7.0

TURBO PASCAL®

USER'S GUIDE

- INSTALLATION
- INTEGRATED DEVELOPMENT ENVIRONMENT (IDE)
- UNITS
- POINTERS
- OOP

BORLAND

Turbo Pascal®

Version 7.0

User's Guide

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INTRODUCTION

Turbo Pascal is designed for all types of users who want to develop applications for the DOS operating system. Whether you are a beginner about to write your first program, an experienced developer curious about object-oriented programming, or a longtime Turbo Pascal user, Turbo Pascal offers you a rich programming environment that makes software development more productive—and more fun. Using Pascal's structured, high-level language, you can write programs for any type or size of application.

Turbo Pascal 7.0 brings you new capabilities while remaining compatible with code written using earlier versions. While exploring the opportunities that await you, remember that this is still Turbo Pascal, the quick and efficient Pascal compiler that is the world's standard.

How to use the Turbo Pascal manuals

Turbo Pascal comes with four manuals, each with a different purpose.

Read the User's Guide if you're a new Turbo Pascal user.

You'll find the *User's Guide* helpful if

- You want to know how to install Turbo Pascal
- You've used Turbo Pascal before and you want to know what is new in this release
- You want to learn how to use Borland's integrated development environment (the IDE) to develop and debug programs
- You want to learn about units and how to write your own
- You haven't used pointers in your programs before or you need to refresh your pointer knowledge
- You're new to object-oriented programming

Read the Language Guide to learn about the Turbo Pascal language.

The *Language Guide* focuses on the Turbo Pascal language and explains how to get the most out of it. Use the *Language Guide* to

- Find the formal definition of the Turbo Pascal language including detailed syntax diagrams covering every Turbo Pascal construct
- Learn how the run-time library is organized and how to use it
- Discover the procedures, functions, predeclared variables, constants, and so on that are in the run-time library and available for your programs to use
- Find out how Turbo Pascal programs use memory
- Learn how Turbo Pascal implements program control
- Find out how your programs can use a 80x87 coprocessor
- Learn how Turbo Pascal optimizes code
- Find out how to use Turbo Pascal with assembly language

Use the Programmer's Reference as your primary reference when programming in Turbo Pascal.

The *Programmer's Reference* is a reference to the details you'll need as you write your programs. You'll want to keep this volume by your computer as you program. Use the *Programmer's Reference* when you want to

- Look up the details of a particular run-time library procedure, function, variable, type, or constant and find out how to use it
- Understand how compiler directives work, what each compiler directive does, and how to use them
- Find out what an error message means
- Learn how to use the command-line compiler
- Look up editor commands
- Look up compiler directives in a quick reference
- See a list of reserved words and standard directives

Use the Turbo Vision Programming Guide to learn about developing Turbo Vision applications.

The *Turbo Vision Guide* is your guide to Turbo Vision, the application framework that gives you a head start on object-oriented programming. To master Turbo Vision, you'll want to

- Work through the tutorial to get hands-on experience developing a Turbo Vision application
- Study the Turbo Vision hierarchy and become acquainted with the object types
- Learn the meaning of event-driven programming and what it entails

- Use the Turbo Vision reference to look up the details about the objects in the Turbo Vision hierarchy and all the associated types, constants, and variables

Typefaces used in these books

All typefaces used in this manual were produced by Borland's Sprint: The Professional Word Processor, on a PostScript laser printer. Their uses are as follows:

`Monospace type`	This typeface represents text as it appears onscreen or in a program. It is also used for anything you must type (such as `TPX` to start up Turbo Pascal).
[ ]	Square brackets in text or DOS command lines enclose optional items that depend on your system. *Text of this sort should not be typed verbatim.*
Boldface	This typeface is used in text for Turbo Pascal reserved words, for compiler directives {**$I-**} and for command-line options (**/A**).
Italics	Italics indicate identifiers that appear in text. They can represent terms that you can use as they are, or that you can think up new names for (your choice, usually). They are also used to emphasize certain words, such as new terms.
Keycaps	This typeface indicates a key on your keyboard. For example, "Press *Esc* to exit a menu."
	This icon indicates keyboard actions.
	This icon indicates mouse actions.

How to contact Borland

Borland offers a variety of services to answer your questions about Turbo Pascal.

☞ Be sure to send in the registration card; registered owners are entitled to technical support and may receive information on upgrades and supplementary products.

TechFax

800-822-4269 (voice)

TechFax is a 24-hour automated service that sends free technical information to your fax machine. You can use your touch-tone phone to request up to three documents per call.

Borland Download BBS

408-439-9096 (modem) up to 9600 Baud

The Borland Download BBS has sample files, applications, and technical information you can download with your modem. No special setup is required.

Online information services

Subscribers to the CompuServe, GEnie, or BIX information services can receive technical support by modem. Use the commands in the following table to contact Borland while accessing an information service.

Online information services

Service	Command
CompuServe	`GO BORLAND`
BIX	`JOIN BORLAND`
GEnie	`BORLAND`

Address electronic messages to Sysop or All. Don't include your serial number; messages are in public view unless sent by a service's private mail system. Include as much information on the question as possible; the support staff will reply to the message within one working day.

Borland Technical Support

408-461-9177 (Pascal) 6 a.m. to 5 p.m. PT

Borland Technical Support is available weekdays from 6:00 a.m. to 5:00 p.m. Pacific Time to answer technical questions about Borland products. Please call from a telephone near your computer, with the program running and the following information available:

- Product name, serial number, and version number

- Brand and model of the hardware in your system
- Operating system and version number—use the operating system's VER command to find the version number
- Contents of your AUTOEXEC.BAT and CONFIG.SYS files (located in the root directory (\) of your computer's boot disk)
- Contents of your WIN.INI and SYSTEM.INI files (located in your Windows directory)
- Windows version number—use the WINVER command to find the versions number
- Daytime phone number where you can be reached

If the call concerns a software problem, please be able to describe the steps that will reproduce the problem.

Borland Technical Support also publishes technical information sheets on a variety of topics.

Borland Advisor Line

900-555-1001
6 a.m. to 5 p.m. PT

The Borland Advisor Line is a service for users who need immediate access to advice on Turbo Pascal issues.

The Advisor Line operates weekdays from 6:00 a.m. to 5:00 p.m. Pacific Time. The first minute is free; each subsequent minute is $2.00.

Borland Customer Service

408-461-9000 (voice)
7 a.m. to 5 p.m. PT

Borland Customer Service is available weekdays from 7:00 a.m. to 5:00 p.m. Pacific time to answer nontechnical questions about Borland products, including pricing information, upgrades, and order status.

C H A P T E R

1

Installing and running Turbo Pascal

Your Turbo Pascal package includes three different versions of Turbo Pascal:

- TPX.EXE, an integrated development environment (IDE) that runs in DOS protected mode
- TURBO.EXE, an IDE that runs in DOS real mode
- TPC.EXE, a command-line compiler that runs in DOS real mode

Turbo Pascal comes with an automatic installation program called INSTALL. Because we use file-compression techniques, you must use this program; you can't just copy the Turbo Pascal files onto your hard disk. INSTALL automatically copies and uncompresses the Turbo Pascal files.

We assume you're already familiar with DOS commands. For example, you'll need the DISKCOPY command to make backup copies of your distribution disks (the ones you bought). Make a complete working copy of your distribution disks when you receive them, then store the original disks away in a safe place.

This chapter contains the following information:

- Installing Turbo Pascal on your system
- Accessing the README file
- Accessing the HELPME!.DOC file
- Using Borland's example programs

Using INSTALL

We recommend that you read the README file before installing.

Among other things, INSTALL detects what hardware you're using and configures Turbo Pascal appropriately. It also creates directories as needed and transfers files from your distribution disks to your hard disk. Its actions are self-explanatory; the following text tells you all you need to know.

To install Turbo Pascal:

1. Insert the installation disk (disk 1) into drive A. Type the following command, then press *Enter.*

   ```
   A:INSTALL
   ```

2. Press *Enter* at the installation screen.
3. Follow the prompts.
4. INSTALL needs disk space to store temporary files before decompressing them. INSTALL's opening screen lists the disk-space requirements; if you don't have enough, exit INSTALL and make room. Once INSTALL is complete, those temporary files are deleted.
5. At the end of installation, you might want to add this line to your CONFIG.SYS file:

   ```
   FILES = 20
   ```

   If you changed the default installation directory, you need to change this PATH setting.

   and this line to your AUTOEXEC.BAT file (or modify your existing PATH statement, if you already have one):

   ```
   PATH = C:\TP\BIN
   ```

When INSTALL is finished, it allows you to read the latest about Turbo Pascal in the README file, which contains important, last-minute information.

Running Turbo Pascal

To start Turbo Pascal, go to the Turbo Pascal directory created with INSTALL. Usually this directory is C:\TP\BIN. To start the protected-mode IDE, type

```
TPX
```

☞ The files DPMI16BI.OVL and RTM.EXE must be in your current directory or on your path or TPX.EXE won't start.

To start the IDE that runs in real mode, type

```
TURBO
```

Protected mode and memory

The Turbo Pascal protected-mode IDE (TPX.EXE) uses DPMI (DOS Protected Mode Interface) to run the compiler in protected mode, giving the IDE access to all your computer's memory. The protected-mode interface is completely transparent to the user, and you should never have to think about it, with a few possible exceptions.

DPMIINST

One such exception might be when you run the protected-mode IDE for the very first time. Turbo Pascal uses an internal database of various machine characteristics to determine how to enable protected mode on your machine, and configures itself accordingly. If you have a computer with an older 80286 microprocessor, Turbo Pascal might not recognize your machine. You'll see this message when you try to run Turbo Pascal:

```
Machine not in database (RUN DPMIINST)
```

If you get this message, simply run the DPMIINST program by typing `DPMIINST` at the DOS prompt and following the program's instructions.

DPMIINST runs your machine through a series of tests to determine the best way of enabling protected mode, and automatically configures the protected-mode IDE accordingly. Once you have run DPMIINST, you won't have to run it again.

