n_id             > 0                      and
     v_description    = &_USER..TEST.v_TEST_80 then
    &_USER..TEST.ok();
  else
    &_USER..TEST.error();
  end if;
exception
  when OTHERS then
    &_USER..TEST.error(SQLERRM);
end;

&_USER..TEST.set_test('WORKER_TYPE', 'get_code_id_descr()', 5,
  'Get the code, ID, and description for the specified date');
begin
  v_code := 'TEST';
  -- This test should raise a TOO_MANY_ROWS exception
  -- because at least three duplicate values will
  -- on the date specified
  get_code_id_descr(
    v_code,
    n_id,
    v_description,
    &_USER..TEST.d_TEST_99991231);
    if v_code           = &_USER..TEST.v_TEST_30 and
       n_id > 0                 and
       v_description    = &_USER..TEST.v_TEST_80 then
      &_USER..TEST.ok();
    else
      &_USER..TEST.error();
    end if;
  exception
    when TOO_MANY_ROWS then
      &_USER..TEST.ok();
    when OTHERS then
      &_USER..TEST.error(SQLERRM);
  end;

  &_USER..TEST.set_test('WORKER_TYPE', 'help()', 6,
    'Display help');
  begin
    help();
    &_USER..TEST.ok();
  exception
    when OTHERS then
      &_USER..TEST.error(SQLERRM);
  end;

  -- Let's make sure they don't already exist: DELETE
  &_USER..TEST.set_test('WORKER_TYPE', 'DELETE', 7,
    'Delete test entries');
  begin
    delete WORKER_TYPES
    where  code in (
      &_USER..TEST.v_TEST_30,
      &_USER..TEST.v_TEST_30_1,
      &_USER..TEST.v_TEST_30_2);
    &_USER..TEST.ok();
  exception
    when OTHERS then
      &_USER..TEST.error(SQLERRM);
  end;

  &_USER..TEST.set_test('WORKER_TYPE', NULL, NULL, NULL);
  &_USER..TEST.success();
end test;
```

If you include and code method `test` in every package, then you can totally automate the testing of your PL/SQL executables, as I outlined at the end of Chapter 9.

Divide and Conquer

The traditional concept of "divide and conquer" is a tactic to destroy teamwork. Your actions cause dissention among team members, so they no longer work together toward a mutual goal, but instead each works on his own goals. Hence, they are no longer a team.

So where you had a team of discrete members working together at various tasks to achieve a common goal, you end up with a group of individuals competing with each other to achieve many goals. The latter is what we normally end up with in an application.

- The database tries to optimize its work around the overall use of reads and writes to the file system while maintaining a transaction context.
- SQL tries to optimize the overall access to data in the database.
- PL/SQL tries to optimize the overall performance of its executables.
- The communication network tries to optimize the overall consumption of bandwidth.
- The application server tries to optimize the overall performance of its hosted executables.
- The presentation layer tries to optimize the overall end-user experience.

What do these layers of technology all have in common? They are all optimized for a fictitious set of events: "the average." They work as a group of individuals competing with each other to achieve their own goals. So how can you turn them into a team whose members work together for a common goal? You divide and conquer. But this time, divide and conquer means you divide up a larger goal into tasks, and then have the best team member perform each task. I know, it's 180 degrees from the traditional definition of divide and conquer, but it works.

For example, if there is data-intensive work to be accomplished, it should be done in the database. Retrieving data from the database through a network to an application server, or worse, a presentation layer, in order to accomplish data migration or data processing is ludicrous. In addition, you should use SQL and PL/SQL to manipulate data. When you combine the use of these two languages, you have the easiest to code, yet most powerful combination for data processing that has ever existed.

In addition, if there is behavior related to data, like so-called business rules, it should reside in the database. Otherwise, each additional layer may have its own version of "the rules," and you'll end up with business rule anarchy. As I tried to convince you earlier, behavior is just as important to store as the data to which it "belongs."

Overall, I'm suggesting that you use PL/SQL and SQL to create actors—program units to fulfill particular roles—in order to accomplish the following kinds of tasks:

- Data migration
- Data processing
- Reporting

Accordingly, this section will cover each of these roles and the polymorphic commands they typically employ.

Data Migration

As I stated earlier, my concept of data migration (DM) is a one-time task where you move external data into a highly structured schema in a database. The notion of it being a "one-time" task is important here. If you needed to move external data into a database on a regular basis, I would call it *data processing* instead.

Here's the high-level idea: load the external data that is to be moved into an application's data structure into staging tables with whatever method is quickest, and then use a PL/SQL data processing program unit to move the data into the application's data structure.

As illustrated in Figure 10-6, you can use an Oracle database link if you're moving data from one database to another, or you can use C/C++ with the Oracle Call Interface (OCI) API, Java and JDBC, XML, or better yet SQL*Loader, if you're loading the data from a file system into the database. Use whatever method is the most efficient.

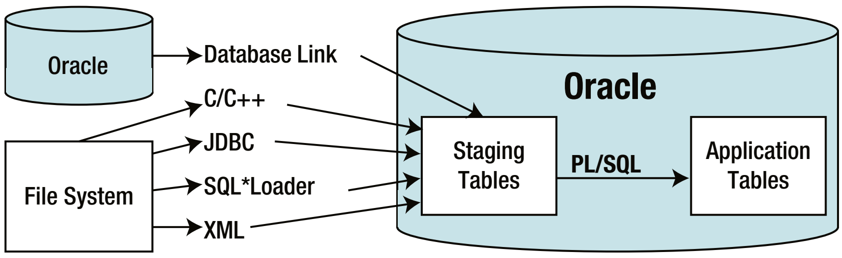


Figure 10-6. *An illustration of data migration*

After the data is loaded into the database, you can then write a PL/SQL package to move the data from the staging tables into a target application's schema. Such a package would have at least one public method: `process`. When executed, `process` would do the following:

1. Use the package's initialization section to load code value IDs that can then be used in a cross-reference `IF` statement to map external code values to ones in the target schema.
2. Initialize the `set_row()` counters—the public package variables `n_inserted` and `n_updated`—to zero for each target table.
3. Use a cursor and cursor `FOR LOOP` to read through the rows of the staging table.
4. Use the `set_row()` method on the target table(s) to insert the external data.
5. Display the `n_insert` and `n_update` counts upon completion in order to confirm that the data migration completed successfully.

After you've coded `PROCEDURE process`, all you would need to do is execute the method in order to move the data from a staging table to a (or set of) corresponding application table(s).

process

Method `process` is used to start an on-demand or polling process. The following is an example of the method from data migration package `TOP_100_NAME`:

```
PROCEDURE process is

-- This is the cursor for the last names.
cursor c_last is
select last_name
from   TOP_100_LAST_NAMES
order by 1;

-- This is the cursor for the first names.
cursor c_first is
select first_name,
       gender_code
from   TOP_100_FIRST_NAMES
order by 1;
```

```
-- This is the cursor for the middle initials.
cursor c_middle is
select letter
from   A_THRU_Z
order by 1;

-- This is the number of seconds since midnight
-- I'll use it to profile my code's performance.
n_start                               number :=
  to_number(to_char(SYSDATE, 'SSSSS'));

-- I'll use this to keep track of how many rows were selected
n_selected                            number := 0;

-- Here, I declare a record anchored to the table so
-- I can set the column values and then insert using
-- the record.
r_worker                              WORKERS%ROWTYPE;

begin
  -- Reset the insert/update counters for set_row()
  WORKER.n_inserted := 0;
  WORKER.n_updated  := 0;

  -- Loop through the last names
  for r_last in c_last loop

    -- While looping through the last names,
    -- loop through the first names
    for r_first in c_first loop

      -- While looping through the last and first names
      -- loop through the 26 letters in the English
      -- Alphabet in order to get middle initials
      for r_middle in c_middle loop
        n_selected                := n_selected + 1;
        -- Initialize the record

        -- Set the PK to NULL so set_row() determines
        -- whether or not the entry already exists
        -- by it's unique keys
        r_worker.id               := NULL;

        -- Flip flop from contractor to employee and back again
        if r_worker.worker_type_id = WORKER_TYPE.contractor then
          r_worker.worker_type_id := WORKER_TYPE.employee;
        else
          r_worker.worker_type_id := WORKER_TYPE.contractor;
        end if;
        -- Set the External ID, UK1, to NULL so set_row() determines
        -- whether or not the entry already exists
        -- by it's unique keys
        r_worker.external_id      := NULL;

        -- The first, middle, and last names come from the cursors
        r_worker.first_name       := r_first.first_name;
        r_worker.middle_name      := r_middle.letter||'.';
        r_worker.last_name        := r_last.last_name;

        -- get the name using the table's package
        r_worker.name             := WORKER.get_formatted_name(
          r_worker.first_name, r_worker.middle_name, r_worker.last_name);

        -- get the date from determinate function create_birth_date()
        r_worker.birth_date       := create_birth_date(r_worker.name);

        -- select the corresponding ID value
        if r_first.gender_code = 'F' then
          r_worker.gender_type_id := GENDER_TYPE.female;
        else
          r_worker.gender_type_id := GENDER_TYPE.male;
        end if;

        -- Insert the row into the database
        begin
          WORKER.set_row(r_worker);
        exception
          when OTHERS then
            raise_application_error(-20001, SQLERRM||
              ' on call WORKER.set_row()'||
              ' in TOP_100_NAME.process()');
        end;
      end loop; -- c_middle

      commit;  -- commit every 26 rows

    end loop; -- c_first

  end loop; -- c_last

  -- Display the results
  pl(to_char(n_selected)||' rows selected');
  pl(to_char(WORKER.n_inserted)||' rows inserted');
  pl(to_char(WORKER.n_updated)||' rows updated');
  pl('in '||to_char(to_number(to_char(SYSDATE, 'SSSSS')) - n_start)||
    ' seconds.');
end process;
```

When migrating data, you should be able to take advantage of methods `get_row()` and `set_row()` on the target content or intersection tables. Now let's take a look at an on-demand, data processing PL/SQL program unit.

On-Demand Data Processing

If you have a task that needs to be done now, or on an hourly, daily, weekly, or monthly basis, you'll use some kind of external scheduler like cron in UNIX or Linux, or a Scheduled Tasks in Windows, or perhaps the internal Oracle job queue to execute the process. I call this kind of processing on-demand data processing (ODDP).

Just like its data migration sibling, on-demand data processing is executed through PROCEDURE process. What's different here is the fact that this is not a one-time event. You expect to use this process over and over again. Accordingly, I usually create a table to log when the process runs, along with any performance statistics like how long it took to run, how many rows it inserted, how many rows it updated, and so on.

Since I want to keep track of when a process executes, I now have three common method names used for an on-demand data processing program unit: process, start_logging(), and stop_logging(). Let's look at process first.

process

As before, process is used to start an on-demand or polling process. This time, process incorporates the use of a log so it can record that the process took place, along with some performance statistics. The following is an example of the method from package REPORT_STAGING_TABLE:

```
PROCEDURE process is

-- Get a list of all the tables that start with REPORT_ in the USER's schema
cursor c_table is
select table_name
from   SYS.USER_TABLES
where  table_name like 'REPORT\_%' escape '\'
order by 1;

n_selected                          number := 0;
n_deleted                           number := 0;

begin
  -- Start logging
  ON_DEMAND_PROCESS_LOG.start_logging(
    'REPORT_STAGING_TABLE', 'process');

  -- For each report "staging" table, delete any data over 2 days old
  for r_table in c_table loop
    n_selected := n_selected + 1;

    execute immediate 'delete '||
      r_table.table_name||
      ' where insert_date < SYSDATE - 2';

    n_deleted := n_deleted + nvl(sql%rowcount, 0);
  end loop;

  -- Stop logging
  ON_DEMAND_PROCESS_LOG.stop_logging(
    n_selected, NULL, NULL, n_deleted, NULL);
```

```
exception
  when OTHERS then
    -- Stop logging, but report an error
    ON_DEMAND_PROCESS_LOG.stop_logging(
      n_selected, NULL, NULL, n_deleted, SQLERRM);
    raise;
end process;
```

If you examine this example, you'll see that the process starts out by calling method `start_logging()` at the beginning, and then calls method `stop_logging()` at the end. The underlying log package, `ON_DEMAND_PROCESS_LOG`, keeps track of the start and stop time, and then records the statistics to table `ON_DEMAND_PROCESS_LOGS` when method `stop_logging()` is called.

The process itself deletes any staged reporting data that is over two days old. As with its data migration sibling, if processing data, you should be able to take advantage of methods `get_row()` and `set_row()` on any target content or intersection tables.

Now let's take a look at what supporting method `start_logging()` does.

start_logging()

Method `start_logging()` stores the time it was called, in memory, allocates and stores a new primary key value, and then inserts a "starting" row in a log table. In this case, it inserts a row into table `ON_DEMAND_PROCESS_LOGS` as defined in the following partial listing from script `on_demand_process_logs.tab`:

```
create table ON_DEMAND_PROCESS_LOGS (
id                              number                          not null,
object_name                     varchar2(30)                    not null,
method_name                     varchar2(30)                    not null,
rows_selected                   number,
rows_inserted                   number,
rows_updated                    number,
rows_deleted                    number,
result                          varchar2(256),
elapsed_time                    number,
insert_user                     varchar2(30)  default USER      not null,
insert_date                     date          default SYSDATE   not null,
update_user                     varchar2(30)  default USER      not null,
update_date                     date          default SYSDATE   not null)

...
```

This log table holds information about how long it took to execute the process, row processing statistics, and the time when the process was started and stopped. The following is an example of the method `start_logging()` from package `ON_DEMAND_PROCESS_LOG`:

```
PROCEDURE start_logging(
aiv_object_name                 in     ON_DEMAND_PROCESS_LOGS.object_name%TYPE,
aiv_method_name                 in     ON_DEMAND_PROCESS_LOGS.method_name%TYPE) is

pragma AUTONOMOUS_TRANSACTION;
```

```
begin
  n_start := to_number(to_char(SYSDATE, 'SSSSS'));
  n_id    := get_id();

  insert into ON_DEMAND_PROCESS_LOGS (
         id,
         object_name,
         method_name )
  values (
         n_id,
         upper(aiv_object_name),
         upper(aiv_method_name) );
  commit;
end start_logging;
```

Variable `n_start` in method `start_logging()` is an instance (package body) variable used to capture the time when the method was called. Similarly, variable `n_ id` is used to capture the new log entry's primary key so the same entry can be updated in method `stop_logging()`. In addition, this method employs the use of `pragma autonomous_transaction` so a process that starts but fails will still leave a starting entry in the log.

Now let's look at `stop_logging()`.

stop_logging()

Method `stop_logging()` takes the row processing information and a result description passed to it, and uses that information along with the stored start time and primary key to update the starting log entry. As part of updating the log entry, the method calculates the elapsed time in seconds between the start and stop of logging. The following is an example of the method from package `ON_DEMAND_PROCESS_LOG`:

```
PROCEDURE stop_logging(
ain_rows_selected            in     ON_DEMAND_PROCESS_LOGS.rows_selected%TYPE,
ain_rows_inserted            in     ON_DEMAND_PROCESS_LOGS.rows_inserted%TYPE,
ain_rows_updated             in     ON_DEMAND_PROCESS_LOGS.rows_updated%TYPE,
ain_rows_deleted             in     ON_DEMAND_PROCESS_LOGS.rows_deleted%TYPE,
aiv_result                   in     ON_DEMAND_PROCESS_LOGS.result%TYPE) is

pragma AUTONOMOUS_TRANSACTION;

n_elapsed_time                      number;

begin
  n_elapsed_time := to_number(to_char(SYSDATE, 'SSSSS')) - n_start;

  update ON_DEMAND_PROCESS_LOGS
  set    rows_selected            = ain_rows_selected,
         rows_inserted            = ain_rows_inserted,
         rows_updated             = ain_rows_updated,
         rows_deleted             = ain_rows_deleted,
         result                   = aiv_result,
         elapsed_time             = n_elapsed_time,
         update_user              = USER,
         update_date              = SYSDATE
  where  id = n_id;
  commit;

  n_id := NULL;

  -- Display the results
  if ain_rows_selected is not null then
    pl(to_char(ain_rows_selected)||' rows selected.');
  end if;
  if ain_rows_inserted is not null then
    pl(to_char(ain_rows_inserted)||' rows inserted.');
  end if;
  if ain_rows_updated is not null then
    pl(to_char(ain_rows_updated)||' rows updated.');
  end if;
  if ain_rows_deleted is not null then
    pl(to_char(ain_rows_deleted)||' rows deleted.');
  end if;
  if aiv_result is not null then
    pl(aiv_result);
  end if;
  pl('Elapsed time: '||to_char(n_elapsed_time)||' seconds.');
end stop_logging;
```

In addition to recording the log statistics, `stop_logging()` also echoes those statistics to the screen if `serveroutput` is `set` to `on` in SQL*Plus. Like its sibling `start_logging()`, this method employs the use of `pragma autonomous_transaction`, so a process that fails can still leave a completed log entry.

Having log information about when on-demand processes execute is an important part of managing their use. Access to statistics about each on-demand process is even more invaluable. Using these statistics, you can determine whether a process is fast and efficient, and make adjustments accordingly.

If you find you're running an on-demand process every few minutes, or if you're interested in offloading a long-running process from the presentation layer, then the process is probably better done as a polling process. Let's look at that next.

Polling Data Processing

Unlike an on-demand process, a polling data process (PDP) just keeps running. It follows three high-level steps.

1. Check a queue for commands.
2. Process the "next" command.
3. Sleep for a predetermined period of time, then go back to step 1.

I'll give you three common examples here of using "divide and conquer" to offload a portion of data processing to the database rather than the presentation or application layer. Doing so makes the presentation or application layer appear to be fast and efficient. And, since the best place to perform data processing is in the database, the offloaded portion of the larger process is fast and efficient. First, let's look at an example with the application layer.

Let's say you have web or message services that, in turn, update your database whenever there is a transaction on an external system. Rather than tie up the services with the entire business process, you can have your services update a set of staging tables in your database, and then have a polling process on your database wake up every so often and finish processing the staged data.

A second example is one where you have a long-running process in the presentation layer. Let's say you have a security system where an administrator can assign access to worker data based on business organization, location, and so on. Rather than tie up the administrator's computer while the mass assignments take place, you can have the presentation layer submit the processing request to your polling process's queue. Then, when your polling process wakes up from its sleep period, it will process your long-running request in the background. What's the result? To the end user using the presentation layer, the application appears easy, fast, and efficient.

A third example is along the same line of thinking. This time, however, you set up your end user's reporting subsystem to submit long-running reports to your polling process's queue, and then have your polling process email the end user with a link (URL) to a completed report when it finishes executing the report in the background. Once again, the end user's experience is one where submitting the report is easy, fast, and efficient.

Using a polling process requires a different design than an on-demand process. Instead of logging each time a process executes (which you can still do), you need to create a queue for process and processing-related commands, and possibly a table to hold the current status of the polling process. I'll start out by showing you an example of the `process` method, and then follow up with discussions on each of the supporting methods.

process

Once again, `process` is used to start an on-demand or polling process. In this case, it's a polling data process. A polling process is one that does its thing, goes to sleep, and then wakes up to do its thing all over again and again. A polling process is dependent on a queue, at the very least, so you can tell the process to quit executing.

The queue can also be used to indicate what needs to be processed. For example, if you have a long-running process that must take place as part of inserting an entry into a particular table, you could have a trigger on that table insert a row into a polling process's queue, like a primary key ID value, and then have the polling process finish the long-running process asynchronously.

The following is an example of a polling process that you can find in package `POLLING_PROCESS`:

```
PROCEDURE process is

r_polling_process_queues              POLLING_PROCESS_QUEUES%ROWTYPE;

begin
  DEBUG.set_text('POLLING_PROCESS', 'Starting');

  -- perform a manual loop until it recieves a command to quit
  loop
    DEBUG.set_text('POLLING_PROCESS', 'Getting next command');

    -- Get the next command from the queue
    r_polling_process_queues :=
      POLLING_PROCESS_QUEUE.get_next(r_polling_process_queues);
    -- If it's time to quit, pool the queue once more to delete
    -- the quit command, and then exit
    if r_polling_process_queues.command =
         POLLING_PROCESS_QUEUE.v_QUIT then

      POLLING_PROCESS_STATUS.set_status('Quiting');

      DEBUG.set_text('POLLING_PROCESS', 'Quiting');

      r_polling_process_queues :=
        POLLING_PROCESS_QUEUE.get_next(r_polling_process_queues);
      exit;
    elsif r_polling_process_queues.command = 'DISABLE' then
      DEBUG.disable('POLLING_PROCESS');
    elsif r_polling_process_queues.command = 'ENABLE'  then
      DEBUG.enable('POLLING_PROCESS');
    end if;

    -- *** Now do all your groovy data processing here! ***

    POLLING_PROCESS_STATUS.set_status('Processing');

    DEBUG.set_text('POLLING_PROCESS',
      'I''m doing some groovy data processing at '||
      to_char(SYSDATE, 'HH:MI:SS'));

    -- *** End of your groovy data processing section.  ***

    POLLING_PROCESS_STATUS.set_status('Sleeping');

    DEBUG.set_text('POLLING_PROCESS', 'Sleeping');

    -- Sleep for 10 seconds
    SYS.DBMS_LOCK.sleep(10);

    DEBUG.set_text('POLLING_PROCESS', 'Awake');
  end loop;
end process;
```

This example currently has many lines that employ the use of `DEBUG.set_text()` to record what's going on in the process as it runs. The debug logging, as it is called, can be turned on before running the process, or it can be turned on by executing method `enable`. Conversely, debug logging can be turned off by executing `disable`. This means you can enable and disable debug logging on this process from any other database session at any point in time while the process is running. That's helpful when it comes to troubleshooting a new polling process.

This example also employs method `quit` to tell the polling process to stop executing. In addition, it updates a status table `POLLING_PROCESS_STATUSES` with the current status of the process, so you can determine what it's working on at any point in time while it's executing.

In this example, it's sleeping for only 10 seconds in between processing. I've just coded it that way in order to make it easy to demonstrate. In practice, I normally have a polling process sleep 3 to 5 minutes (180 to 300 seconds).

Let's look at method get_next() next.

get_next()

Method get_next() deletes the last item processed from the queue as specified by the passed parameter, and then retrieves the next command from a queue. In this case, it deletes and selects an entry from table POLLING_PROCESS_QUEUES. The following is an example of a queue table definition from file polling_process_queues.tab:

```
create table POLLING_PROCESS_QUEUES (
id                              number                          not null,
command                         varchar2(256)                   not null,
insert_user                     varchar2(30)  default USER      not null,
insert_date                     date          default SYSDATE   not null)

...
```

FUNCTION get_next(air_queue_entry) is the "heart and soul" of the polling process. Here's an example of the method from table package POLLING_PROCESS_QUEUE:

```
FUNCTION get_next(
air_polling_process_queues     in     POLLING_PROCESS_QUEUES%ROWTYPE)
return                                POLLING_PROCESS_QUEUES%ROWTYPE is

pragma AUTONOMOUS_TRANSACTION;

r_polling_process_queues              POLLING_PROCESS_QUEUES%ROWTYPE;

begin
  delete POLLING_PROCESS_QUEUES
  where  id = air_polling_process_queues.id;

  begin
    select q.*
    into   r_polling_process_queues
    from   POLLING_PROCESS_QUEUES q
    where  q.id = (
    select min(n.id)
    from   POLLING_PROCESS_QUEUES n);
  exception
    when NO_DATA_FOUND then
      r_polling_process_queues := NULL;
  end;

  commit;

  return r_polling_process_queues;
end get_next;
```

The way that this method is written, an entry is removed from the queue only after it has completed successfully.

Let's look at the one method that always uses the queue, `quit`, next.

quit

Method `quit` is used to tell a polling or long-running process to quit before its next round of processing. With a polling process, this method stores a quit command in the polling process's queue, so the next time it wakes and starts processing, it quits executing.

`PROCEDURE quit` inserts a new message into its queue table with a primary key value of `-1` so the command jumps to the top of the queue. Here's an example of the method from table package `POLLING_PROCESS_QUEUE`:

```
PROCEDURE quit is

pragma AUTONOMOUS_TRANSACTION;

begin
  begin
    insert into POLLING_PROCESS_QUEUES (
           id,
           command,
           insert_user,
           insert_date )
    values (
           -1,
           v_QUIT,
           USER,
           SYSDATE );
    pl('Queued to quit.');
  exception
    when DUP_VAL_ON_INDEX then
      pl('Already queued to quit.');
  end;

  commit;
end quit;
```

A convenience method `quit` also exists in package `POLLING_PROCESS`, because it's easier to remember to execute `POLLING_PROCESS.quit` to stop the execution of `POLLING_PROCESS.process` than it is to remember the name of the queue's table package.

So you can now start and quit the process. Wouldn't it be nice to be able to see what the process is doing whenever you need to? Well that's what method `enable` is for. Let's look at it next.

enable

Method enable is used to enable something—in this case, the logging of debug information at any desired point in time. PROCEDURE enable inserts a new command into the queue with a primary key value of -2, so enabling debug logging has an even higher priority than quitting. Here's an example of the method from package POLLING_PROCESS_QUEUE:

```
PROCEDURE enable is

pragma AUTONOMOUS_TRANSACTION;

begin
  begin
    insert into POLLING_PROCESS_QUEUES (
           id,
           command,
           insert_user,
           insert_date )
    values (
           -2,
           v_ENABLE,
           USER,
           SYSDATE );
    pl('Queued to enable logging.');
  exception
    when DUP_VAL_ON_INDEX then
      pl('Already queued enable logging.');
  end;

  commit;
end enable;
```

After executing PROCEDURE enable, and after the polling process's next access to the queue, PROCEDURE process enables debug logging. As with its sibling method quit, a convenience method enable also exists in package POLLING_PROCESS.

And disable?

disable

Method disable is used to disable something—in this case, the logging of debug information at any desired point in time. PROCEDURE disable inserts a new command into the queue with a primary key value of -3, so disabling debug logging has an even higher priority than enabling debug logging and quitting. Here's an example of the method from package POLLING_PROCESS_QUEUE:

```
PROCEDURE disable is

pragma AUTONOMOUS_TRANSACTION;

begin
  begin
```

```
    insert into POLLING_PROCESS_QUEUES (
           id,
           command,
           insert_user,
           insert_date )
    values (
           -3,
           v_DISABLE,
           USER,
           SYSDATE );
    pl('Queued to disable logging.');
  exception
    when DUP_VAL_ON_INDEX then
      pl('Already queued to disable logging.');
  end;

  commit;
end disable;
```

After executing PROCEDURE disable, and after the polling process's next access to the queue, PROCEDURE process disables debug logging. As with its sibling methods quit and enable, a convenience method disable also exists in package POLLING_PROCESS.

Now let's look at the methods used to record and read the current status of a polling process.

set_status()

Method set_status() is used to record a process's current status in a status table. In this case, set_status() is updating a row in table POLLING_PROCESS_STATUSES, as defined from following partial listing of file polling_process_statuses.tab:

```
create table POLLING_PROCESS_STATUSES (
status                         varchar2(256)                   not null,
update_user                    varchar2(30)  default USER      not null,
update_date                    date          default SYSDATE   not null)

...
```

This table is supposed to have one, and only one, row at any point in time. PROCEDURE set_status(aiv_status) updates or inserts an entry in this table as needed. The following is an example of this method from table package POLLING_PROCESS_STATUS:

```
PROCEDURE set_status(
aiv_status                     in     POLLING_PROCESS_STATUSES.status%TYPE) is

pragma AUTONOMOUS_TRANSACTION;

begin
  update POLLING_PROCESS_STATUSES
  set    status      = aiv_status,
         update_user = USER,
         update_date = SYSDATE;
  if nvl(sql%rowcount, 0) = 0 then
    insert into POLLING_PROCESS_STATUSES (
           status,
           update_user,
           update_date )
    values (
           aiv_status,
           USER,
           SYSDATE );
  end if;

  commit;
exception
  when OTHERS then
    raise_application_error(-20002, SQLERRM||
      ' on update or insert POLLING_PROCESS_STATUSES'||
      ' in POLLING_PROCESS_STATUS.set_status()');
end set_status;
```

So how do you get the status? Come on now . . .

get_status

Method get_status returns the current status for the associated process from its status table. FUNCTION get_status retrieves the one, and only, row from the table, and then returns the value of column status. Here's an example of the method from table package POLLING_PROCESS_STATUS:

```
FUNCTION get_status
return                                POLLING_PROCESS_STATUSES.status%TYPE is

v_status                              POLLING_PROCESS_STATUSES.status%TYPE;

begin
  select status
  into   v_status
  from   POLLING_PROCESS_STATUSES;

  return v_status;
exception
  when NO_DATA_FOUND then
    return 'UNKNOWN';
  when OTHERS then
    raise_application_error(-20001, SQLERRM||
      ' on select POLLING_PROCESS_STATUSES'||
      ' in POLLING_PROCESS_STATUS.get_status()');
end get_status;
```

And finally, the last polling process method: status.

status

Since we are in such a "commanding (or demanding) mood" with this section, `status` is a convenience method that exists in the polling process's package that executes method `get_status` from the table package for the status table. Once again, it exists in the polling process package because it's simply more intuitive to execute commands for a given process from its own package.

Here's an example from polling process package `POLLING_PROCESS`:

```
PROCEDURE status is

begin
  pl(POLLING_PROCESS_STATUS.get_status);
end status;
```

With the queue and status tables and their associated table packages in place, you can now tell the polling process to do the following:

- Quit
- Enable debug logging
- Disable debug logging
- Process a given command
- Display its current status

A common use for on-demand or polling processing is to build interfaces between systems. Let's discuss some common method names used for just that next.

Interfacing

Interfacing, systems integration, or whatever you want to call it, is just data processing. It is commonly a multistep data process (MSDP) that follows a fairly standard set of tasks.

1. Log that you are going to attempt to download data from a source to your target system.
2. Download data from the source to your target system.
3. Log that you downloaded the data successfully.
4. Verify that you have cross-reference values for all mapped fields.
5. Upload data from its staging tables to its target tables.
6. Log that you uploaded the data successfully.

As you can see, interfacing consists of two high-level steps: downloading and uploading (for lack of better terms). Figure 10-7 shows a visual representation of this division of tasks. These steps can be accomplished synchronously or asynchronously. Regardless, I like to separate the major steps by recording their success or failure in a status table. This allows me to rerun the process, as needed, until both steps are completed.

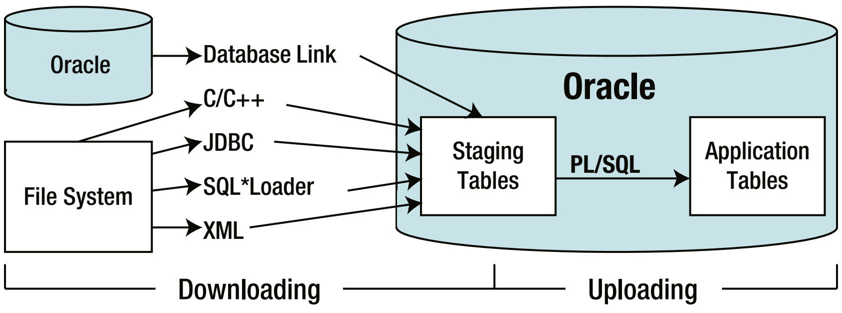


Figure 10-7. *Interfacing with external systems, two steps: downloading and uploading*

Whether or not I use a program external to the database to move data from a source to destination staging tables, the "download" program can record when it starts its processing and when it completes. Then when the upload process starts, it can check to see if the download process has been completed. If the download has been completed, the upload process can log when it starts and when it completes.

Dividing a long-running process into multiple smaller processes like this not only allows you to do asynchronous processing, but also provides you with a framework to build robust processes that can be rerun over and over again until they finish there processing.

For example, if you build an interface with multistep processing that should move data into your database once a week, it can be scheduled to run every day of the week with `cron` or Scheduled Tasks, and it will just quit if the weekly work has already been completed.

Here, I'll discuss commonly used method names for a multistep interface on-demand process. Let's start with `process`.

process

Again, `process` is used to start an on-demand or polling process. In this case, it's a multistep data process. A multistep process is one that checks which portion of a process needs to be done and (re)starts the process at the required step. A multistep process is dependent on a status table that is used to record when a step is completed successfully.

The following is an example of a multistep process that you can find in package `WEEKLY_INTERFACE`:

```
PROCEDURE process is

begin
  if not WEEKLY_INTERFACE_STATUS.is_downloaded() then
    download();
    if not WEEKLY_INTERFACE_STATUS.is_downloaded() then
      pl('WARNING: download() did not complete successfully.');
    end if;
  end if;

  if WEEKLY_INTERFACE_STATUS.is_downloaded() then
    if not WEEKLY_INTERFACE_STATUS.is_uploaded() then
      upload();
      if not WEEKLY_INTERFACE_STATUS.is_uploaded() then
        pl('WARNING: upload() did not complete successfully.');
      end if;
    end if;
  end if;

  pl('process() completed successfully.');
end process;
```

As you can see from this example, PROCEDURE process is concerned only with the status of the multistep process and calls other procedures to accomplish its required steps.

Let's take a look at the supporting methods. We'll start with is_downloaded.

is_downloaded

Method is_downloaded returns a Boolean value that indicates whether the first step, downloading, has been accomplished. FUNCTION is_downloaded returns TRUE if the download process has been completed; otherwise, it returns FALSE.

The following is an example of the method from supporting table package WEEKLY_INTERFACE_STATUS:

```
FUNCTION is_downloaded
return                                boolean is

pragma AUTONOMOUS_TRANSACTION;

d_download_date
  WEEKLY_INTERFACE_STATUSES.download_date%TYPE;

begin
  begin
    select download_date
    into   d_download_date
    from   WEEKLY_INTERFACE_STATUSES
    where  id =
      WEEKLY_INTERFACE_STATUS.get_week();
  exception
    when NO_DATA_FOUND then
      d_download_date := NULL;
  end;

  if d_download_date is not NULL then
    return TRUE;
  else
    return FALSE;
  end if;
end is_downloaded;
```

PROCEDURE WEEKLY_INTERFACE.process calls this method directly from package WEEKLY_INTERFACE_STATUS. In addition, I've added a convenience method, is_downloaded, which returns the number 1 for TRUE and 0 for FALSE to package WEEKLY_INTERFACE, because external programs that might want to know the status of the download process, such as a Java JDBC program, cannot call a stored procedure that returns a Boolean value. Here's an example of the `is_downloaded` convenience method from package `WEEKLY_INTERFACE`:

```
FUNCTION is_downloaded
return                                number is

begin
  -- A function that returns a 1 or 0 from TRUE and FALSE
  -- from WEEKLY_INTERFACE_STATUS.is_downloaded()
  return to_boolean_number(WEEKLY_INTERFACE_STATUS.is_downloaded());
end is_downloaded;
```

Next, let's take a look at the `download` method.

download

Method `download` is used to start a download process—that is, a process to move data between systems—from a data source to your target staging tables. `PROCEDURE download` can be utilized in your multistep process if the data can be moved from its source to the destination staging tables from inside the database. You can do this in a variety of ways, using the following:

- A database link between systems
- An embedded JDBC program to access an external database
- Package `SYS.UTL_MAIL` to access an email server
- Package `SYS.UTL_HTTP` to access a web server
- Package `SYS.UTL_FILE` to access the database server's file system

If you need to perform this step externally with another program, you can simply code a `put_line()` message that reminds the user that this step is accomplished externally. By handling the external process in this fashion, you don't need to modify the code in method `process`.

The following is an example of the method from package `WEEKLY_INTERFACE`:

```
PROCEDURE download is

begin
  pl('Executing download()');
  -- You can code this procedure to move data between systems
  -- using an Oracle database link, loaded JDBC driver and class,
  -- etc. Or, you can change this message to remind the user
  -- that this is an asynchronous process handled by an external
  -- program.

  set_downloaded();
end download;
```

If you code this method, then you'll call `set_downloaded` upon a successful download. If, on the other hand, you code the download process externally, that program will need to call `WEEKLY_INTERFACE.set_downloaded` in order to let `process` know that the first step of the multistep process has been completed asynchronously.

While we're on the topic, let's look at `set_downloaded` next.

set_downloaded

Method set_downloaded is used to set the status of the download process to complete. Supporting table package's PROCEDURE WEEKLY_INTERFACE_STATUS.set_downloaded is called from inside download, if the download method is actually coded to perform the download process.

The following is an example of the supporting status table WEEKLY_INTERFACE_STATUSES from script weekly_interface_statuses.tab:

```
create table WEEKLY_INTERFACE_STATUSES (
id                              number                            not null,
download_date                   date,
upload_date                     date,
insert_user                     varchar2(30)  default USER     not null,
insert_date                     date          default SYSDATE  not null,
update_user                     varchar2(30)  default USER     not null,
update_date                     date          default SYSDATE  not null)

...
```

And, here's an example of the method set_downloaded supporting table package WEEKLY_INTERFACE_STATUS:

```
PROCEDURE set_downloaded is

pragma AUTONOMOUS_TRANSACTION;

begin
  update WEEKLY_INTERFACE_STATUSES
  set    download_date              = SYSDATE,
         update_user                = USER,
         update_date                = SYSDATE
  where  id =
    WEEKLY_INTERFACE_STATUS.get_week();

  if nvl(sql%rowcount, 0) = 0 then
    insert into WEEKLY_INTERFACE_STATUSES (
           id,
           download_date )
    values (
           WEEKLY_INTERFACE_STATUS.get_week(),
           SYSDATE );
  end if;

  commit;
end set_downloaded;
```

I've also created a convenience method set_downloaded in package WEEKLY_INTERFACE, which can be called by an external download program in order to set the download process to complete, as follows:

```
PROCEDURE set_downloaded is

begin
  WEEKLY_INTERFACE_STATUS.set_downloaded();
end set_downloaded;
```

Enough with the download business. Now let's talk about uploading, starting with method is_uploaded.

is_uploaded

Method is_uploaded returns a Boolean value that indicates whether the second step, uploading, has been accomplished. FUNCTION is_uploaded returns TRUE if the upload process has been completed; otherwise, it returns FALSE.

The following is an example of the method from supporting table package WEEKLY_INTERFACE_STATUS:

```
FUNCTION is_uploaded
return                                boolean is

pragma AUTONOMOUS_TRANSACTION;

d_upload_date
  WEEKLY_INTERFACE_STATUSES.upload_date%TYPE;

begin
  begin
    select upload_date
    into   d_upload_date
    from   WEEKLY_INTERFACE_STATUSES
    where  id =
      WEEKLY_INTERFACE_STATUS.get_week();
  exception
    when NO_DATA_FOUND then
      d_upload_date := NULL;
  end;

  if d_upload_date is not NULL then
    return TRUE;
  else
    return FALSE;
  end if;
end is_uploaded;
```

PROCEDURE WEEKLY_INTERFACE.process calls this method directly from package WEEKLY_INTERFACE_STATUS. Unlike its sibling, is_downloaded, there's no need for a convenience method, because the whole point of the multistep process package is to upload the data from staging to application tables. So no external process will ever be used, and hence no convenience method is required.

Now let's look at upload.

upload

Method upload is used to start an upload process—that is, a process to move data from staging tables to an application's tables. This is where you code all your groovy data processing.

Here's an example of the method from package WEEKLY_INTERFACE:

```
PROCEDURE upload is

-- Add cursor(s) used to loop through the staging data here.

begin
  pl('Executing upload()');
  if is_verified() then

    -- Add your data migration code here.

    WEEKLY_INTERFACE_STATUS.set_uploaded();
  end if;
end upload;
```

And last, but not least, is set_uploaded.

set_uploaded

Method set_uploaded is used to set the status of the upload process to complete. Supporting table package's PROCEDURE WEEKLY_INTERFACE_STATUS.set_uploaded is called from inside upload, if the upload method completes successfully.

The following is an example of the method from supporting table package WEEKLY_INTERFACE_STATUS:

```
PROCEDURE set_uploaded is

pragma AUTONOMOUS_TRANSACTION;

begin
  update WEEKLY_INTERFACE_STATUSES
  set    upload_date                = SYSDATE,
         update_user                = USER,
         update_date                = SYSDATE
  where  id =
    WEEKLY_INTERFACE_STATUS.get_week();

  if nvl(sql%rowcount, 0) = 0 then
    insert into WEEKLY_INTERFACE_STATUSES (
           id,
           upload_date )
    values (
           WEEKLY_INTERFACE_STATUS.get_week(),
           SYSDATE );
  end if;

  commit;
end set_uploaded;
```

Using the `WEEKLY_INTERFACE` package as a framework for your database destination interfaces, you can provide a consistent treatment to all interfaces and at the same time have the freedom to perform each high-level step in a manner that is suitable for solving the associated business requirements.

Next, let's look at the polymorphic use of method names in support of the reporting presentation layer.

Reporting

It has become quite fashionable in our industry to develop or implement the data-entry portion of an application and then throw a reporting utility—like Cognos Impromptu, Business Objects, Crystal Reports, BIRT, and so on—at the application's relational database or data warehouse for reporting needs. Since I'm not selling any of these "solutions," I can share my honest opinion. Throwing a reporting utility at an application for its reporting needs is a poor idea. Suddenly, we've decided to give our customers half of a solution. What's with that? I know that it's all about the money. But I've never seen much large-scale reporting success with end users with this strategy. Here's why:

- Most end users know very little about how the information they work with is actually organized and related.
- Most end users know very little about how information is input into their application and how it is consequently stored in the application's database.
- Most end users have no time to spend trying to engineer a set of complex reports to help them run the business.

That's not to say that there aren't exceptions. But for the most part, reporting requirements and deliverables should be a required part of any application's development or implementation (depending on whether you build or buy).

For those exceptional end users who are information and system architects, when they do use reporting utilities, they usually get poor performance from the database. It's not necessarily the database's fault; it's a matter of physics.

A well-designed relational or object-relational database will have tables that are all in their third normal form. Accordingly, any `SELECT` statements written against a well-designed database will have many tables in the `FROM` clause of a given `SELECT` statement. The more tables, the more data must be physically read from physical devices, the more physical devices have to work, the longer it takes. It's not a database problem; it's a physics problem.

Now if you recall from previous chapters, I've spent some time showing you the consequences of physics and a database. You can use the following tactics to "divide and conquer" in order to improve the speed and efficiency of retrieving data for reporting:

- Use pseudo-constants and PL/SQL `IF` statements to replace code tables in a `FROM` clause of a `SELECT` statement. This reduces the use of physical devices.
- Retrieve data from the smallest table that will produce the smallest set of results, and then do programmatic nested loops with cursors to retrieve the "rest" of the data. This reduces the use of physical devices.
- Create thin (narrow) row extracts of data, and then join them together in a `SELECT` statement. This reduces the use of memory and physical devices. For example, if the source table has an average row size of 297 bytes, you may extract data from it into a temporary table that has an average row size of 13 bytes. The temporary table is what I call a *narrow* row table.
- Post-sort results. Sort the rows for a report after the report data has already been placed in a staging table(s). This reduces the use of memory and CPU cycles.

However, you can use these tactics only if you write stored procedures to produce the result sets for your reports, placing the results in staging tables, which are then later queried by the presentation layer. What I'm advocating here is heresy to some, and bliss for others. I know many of you may want to send me an email explaining why this is such a bad idea. Do it. I would love to argue with you about it. Here's what I do know:

- In applications with well over one million rows in each content table, I'm able to produce short reports in less than 3 seconds, most in less than 1 second. That's compared to over 3 minutes trying to accomplish the same task with a large, complicated SQL `SELECT` statement.
- In the same large enterprise applications, I've been able to produce large reports in less than 3 minutes. That's compared to 20 minutes to 28 hours for some of the largest reports. Yes, even reports that took 28 hours to produce using a very large and complicated SQL `SELECT` statement took less than 3 minutes when these "divide and conquer" principles were applied. And no, there were no accidental Cartesian products in the `SELECT` statement.
- When this architecture is adopted, the business intelligence on how to produce the report permanently resides in the database where it is easiest and most efficient to process data. This means that any presentation layer can be used to produce the result set for a given report by executing it in the database, and then simply formatting and displaying the data in whatever fashion is desired. Presentation layers come and go. Does the business knowledge that produces your reports have to go with it? No.

Figure 10-8 demonstrates the reporting architecture I'm advocating. In this architecture, producing a report consists of these three high-level steps.

1. The presentation layer calls a function `get_report()` in the database, passing it any required parameters for producing a report.
2. `get_report()` produces the result set for the report, placing the results in a staging table specific to the report. Then `get_report()` returns an ID for the results.
3. The presentation layer executes a `SELECT` statement against the report's staging table, where the report ID is the one returned from `get_report()`, and orders the results by the report's sequence.

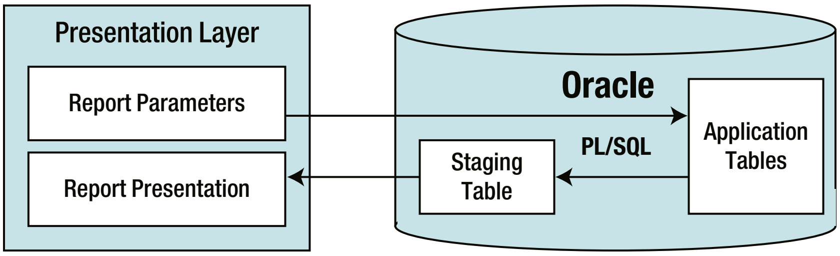


Figure 10-8. *A modular PL/SQL- and SQL-driven reporting architecture*

I call reports produced in this manner "staged data reports." In practice, I've used this architecture to impressively improve the performance and complexity of reports, while also reducing the consumption of server resources. That's a win-win situation. I've called the same report stored procedure from Oracle Reports, PowerBuilder, and a J2EE, Python Django or Ruby on Rails application on the Web. Here, the same result set is used by six different presentation layers. This means you can consistently produce the results for a report, and present the results in whatever way you see fit.

Accordingly, in this section, I'm going to cover the polymorphic method names I use in this reporting architecture. Let's get started with `get_report()`.

get_report()

Method `get_report()` produces a report result set by retrieving data from application tables, placing the results in a report-specific set of staging tables, and then returning an ID to the result set. `FUNCTION get_report(...)` takes runtime parameters passed to it from the presentation layer and uses those to efficiently retrieve and stage the data for a report. Most often, you'll use `get_report()` to simply improve the performance of a report. However, some reports cannot be created with just SQL statements, and that's where the use of `get_report()` becomes critically important.

Here's an example of the method from a report stored procedure that produces a work history report for a given `worker_id`. This method is from package `REPORT_WKHST`:

```
FUNCTION get_report(
ain_worker_id                  in     REPORT_WKHSTS.worker_id%TYPE)
return                                REPORT_WKHSTS.report_wkhst_id%TYPE is

cursor c_date(
ain_worker_id                  in     REPORT_WKHSTS.worker_id%TYPE) is
select v1.active_date
from ( select active_date
       from   LOGICAL_ASSIGNMENTS
       where  worker_id = ain_worker_id
       UNION
       select active_date
       from   PHYSICAL_ASSIGNMENTS
       where  worker_id = ain_worker_id
       UNION
       select active_date
       from   WORK_ASSIGNMENTS
       where  worker_id = ain_worker_id ) v1
order by 1;

d_logical_inactive_date               REPORT_WKHSTS.inactive_date%TYPE;
d_physical_inactive_date              REPORT_WKHSTS.inactive_date%TYPE;
d_work_inactive_date                  REPORT_WKHSTS.inactive_date%TYPE;

r_worker                              WORKERS%ROWTYPE;

r_report_wkhsts                       REPORT_WKHSTS%ROWTYPE;
```

```
begin
  r_report_wkhsts.report_wkhst_id  := get_id();
  r_report_wkhsts.report_wkhst_seq := 0;

  r_worker.id                  := ain_worker_id;
  r_worker                     := WORKER.get_row(r_worker);

  r_report_wkhsts.worker_id   := r_worker.id;
  r_report_wkhsts.worker_name :=
    WORKER.get_formatted_name(
      r_worker.first_name,
      r_worker.middle_name,
      r_worker.last_name);

  for r_date in c_date(ain_worker_id) loop
    r_report_wkhsts.active_date := r_date.active_date;

    get_logical_workplace_name(
      r_report_wkhsts.worker_id,
      r_report_wkhsts.active_date,
      r_report_wkhsts.logical_workplace_name,
      d_logical_inactive_date);

    get_physical_workplace_name(
      r_report_wkhsts.worker_id,
      r_report_wkhsts.active_date,
      r_report_wkhsts.physical_workplace_name,
      d_physical_inactive_date);

    get_work_name(
      r_report_wkhsts.worker_id,
      r_report_wkhsts.active_date,
      r_report_wkhsts.work_name,
      d_work_inactive_date);

    r_report_wkhsts.inactive_date :=
      least(
        d_logical_inactive_date,
        d_physical_inactive_date,
        d_work_inactive_date);

    set_report(r_report_wkhsts);
  end loop;

  commit;

  return r_report_wkhsts.report_wkhst_id;
end get_report;
```

If you examine the listing, you'll notice that I call three private methods: get_logical_workplace_name(), get_physical_workplace_name(), and get_work_name(), which are used to get the data in a programmatic nested loop fashion. I suppose if I spent enough time, I could write a SQL SELECT statement to get these results, but in this case, it's much easier and faster to use PL/SQL.

The following script, report_wkhst.get_report.sql, is a test unit I use to run the report from SQL*Plus during development and troubleshooting:

```
rem report_wkhst.get_report.sql
rem by Donald J. Bales on 2014-10-20
rem Test Unit for REPORT_WKHSTS_TS.get_report()

column worker_name             format a21 trunc;
column logical_workplace_name  format a11 trunc;
column physical_workplace_name format a11 trunc;
column work_name               format a11 trunc;
column active_date             format a8;
column inactive_date           format a8;

execute pl('report_wkhst_id='||to_char(REPORT_WKHST.get_report(11649889)));

select worker_name,
       logical_workplace_name,
       physical_workplace_name,
       work_name,
       to_char(active_date,   'YYYYMMDD') active_date,
       to_char(inactive_date, 'YYYYMMDD') inactive_date
from   REPORT_WKHSTS
where  report_wkhst_id = &report_wkhst_id
order by report_wkhsts_seq;
;
```

When executed with worker_id 11649889, the script produces the following output:

```
WORKER_NAME           LOGICAL_WOR PHYSICAL_WO WORK_NAME   ACTIVE_D INACTIVE
--------------------- ----------- ----------- ----------- -------- --------
PATTERSON, MICHELLE D BIOLOGICALS GRAVITRON 1 ENGINEER1   19740520 19850507
PATTERSON, MICHELLE D BIOLOGICALS GRAVITRON 1 ENGINEER2   19850508 19960425
PATTERSON, MICHELLE D BIOLOGICALS GRAVITRON 1 ENGINEER3   19960426
```

In practice, every report has a different package name that starts with REPORT_, whose associated table is the plural form of the package's name. All reports use the same method name, get_report(), with the presentation layer passing the method any required parameter values. Since a report package has an associated table, it's only fitting for it to have an associated method name for inserting values into that table, and that name is set_report().

set_report()

Since you're an astute reader, you're probably thinking, "Why doesn't he just use the method name set_row()?" It's because set_report() does something different than set_row(), so I consistently use the name set_report() in order to emphasize that difference.

Before I get into an explanation of the difference, let's look at an example of the definition of an associated report staging table. This is the report staging table definition for the work history report. You can find this listing in script report_wkhsts.tab:

```
create table REPORT_WKHSTS (
report_wkhst_id             number                         not null,
report_wkhst_seq            number                         not null,
worker_id                   number                         not null,
worker_name                 varchar2(100)                  not null,
active_date                 date,
logical_workplace_name      varchar2(80),
physical_workplace_name     varchar2(80),
work_name                   varchar2(80),
inactive_date               date,
insert_user                 varchar2(30)  default USER     not null,
insert_date                 date          default SYSDATE  not null)
nologging
```

And here is an example of method set_report() that inserts the data into the report staging table:

```
PROCEDURE set_report(
aior_report_wkhsts              in out REPORT_WKHSTS%ROWTYPE) is

begin
  aior_report_wkhsts.report_wkhst_seq := aior_report_wkhsts.report_wkhst_seq + 1;

  if aior_report_wkhsts.inactive_date  = DATE_.d_max then
    aior_report_wkhsts.inactive_date  := NULL;
  end if;

  aior_report_wkhsts.insert_user      := USER;
  aior_report_wkhsts.insert_date      := SYSDATE;

  insert into REPORT_WKHSTS values aior_report_wkhsts;
exception
  when OTHERS then
    raise_application_error(-20004, SQLERRM||
      ' on insert REPORT_WKHSTS'||
      ' in REPORT_WKHST.set_report()');
end;
```

In contrast to method set_row(), which selects and then inserts or updates, PROCEDURE set_report(air_row) strictly inserts. In addition, set_report() increments the value of the report's sequence number. The sequence number is the second half of a two-column primary key for the staging table. With this design, get_report() can return a single value, an ID, that will allow the presentation layer to select all the subject rows for a report, and then sort against the sequence value.

This means that the order of the information on the report is driven by a given report's engine in the database, not the presentation layer. This is also what allows you to, as I mentioned earlier, post-sort.

You can code a report stored procedure so that, after it places all of its data in its staging table, you sort the data in the table by opening a cursor against the staging table with an ORDER BY clause, and then update the sequence numbers in the same staging table so the results will have a new sort order.

Now you have a means to get the presentation layer to use a modular and efficient approach to creating reports, but what if you want to email a report from the database? That's the purpose of method report().

report()

Not all reports need human interaction to produce them. Sometimes, an application has a list of reports that should be produced on an hourly, daily, weekly, or monthly basis. Why should you require users to run them? A better design is to provide end users with a set of batch-processed report distribution screens, where they can configure who gets what report, and then have the application produce the reports for them.

If the database produces the reports, it can send the report via email as fixed-length text, HTML, PDF, and so on, or as a link. The following is an example of an HTML emailed report from report procedure REPORT_WKHST:

```
PROCEDURE report(
ain_worker_id                in     REPORT_WKHSTS.worker_id%TYPE,
aiv_to                       in     varchar2) is

cursor c_report_wkhsts(
ain_report_wkhst_id          in     REPORT_WKHSTS.report_wkhst_id%TYPE) is
select initcap(worker_name) worker_name,
       active_date,
       initcap(logical_workplace_name) logical_workplace_name,
       initcap(physical_workplace_name) physical_workplace_name,
       initcap(work_name) work_name,
       inactive_date
from   REPORT_WKHSTS
where  report_wkhst_id = ain_report_wkhst_id
order by report_wkhst_seq;

n_line                              number;
t_lines                             EMAIL.LINES;
n_report_wkhst_id                   REPORT_WKHSTS.report_wkhst_id%TYPE;
v_worker_name                       REPORT_WKHSTS.worker_name%TYPE;

begin
  n_report_wkhst_id := get_report(ain_worker_id);

  t_lines(incr(n_line)) := '</pre><table>';
  for r_report_wkhsts in c_report_wkhsts(n_report_wkhst_id) loop
    if c_report_wkhsts%rowcount = 1 then
      v_worker_name         := r_report_wkhsts.worker_name;
      t_lines(incr(n_line)) := '<tr><td align="center" colspan="5">'||
        '<big>Work History Report</big></td></tr>';
      t_lines(incr(n_line)) := '<tr><td align="center" colspan="5">'||
        'for '||v_worker_name||'</td></tr>';
      t_lines(incr(n_line)) := '<tr><td align="center" colspan="5">'||
       '</td></tr>';
      t_lines(incr(n_line)) := '<tr>'||
        '<th align="left">Logical</th>'||
        '<th align="left">Physical</th>'||
        '<th align="left"></th>'||
        '<th align="left">Active</th>'||
        '<th align="left">Inactive</th>'||
        '</tr>';
      t_lines(incr(n_line)) := '<tr>'||
        '<th align="left">Workplace</th>'||
        '<th align="left">Workplace</th>'||
        '<th align="left">Work</th>'||
        '<th align="left">Date</th>'||
        '<th align="left">Date</th>'||
        '</tr>';
    end if;
    t_lines(incr(n_line)) := '<tr>'||
      '<td align="left">'||
        r_report_wkhsts.logical_workplace_name||'</td>'||
      '<td align="left">'||
        r_report_wkhsts.physical_workplace_name||'</td>'||
      '<td align="left">'||
        r_report_wkhsts.work_name||'</td>'||
      '<td align="left">'||
        to_char(r_report_wkhsts.active_date, 'MM/DD/YYYY')||'</td>'||
      '<td align="left">'||
        to_char(r_report_wkhsts.inactive_date, 'MM/DD/YYYY')||'</td>'||
      '</tr>';
  end loop;
  t_lines(incr(n_line)) := '</table><pre>';

  EMAIL.send(
    EMAIL.get_username,
    aiv_to,
    'Work History Report for '||v_worker_name,
    t_lines);
end report;
```

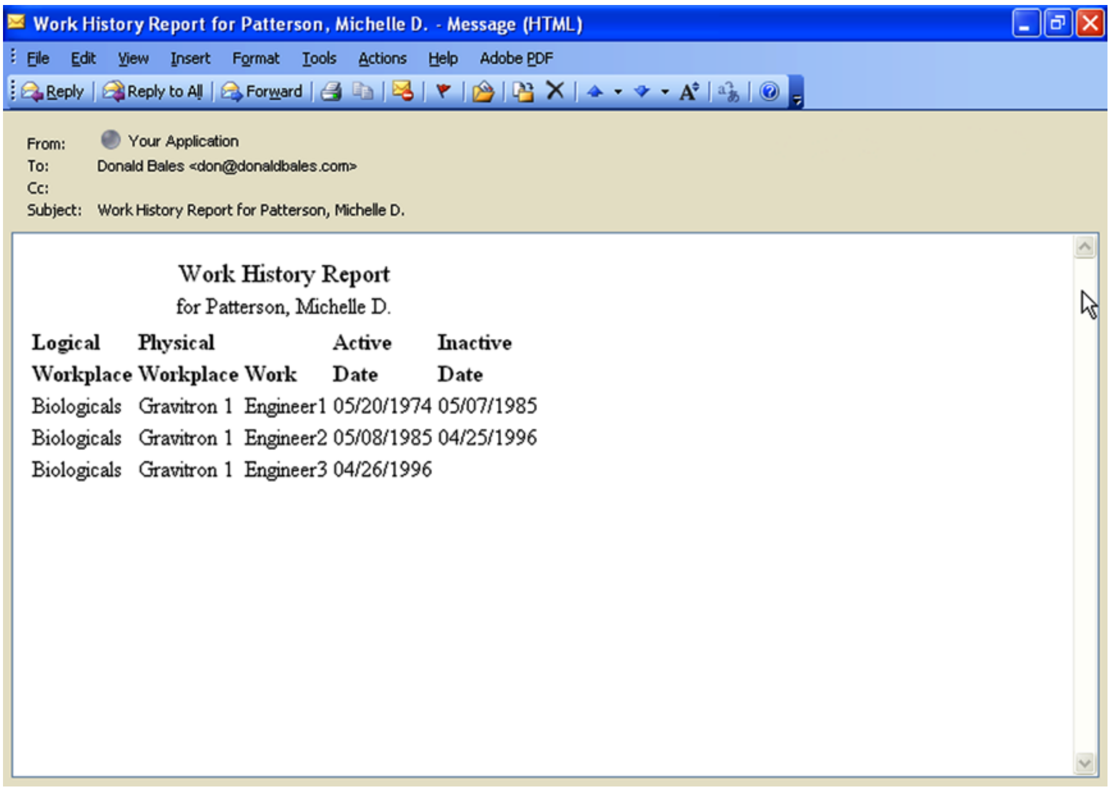
In this case, `PROCEDURE report(ain_worker_id, aiv_to)` calls `get_report()` to produce the result set, and then queries the staging table to produce an HTML report. `report()` then calls supporting package `EMAIL.send()` to send the report.

The following is an example of a test unit for `report()`. This is from script `report_wkhst.report.sql`:

```
rem report_wkhst.report.sql
rem by Donald J. Bales on 2014-10-20
rem Test Unit for REPORT_WKHSTS_TS.report()