☞ Some memory managers, device drivers, and memory-resident (TSR) programs might interfere with DPMIINST's ability to analyze your machine. If DPMIINST fails, try temporarily disabling or removing these programs. That gives DPMIINST the unrestricted access it needs to determine the best way to enter protected mode.

DPMIMEM

By default, the Turbo Pascal DPMI interface allocates all available extended and expanded memory for its own use. If you don't want all of the available memory to be taken by the DPMI kernel, you can set an environment variable to specify the maximum amount of memory to use. This variable can be entered directly at the DOS prompt or inserted as a line in your AUTOEXEC.BAT file, using this syntax:

```
SET DPMIMEM=MAXMEM nnnn
```

where *nnnn* is the amount of memory in kilobytes.

For example, if you have a system with 4MB and want the DPMI kernel to use 2MB of it, leaving the other 2MB alone, the DPMIMEM variable would be set as follows:

```
SET DPMIMEM=MAXMEM 2000
```

DPMILOAD

DPMILOAD preloads the DPMI server. It enables DPMI and spawns a DOS command shell. Preloading the DPMI server lets you load Turbo Pascal's the protected-mode IDE slightly faster. Type `EXIT` to close the shell.

Turbo Pascal and extended memory

Once the DPMI kernel is loaded (either by running TPX.EXE or with the DPMILOAD utility), the protected-mode IDE interacts with the DPMI server through Borland's run-time manager (RTM.EXE) to allocate memory so that the IDE can load and operate. By default, the IDE uses all the extended memory reserved by the DPMI kernel.

Running Turbo Pascal in Windows

If you are uncertain about how to modify PIF files with the Windows PIF editor, see your Microsoft Windows User's Guide.

Although Turbo Pascal 7.0 isn't a Windows application, you can still run it from Windows:

- If you choose to start the protected-mode IDE in a Windows DOS box, you must first modify the DOSPRMPT.PIF file found in your Windows directory so that the protected-mode IDE will be able to use extended memory.

  Using the Windows PIF editor, open the DOSPRMPT.PIF file, and indicate the amount of extended memory you want the protected-mode IDE to use.

- If you choose to run the protected-mode IDE from the Windows Program Manager, you must first modify the _DEFAULT.PIF file found in your Windows directory so that protected-mode IDE will be able to use extended memory.

  Using the Windows PIF editor, open the _DEFAULT.PIF file, and indicate the amount of extended memory you want the protected-mode IDE to use.

LCD or plasma displays

If you have a computer with an LCD or plasma display, you should start Turbo Pascal using the **/L** startup option. Type this:

```
TPX /L
```

or

```
TURBO /L
```

Although you could always start Turbo Pascal this way, you can also easily configure the IDE for a black-and-white screen from within the IDE, using the Options | Environment | Startup dialog box. Select the LCD Color Set option.

The README file

The README file contains last-minute information that might not be in the manuals.

After you install Turbo Pascal, the README file appears. To access the README file at a later time, you can use the Turbo Pascal README program by typing these commands at the DOS command line when you're in the C:\TP directory:

```
README
```

FILELIST.DOC and HELPME!.DOC

Your installation disk also contains a file called FILELIST.DOC, which lists every file on the distribution disks and a brief description of what each one contains, and HELPME!.DOC, which contains answers to problems that users commonly run into. Consult it if you find yourself having difficulties. You can use the README program to look at FILELIST.DOC or HELPME!.DOC. Type this at the command line:

```
README HELPME!.DOC
```

or

```
README FILELIST.DOC
```

Example programs

Your Turbo Pascal package includes the source code for a large number of example programs. These programs are located in subdirectories of the TP directory created by INSTALL. Spend a few moments browsing through these directories to see the wealth of program examples available to you.

C H A P T E R

2

What's new in Turbo Pascal

Turbo Pascal is an object-oriented programming system. If you are a Turbo Pascal user, this chapter tells you about all the new features in Turbo Pascal and where you can find information about them.

Two integrated development environments

Turbo Pascal gives you two integrated development environments (IDEs):

You must have a 80286 or higher microprocessor in your computer and at least 2MB of memory to run the DOS protected-mode IDE.

- TPX.EXE, an IDE that runs in DOS protected mode. A protected-mode IDE means even your very large applications will have the memory necessary to compile.
- TURBO.EXE, an IDE that runs on all 80x86 systems.

To read about the IDEs, see Chapter 4, "Programming in the IDE," in this book.

New IDE features

Within these IDEs, you'll find these new features:

- ObjectBrowser. With the ObjectBrowser, you can browse through the objects and units in your program, examine your source code, obtain a complete cross-reference to every symbol used in your program, and see your program in a new perspective. To read about the ObjectBrowser, see page 55 in this book.

- Syntax highlighting. You can color code syntax elements of your programs so you can quickly identify parts of your code. You can also print your syntax-highlighted code. To learn how to use syntax highlighting, see page 43 in Chapter 4, "Programming in the IDE."
- Undo and Redo. Make a mistake while editing your program? Press Undo and your mistake disappears. Press Redo, and it reappears. For more about Undo and Redo, see page 38 in this book.
- A Tools menu. You can run the tools and utilities that come with Turbo Pascal directly from the IDE. You can also add your own utilities to the Tools menu and change the hot keys to your liking. To learn about the Tools menu, see page 67 in this book.
- A Messages window. You can use the Messages window to display output messages from utilities such as GREP. You can choose to edit a program line referenced in a message, or track messages in your source code as you scroll through the messages. To learn about the Messages window, see page 68 in this book.
- Local menus. With just a click of your right mouse button or by pressing *Alt+F10*, you can display a local menu that lists menu commands specific to the active window. Read about local menus on page 43 in this book.
- Multiple user-installable Help file support. You can load additional Help files into the Turbo Pascal Help system. The IDE merges the indexes of the newly-loaded Help files with the standard Help system index. For more information about loading new help files, see page 36 in this book.
- Symbol information saved across sessions. This enables you to browse, debug, or run your program without recompiling after you have exited and then restarted the IDE; see page 72 in this book.
- Symbol information saved across compilations. If a compilation fails, symbol information from your last successful compilation is still available so you can use the ObjectBrowser to help you find the source of the problem. To learn how to enable this feature, see page 33 and read about the **/Y** startup option.

Additions to the Pascal language

Turbo Pascal has several new language extensions that make writing your programs easier:

- Open parameters. Open parameters allow strings and arrays of varying sizes to be passed to a procedure or function. Read about open parameters in the "Open parameters" section on page 111 in Chapter 9, "Procedures and functions," in the *Language Guide*.
- **Public** standard directive. Turbo Pascal 6.0 and Turbo Pascal for Windows permitted **private** component sections in objects. Turbo Pascal introduces **public** component sections that have no restrictions on the scope of fields and methods declared in them. You can mix **public** and **private** component sections in your objects as you see fit. To read more about the new **public** standard directive, see the "Components and scope" section on page 36 in Chapter 4, "Types," in the *Language Guide*.
- **Inherited** reserved word. The **inherited** reserved word can be used within a method to refer to the ancestor of the method's object type. See the "Qualified-method activations" section on page 41 in Chapter 4, "Types," in the *Language Guide*.
- Constant parameters. Procedures and functions can list constant parameters: a parameter group preceded by the **const** reserved word and followed by a type. Constant parameters protect against accidental assignments to a formal parameter, and in some cases, permit the compiler to generate more efficient code. See the "Parameters" section on page 107 in Chapter 9, "Procedures and functions," in the *Language Guide*.
- Dynamic methods and dynamic method tables (DMTs). If you've used Turbo Pascal for Windows, you know about dynamic methods and DMTs. With Turbo Pascal, your DOS programs can use them too.

  Dynamic methods differ from virtual methods in the way dynamic methods are dispatched at run time. Instead of building a virtual method table (VMT) for dynamic methods, the compiler builds a DMT. Usually DMTs decrease the memory requirements of your applications when you program with objects. To learn more about dynamic methods, see the "Dynamic methods" section on page 38 in Chapter 4, "Types," in the *Language Guide*. To read more about dynamic method tables, see the "Dynamic method tables" section on page 225 in Chapter 19, "Memory issues," in the *Language Guide*.

Enhancements to the run-time library

Improvements to the run-time library include these items:

- Quicker text-file input and output
- A faster *Pos* function
- 80386 optimizations for *Longint* multiply, divide, shift left, and shift right operations

New routines in the System unit

The *System* unit has seven new procedures and functions. You can find them all in Chapter 1, "Library reference," in the *Programmer's Reference*:

- The *Assigned* procedure tests to determine if a pointer or procedural variable is **nil**.
- The *Break* procedure terminates a **for**, **while**, or **repeat** statement.
- The *Continue* procedure continues with the next iteration of a **for**, **while**, or **repeat** statement.
- The *Include* procedure includes an element in a set.
- The *Exclude* procedure excludes an element in a set.
- The *High* function returns the highest value in the range of the argument.
- The *Low* function returns the lowest value in the range of the argument.

New units

If you've used Turbo Pascal for Windows, you know that the *Strings* unit enabled you to use null-terminated (C-style) strings. Now Turbo Pascal programmers can use the *Strings* unit also. To learn more about null-terminated strings, see Chapter 16, "Using null-terminated strings," in the *Language Guide*. For complete information about all the procedures and functions in the *Strings* unit, see Chapter 1, "Library reference," in the *Programmer's Reference*.

Turbo Pascal for Windows programmers are already familiar with the *WinDos* unit. DOS programmers can also use the *WinDos* unit to implement operating system and file-handling routines. To help you decide if you should use the *WinDos* or the *Dos* unit, read Chapter 15, "Interfacing with DOS," in the *Language Guide*. All *WinDos* procedures and functions are explained in detail in Chapter 1, "Library reference," in the *Programmer's Reference*.

New compiler directives

Turbo Pascal has four new compiler directives; read more about them in Chapter 2, "Compiler directives," in the *Programmer's Reference*:

- The **$P** directive, Open String Parameters, controls the meaning of variable parameters declared using the **string** keyword.
- The **$T** directive, Type-checked Pointers, controls the types of pointer values generated by the @ operator.
- The **$Q** directive, Overflow Checking, controls the generation of overflow-checking code for certain integer arithmetic operations.
- The **$Y** directive, Symbol Information, generates symbol reference information in a compiled program or unit so that the ObjectBrowser can display symbol definition and reference information for that module.