execute REPORT_WKHST.report(11649889, 'don@donaldbales.com');
```

After I execute this test unit, I get an email report, as shown in Figure 10-9. In practice, I even use this functionality to send an email report to the support personnel any time a user encounters an error. That way, support personnel can start troubleshooting a given problem before the customer even calls. How's that for customer service?


Work History Report for Patterson, Michelle D. - Message (HTML)
File Edit View Insert Format Tools Actions Help Adobe PDF
Reply Reply to All Forward

From: Your Application
To: Donald Bales <don@donaldbales.com>
Cc:
Subject: Work History Report for Patterson, Michelle D.

Work History Report
for Patterson, Michelle D.

Logical Workplace	Physical Workplace	Work	Active Date	Inactive Date
Biologicals	Gravitron 1	Engineer1	05/20/1974	05/07/1985
Biologicals	Gravitron 1	Engineer2	05/08/1985	04/25/1996
Biologicals	Gravitron 1	Engineer3	04/26/1996	

Figure 10-9. *An example of an emailed report*

Well, that's it for polymorphism. I hope you can appreciate the power and simplicity that the use of polymorphic command names provides when used in the development of software. I also hope you take the time to sit down and think about what method names you should use before you start coding your next program.

Summary

In this chapter, I introduced the concept of organizing the nature of behavior behind a common set of method names. In addition, I demonstrated how I've used each method name in the past. With all the content you've seen in this book, you should be well on your way to solving business and science problems with the use of SQL and PL/SQL in a relational of object-relational setting.

Some have given me the feedback that perhaps the object-relational stuff should be treated as an advanced topic. Phooey! There's nothing advanced about object-relational. It's actually the correct and natural way of thinking. We should have been doing it this way for at least the past 20 years. So I hope you'll find yourself in a position to use it.

Just how astute are you? Did you notice that I even used polymorphism with table column names? Normally, I even use `id` for the primary key column name, and then the singular of the table name concatenated to `_id` for the corresponding foreign key column name. I used the same names in this book in order to make the relationships obvious. By treating column names polymorphically, you can implicitly note what the column is for in every table, just as you do with method names in executable code.

Wow! That was fast, wasn't it? Did I make you work hard? Did you learn anything? I sure hope so. As I stated in the introduction, this was a tutorial—a place to get started. The only way you can learn how to program is to discover the possibilities of a programming language and start mimicking someone else's work by writing programs.

I've been extremely successful in my career when working with Oracle and PL/SQL, so if you mimic my coding behavior, I'm guessing that you will be successful, too. But you've just started. Here's what I suggest you do next:

- Browse the *Oracle Database SQL Reference*, so you can get an idea of what can be accomplished using SQL. You don't have to remember it all; you just need to remember where to look for the information when you realize you can put a possibility to work!
- Read Oracle's *PL/SQL User's Guide and Reference*, or Steven Feuerstein's *Oracle PL/SQL Programming* (O'Reilly, 2014). These are both good references. Once again, you don't need to remember everything you read, just the possibilities. You can always refer to the reference later. You have better use for your memory, like remembering your lover's birthday or your anniversary!
- Browse Oracle's *PL/SQL Packages and Types Reference*. Why should you build something that's already been built by experts? Just catalog the possibilities in your gray matter.
- Check out Oracle's *Application Developer's Guides*.
- Share your ideas by writing an article, a white paper, or at least an email about your experience. After you do, go back and write an `INSERT` statement in order to add yourself to the list of database geniuses from Chapter 1.

As I said before, good skill. Luck is for losers.

APPENDIX A

How to Download, Install, and Use Oracle

Since knowing Oracle SQL is a prerequisite for learning PL/SQL, I could simply assume that you already have resource-level access to Oracle (you can create objects like tables, views, and so on), already have access to SQL*Plus, and already know SQL. But that might not be the case.

Just in case you don't have access to Oracle, I'm going to give you some advice on the following subjects:

- How to download Oracle Database software
- How to install Oracle Database software
- How to use Oracle SQL*Plus

This should get you started in the right direction. Keep in mind that I have no idea what the Apress and Oracle web sites or the Oracle software will look like by the time you read this. Nothing may have changed, but I kind of doubt that. It's more likely that everything will have changed. So my directions will probably no longer be correct, but I think some direction is better than none.

How to Download Oracle Database Software

At the time of this writing, you can download a trial copy of Oracle Database software from Oracle's web site. You can use this trial software for learning purposes only. If you decide to do something commercial with it, like write software that you can then sell, then you'll need to pay for a license. Keep that in mind. Play for free, but earn a fee and you must pay. You should read the license agreement so you know exactly what you can do.

The URL you use to download trial software at Oracle changes all the time. Try `www.oracle.com/technetwork/index.html`. When you get to that web page, as in the example in Figure A-1, look for a menu item that says Downloads.

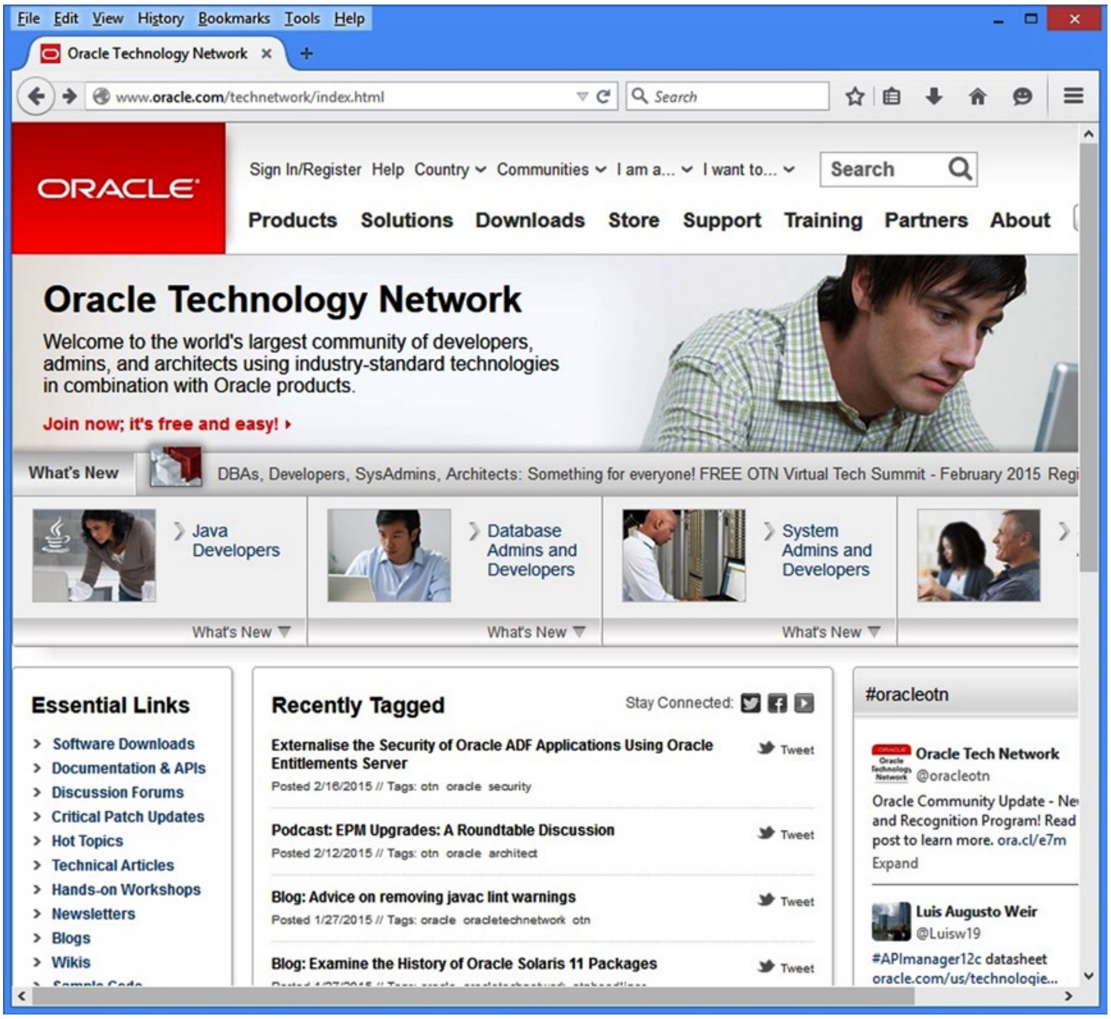

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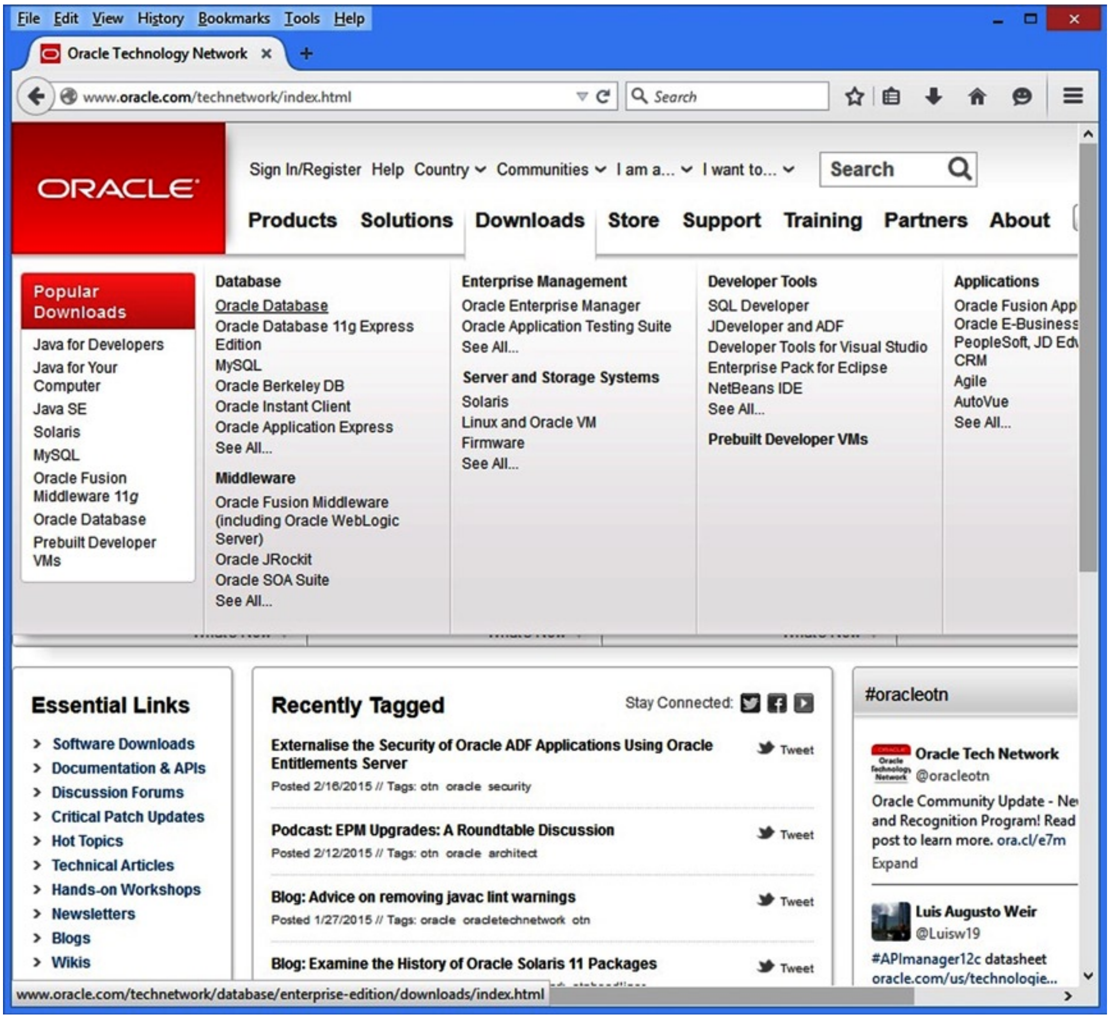
Figure A-1. *An example of an Oracle Technology Network web page*

When you find the Downloads link, click it. When you do, a web page like the one in Figure A-2 may appear. I say “may appear” because who knows how this web site will be organized in the future.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MySQL
Oracle Berkeley DB
Oracle Instant Client
Oracle Application Express
See All...

Middleware
Oracle Fusion Middleware (including Oracle WebLogic Server)
Oracle JRockit
Oracle SOA Suite
See All...

Enterprise Management
Oracle Enterprise Manager
Oracle Application Testing Suite
See All...

Server and Storage Systems
Solaris
Linux and Oracle VM
Firmware
See All...

Developer Tools
SQL Developer
JDeveloper and ADF
Developer Tools for Visual Studio
Enterprise Pack for Eclipse
NetBeans IDE
See All...

Prebuilt Developer VMs

Applications
Oracle Fusion App
Oracle E-Business
PeopleSoft, JD Edw
CRM
Agile
AutoVue
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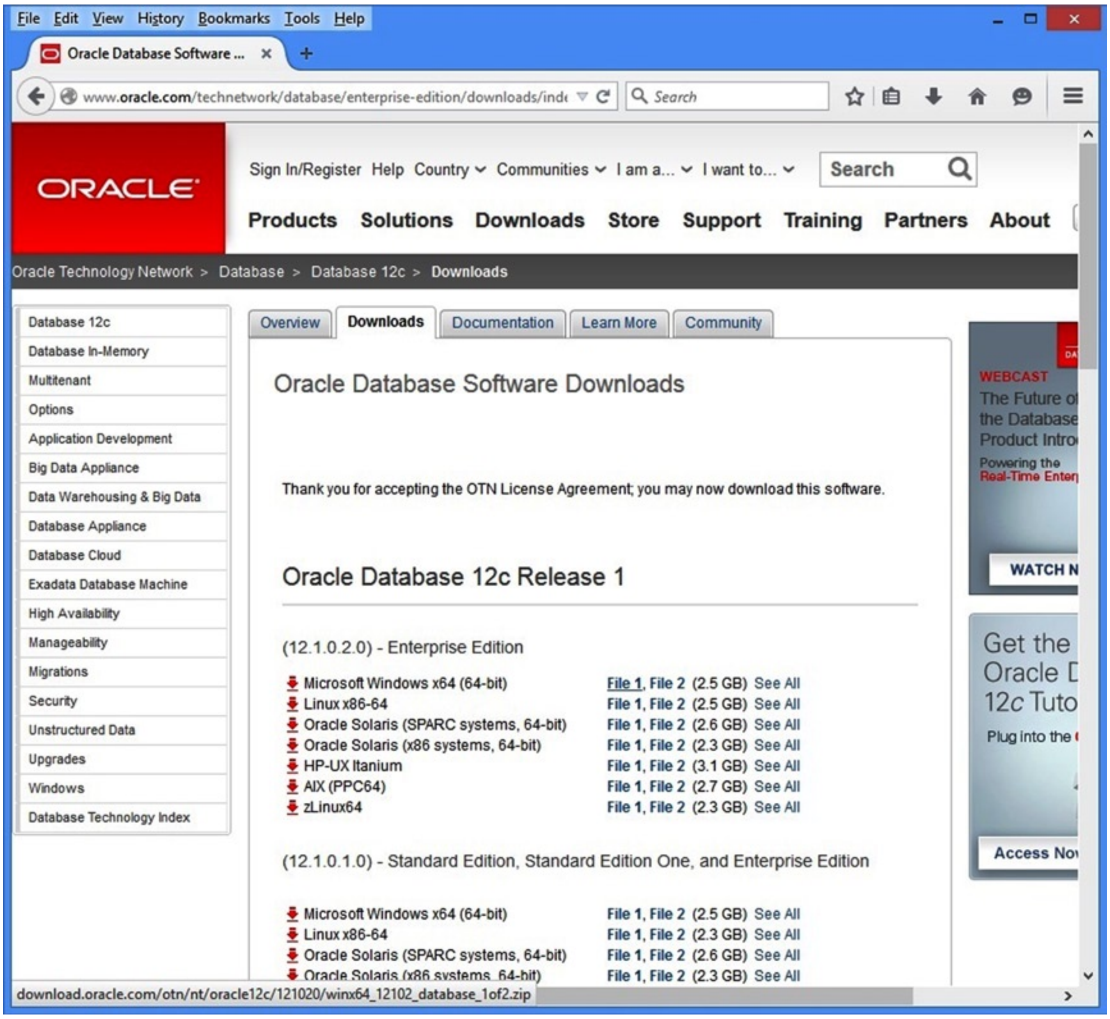
Figure A-2. *An example of an Oracle Downloads menu*

On the Oracle Software Downloads menu, click the *Oracle Database* option. When you do, a web page like the one in Figure A-3 may appear.


File Edit View History Bookmarks Tools Help
Oracle Database Software ...
www.oracle.com/technetwork/database/enterprise-edition/downloads/inde
Search
ORACLE
Sign In/Register Help Country Communities I am a... I want to...
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Oracle Database Software Downloads

Thank you for accepting the OTN License Agreement; you may now download this software.

Oracle Database 12c Release 1

(12.1.0.2.0) - Enterprise Edition

Microsoft Windows x64 (64-bit)	File 1, File 2 (2.5 GB) See All
Linux x86-64	File 1, File 2 (2.5 GB) See All
Oracle Solaris (SPARC systems, 64-bit)	File 1, File 2 (2.6 GB) See All
Oracle Solaris (x86 systems, 64-bit)	File 1, File 2 (2.3 GB) See All