You can also use the IDE to enable these features instead of using compiler directives. Choose Options | Compiler and set the options in the Compiler Options dialog box.

Improvements to the compiler

In addition to the extensions to the Turbo Pascal language and the new compiler directives, the compiler itself continues to improve:

- The compiler permits easier linking with C and assembler code by passing .OBJ line number information to your executable file. Therefore, you can use the integrated debugger to step through C and assembler code; see page 83 in Chapter 5, "Debugging in the IDE," in this book.

- The compiler generates more efficient code when the right operand of the **in** operator is a set constant. See "Constant set inlining" on page 247 in Chapter 21, "Optimizing your code," in the *Language Guide*.
- The compiler generates more efficient code for small sets. To read about small sets, see page 248 in Chapter 21, "Optimizing your code," in the *Language Guide*.
- The compiler permits unlimited unit nesting.
- A **uses** clause in the **implementation** section of a unit no longer causes a circular unit reference.
- The compiler suppresses redundant pointer load operations in certain situations; see Chapter 21, "Optimizing your code," in the *Language Guide*.

Enhancements to Turbo Vision

Turbo Vision 2.0 adds new objects to the hierarchy and adds some new capabilities to the existing objects. Changes to existing objects are backward-compatible, so existing Turbo Vision code should compile without changes, and existing streams and resources should load without error.

These are the new features in Turbo Vision 2.0; read about them in the *Turbo Vision Programming Guide*.

- Support for data validation. Your Turbo Vision applications can ensure that they receive valid data to process.
- Multistate check boxes. Check boxes can have states other than checked and unchecked.
- Outline viewer objects. Your applications can use two objects, *TOutlineViewer* and *TOutline*, to display outlines. We used them in building the ObjectBrowser.
- Object versioning on a stream. Even if your objects were created with Turbo Vision 1.0, your programs will still be able to read them as objects compatible with Turbo Vision 2.0.
- New tutorial and revised documentation. You'll find it easier to learn Turbo Vision and become proficient sooner.

C H A P T E R

3

Introduction to the IDE

If you prefer using a command-line compiler, see Chapter 3, "Command-line compiler," in the Programmer's Reference.

Turbo Pascal is more than just a fast, efficient Pascal compiler; it also features an easy-to-learn and easy-to-use integrated development environment (IDE). With Turbo Pascal, you don't need to use a separate editor, compiler, linker, and debugger to create, debug, and run your Pascal programs. All these features are built into Turbo Pascal, and they are all accessible from the IDE.

To learn more about the Turbo Pascal Help system, see page 34.

Online context-sensitive help is only a keystroke or a mouse click away. You can get help at any point, except when *your* program has control, by pressing *F1*.

Starting Turbo Pascal

For more details about starting Turbo Pascal including startup options, see page 30.

To start Turbo Pascal, go to the Turbo Pascal subdirectory you created with INSTALL. Usually this directory is C:\TP. To start the protected-mode IDE, type

```
TPX
```

☞ The files DPMI16BI.OVL and RTM.EXE must be in your current directory or on your path or TPX.EXE won't start.

To start the IDE that runs in real mode, type

```
TURBO
```

IDE components

There are three visible components to the IDE: the Menu bar at the top, the desktop, and the status line at the bottom.

The Menu bar and menus

The Menu bar is your primary access to all the menu commands. When the Menu bar is active, you'll see a highlighted menu title; this is the currently *selected* menu.

You can choose commands with either the keyboard or a mouse.

Here's how you choose menu commands using the keyboard:

To cancel an action, press Esc.

1. Press *F10*. This activates the Menu bar.
2. Use the arrow keys to select the menu command you want to display. Then press *Enter*.

   As a shortcut for this step, you can press the highlighted letter of the menu title. For example, from the Menu bar, press *E* to quickly display the Edit menu. Or, without activating the Menu bar, you can press *Alt* and the highlighted letter to display the menu you want.
3. Use the arrow keys again to select the command you want. Then press *Enter*.

   Again, as a shortcut, you can press the highlighted letter of a command to choose it once the menu is displayed.

   At this point, Turbo Pascal either carries out the command, displays a dialog box, or displays another menu.

You can customize the action of the Ctrl+right mouse button combination and even reverse the action of the mouse buttons; choose Options | Environment | Mouse.

To choose commands with a mouse, do this:

1. Click the desired menu title to display the menu.
2. Click the desired command.

You can also drag straight from the menu title down to the menu command. Release the mouse button on the command you want. If you change your mind, just drag off the menu; no command will be chosen.

If a menu command is followed by an ellipsis (...), choosing the command displays a dialog box. If the command is followed by an arrow (▸), the command leads to another menu (a pop-up menu). A command without either an ellipsis or an arrow indicates that the action occurs once you choose it.

At times menu commands appear dim and, when you choose them, nothing happens. This occurs when choosing a particular command doesn't make sense in your current context. For example, if you don't have a block selected in your current edit window, you won't be able to cut, copy, or clear text because you haven't told the editor what text you want cut, copied, or cleared. The Cut, Copy, and Clear commands therefore are dimmed on the Edit menu. Once you select text in your edit window, you can choose these commands.

Shortcuts

From the keyboard, you can use a number of shortcuts to access the Menu bar and choose commands. As you've already learned, you can get to, or activate, main menu items by pressing *Alt* and the highlighted letter. Once you're in a menu, you can press an item's highlighted letter or the *hot key* next to it. You can use a hot key from anywhere in the IDE—you don't have to display a menu first.

The status line also contains hot keys. Press the hot key or click the actual hot key representation on the status line to choose the associated command.

IDE windows

Most of what you see and do in the IDE happens in a *window*. A window is a screen area that you can move, resize, zoom, tile, overlap, close, and open.

You can have any number of windows open in Turbo Pascal that memory and heap space allows, but only one window can be *active* at any time. The active window is the one that you're currently working in. Any command you choose or text you type generally applies only to the active window. If you have the same file open in several windows, any action to that file happens in all windows containing that file.

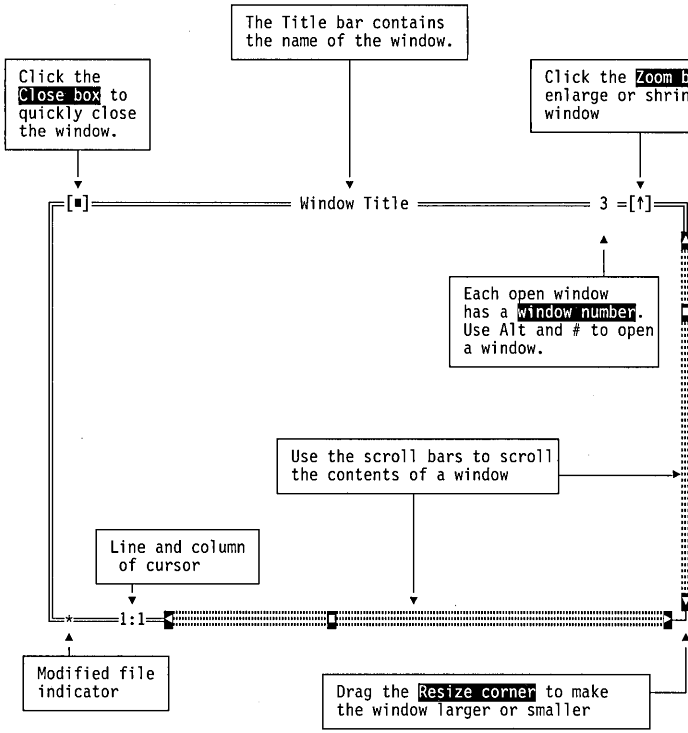
There are several types of windows, but most of them have these things in common: a Title bar, a Close box, scroll bars, a Resize corner, a Zoom box, and a window number.

Turbo Pascal makes it easy to spot the active window by placing a double-lined border partially around it. The active window always has a Close box, a Zoom box, scroll bars, and a Resize corner. If your windows are overlapping, the active window is always the one on top of all the others (the frontmost one).

The active edit window also displays the current line and column numbers in the lower-left corner. If you've modified your file since you opened it or since you last saved it, an asterisk (*) will appear to the left of the column and line numbers.

This is what a typical edit window looks like:

Figure 3.1
A typical window



The *Close box* of a window is the box in the upper-left corner. You click this box to quickly close the window. (Or choose Window | Close or press *Alt+F3*.) The Help and browser windows are considered temporary; you can close them by pressing *Esc*.

The *Title bar*, the topmost horizontal bar of a window, contains the name of the window and the window number. Double-clicking the Title bar zooms the window or restores it to its normal size it if it is already enlarged. You can also drag the Title bar to move the window around.

Turbo Pascal numbers only the first nine windows you open.

Each of the windows you open in Turbo Pascal has a *window number* in the upper-right border. *Alt+0* (zero) gives you a list of all windows you have open. You can make a window active by pressing *Alt* in combination with the window number. For example, if the Help window is #5 but has gotten buried under the other windows, *Alt+5* brings it to the front.

***Shortcut:** Double-click the Title bar of a window to zoom or restore it.*

The *Zoom box* of a window appears in the upper-right corner. If the icon in that corner is an up arrow (↑), you can click the arrow to enlarge the window to the largest size possible. If the icon is a double-headed arrow (↕), the window is already at its maximum size. In that case, clicking it returns the window to its previous size. To zoom or shrink a window from the keyboard, choose Window | Zoom, or press *F5*.

Scroll bars are horizontal or vertical bars. This is a horizontal scroll bar:

Scroll bars let you see how far into the file you've gone.

You use scroll bars with a mouse to scroll the contents of the window.

- To scroll one line at a time, click the arrow at either end.
- To scroll continuously, keep the mouse button pressed.
- To scroll one page at a time, click the shaded area to either side of the scroll box.
- To quickly move to a spot in the window relative to the position of the scroll box, drag the scroll box to any spot on the scroll bar.

The *Resize corner* is in the lower-right corner of a window. Drag the Resize corner to make the window larger or smaller. You can spot the Resize corner by its single-line border instead of the double-line border used in the rest of the window.

To resize a window using the keyboard, do this:

1. Choose Size/Move from the Window menu, or press *Ctrl+F5*.
2. Hold down the *Shift* key while you use the arrow keys to resize the window.

Window management

Table 3.1 gives you a quick rundown of how to handle windows in Turbo Pascal. Note that you don't need a mouse to perform these actions—a keyboard works just fine.

Table 3.1
Manipulating windows

To accomplish this:	Use one of these methods:
Open an edit window	Choose File | Open to open a file and display it in a window, or press *F3*.
Open other windows	Choose the desired window from the Debug or Tools menus.
Close a window	Choose Window | Close, press *Alt+F3*, or click the Close box of the window.
See the previous window	Choose Window | Previous or press *Shift+F6*.
Activate a window	Click anywhere in the window, or Press *Alt* plus the window number in the upper right border of the window), or Choose Window | List or press *Alt+0* and select the window from the list, or Choose Window | Next or *F6* to make the next window active (next in the order you first opened them). Press *Shift+F6* to make the previous window active.
Move the active window	Drag its Title bar, or press *Ctrl+F5* (Window | Size/Move) and use the arrow keys to place the window where you want it, then press *Enter*.
Resize the active window	Drag the Resize corner (or any other corner). Or choose Window | Size/Move and press *Shift* while you use the arrow keys to resize the window, then press *Enter*. The shortcut is to press *Ctrl+F5* and then use *Shift* and the arrow keys.
Zoom the active window	Click the Zoom box in the upper right corner of the window, or Double-click the window's Title bar, or Choose Window | Zoom, or press *F5*.

The status line

The status line appears at the bottom of the screen. It has four purposes:

- It reminds you of basic keystrokes and hot keys applicable at that moment in the active window.
- It presents hot key representations you can click to carry out the action instead of choosing the command from the menu or pressing the actual hot key.
- It tells you what the program is doing. For example, it displays "Saving *filename*..." when you save a file in an edit window.
- It offers one-line descriptions about any selected menu command and dialog box items.

The status line changes as you switch windows or activities. One of the most common status lines is the one you see when you're actually writing and editing programs in an edit window. Here is what it looks like:

Figure 3.2
A typical status line

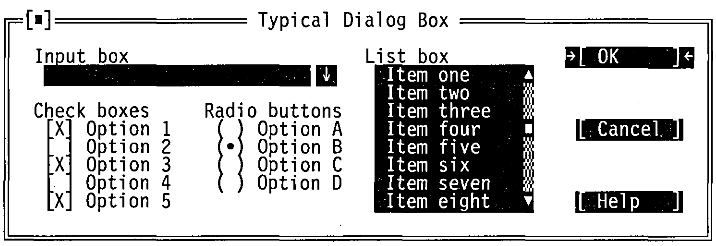
```
F1 Help   F2 Save   F3 Open   Alt+F9 Compile   F9 Make   F10 Menu
```

Dialog boxes

If a menu command has an ellipsis after it (...), the command opens a *dialog box*. A dialog box is a convenient way to view and set multiple options.

When you're selecting options in dialog boxes, you work with five basic types of onscreen controls: radio buttons, check boxes, action buttons, input boxes, and list boxes. Here's a typical dialog box that illustrates these items:

Figure 3.3
A typical dialog box



Action buttons

This dialog box has three standard action buttons: OK, Cancel, and Help.

- If you choose OK, the choices in the dialog box are made in the IDE.
- If you choose Cancel, nothing changes and no action is done, but the dialog box is put away; the same thing happens if you click the Close box. *Esc* is always a keyboard shortcut for Cancel even if no Cancel button appears.
- If you choose Help, the IDE opens a Help window about the dialog box.

If you're using a mouse, you can click the button you want. When you're using the keyboard, you can press the highlighted letter of an item to activate it. For example, pressing *K* selects the **OK** button. Press *Tab* or *Shift+Tab* to move forward or back respectively from one group to another in a dialog box, then use the ↑ and ↓ keys to select an item within the group. Each element highlights when it becomes active. When the button is selected, press *Enter* to choose it.

You can select another button with Tab. Once a button is selected, you press Enter to choose the action of the button.

In this dialog box, OK is the *default button*, which means you only need to press *Enter* to choose that button. (On monochrome systems, arrows indicate the default; on color monitors, default buttons are highlighted.) Be aware that selecting a button makes that button the default.

Check boxes and radio buttons

You can have any number of check boxes checked at any time. When you select a check box, an X appears in it to show you it's on. An empty box indicates it's off.

There are three ways to check a check box (set it to on):

- Click it or its text.
- Press *Tab* (and then the arrow keys) until the check box (or its group) is highlighted; press *Spacebar*
- Type the highlighted letter in its text

On monochrome monitors, Turbo Pascal indicates the active check box or group of check boxes by placing a chevron symbol (») next to it. When you press *Tab*, the chevron moves to the next group of check boxes or radio buttons.

Radio buttons act like the old-style station-selection buttons on a car radio. There is always one—and only one—button pushed in at a time. Push one in, and the one that was in pops out.

Radio buttons differ from check boxes in that they present mutually exclusive choices. For this reason, radio buttons *always* come in groups, and only one radio button can be on in any one group at any one time.

There are three ways to choose a radio button:

- Click it or its text.
- Type the highlighted letter in its associated text.
- Press *Tab* until the group is highlighted and then use the arrow keys to choose a particular radio button. Press *Tab* or *Shift+Tab* again to leave the group with the new radio button chosen.

Input boxes

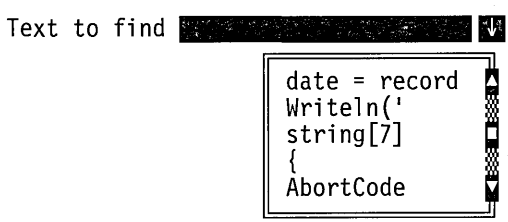
An input box is where you enter text into the application. Most basic text-editing keys such as arrow keys, *Home*, *End*, and *Ins* work in the input box. If you continue to type once you reach the end of the box, the contents automatically scroll. If there's more text than what shows in the box, arrowheads appear at the end (◂ and ▸). You can click the arrowheads to scroll the text.

If you need to enter control characters (such as ^L or ^M) in the input box, prefix the character with a ^P. For example, typing ^P^L enters a ^L into the input box. This is useful for search strings.

If an input box has a ↓ icon to its right, there is a *history list* associated with that input box. Press ↓ or click the ↓ to view the history list and *Enter* to select an item from the list. The list will display any text you typed into the box the last few times you used it. If you want to re-enter text, press ↓ or click the ↓ icon. You can also edit an entry in the history list. Press *Esc* to exit from the history list without making a selection.

Here is what a history list for the Find input box might look like if you had used it several times previously:

Figure 3.4
Example of a history list in a dialog box



List boxes A final component of many dialog boxes is a *list box*. A list box lets you scroll through and select from variable-length lists without leaving a dialog box. If a blinking cursor appears in the list box and you know what you're looking for, you can begin typing the word or the first few letters of it, and the IDE searches the list for it.

You make a list box active by clicking it or by choosing the highlighted letter of the list title. You can also press *Tab* or the arrow keys until it's highlighted. Once a list box is displayed, you can use the scroll box to move through the list or press ↑ or ↓ from the keyboard.

Now that you know the fundamentals of using the IDE, you're ready to learn how to use the IDE to develop applications. See the next chapter, "Programming in the IDE."

C H A P T E R

5

Programming in the IDE

As you develop an application in the IDE, these are the major tasks you perform:

- Starting and exiting the IDE
- Writing and editing your source code
- Working with files (opening, closing, and saving them)
- Compiling and running your program
- Debugging your program
- Browsing through your source code
- Configuring the IDE to your preferences
- Managing your programming project

This chapter will give the basics on each of these topics, with the exception of debugging your program. Read Chapter 5, "Debugging in the IDE," to learn about debugging.

Starting and exiting

Starting Turbo Pascal is simple. Go to your C:\TP\BIN directory you created with INSTALL. To start the protected-mode IDE, enter this command:

```
TPX
```

☞ The files DPMI16BI.OVL and RTM.EXE must be in your current directory or on your path, or TPX.EXE won't start.

To start the IDE that runs in real mode, enter this command:

```
TURBO
```

You can use one or more options and file names along with the command to start the IDE.

Startup options

The startup options use this syntax:

TPX [/*options*] [*files*]

or

TURBO [/*options*] [*files*]

Placing a **+** or a space after the option turns it on. Placing a **–** after it turns it off. For example,

```
TPX /G /P- myfile
```

starts up the protected-mode IDE, opens an edit window with MYFILE in it, enables graphics memory save, and disables palette swapping.

You can also use a hyphen (**-**) before the option instead of a slash (**/**). For example,

```
TPX -G -P- myfile
```

Some startup options apply only to the real-mode IDE, TURBO.EXE. You'll see the words "TURBO only" in the margin next to these. Two options apply only to the protected-mode IDE, TPX.EXE; you'll see the words "TPX only" in the margin.

The /C option

If you use the **/C** option followed by a configuration file name with no space in between, the IDE loads that configuration file when it starts. For example,

```
TURBO /Cmyconfig
```

For information about configuration files, see page 70.

The /D option

If you specify the **/D** option, Turbo Pascal can use dual monitors at the same time. The IDE checks to see if your computer has the appropriate hardware such as a monochrome card and a color card. If it doesn't, the IDE ignores this option. Dual-monitor mode is useful when debugging a program. You can see the program's output screen on one monitor and watch the debugger on the other. You can also shell to DOS (File | Shell to DOS) using two monitors so that one screen continues to display the IDE while the other gives you access to the DOS command line.

If your system has two monitors, DOS treats one monitor as the active monitor. Use the DOS MODE command to switch between the two monitors. For example, MODE CO80 makes the color monitor active and MODE MONO makes the monochrome monitor active. In dual-monitor mode, the normal Turbo Pascal screen appears on the inactive monitor and program output goes to the active monitor.