HP-UX Itanium	File 1, File 2 (3.1 GB) See All
AIX (PPC64)	File 1, File 2 (2.7 GB) See All
zLinux64	File 1, File 2 (2.3 GB) See All

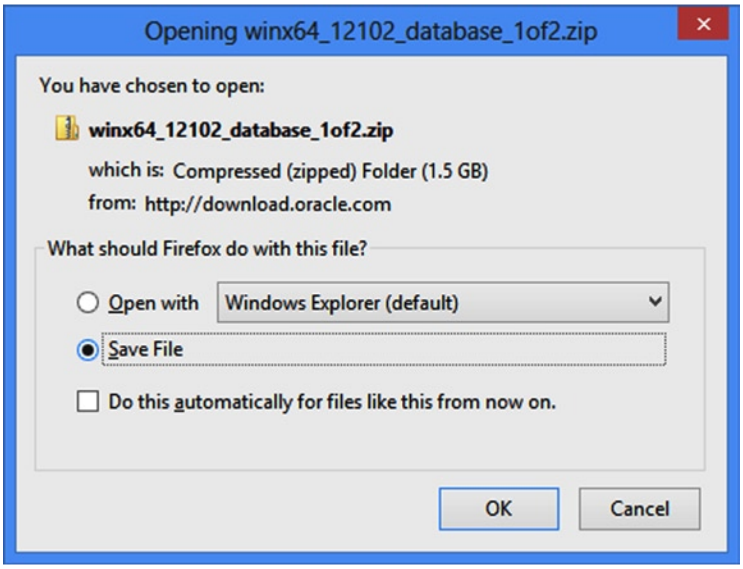
(12.1.0.1.0) - Standard Edition, Standard Edition One, and Enterprise Edition

Microsoft Windows x64 (64-bit)	File 1, File 2 (2.5 GB) See All
Linux x86-64	File 1, File 2 (2.3 GB) See All
Oracle Solaris (SPARC systems, 64-bit)	File 1, File 2 (2.6 GB) See All
Oracle Solaris (x86 systems, 64-bit)	File 1, File 2 (2.3 GB) See All

download.oracle.com/otn/nt/oracle12c/121020/winx64_12102_database_1of2.zip

Figure A-3. *An example of an Oracle Database Software Downloads web page*

On the Oracle Database Software Downloads page, first click the *Accept License Agreement* radio button. Next, find the latest version of the database software (currently Oracle Database 12c) and click the link for File 1. A file download dialog like the one in Figure A-4 may appear.


Opening winx64_12102_database_1of2.zip

You have chosen to open:

winx64_12102_database_1of2.zip

which is: Compressed (zipped) Folder (1.5 GB)

from: http://download.oracle.com

What should Firefox do with this file?

○ Open with Windows Explorer (default)

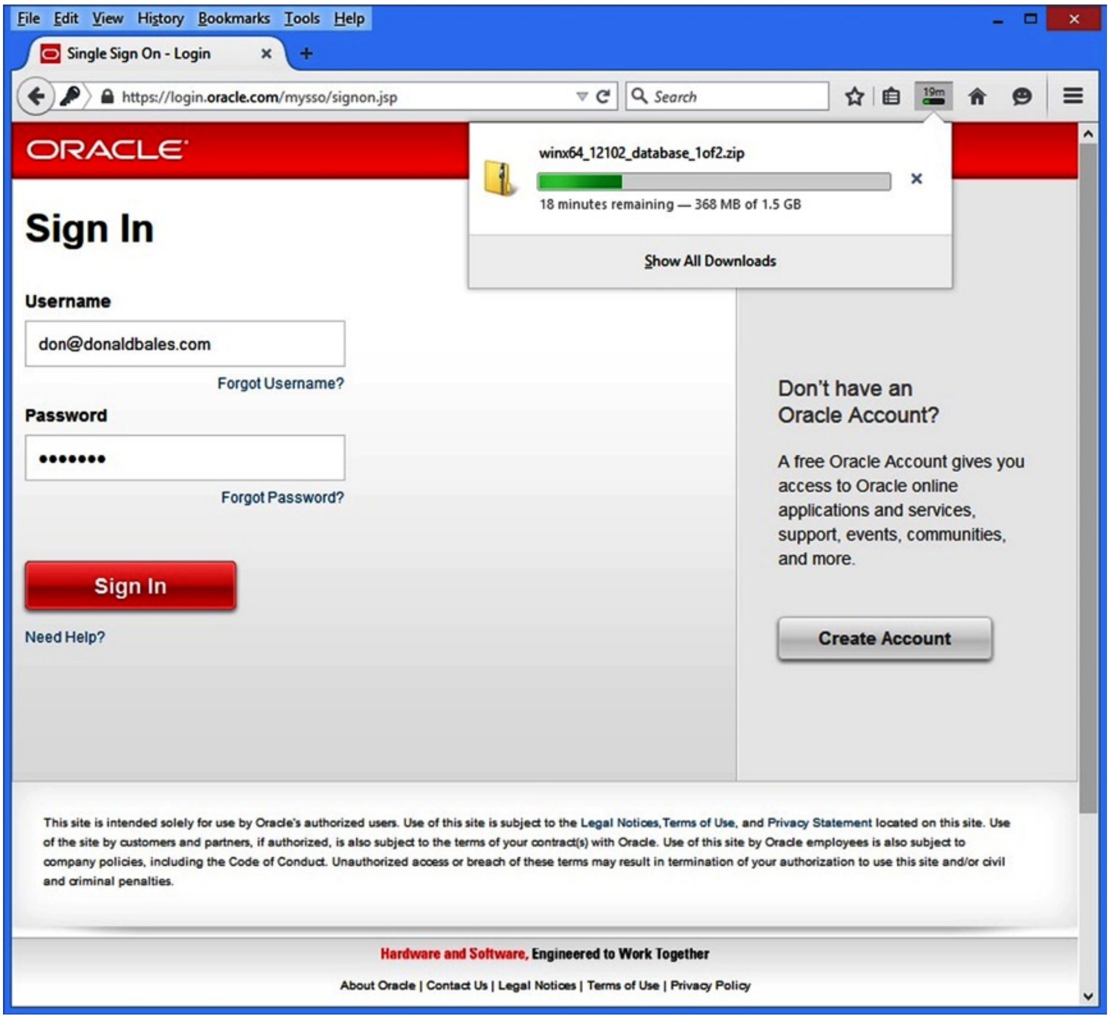
● Save File

☐ Do this automatically for files like this from now on.

OK Cancel

Figure A-4. *An example of a Firefox File Download dialog*

Write down the name of the archive so you know it when you go to install the software. Click the OK button in the File Download dialog box. When you do, the Oracle Single Sign On web page will appear, as in Figure A-5.


File Edit View History Bookmarks Tools Help
Single Sign On - Login
https://login.oracle.com/mysso/signon.jsp
Search
ORACLE
Show All Downloads
Sign In
Username
Forgot Username?
Password
Forgot Password?
Sign In
Need Help?
Create Account
Hardware and Software, Engineered to Work Together
About Oracle | Contact Us | Legal Notices | Terms of Use | Privacy Policy

winx64_12102_database_1of2.zip

18 minutes remaining — 368 MB of 1.5 GB

Username: don@donaldbales.com

Password: •••••••

Don't have an Oracle Account?

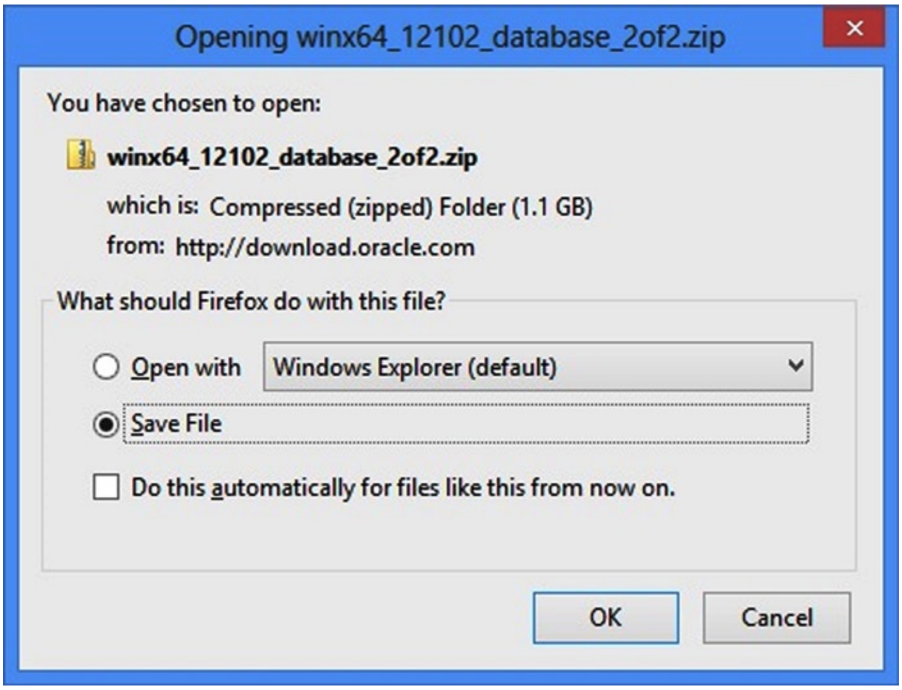
A free Oracle Account gives you access to Oracle online applications and services, support, events, communities, and more.

This site is intended solely for use by Oracle's authorized users. Use of this site is subject to the Legal Notices, Terms of Use, and Privacy Statement located on this site. Use of the site by customers and partners, if authorized, is also subject to the terms of your contract(s) with Oracle. Use of this site by Oracle employees is also subject to company policies, including the Code of Conduct. Unauthorized access or breach of these terms may result in termination of your authorization to use this site and/or civil and criminal penalties.

Figure A-5. *An example of Oracle's Single Sign On web page*

At this point, if you already have an account, sign in, and then Firefox will save the file in your Downloads directory. If you don't have an Oracle Technet account, you'll need to create one. Just click the Create Account button, and then return to this page to sign in and continue the download.

Once the download is complete, return to the Oracle Database Downloads web page and repeat the process for File2, as shown in Figure A-6.


Opening winx64_12102_database_2of2.zip

You have chosen to open:

winx64_12102_database_2of2.zip

which is: Compressed (zipped) Folder (1.1 GB)

from: http://download.oracle.com

What should Firefox do with this file?

( ) Open with: Windows Explorer (default)

(●) Save File

☐ Do this automatically for files like this from now on.

Figure A-6. *An example of a Firefox file download dialog for file 2*

Once again, write down the name of the archive so you know it when you go to install the software. Click the OK button in the File Download dialog box.

After both files have been downloaded, you can move on to the next step, which is to install the Oracle Database software. But first, I suggest you go back to the Downloads link web page and download the installation instructions. Read them before you start the installation.

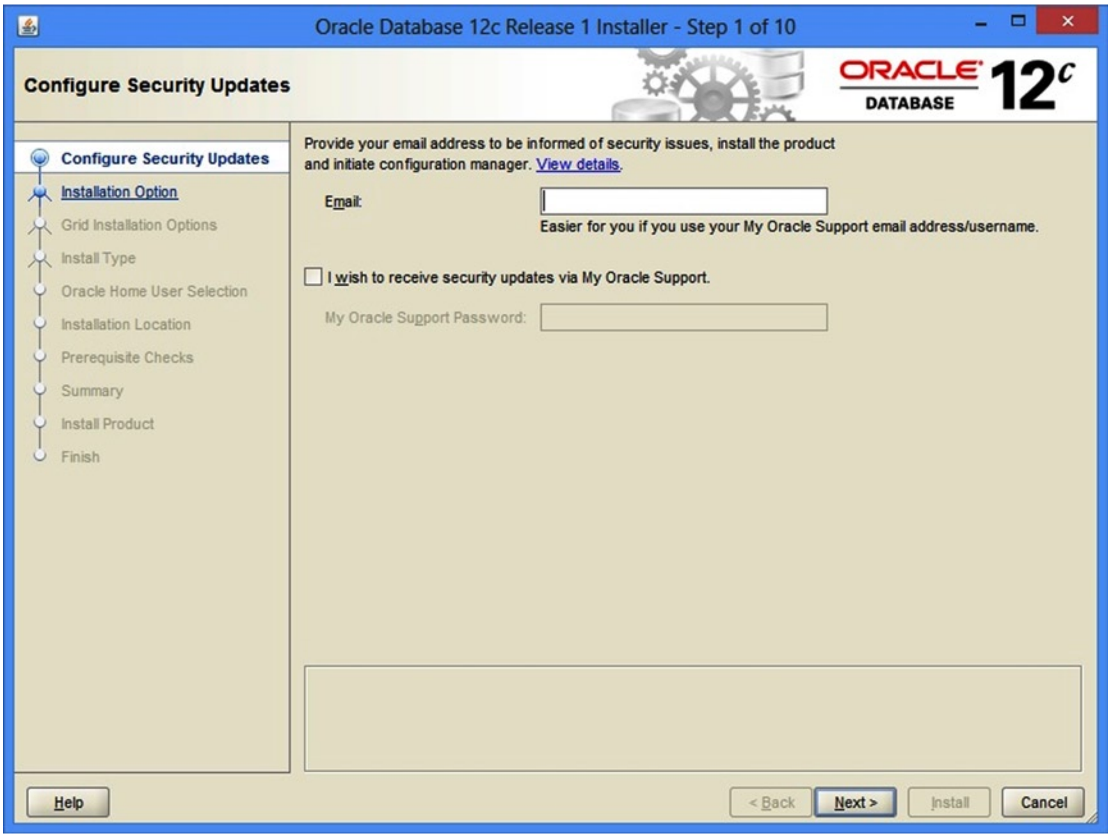
How to Install Oracle Database Software

I'm going to show you an overview of installing the Oracle database software on a Windows machine. On a computer running the Windows OS, here are the steps.

1. Unzip the archives in the `Downloads` directory.
2. Navigate to the directory where you unzipped the files with Windows Explorer, and then run `setup.exe` in the `database` directory.
3. Follow the instructions on the installation screens, answering any prompts as required.

The following screen shots are from an installation I made on one of my desktop PCs called windows8-pc. It's important that you name your machine (in the OS) before you install Oracle because this is the name that will be used to specify the machine's network address throughout the installation process.

When you execute `setup.exe`, the Oracle Universal Installer will start and display the Configure Security Updates screen, as shown in Figure A-7. Specify your email address and uncheck "I wish to receive security updates via My Oracle Support."


Oracle Database 12c Release 1 Installer - Step 1 of 10
Configure Security Updates
ORACLE DATABASE 12c
Configure Security Updates
Installation Option
Grid Installation Options
Install Type
Oracle Home User Selection
Installation Location
Prerequisite Checks
Summary
Install Product
Finish
Help
< Back
Next >
Install
Cancel

Provide your email address to be informed of security issues, install the product and initiate configuration manager. View details.

Email:

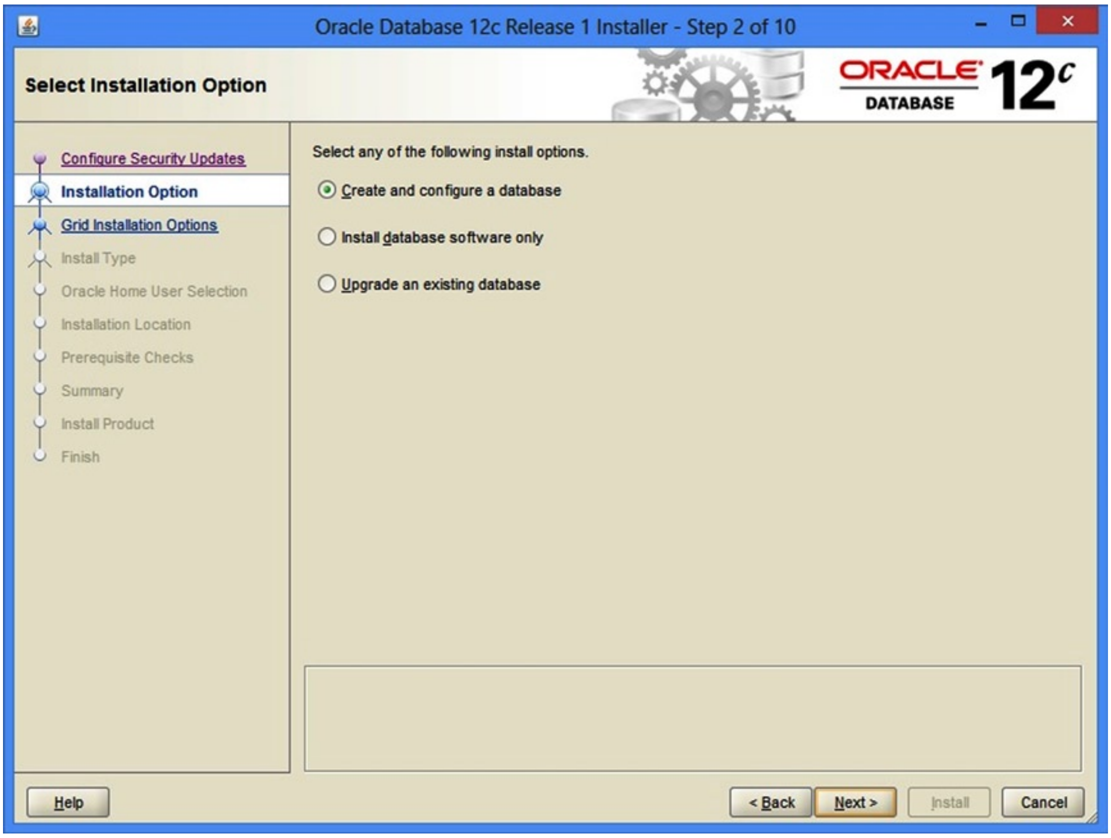
Easier for you if you use your My Oracle Support email address/username.

☐ I wish to receive security updates via My Oracle Support.

My Oracle Support Password:

Figure A-7. *An example of the first Oracle Universal Installer screen*

Click Next and the Installation Option screen will appear, as shown in Figure A-8. Here, I suggest you specify "Create and conFigure 1 database."


Oracle Database 12c Release 1 Installer - Step 2 of 10

Select Installation Option

Select any of the following install options.

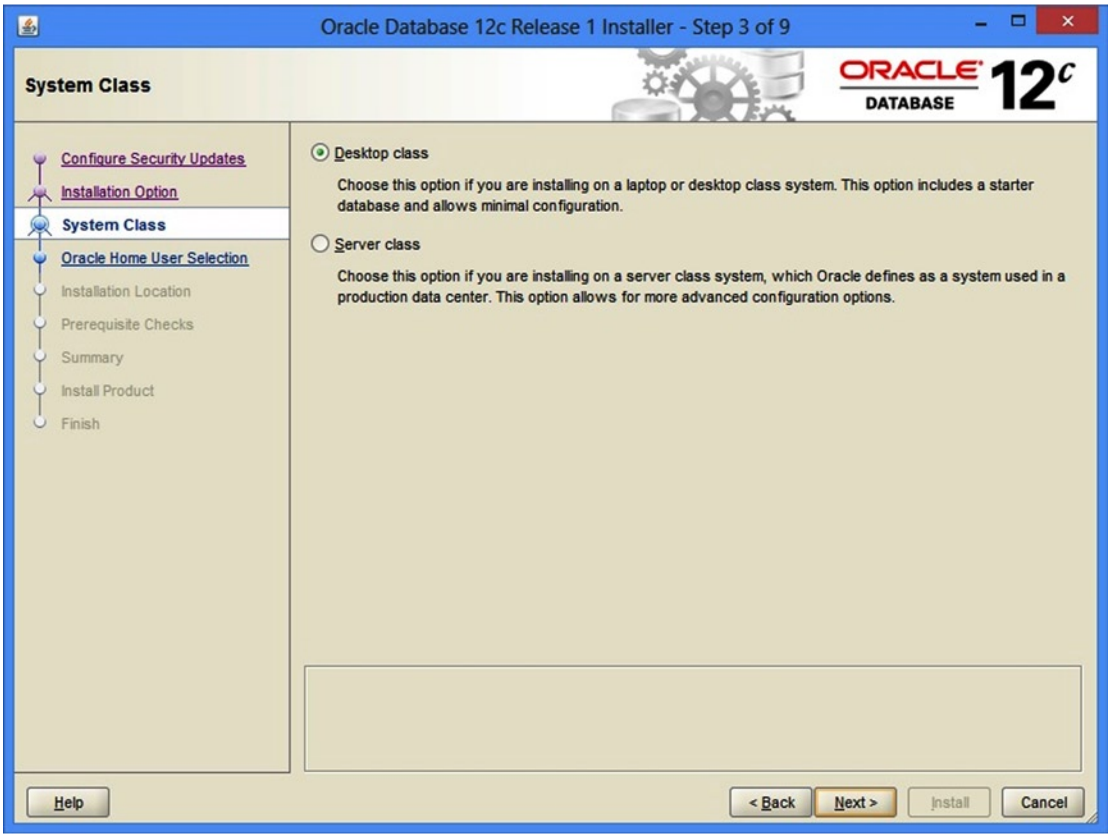
(● Create and configure a database ✓)

○ Install database software only

○ Upgrade an existing database

Figure A-8. *An example of the second Oracle Universal Installer screen*

Click Next and the System Class screen may appear, as shown in Figure A-9. Select Desktop class.



[✓ Desktop class]

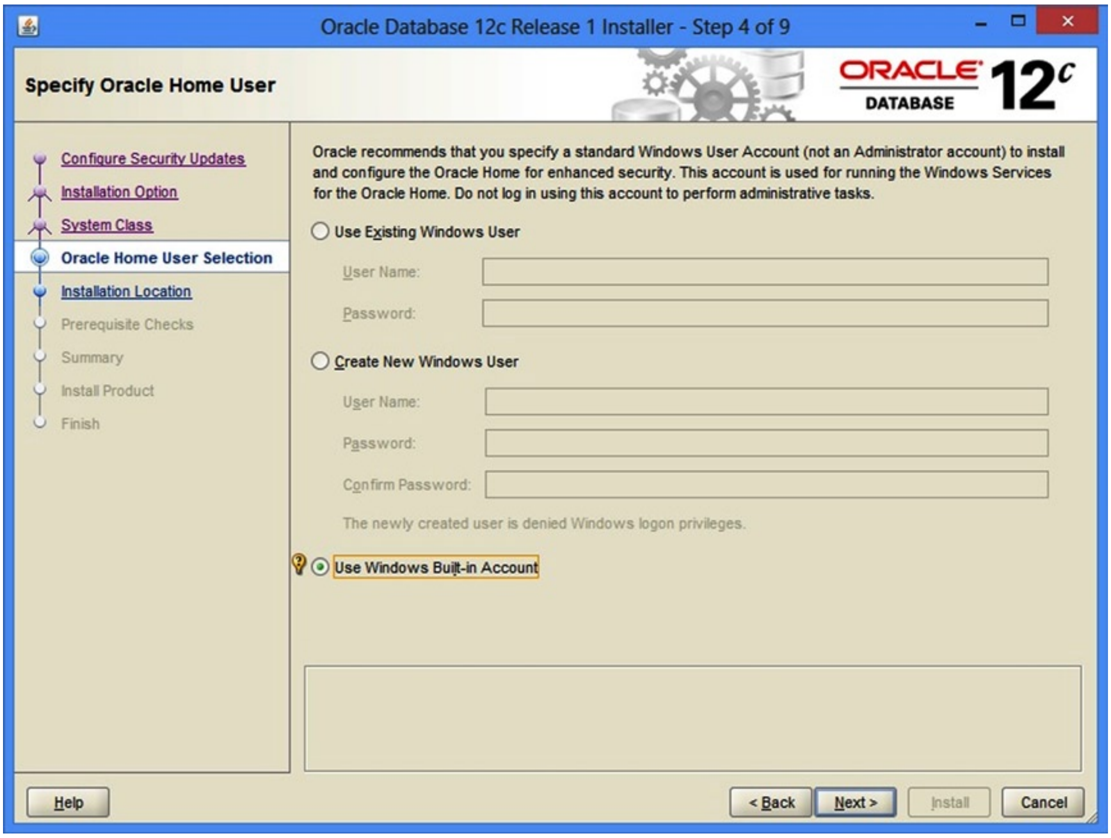
Choose this option if you are installing on a laptop or desktop class system. This option includes a starter database and allows minimal configuration.

Server class

Choose this option if you are installing on a server class system, which Oracle defines as a system used in a production data center. This option allows for more advanced configuration options.

Figure A-9. *An example of the Oracle Univeral Installer's Prerequisites screen*

Click Next and the Oracle Home User Selection screen may appear, as in Figure A-10. Select Use Windows Built-in Account.



Oracle recommends that you specify a standard Windows User Account (not an Administrator account) to install and configure the Oracle Home for enhanced security. This account is used for running the Windows Services for the Oracle Home. Do not log in using this account to perform administrative tasks.

Use Existing Windows User

User Name:

Password:

Create New Windows User

User Name:

Password:

Confirm Password:

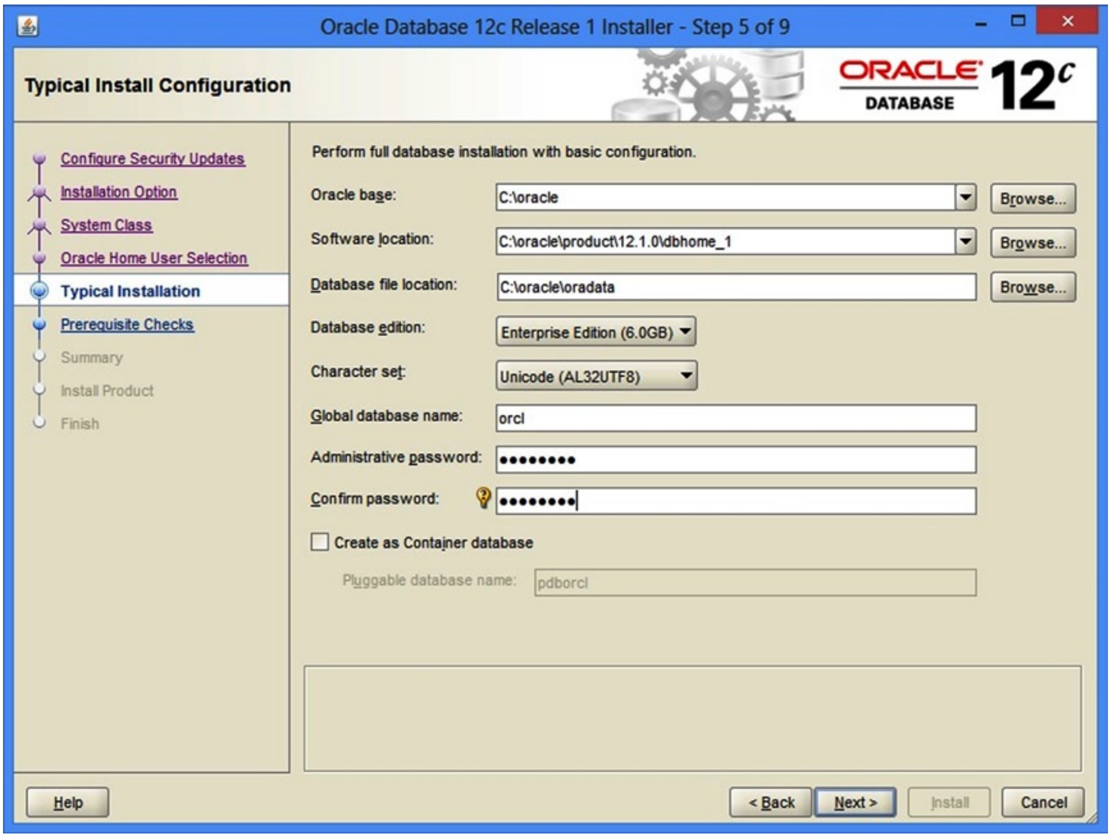
The newly created user is denied Windows logon privileges.

[✓ Use Windows Built-in Account]

Figure A-10. *An example of the Oracle Universal Installer's Oracle Home User Selection screen*

Click Next and the Typical Installation Configuration screen may appear, as in Figure A-11. Here I suggest you specify the following:

- An Oracle base of `C:\oracle`
- A Character set of Unicode (AL32UTF8)
- A password that will be used by the SYSTEM account
- Uncheck the Create as Container Database box



Perform full database installation with basic configuration.

Oracle base: C:\oracle

Software location: C:\oracle\product\12.1.0\dbhome_1

Database file location: C:\oracle\oradata

Database edition: Enterprise Edition (6.0GB)

Character set: Unicode (AL32UTF8)

Global database name: orcl

Administrative password: ••••••••

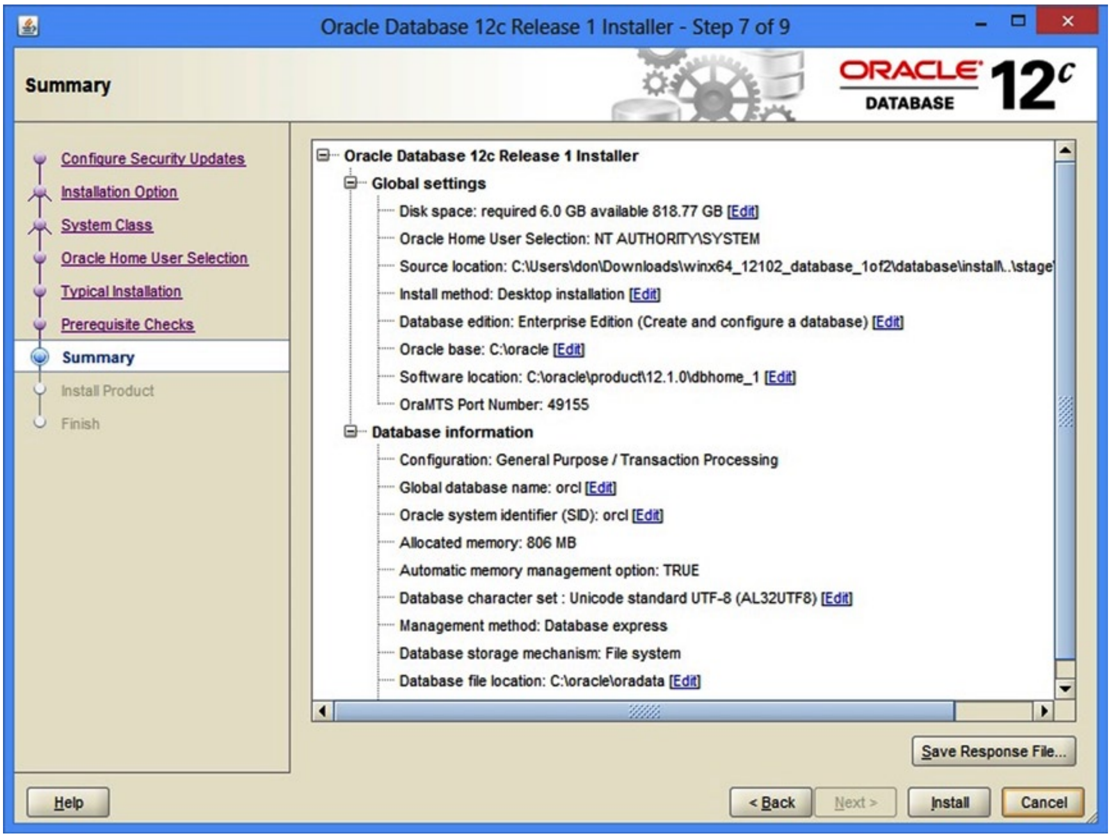
Confirm password: ••••••••

☐ Create as Container database

Pluggable database name: pdborcl

Figure A-11. *An example of the Oracle Universal Installer's Typical Installation Configuration screen*

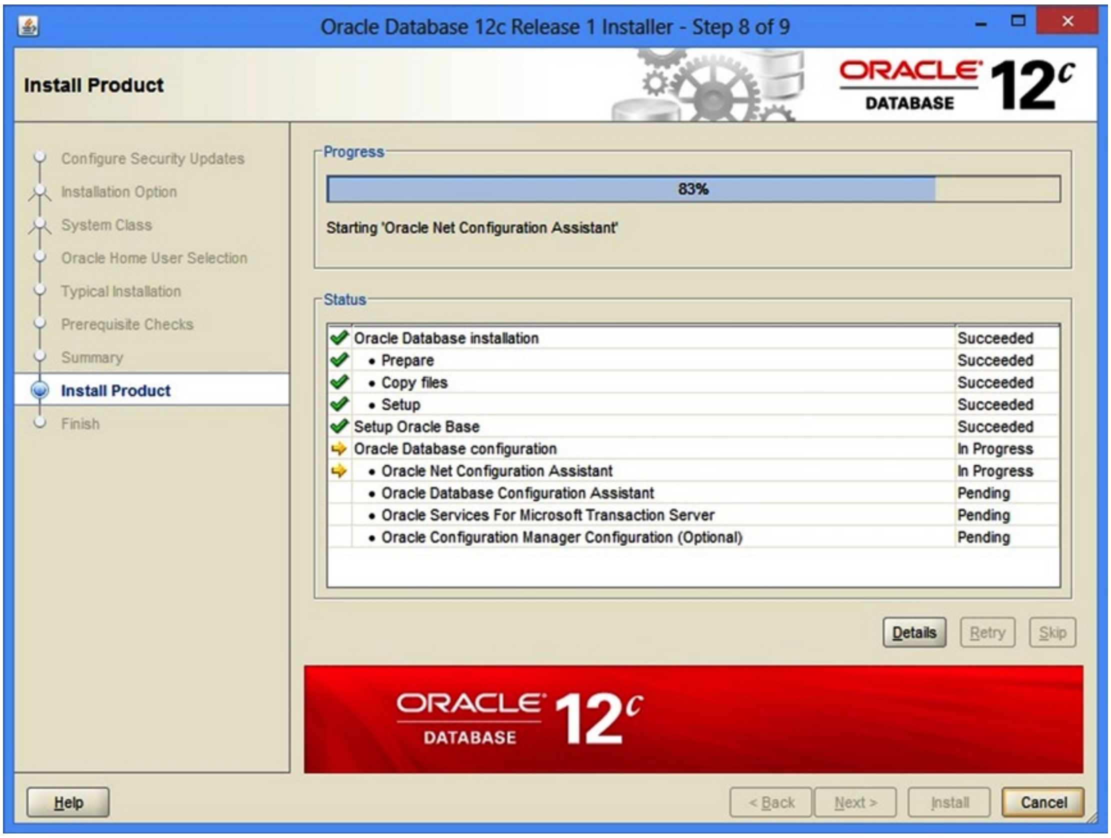
Click Next and the Summary screen may appear, as in Figure A-12.



Oracle Database 12c Release 1 Installer
- Global settings
  - Disk space: required 6.0 GB available 818.77 GB [Edit]
  - Oracle Home User Selection: NT AUTHORITY\SYSTEM
  - Source location: C:\Users\don\Downloads\winx64_12102_database_1of2\database\install\..\stage
  - Install method: Desktop installation [Edit]
  - Database edition: Enterprise Edition (Create and configure a database) [Edit]
  - Oracle base: C:\oracle [Edit]
  - Software location: C:\oracle\product\12.1.0\dbhome_1 [Edit]
  - OraMTS Port Number: 49155
- Database information
  - Configuration: General Purpose / Transaction Processing
  - Global database name: orcl [Edit]
  - Oracle system identifier (SID): orcl [Edit]
  - Allocated memory: 806 MB
  - Automatic memory management option: TRUE
  - Database character set : Unicode standard UTF-8 (AL32UTF8) [Edit]
  - Management method: Database express
  - Database storage mechanism: File system
  - Database file location: C:\oracle\oradata [Edit]

Figure A-12. *An example of the Oracle Universal Installer's Summary screen*

Assuming that the summary is correct, you should click the Install button. Clicking the Install button may display the Install screen, as shown in Figure A-13. This is where you can get up and get a cup of coffee (joe).

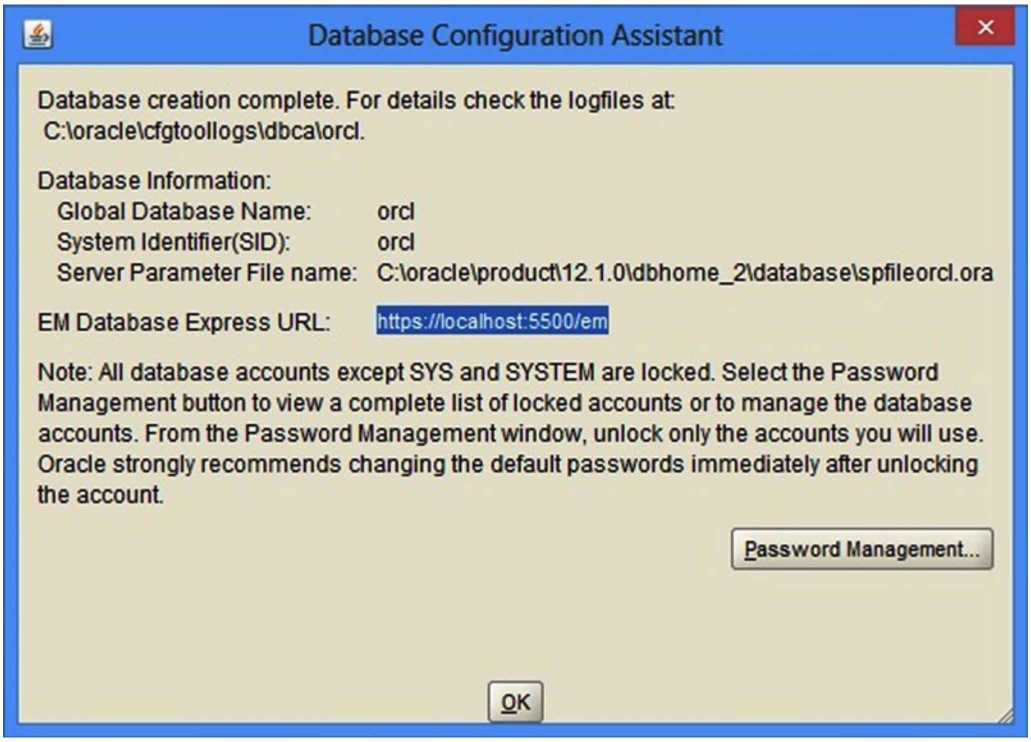


Starting 'Oracle Net Configuration Assistant'

✓	Oracle Database installation	Succeeded
✓	• Prepare	Succeeded
✓	• Copy files	Succeeded
✓	• Setup	Succeeded
✓	Setup Oracle Base	Succeeded
⇨	Oracle Database configuration	In Progress
⇨	• Oracle Net Configuration Assistant	In Progress
	• Oracle Database Configuration Assistant	Pending
	• Oracle Services For Microsoft Transaction Server	Pending
	• Oracle Configuration Manager Configuration (Optional)	Pending

Figure A-13. *An example of the Oracle Universal Installer's Install Product screen*

After some annoying period of time, the Database Configuration Assistant screen may display, as shown in Figure A-14.



Database creation complete. For details check the logfiles at:
C:\oracle\cfgtoollogs\dbca\orcl.

Database Information:

Global Database Name:	orcl
System Identifier(SID):	orcl
Server Parameter File name:	C:\oracle\product\12.1.0\dbhome_2\database\spfileorcl.ora

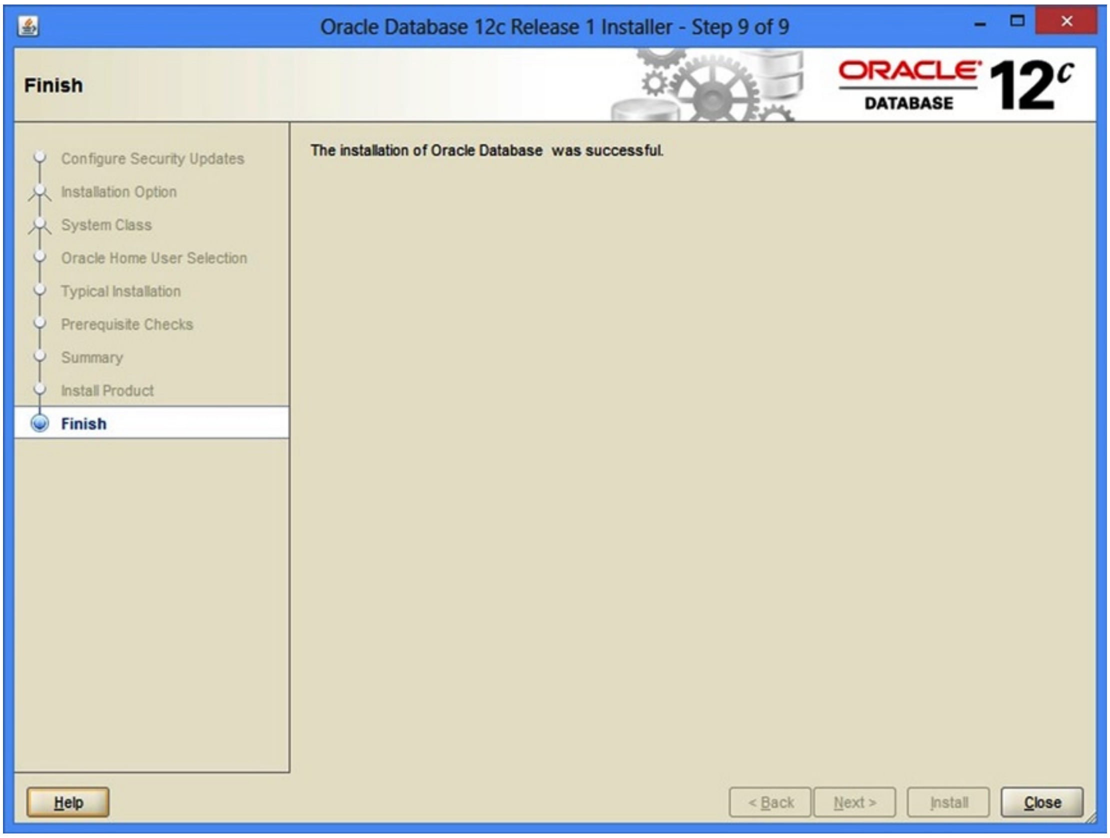
EM Database Express URL: https://localhost:5500/em

Note: All database accounts except SYS and SYSTEM are locked. Select the Password Management button to view a complete list of locked accounts or to manage the database accounts. From the Password Management window, unlock only the accounts you will use. Oracle strongly recommends changing the default passwords immediately after unlocking the account.

Figure A-14. *An example of the Oracle Universal Installer's Configuration Assitant screen*

Write down the URLs on this screen. You will need them!

You're on the home stretch now! After you click the OK button to dismiss the summary screen, the Finish screen may appear, as shown in Figure A-15.



The installation of Oracle Database was successful.

Figure A-15. *An example of the Oracle Universal Installer's Finish screen*

Click Exit to complete the installation. At this point, Oracle should be installed, and up and running on your computer. Congratulations!

To manage Oracle from this point forward, access the Enterprice Manager from your browser using the URL displayed on Figure A-14 of your installation, which is typically `https://localhost:5500/em`.

Now you need to open SQL*Plus to create a resource-enabled account.

How to Use SQL*Plus

You are going to be using SQL*Plus as your primary user interface to the Oracle database. With it, you will do the following:

- Create two usernames to use when doing the assignments in this book: `rps` and `ops`.
- Execute Data Definition Language (DDL) in order to create tables, indexes, views, types, and stored procedures.
- Execute Data Manipulation Language (DML) in order to insert into, update, delete from, and select data from tables in the database.

To get started, create a directory named `\bps` on your file system. You'll download this book's source code and solutions to that directory.

How to Download This Book's Source Code

To download the source code for this book, go to the Apress web site at `www.apress.com`, which may look something like Figure A-16. Click the Source Code menu item, and then search for and download the source code for this book.

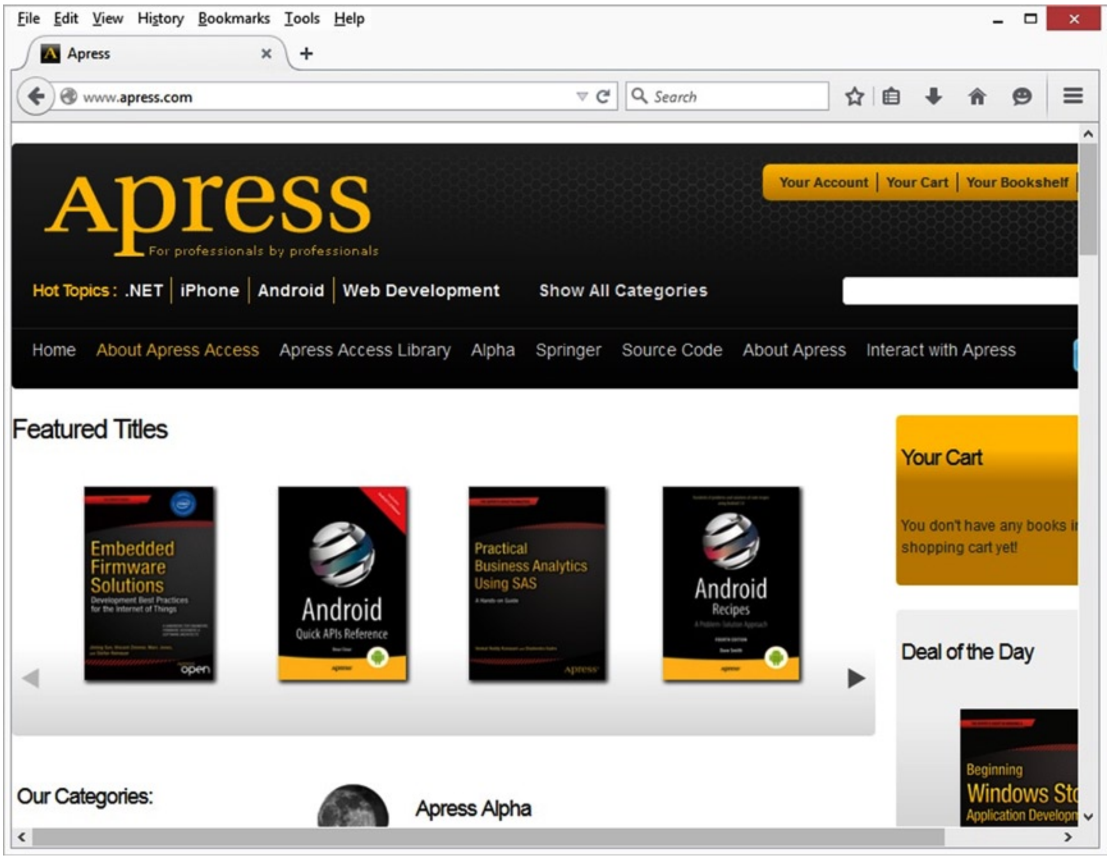

File Edit View History Bookmarks Tools Help
Apress
www.apress.com
Search
Apress
For professionals by professionals
Your Account | Your Cart | Your Bookshelf
Hot Topics : .NET | iPhone | Android | Web Development
Show All Categories
Home About Apress Access Apress Access Library Alpha Springer Source Code About Apress Interact with Apress
Featured Titles
Your Cart
You don't have any books in shopping cart yet!
Deal of the Day
Our Categories:
Apress Alpha

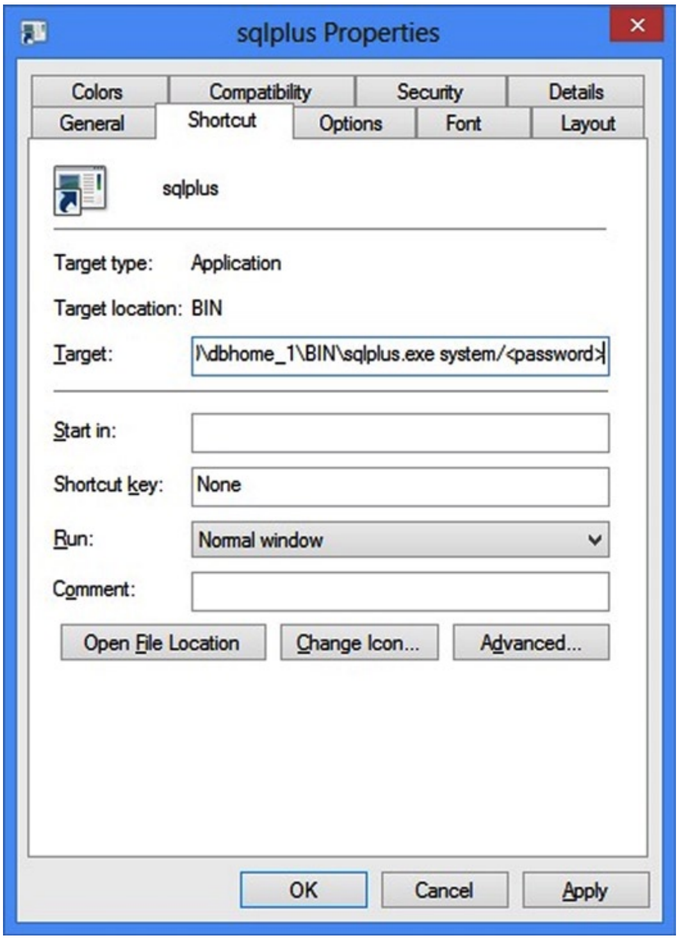
Figure A-16. *An example of the Apress web site's home page*

Next, decompress the archive (unzip it) into a `\bops` directory.

Now that you have the book's source code in place, you can create a shortcut to SQL*Plus in directory `\bops\Appendix`.

1. Navigate to directory `Appendix` using Windows Explorer.
2. Right-click any empty part of the directory's listing window.
3. Select New ~TRA Shortcut.
4. Specify the location of the SQL*Plus executable, `sqlplus.exe`, and then click the Next button. The SQL*Plus executable should be in the "Oracle Home" BIN directory, such as `c:\oracle\product\12.1.0\dbhome_1\BIN\sqlplus.exe`.

5. Specify the name for the shortcut. I name the shortcut after the database, so I suggest `orcl`. Click the Finish button.
6. Right-click your new shortcut and select Properties.
7. Delete the entry for the Start-in directory, then type in one space character, as in Figure A-17, and then click the OK button. This will make SQL*Plus use the directory where the shortcut exists as the default source directory when running a script, and that will make your life a lot easier.



sqlplus Properties

Colors | Compatibility | Security | Details
General | Shortcut | Options | Font | Layout

sqlplus

Target type: Application

Target location: BIN

Target: l\dbhome_1\BIN\sqlplus.exe system/<password>

Start in:

Shortcut key: None

Run: Normal window

Comment:

Open File Location | Change Icon... | Advanced...

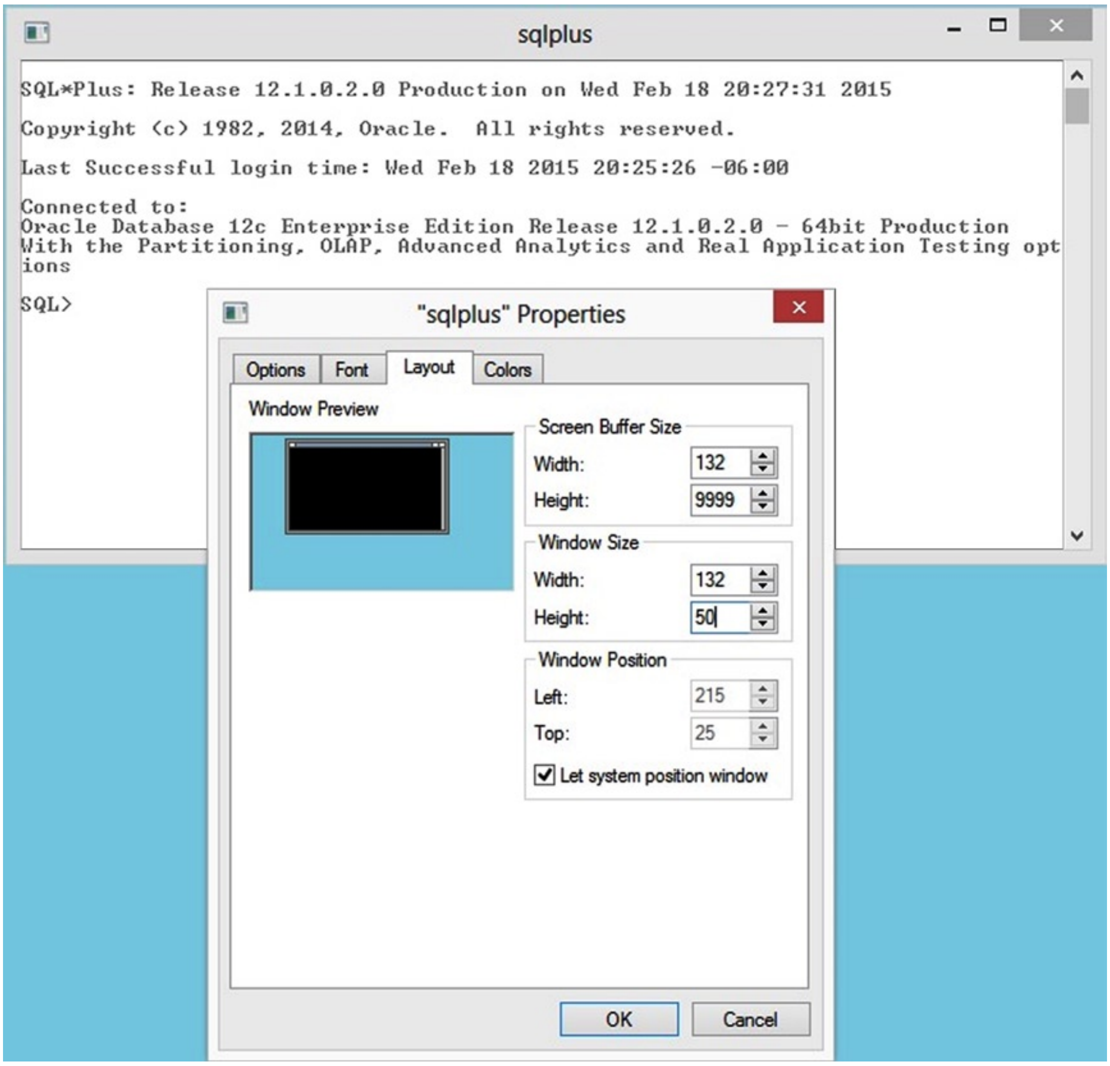
OK | Cancel | Apply

Figure A-17. *An example of a shortcut's Properties dialog box for SQL*Plus*

At this point, you should have a SQL*Plus shortcut icon in directory `\bops\Appendix`. Double-click the icon to start SQL*Plus. When you do, SQL*Plus will display a Login dialog box, where you specify the following:

- The username `SYSTEM`
- The password you decided to use
- Host string `orcl`, or whatever you decided to name the database

After you specify the login information, SQL*Plus should log you in to the database as user SYSTEM. If you see a screen like the one shown in Figure A-18, you have successfully logged in to your Oracle database.