So when you type `TURBO /D` or `TPX /D` at the DOS prompt on one monitor, the IDE will come up on the other monitor. When you want to test your program on a particular monitor, exit the IDE, switch the active monitor to the one you want to test with, and then issue the `TURBO /D` or `TPX /D` command again. Program output then goes to the monitor where you typed the command.

☞ Keep the following in mind when using the **/D** option:

- Don't change the active monitor (by using the DOS MODE command, for example) while you are in a DOS shell (File | DOS Shell).
- User programs that directly access ports on the inactive monitor's video card aren't supported, and can cause unpredictable results.
- When you run or debug programs that explicitly make use of dual monitors, don't use the IDE dual-monitor option (**/D**).

The /E option

TURBO only

Use the **/E** option to change the size of the editor heap. The default size is 28K, the minimum setting; the maximum is 128K. Making the editor heap larger than 28K improves IDE performance only if you're using a slow disk as a swap device. If you have EMS or have placed your swap file on a RAM disk (see **/S** option), don't change the default setting.

The /F option

TPX only

With the **/F** option, you can specify a swap file for Turbo Pascal's run-time manager (RTM.EXE). For example, if you're compiling an application that requires 4MB of memory, but your computer only has 2MB available, you can specify a virtual memory 4MB swap file; your application will now have the memory it needs to compile. Legal sizes for the swap file are 1024K to 16384K. Use this format:

```
TPX /F2048
```

When you no longer want a virtual memory swap file, disable this option by specifying a file size of 0:

```
TPX /F0
```

The /G option

Use the **/G** option to enable a full graphics memory save while you're debugging graphics programs on EGA, VGA, and MCGA systems. With Graphics Screen Save on, the IDE will reserve another 8K for the buffer, which will be placed in EMS if it's available.

The /L option

Use the **/L** option if you're running Turbo Pascal on an LCD screen.

The /N option

Use the **/N** option to enable or disable CGA snow checking; the default setting is on. Disable this option if you're using a CGA that doesn't experience snow during screen updates. This option has no effect unless you're using a CGA.

The /O option

TURBO only

Use the **/O** option to change the IDE's overlay heap size. The default is 112K. The minimum size you can adjust this to is 64K; the maximum is 256K. If you have EMS, you can decrease the size of the overlay heap without degrading IDE performance and free more memory for compiling and debugging your programs.

The /P option

Use the **/P** option, which controls palette swapping on EGA video adapters, when your program modifies the EGA palette registers. The EGA palette will be restored each time the screen is swapped.

In general, you don't need to use this option unless your program modifies the EGA palette registers or unless your program uses BGI to change the palette.

The /R option

If the **/R** option is on and the IDE starts up, the last directory you were in the last time you exited the IDE becomes the current directory. The default setting is on. For this option to take effect, you must also choose Options | Environment | Preferences and check the Desktop Auto Save option. If you don't want the IDE to remember your last directory, turn the **/R** option off.

The /S option

If your system has no expanded memory available, use the **/S** option to specify the drive and path of a "fast" swap area, such as a RAM disk (for example, `/Sd:\`, where *d* is the drive). If no swap directory is specified, a swap file is created in the current directory.

The /T option

Disable the **/T** option if you don't want the IDE to load the Turbo Pascal run-time library, TURBO.TPL, at startup. If TURBO.TPL is not loaded, you'll need the *System* unit (SYSTEM.TPU) available before you can compile or debug programs. You can increase the IDE's capacity by disabling the **/T** option and extracting SYSTEM.TPU from TURBO.TPL using TPUMOVER; see the Help system for details about using TPUMOVER.

The /W option

TURBO only

Use the **/W** option if you want to change the window heap size. The default setting is 32K. The minimum setting is 24K; the maximum is 64K. Reduce the window heap size to make more memory available for your programs if you don't need a lot of windows open on your desktop. The default gives the IDE good capacity and ample window space.

The /X option

TURBO only

Disable the **/X** option if you don't want the IDE to use expanded memory (EMS). The default setting is on. When this option is enabled, the IDE improves performance by placing overlaid code, editor data, and other system resources in expanded memory.

The /Y option

TPX only

You can choose to have the compiler "remember" symbol information between compilations. If this option is on and you make a change to your program, but your next compilation fails, you still have the symbol information available to you from the previous compilation. Therefore, you can still browse through your program to help you determine what the problem is. The default option is on.

Setting startup options in the IDE

You can also set startup options in the IDE itself:

1. Choose Options | Environment | Startup to display the Startup Options dialog box.
2. Select your options and choose OK.

Your startup options will be in effect the next time you start up the IDE.

Exiting Turbo Pascal

There are two ways to leave Turbo Pascal:

- To exit the IDE completely, choose File | Exit. If you've made changes that you haven't saved, the IDE prompts you on whether you want to save your programs before exiting.
- To leave the IDE temporarily to enter commands at the DOS command line, choose File | DOS Shell. The IDE stays in memory but transfers you to DOS. You can enter DOS commands and even run other programs. When you're ready to return to the IDE, type `EXIT` at the command line and press *Enter*. The IDE reappears just as you left it.

Using the Help system

The Help system gives you easy access to detailed information about the Turbo Pascal language, the IDE, the run-time library, compiler directives, and so on.

If you've never used Borland language DOS Help systems before, you'll want to bring up a Help screen as you read the next sections. Choose Help | Contents and the Turbo Pascal Help Contents screen appears.

Moving around in the Help system

As you look at Help screens you're likely to notice text that appears in a different color than the surrounding text. These are *links*. Links are text that you can select to obtain additional information. You can use links to display a new Help screen that presents new information on the linked topic; choose from these methods:

- Double-click the link
- If the Help screen doesn't have buttons:

  Press *Tab* repeatedly until the link is highlighted, then press *Enter*.
- If the Help screen is actually a dialog box with buttons:

- If you're using a mouse, click the Cross-ref button.
- If you're using a keyboard, press *Enter*; this chooses the default Cross-ref button. To choose another button, press the *Tab* key until the button you want is selected, then press *Enter*.

A new Help screen appears with information on the topic you selected. You have "jumped" to a new location in the Help system. You might see more links on this screen which you can select for even more information.

To return to a previous Help screen, choose Help | Previous Topic or press *Alt+F1*.

Asking for Help

You can access Help in several ways:

- Choose Help on the Menu bar or press *Alt+H* to display the Help menu.

  From the Help menu, you can choose to see a Contents screen, an Index screen for the entire Help system, detailed information on the topic your cursor is resting on in the active edit window, or get Help on using the Help system. You can also bring up additional Help files; see page 36.
- Press *Shift+F1* to display the Turbo Pascal Help Index screen.

  The Index screen is very similar to an index in a book. Instead of turning to a page to see information about an indexed topic, however, you choose a topic by double-clicking a topic or pressing *Tab* to reach the topic and pressing *Enter*.
- Press *F1*.

  You get context-sensitive information depending on what you were doing at the time you pressed *F1*—editing, debugging, selecting menu options, and so on.

  If you were in a dialog box, you'll see a Help screen on the option you had selected at the time you pressed *F1*.
- Choose the Help button from within a dialog box.

  You get information about the dialog box and the options it contains.
- Place your cursor on a term in an edit window and choose Topic Search. Use any of these four methods:

  - Press *Ctrl+F1*.

- Choose Help | Topic Search.
- Hold down the *Ctrl* key and click your right mouse button. (You must have customized your *Ctrl*+right mouse button combination first—choose Options | Environment | Mouse and check the Topic Search option.)
- Choose Topic Search on the edit window local menu. (Press *Alt+F10* to display the local menu or click your right mouse button.)

For information about local menus, see page 43.

A Help screen appears displaying information about the term your cursor is on in the active edit window.

Copying code examples

The Help system has a code example for each procedure and function. You can copy these examples from the Help system into an edit window:

1. Display the Help screen for a procedure or function you are interested in.
2. Scroll the Help window until you see the code example in the window.
3. Press *Alt+F10* or click your right mouse button to display the Help local menu.
4. Copy the example:
   - To copy the entire sample code, choose Copy Example.
   - To copy only a portion of the sample code, select the text you want to copy and choose Copy.
5. Return to the edit window and choose Edit | Paste, press *Shift+Ins*, or choose Paste on the edit window local menu.

To learn how to select text, see page 39.

Loading other Help files

The IDE lets you merge other Help files into the Help system. For example, if you want help with Turbo Vision, you can load the Turbo Vision Help file. The IDE merges the indexes for the two Help files so you can access both the usual Help system and Turbo Vision Help from the Index screen.

To load a new Help system, follow these steps:

1. Choose Help | Files.

The Install Help Files dialog box appears.

2. Choose New.

   The Help Files dialog box appears. All the Help files in your C:\TP\BIN directory appear in the list box. If you don't see any Help files, change to the C:\TP\BIN directory.

3. Double-click the Help file you want to merge into the Help system and or select it and press *Enter.*

   The Install Help Files dialog box reappears with the Help file you chose listed in the list box.

4. Choose OK.

5. Choose Help | Index or press *Shift+F1.*

   You might see a brief message on the status line indicating the indexes are merging. When the merging is complete, you can scroll through the Index screen and see that all the topics in the selected Help files are available to you.

   The indexes remain merged throughout your current session. If you have checked the Environment Auto Save option in the Preferences dialog box (Options | Environment | Preferences), the indexes will remain merged for your next sessions, also. If you don't save your environment, the next time you start up the IDE, the Help index reverts to its original state. In other words, the indexes won't remain merged across sessions.

If no longer want to see a particular Help file's index entries on the Index screen, you can "delete" the Help file:

1. Choose Help | Files.
2. Select the Help file name you no longer want to see.
3. Choose Delete.
4. Choose OK.

Exiting Help

To close a Help window and return to your application, you can choose one of these methods:

- Press *Esc.*
- Click the Help window's Close box.
- Click outside the Help window.

If you want to redisplay your previous Help screen, press *Alt+F1.*

Writing and editing your code

You can open as many windows in the IDE as the amount of memory in your system allows.

You enter text much as if you were using a typewriter. To end a line, press *Enter*. When you've entered enough lines to fill the screen, the top line scrolls off the screen.

For a complete list of editing commands, see Appendix A, "Editor reference," in the *Programmer's Reference*.

Configuring the editor

You have several options to modify the behavior of the Turbo Pascal editor. Choose Options | Environment | Editor to display the Editor dialog box.

For information about syntax highlighting in the editor, see page 43.

To find out more about each option, select the option and choose Help or press *F1*. The Help system explains what the option does.

Changing your mind: Undo

The editor has an Undo command that makes it easy to change your mind or correct a mistake. To reverse your previous editing operation, choose Edit | Undo or press *Alt+Backspace*. If you continue to choose Undo, the editor continues to reverse actions. You can even "undo" an Undo command each time you use the Edit | Redo command.

Undo inserts any characters you deleted, deletes any characters you inserted, replaces any characters you overwrote, and moves your cursor back to a prior position. If you undo a block operation, your file appears as it did before you executed the block operation.

Undo doesn't change an option setting that affects more than one window. For example, if you use the *Ins* key to change from Insert to Overwrite mode, then choose Undo, the editor won't change back to Insert mode. But if you delete a character, switch to Overwrite mode, then select Undo, your previously deleted character reappears.

Grouping undos

The Group Undo option in the Options | Environment | Editor dialog box affects how Undo and its related command, Redo, behave. If you select the Group Undo option, the editor reverses your last *group* of commands when you press *Alt+Backspace* or choose Edit | Undo.

A group is a series of commands of the same type.

Here is an example of how the group option works. If you type `MISTAKE` and Group Undo is on, Undo deletes the entire word. If Group Undo is *not* selected and you type `MISTAKE`, Undo deletes only the last character, the letter `E`. You need to press Undo seven times to undo the word `MISTAKE` when Group Undo is off.

Insertions, deletions, overstrikes, and cursor movements are all groups. Once you change the type of command, the old group ends and a new one begins. To the editor, inserting a carriage return by pressing *Enter* is an insertion followed by a cursor movement. Because the type of editing changed (you inserted characters, then you moved your cursor), the grouping of inserted characters halts when you press *Enter.*

Redoing what you have undone

The Edit | Redo command reverses the effect of the most recent Undo command. Redo is effective immediately only after an Undo or another Redo. A series of Redo commands reverses the effects of a series of Undo commands. Just as it does with Undo, the Group Undo option also affects Redo.

Working with blocks of text

A block of text is any amount of text, from a single character to hundreds of lines, that is selected on your screen. There can be only one block in a window at a time.

Selecting a block

There are at least three ways to select a block of text:

- Drag your mouse over the text you want to select.

- Place your cursor at the beginning of the block, hold down *Shift,* and move your cursor to the end of the block with the arrow keys.
- Click at the beginning of the block, move your cursor to the end of the block using the arrow keys, then hold down *Shift* while you click your mouse again.

If you've used Borland editors in the past, you can also use the old block commands you're used to. See Appendix A, "Editor reference," in the *Programmer's Reference* for a table of Borland-style block commands.

Cutting, copying, and pasting blocks

Once selected, the block can be copied, moved, deleted, or written to a file.

- To cut selected text, press *Shift+Del* or choose Edit | Cut. The selected block is deleted from your text and placed in the Clipboard, a temporary storage location.
- To copy selected text, press *Ctrl+Ins* or choose Edit | Copy. The selected block remains in your text and a copy is placed in the Clipboard ready to paste into your active edit window.
- To paste (copy) text held in the Clipboard into the active edit window, press *Shift+Ins* or choose Edit | Paste. The block held in the Clipboard is pasted at the current cursor position.
- To clear (delete) selected text, press *Ctrl+Del* or choose Edit | Clear. The selected block is deleted from your text and a copy is not placed in the Clipboard. The only way you can recover text that has been cleared is to choose Edit | Undo.

Modifying the behavior of selected blocks

Two options affect the behavior of selected blocks in the editor: Persistent Blocks and Block Overwrite. Find them in the Options | Environment | Editor dialog box.

- If Persistent Blocks is on, selected blocks remain selected until you delete or deselect them (or until you select another block).
- If Persistent Blocks is off and you move the cursor after a block is selected, the entire block of text is deselected.
- If Block Overwrite is on and you type a letter, the selected text is replaced with the letter you typed.
- If Block Overwrite is off, and you type a letter, the letter is inserted after the selected text.
- If Block Overwrite is on *and* Persistent Blocks is off, and you press the *Del* key or the *Backspace* key the entire selected text is cleared.

If you insert text (by pressing a character or pasting from the Clipboard) the entire selected text is replaced with the inserted text.

Searching

You can use the editor to find a text string in your code. To search for a string of text in the active edit window, follow these steps:

1. Choose Search | Find. This opens the Find Text dialog box.
2. Type the string you are looking for into the Text to Find input box.
3. You can also set various search options:

See Help if you need more information about these options.

   - The Options check boxes determine if the search
     - Is case sensitive.
     - Looks for whole words only.
     - Uses regular expressions. See Appendix A in the *Programmer's Reference* for information about using regular expressions in search strings.
   - The Scope radio buttons control how much of the file you search—the whole file or only the selected text.
   - The Direction radio buttons control whether you do a forward or backward search.
   - The Origin radio buttons control where the search begins.
4. Choose OK to perform the search.
5. If you want to search for the same item again, choose Search | Search Again.

You can choose to have the word your cursor rests on in your source code appear in the Text to Find input box when you display the Find dialog box:

1. Choose Options | Environment | Editor.
2. Select the Find Text at Cursor option.
3. Choose OK.

When you display the Find dialog box, the word your cursor rests on appears in the input box. If you want to search for a phrase or group of words instead of a single word, while your cursor is in the Find Text input box, press the → key. More text appears in the input box as if the text were being "pulled" from the edit window.

Search and replace

To search for a string of text and replace it with another string, choose Search | Replace. Select options in the dialog box as you did for Search, but also include a replacement string in the New Text box.

If you want to replace all occurrences of a string in your file, choose Change All. If you check the Prompt on Replace option, the editor searches until it finds the string you indicated and asks if you want to replace it. To stop the operation, choose Cancel when the search has pauses.

If you don't check the Prompt on Replace option, all the search strings are replaced with the new text. It's a good idea to select the Whole Words Only option if you don't use the Prompt on Replace option. That way you won't risk replacing characters in a middle of a word—something you probably don't want to happen.

Delimiter pair matching

Sometimes you don't need to search for text, but for the match to a particular delimiter (a brace, parenthesis, bracket, single quotation mark, double quotation mark, or the parenthesis-asterisk combination that denotes a comment). Suppose you have a complicated expression with a number of nested expressions and you want to make sure all the parentheses are properly balanced. Here's what to do:

1. Place the cursor on the delimiter.
2. Press *Ctrl+Q[*.

The editor immediately moves the cursor to the delimiter that matches the one you selected. If it moves to a delimiter other than the one you expected, you know you have made a mistake.

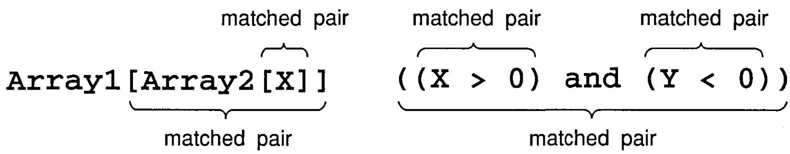
If there is no mate for the delimiter you've selected, the editor doesn't move the cursor.

There are actually two match-pair editing commands: one for forward matching (*Ctrl+Q[ ) and the other for backward matching (Ctrl+Q]).*

If you place your cursor on a single or double quote, the editor doesn't know if it should search forward or backward to find its mate. You must specify the correct match pair command for single and double quotes. It doesn't matter which match-pair command you use to search for braces, brackets, and parentheses. The editor knows which way to search for the mate.

Here is an illustrated example of pair matching:

Figure 4.1
Search for match to square bracket or parenthesis



Going to a line number

You'll notice that the editor keeps track of what line your cursor is on and displays the line number on the edit window status line. A quick way to jump to a place in your file is to use the Go to Line Number command:

1. Choose Search | Go to Line Number.
2. Type in the number of the line where you want to go.
3. Choose OK.

Using the edit window local menu

Many of the tasks you perform while you're working in an edit window are conveniently located on the edit window *local menu.* While an edit window is active, there are two ways to display the local menu:

- Press *Alt+F10.*
- Click your right mouse button.

The IDE has other local menus as well. As you read about using Help, browsing, and debugging, you'll learn where other local menus are available.

Syntax highlighting

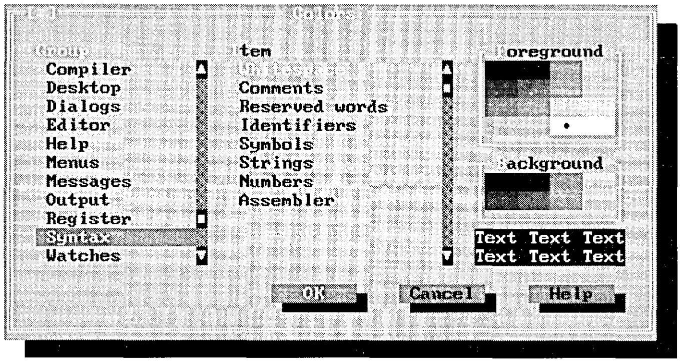
As you write or edit your Pascal program, you'll notice that some of the code appears in different colors on your screen. For example, Turbo Pascal reserved words display in white while the remainder of the text displays in yellow. This color coding makes it easier to quickly identify parts of your code.

Coloring your text

To change the color of an element, follow these steps:

1. Choose Options | Environment | Colors and the Colors dialog box appears.

Figure 4.2
Colors dialog box



The list box on the left displays all the groups of items you can color in the IDE.

2. Scroll the Group list box entries until you see the Syntax group. Select the Syntax group, and the Pascal code elements you can color appear in the Item list box.
3. Select the item you want to change in the Item list box.
4. Select the foreground and background color you want for that item.

    - To select a foreground color with your mouse, click the color you want in the Foreground color matrix. To select the color with your keyboard, press *Tab* until the Foreground color matrix is selected, then use the arrow keys to select a color.
    - To select a background color, choose the color you want in the Background color matrix.