```
SQL*Plus: Release 12.1.0.2.0 Production on Wed Feb 18 20:27:31 2015

Copyright (c) 1982, 2014, Oracle.  All rights reserved.

Last Successful login time: Wed Feb 18 2015 20:25:26 -06:00

Connected to:
Oracle Database 12c Enterprise Edition Release 12.1.0.2.0 - 64bit Production
With the Partitioning, OLAP, Advanced Analytics and Real Application Testing opt
ions

SQL>
```

Screen Buffer Size
Width: 132
Height: 9999

Window Size
Width: 132
Height: 50

Window Position
Left: 215
Top: 25
[✓] Let system position window

Figure A-18. *An example of a SQL*Plus screen and the window's Properties screen*

The reason you create the shortcut in the same directory that contains the example source code files is to give yourself easy access to those files. When you invoke SQL*Plus using the shortcut that you've just created, the source code directory becomes the default directory that SQL*Plus will search when you invoke a SQL script.

If you click the icon in the upper left hand corner, the window's Properties screen will appear, as in Figure A-18. Here I suggest you specify the following:

- A screen buffer size width of 132
- A screen buffer size height of 9999
- A window size width of 132
- A window size height of at least 50

The click OK to save your new shortcut's windows property settings. The next time you open SQL*Plus the window will be larger by default. This will also make your life easier.

How to Create a New Username

I suggest you create two usernames, `ops` and `rps`, just for working with the examples and doing the exercises in this book. To do that, type the following at the SQL*Plus prompt (`SQL>`), and then press the Enter key:

```
SQL> @create_users.sql
```

This will execute SQL*Plus script `create_users.sql` in directory `\bops\Appendix`, which will create two new usernames (`ops` with password `ops`, and rps with password `rps`) that you can use while learning from this book. The next time your log in to your database, use username `rps`.

How to Write a SQL*Plus Script

You may type a command directly into SQL*Plus. However, I don't recommend this if you're programming. I think you should write a SQL*Plus script so you can make corrections to your code as needed, and then execute the code again without needing to retype it. Having your code in a script file will allow you to do just that.

You may use any text editor you like—Notepad++, WordPad, TextPad, SQLDeveloper, and so on—but you can't use Word. (I prefer to use TextPad when I edit my SQL or PL/SQL scripts. You can search for TextPad on the Internet, and download a trial copy.)

To create a SQL*Plus script, follow these steps.

1. Open a new text file.
2. Type one or more SQL or PL/SQL commands using the correct syntax.
3. Save the script to a directory that is accessible by SQL*Plus.

Once you've created a script, you can run it whenever you like, and your commands will not be lost. They will forever reside in your script file. So how do you execute a SQL*Plus script?

How to Execute a SQL*Plus Script

I had you execute a SQL*Plus script earlier in order to create usernames `ops and rps` for this book. To execute a SQL*Plus script, you type an at sign character (`@`) followed by the name of the script to execute. SQL*Plus expects this script to exist in the SQL*Plus startup directory.

If the script isn't in the startup directory, you must specify the entire path and filename. If the path or filename has space characters in it, you need to enclose the path and filename in double quote characters ("). Here's an example:

```
SQL> @"c:\Program Files\Not a convenient location\my script.sql"
```

So I suggest you be lazy and create a shortcut with a blank (space) "start in" directory in every directory where you have scripts. This way, you can start a SQL*Plus session with the default directory set to where your script files exist.

How to Describe Your Tables and Stored Procedures

While you're in SQL*Plus, you can use the `describe` command to display the definition of a table or stored procedure. For example, you can type the following to get a definition for view `SYS.USER_OBJECTS`:

```
SQL> desc SYS.USER_OBJECTS
```

SQL*Plus will respond with the following:

```
Name                                      Null?    Type
----------------------------------------- -------- -------------
OBJECT_NAME                                        VARCHAR2(128)
SUBOBJECT_NAME                                     VARCHAR2(128)
OBJECT_ID                                          NUMBER
DATA_OBJECT_ID                                     NUMBER
OBJECT_TYPE                                        VARCHAR2(23)
CREATED                                            DATE
LAST_DDL_TIME                                      DATE
TIMESTAMP                                          VARCHAR2(19)
STATUS                                             VARCHAR2(7)
TEMPORARY                                          VARCHAR2(1)
GENERATED                                          VARCHAR2(1)
SECONDARY                                          VARCHAR2(1)
NAMESPACE                                          NUMBER
EDITION_NAME                                       VARCHAR2(128)
SHARING                                            VARCHAR2(13)
EDITIONABLE                                        VARCHAR2(1)
ORACLE_MAINTAINED                                  VARCHAR2(1)
```

However, SQL*Plus has this annoying feature: it aligns the right portion of a table description to the right side of the line width, and that usually prevents you from seeing the `Type`, so I use a script, `desc.sql`, to describe a table or stored procedure instead. For example, to describe utility package `SYS.DBMS_OUTPUT`, I type the following at the SQL*Plus prompt (`SQL>`):

```
SQL> @desc SYS.DBMS_OUTPUT
```

SQL*Plus will respond with the following:

```
SYS.DBMS_OUTPUT
SQL> @desc SYS.DBMS_OUTPUT
SYS.DBMS_OUTPUT
PROCEDURE DISABLE
PROCEDURE ENABLE
 Argument Name                  Type                   In/Out Default?
 ------------------------------ ---------------------- ------ --------
 BUFFER_SIZE                    NUMBER(38)             IN     DEFAULT
PROCEDURE GET_LINE
 Argument Name                  Type                   In/Out Default?
 ------------------------------ ---------------------- ------ --------
 LINE                           VARCHAR2               OUT
 STATUS                         NUMBER(38)             OUT
PROCEDURE GET_LINES
 Argument Name                  Type                   In/Out Default?
 ------------------------------ ---------------------- ------ --------
 LINES                          TABLE OF VARCHAR2(32767) OUT
 NUMLINES                       NUMBER(38)             IN/OUT
PROCEDURE GET_LINES
 Argument Name                  Type                   In/Out Default?
 ------------------------------ ---------------------- ------ --------
 LINES                          DBMSOUTPUT_LINESARRAY   OUT
 NUMLINES                       NUMBER(38)             IN/OUT
PROCEDURE NEW_LINE
PROCEDURE PUT
 Argument Name                  Type                   In/Out Default?
 ------------------------------ ---------------------- ------ --------
 A                              VARCHAR2               IN
PROCEDURE PUT_LINE
 Argument Name                  Type                   In/Out Default?
 ------------------------------ ---------------------- ------ --------
 A                              VARCHAR2               IN
```

This description looks different from the first one, not because I used `@desc.sql`, but because the described object is a stored procedure, not a view. All that `@desc.sql` does for you is set the SQL*Plus `linesize` property to 80, use the `describe` command, and then return the `linesize` to its prior length.

At this point, you should know how to do the following:

- Download Oracle
- Install Oracle
- Create usernames `ops` and `rps`
- Write a SQL*Plus script
- Execute a SQL*Plus script
- Describe a table or stored procedure

So now it's time for you to get started with Chapter 1. I wish you good skill on your journey. Feel free to contact me if you have any questions about the book.

Index

Beginning Oracle PL/SQL

Second Edition

Donald J. Bales

IOUG independent oracle users group

Apress®

Beginning Oracle PL/SQL

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To my wife, Terry Moro,
you’re the wind that feeds the flame

To my daughter, Kristyn,
“Every day, in every way, you get better and better!”

To Antoneo Bolagnao,
my Buddha

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About the Author

Donald Bales is an Information/Systems Architect, Business/Systems Analyst, Designer, and Programmer with over 30 years of professional experience in Business and Information Technology. He's an author of books and articles on Oracle, Java, and PL/SQL. His area of expertise is in the use of object-oriented analysis, design, and programming, along with service-oriented architecture, for scientific data analysis, business process modeling, enterprise application development and integration, most recently using Python Django, Ruby on Rails, Java JEE, XML, HTML, CSS, JavaScript, AJAX, Oracle, and Postgresql, to name a few. In addition, he possess more than 30 years of IT project management experience.

When he is not developing software applications, Don can often be found working with horses, or playing the piano or Native American flute. Don has had several careers, and has at various times been a mechanic, a general contractor, Mr. Mom, a developer, and a consultant. He is currently the Principal Technology Lead, Environmental Software and Data Management at Argonne National Laboratory. He has a bachelor of science degree in business from Elmhurst College in Illinois. Don resides in Downers Grove, Illinois, with his wife, Terry Moro. He can be contacted by e-mail at `don@donaldbales.com`.

About the Technical Reviewer

Michael Rosenblum is a Software Architect/Senior DBA at Dulcian, Inc. where he is responsible for system tuning and application architecture. Michael supports Dulcian developers by writing complex PL/SQL routines and researching new features. He is the co-author of *Oracle PL/SQL Performance Tuning Tips & Techniques* (McGraw-Hill, 2014) and *PL/SQL for Dummies* (Wiley Press, 2006), contributing author of *Expert PL/SQL Practices* (Apress, 2011), and author of a number of database-related articles (*IOUG Select Journal*, *ODTUG Tech Journal*, *OTech Magazine*) and conference papers. Michael is an Oracle ACE, a frequent presenter at various Oracle user group conferences (Oracle OpenWorld, ODTUG, IOUG Collaborate, RMOUG, NYOUG), and winner of the ODTUG Kaleidoscope 2009 Best Speaker Award. In his native Ukraine, he graduated summa cum laude from the Kiev National Economic University where he received a Master of Science degree in Information Systems.

Acknowledgments

Everything in the universe is constantly trying to change the behavior of everything else in the universe, all the time. Some behavioral modifications promote order; others promote chaos. So nothing we do–any of us–is actually a totally independent action. Whether we realize it or not, others as well as ourselves are taking part in both our successes and failures.

With that in mind, you should be able to understand why I say this book is the result of collaboration. Every person I've known, along with every situation I've experienced, has helped shape the text of this tutorial.

Since I have a seeming limited amount of memory, let me at least thank those who are directly responsible for bringing it to you:

Terry Moro, my wife, for reminding me how to maintain balance, even when I'm writing a book!

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Foreword

I have some bad news and some good news. The bad news is: when you first meet Don Bales, he seems like an overly confident know-it-all. The good news is: he's not. Actually, he's a great teacher/author and perhaps does know it all when it comes to Oracle! I've not only read this book, but lived it. You see, I ended up working for him. Because of this, I think I am the perfect person to introduce you to *Beginning Oracle PL/SQL*.

A good programmer knows that the purpose of a good book, like this one, is to introduce the concepts of, the application of, and good examples of the subject: PL/SQL. *Beginning Oracle PL/SQL* goes above and beyond the call by explaining when you can use PL/SQL and when you should not. It starts with a low level understanding of basic SQL and builds your skills into understanding all types of complex PL/SQL.

My background may help you understand the profound effect that this book had on my career. I graduated with a computer science degree from a small private school. When I graduated, I had a basic understanding of databases and a good understanding of object-oriented programming languages.

My first job was at that same school, and it involved a lot of Java and a fair bit of PL/SQL. I was hired to be an object-oriented Java programmer and to hack through whatever else needed to be done. Although I never had formal training in it, or even understood the fundamentals of PL/SQL, I was able to hack together applications written in the language.

Before reading this book and working with Don, I had programmed in PL/SQL for five years. Working with Don reading this book changed the trajectory of my career. I looked both backward and forward to identify my mistakes and future direction. Since reading this book, I write much less PL/SQL to accomplish much more. It's amazing what a difference the strong fundamentals taught in *Beginning Oracle PL/SQL* provide to a person who has been effectively writing code for years, and that's not even who it was written for!

I believe Don asked me to write this forward because he saw my abilities before and after reading and learning from his book. I am the poster child for what his book can do for a programmer who has always been able to cobble things together. It turned me from someone who was able to accomplish a task into someone who can write PL/SQL in an efficient and consistent manner, and know when and why to use the various features of the language.

The nature of this book sets it apart from others in its category. PL/SQL is a procedural language. Therefore, it only makes sense that everything is taught in a procedural way, right? This is not the case, nor should it be. Don is able to apply object-oriented principles where they make sense to greatly enhance the use and effectiveness of PL/SQL.

Don is the perfect person to write this book. His background is unparalleled. He started off as a general contractor and was able to teach himself how to be a strong programmer. That's the least of it. Yes, his programming skills are superior, but he has two, much bigger, assets: building skills/getting the most out of others and delivering products that satisfy his customer's needs. He does both with this book. If you read and study it, your skills will be enhanced and you will become a confident PL/SQL programmer.

Don approached writing *Beginning Oracle PL/SQL* like everything else he does, by asking, “What is the goal?” The goal of this book is to teach you, the reader, everything you should know about PL/SQL. This is not an encyclopedia of every last Oracle function, procedure, etc. Instead, it’s a great tool that will show you how to use PL/SQL, when to use PL/SQL, and what is possible with PL/SQL, when writing an application that utilizes Oracle.

—T.J. Eakle
Web Developer
Argonne National Laboratory

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independent oracle users group

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IOUG represents the **voice of Oracle technology and database professionals** - empowering you to be **more productive in your business** and career by **delivering education,** sharing **best practices** and providing technology direction and **networking opportunities.**

Context, Not Just Content

IOUG is dedicated to helping our members become an #IOUGenius by staying on the cutting-edge of Oracle technologies and industry issues through practical content, user-focused education, and invaluable networking and leadership opportunities:

- ***SELECT Journal*** is our quarterly publication that provides in-depth, peer-reviewed articles on industry news and best practices in Oracle technology
- Our #IOUGenius blog highlights a featured weekly topic and provides **content driven by Oracle professionals and the IOUG community**
- Special Interest Groups provide you the chance to collaborate with peers on the specific issues that matter to you and even take on leadership roles outside of your organization
- COLLABORATE is our once-a-year opportunity to connect with the members of not one, but three, Oracle users groups (IOUG, OAUG and Quest) as well as with the top names and faces in the Oracle community.

Who we are...

... **more than 20,000** database professionals, developers, application and infrastructure architects, business intelligence specialists and IT managers

... a **community of users** that share experiences and knowledge on issues and technologies that matter to you and your organization

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