    As soon as you make a color selection, you'll see it reflected in the sample text window.
5. Choose OK.

Selecting files to highlight

By default, only files with a .PAS or .INC extension display syntax highlighting. You might want to highlight other file types.

To change the type of files displayed with syntax highlighting:

1. Choose Options | Environment | Editor.
2. Change the text in the Highlight Extensions box.

    Any DOS file name, including one with wildcards, is valid. You can specify multiple file names; place a semicolon between each one.

Disabling syntax highlighting

If you don't want to use syntax highlighting, you can turn it off:

1. Choose Options | Environment | Editor.
2. Uncheck the Syntax Highlight option.

☞ Normal text color is changed by altering the colors for the Editor | Normal Text option in the Options | Environment | Colors dialog box. If you don't turn off syntax highlighting, changing the normal text color will have no effect.

Printing your code

When you want a printed copy of your code, choose File | Print. The IDE expands tabs (replaces tab characters with the appropriate number of spaces) and then prints your file.

Syntax highlighting printing

It's possible to print your text so that syntax elements are highlighted. Your output must go through the PRNFLTR.EXE filter program before it prints:

1. Choose File | Printer Setup.
2. If PRNFLTR.EXE isn't on your path or in your current directory, add the current path information to the PRNFLTR entry in the Filter Path input box.
3. In the Command Line input box, you can indicate either an Epson, HP LaserJet, or PostScript printer.
   - If you have an Epson printer, enter this:
     ```
     $NOSWAP /EPSON
     ```
   - If you have an HP LaserJet, enter this:
     ```
     $NOSWAP /HP
     ```
   - If you have a PostScript printer, enter this:
     ```
     $NOSWAP /PS
     ```

   If you have a different type of printer, you can modify PRNFLTR.PAS to accept the codes your printer sends it.
4. Check the Send Highlighting Escape Codes option.
5. Choose OK.
6. Choose File | Print.

If Syntax Highlight is on, your text prints with syntax elements highlighted.

Working with files

As you program in the IDE, you create new files, open existing ones, and save them. This table summarizes the basic tasks involved in file management:

Table 4.1
File operations

Operation	Description
File | New	Opens a new edit window and gives it a temporary name
File | Open	Opens an existing file or creates a new one with a name you specify
File | Save	Saves the file in the active edit window to disk
File | Save As	Saves the file in the active edit window under a different name
File | Save All	Saves all modified files

Opening files

To open a file, follow these steps:

1. Choose File | Open and the Open a File dialog box appears. You can then take any of the following actions to specify a file to open.
   - Type a full file name in the input box.
   - Type a file name with wildcards. This filters the file list to match your file specification. In the file list, select the file name you want to edit.
   - Press ↓ to display a history list of file specifications or file names you've entered earlier. Select the file name or specification you want. Selecting a file specification will display files that match that specification.
   - View the contents of other directories by double-clicking a directory name in the file list. Select the name of the file you want to edit.
2. Once the file name you want to edit is selected in the input box, choose Open or Replace. Open loads the file into a new

edit window; Replace replaces the contents of the active edit window with the selected file.

You can also just press *Enter* once the file is selected, or simply double-click the name of the file you want when you see it listed, and the file opens.

If you open one or more files and then close them, you'll see them listed at the bottom of the File menu, up to a maximum of five files. If you select one of these file names on the menu, the file opens in an edit window. When you work with many open files, you can close some, yet open them again quickly using the list and reduce clutter on your desktop.

Opening the file at the cursor

The IDE gives you a quick way to open a file whose name is in your source code. You'll find this handy when you want to look at the code of a unit or Include file your program uses.

1. Place your cursor on the name of the file you want to open.
2. Press *Ctrl+Enter* or display the local edit menu and choose Open File at Cursor.

Compiling and running

Turbo Pascal gives you several ways to create an executable program or unit. You can

- Compile the current file with (Compile | Compile)
- Compile all changed files (Compile | Make)
- Compile all files in your project (Compile | Build)
- Compile and run your program (Run | Run)

Each of these options is suitable for a particular situation. The following sections will help you decide which option you need.

Compiling

The Compile | Compile command compiles only the file in the active edit window. While Turbo Pascal is compiling, a status box pops up to display the compilation progress and results. When compiling and linking is complete, press any key to put the status box away. If an error occurred, you'll see an error message at the top of the edit window and your cursor will be positioned on the line in your code where the error occurred.

If the file you are compiling depends on a unit that isn't up-to-date, your file won't compile.

Choosing a destination

TURBO only

If you're using the real-mode IDE, you can choose to compile your program to disk or to memory with the Compile | Destination command. If you choose to compile to disk, your executable code is stored on disk as an .EXE file. Compiling to disk increases the memory available in the IDE to compile and debug your program. If you choose to compile to memory, your program is stored in memory, and, if you don't save it, is lost when you exit Turbo Pascal.

If you compile to disk, the resulting .EXE or .TPU files are stored in the same directory as the source files, or in the EXE and TPU directory (Options | Directories), if one is specified.

Making

If your program includes more than just the code in the active window—for example, it includes a primary file, one or more units, external assembly language modules, and so on—you might want to *make* your program. Make compiles all code that has been modified since it was last compiled.

The Compile | Make command creates an .EXE file or a unit (.TPU) according to the following rules:

See more about primary files on page 72.

Find out more about units in Chapter 6, "Turbo Pascal units."

- If a primary file has been specified, it is compiled; otherwise, the file in the active edit window is compiled. Turbo Pascal checks all files upon which the file being compiled depends to make sure they exist and are current.
- If the source file for a given unit has been modified since the .TPU (object code) file was created, that unit is recompiled.
- If the interface for a given unit has been changed, all other units that depend on it are recompiled.
- If a unit links in an .OBJ file (external routines), and the .OBJ file is newer than the unit's .TPU file, the unit is recompiled.
- If a unit contains an Include file and the Include file is newer than that unit's .TPU file, the unit is recompiled.

If the compiler can't locate the source code for a unit, the unit is *not* compiled and is used as is.

If you've chosen to compile to memory with the DOS real-mode IDE, any units recompiled with Make have their .TPU files updated on disk.

Building

The Compile | Build command rebuilds all the components of your program, regardless of whether they're current.

This command is similar to Compile | Make except it compiles everything, even if a file doesn't change. If you stop a Build command by pressing *Ctrl+Break* or get errors that halt the build, you can pick up where it left off by choosing Compile | Make.

If you've chosen to compile to memory with the DOS real-mode IDE, any units recompiled with Build have their .TPU files updated on disk.

Running

After you create an executable file, you'll want to try out your program with the Run | Run command. You really don't have to compile your program first and then run it, however. Run also "makes" your program if your code changed since you last compiled it, and then executes it.

Passing parameters to your program

You can pass command-line parameters to your program when you run it. Choose Run | Parameters to display a Parameters dialog box and type in the list of parameters you want your program to use.

Compiler and linker options

The IDE lets you choose from several options that affect the way your code is compiled. Choose Options | Compiler to display the Compiler Options dialog box. If you are unsure what a particular option does, select it in the dialog box and a help hint appears on the status line. Press *F1* to display in-depth information about this option or choose Help for information about the entire Compiler Options dialog box.

How your code is linked depends on the settings in the Linker Options dialog box. Choose Options | Linker to display it. Choose Help if you need more details.

For a complete discussion of compiler directives and how to use them, see Chapter 2, "Compiler directives," in the Programmer's Reference.

There is a second way to specify how your code is compiled. Instead of using dialog boxes to set options, you can insert a *compiler directive* right in your code. For example, you can turn range checking on for your program by choosing the Range Checking option in the Options | Compiler dialog box, or you can put the {**$R+**} compiler directive in your code.

☞ Compiler directives that you insert in your code take precedence over compiler options you set in the IDE. For example, if you have Range Checking turned on in the IDE, but your program includes the {**R-**} directive, your program compiles with range checking disabled.

Optimizing code

A number of compiler options influence both the size and the speed of the code. This is because they insert error-checking and error-handling code into your program. Although these type of options are good to use while you're developing your program, you can gain speed and smaller code size without them.

Here are those options with their settings for code optimization. The corresponding compiler directive follows each mention of a compiler option. Consider using these options for your final compilation:

- Word Align Data ({**$A+**}) aligns variables and type constants on word boundaries, resulting in faster memory access on 80x86 systems.
- Turning off Complete Boolean Evaluation ({**$B-**}) produces code that can run faster, depending upon how you set up your Boolean expressions.
- When Emulation is off ({**$E-**}), the compiler won't link with a run-time library that emulates an 80x87. Turbo Pascal must either use the 80x87 if it is present, or use only the standard 6-byte type *Real*.
- When 80286 Code Generation is on ({**$G+**}), the compiler uses additional instructions of the 80286 to improve code generation. Programs compiled this way cannot run on 8088 and 8086 processors.
- When I/O Checking is off ({**$I-**}), the compiler doesn't check for errors. By calling the predefined function *IOResult*, you can handle I/O errors yourself.
- When Numeric Processing is off ({**$N-**}), the compiler generates code capable of performing all floating-point operations using

the built-in 6-byte type *Real*. When the Numeric Processing is on ({**$N+**}), Turbo Pascal uses the 80x87 coprocessor or emulates the coprocessor in software routines instead, depending on whether an 80x87 is present. The resulting code will be able to use the four additional real types (*Single*, *Double*, *Extended*, and *Comp*).

- When Range Checking is off ({**$R-**}), the compiler doesn't check for array subscripting errors and assignment of out-of-range values.
- When Stack Checking is off ({**$S-**}), the compiler doesn't ensure that there is enough space on the stack for each procedure or function call.
- When Relaxed String Var Checking is on ({**$V-**}), Turbo Pascal doesn't check **var** parameters that are strings. This lets you pass actual parameter strings that are of a different length than the type defined for the formal **var** parameter.
- When Extended Syntax is on ({**$X+**}), function calls can be used as statements because the result of a function call can be discarded.

Optimizing your code using these options has two advantages. First, it usually makes your code smaller and faster. Second, it allows you to get away with something that you couldn't normally. However, they all have corresponding risks as well, so use them carefully, and turn them back on if your program starts behaving strangely.

Conditional compilation

To make your job easier, Turbo Pascal offers conditional compilation. This means that you can now decide what portions of your program to compile based on options or defined symbols.

For a complete reference to conditional directives, refer to Chapter 2, "Compiler directives," in the Programmer's Reference.

The conditional directives are similar in format to the compiler directives you're accustomed to; in other words, they take the format

```
{$directive arg}
```

where *directive* is the directive (such as **DEFINE**, **IFDEF**, and so on), and *arg* is the argument, if any. Note that there *must* be a separator (blank, tab) between *directive* and *arg*. Table 4.2 lists all the conditional directives, with their meanings.

Table 4.2
Conditional compilation directives

Directive	Description
{**$DEFINE** *symbol*}	Defines *symbol* for other directives
{**$UNDEF** *symbol*}	Removes definition of *symbol*
{**$IFDEF** *symbol*}	Compiles following code if *symbol* is defined
{**$IFNDEF** *symbol*}	Compiles following code if *symbol* is not defined
{**$IFOPT** x+}	Compiles following code if directive *x* is enabled
{**$IFOPT** x-}	Compiles following code if directive *x* is disabled
{**$ELSE**}	Compiles following code if previous **IF***xxx* is not *True*
{**$ENDIF**}	Marks end of **IF***xxx* or **ELSE** section

The DEFINE and UNDEF directives

The **IFDEF** and **IFNDEF** directives test to see if a given symbol is defined. These symbols are defined using the **DEFINE** directive and undefined **UNDEF** directives. (You can also define symbols on the command line and in the IDE.)

To define a symbol, insert this directive into your program:

```
{$DEFINE symbol}
```

symbol follows the usual rules for identifiers as far as length, characters allowed, and other specifications. For example, you might write

```
{$DEFINE debug}
```

This defines the symbol *debug* for the remainder of the module being compiled, or until this statement is encountered:

```
{$UNDEF debug}
```

As you might guess, **UNDEF** "undefines" a symbol. If the symbol isn't defined, **UNDEF** has no effect.

Defining conditional symbols in the IDE

Rather than inserting a **DEFINE** directive in your code, you can also define conditional symbols in the Conditional Defines input box (Options | Compiler). Define multiple symbols by entering them in the input box, separated by semicolons. For example,

```
TestCode;DebugCode
```

defines two conditional symbols, *TestCode* and *DebugCode*.

Predefined symbols

In addition to any symbols you define, you also can test certain symbols that Turbo Pascal has defined. Table 4.3 lists these symbols.

Table 4.3 Predefined conditional symbols

Symbol	Description
CPU86	Indicates that this version of Turbo Pascal is for the 80x86 family of processors.
CPU87	Used to indicate the presence of an 80x87 numeric coprocessor.
VER70	Indicates this is version 7.0 of Turbo Pascal.
MSDOS	Indicates this version is for the MS-DOS operating system

See Chapter 2, "Compiler directives," in the *Programmer's Reference* for more information about Turbo Pascal's predefined conditional symbols.

The IFxxx, ELSE, and ENDIF symbols

The idea behind conditional directives is that you want to select some amount of source code to be compiled if a particular symbol is (or is not) defined or if a particular option is (or is not) enabled. The general format follows:

```
{$IFxxx}
  source code
{$ENDIF}
```

where **IF***xxx* is **IFDEF**, **IFNDEF**, or **IFOPT**, followed by the appropriate argument, and *source code* is any amount of Turbo Pascal source code. If the expression in the **IF***xxx* directive is *True*, then *source code* is compiled; otherwise, it is ignored as if it had been commented out of your program.

Often you have alternate chunks of source code. If the expression is *True*, you want one chunk compiled, and if it's *False*, you want the other one compiled. Turbo Pascal lets you do this with the **$ELSE** directive:

```
{$IFxxx}
  source code A
{$ELSE}
  source code B
{$ENDIF}
```

If the expression in **IF***xxx* is *True, source code A* is compiled; otherwise *source code B* is compiled.

Note that all **IF***xxx* directives must be completed within the same source file, which means they can't start in one source file and end in another. However, an **IF***xxx* directive can encompass an Include file:

```
{$IFxxx}
{$I file1.pas}
{$ELSE}
{$I file2.pas}
{$ENDIF}
```

That way, you can select alternate include files based on some condition.

You can nest **IF***xxx*..**ENDIF** constructs so that you can have something like this:

```
{$IFxxx}                                        { First IF directive }
   :
{$IFxxx}                                       { Second IF directive }
   :
{$ENDIF}                            { Terminates second IF directive }
   :
{$ENDIF}                             { Terminates first IF directive }
```

The IFDEF and IFNDEF directives

The **IFDEF** and **IFNDEF** directives let you conditionally compile code based on whether those symbols are defined or undefined.

It is common to use the **IFDEF** and **IFNDEF** directives to insert debugging information into your compiled code. For example, if you put the following code at the start of each unit:

```
{$IFDEF debug}
{$D+,L+}
{$ELSE}
{$D-,L-}
{$ENDIF}
```

and the following directive at the start of your program:

```
{$DEFINE debug}
```

and compile your program, then complete debugging information will be generated by the compiler for use with Turbo Debugger. In a similar fashion, you can have sections of code that you want compiled only if you are debugging; in that case, you would write

```
{$IFDEF debug}
  source code
{$ENDIF}
```

where *source code* will be compiled only if *debug* is defined at that point.

The IFOPT directive

You might want to include or exclude code, depending upon which compiler options (range checking, I/O checking, and so on) have been selected. Turbo Pascal lets you do that with the **IFOPT** directive, which takes two forms:

```
{$IFOPT x+}
```

and

```
{$IFOPT x-}
```

See Chapter 2 in the Programmer's Reference, "Compiler directives," for a complete description of all compiler options.

where *x* is one of the compiler options. With the first form, the following code is compiled if the compiler option is currently enabled; with the second, the code is compiled if the option is currently disabled. So, as an example, you could have the following:

```
var
  {$IFOPT N+}
    Radius,Circ,Area: Double;
  {$ELSE}
    Radius,Circ,Area: Real;
  {$ENDIF}
```

This selects the data type for the listed variables based on whether or not 80x87 support is enabled.

Browsing through your code

TPX only

The DOS protected-mode IDE has a new programming tool, the ObjectBrowser. It lets you explore the objects and units in your programs and much more. Even if the applications you develop don't use object-oriented programming, you'll still find the ObjectBrowser an extremely valuable tool. You can browse through your object hierarchies, units, and all the procedures, functions, variables, types, constants, and other symbols your program uses. Using the ObjectBrowser, you can do these things:

- You can view the object hierarchies in your application, then select an object and view all the procedures, functions, and other symbols it contains. As you examine a symbol, you can choose to list all references to it in your program and, if you want, go directly to where it is used in your source code.

- You can list the global symbols your program uses and see their declarations. If you select one, you can list all references to it in your program and, if you want, go directly to where it is used in your source code.
- You can list all the units your program uses, then select one and list all the symbols in its interface part.
- You can select a symbol in your source code, then view its details by holding down the *Ctrl* key and clicking the right mouse button.
- You can open multiple browser windows, compare the symbols displayed in different windows, and then return to a previously opened browser window.

Before you use the ObjectBrowser, be sure to check these options in the Options | Compiler dialog box:

- Debug Information
- Local Symbols
- Symbol Information

Also make sure the Integrated Debugging/Browsing option is check in the Debugging/Browsing dialog box (Options | Debugger).

Compile the program you want to browse.

To activate the ObjectBrowser, choose Objects, Unit, or Globals on the Search menu. You can also place your cursor on a symbol in your code and choose Search | Symbol to bring up the ObjectBrowser.

☞ You can choose to have the compiler "remember" symbol information between compilations. If this option is on and you make a change to your program, but your next compilation fails, you still have the symbol information available to you from the previous compilation. Therefore, you can still browse through your program to help you determine what the problem is. To have the compiler keep symbol information between compilations:

Because Preserve Symbols is a startup option, a change to this setting won't take effect until you exit the IDE and then start it again.

1. Choose Options | Environment | Startup.
2. Check the Preserve Symbols option; this is the default setting.
3. Choose OK.

4. Choose File | Exit to exit the IDE.
5. Start the IDE again.

You can also choose Browse Symbol at Cursor from the edit window local menu to quickly browse the symbol your cursor is resting on in your code.

If you have a mouse, you'll find browsing through your code more convenient if you set up your right mouse button to activate the ObjectBrowser. Then you can hold down the *Ctrl* key while you use your right mouse button to click an object, procedure, function, variable, or other symbol in your source code and inspect it (view its details).

To set up your mouse for browsing, follow these steps:

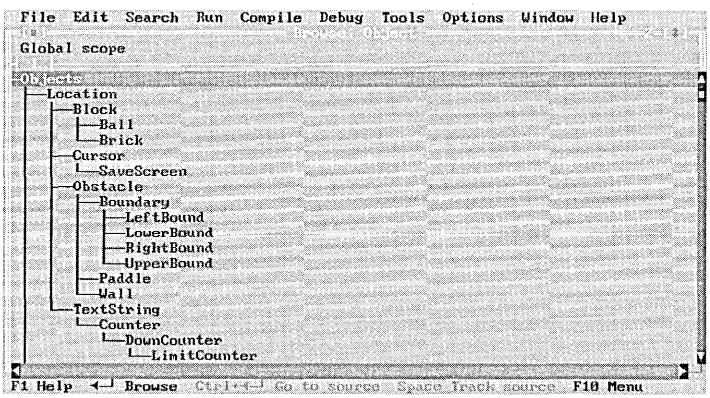
1. Choose Options | Environment | Mouse.
2. Select Browse as the Ctrl + Right Mouse Button option.
3. Choose OK.

Browsing objects

For detailed information about using object types, refer to Chapter 8, "Object-oriented programming."

Search | Objects opens a window that displays all of the objects used in your program, arranged in a hierarchical structure. At the top of the window, the ObjectBrowser shows the base type and displays descendants beneath and to the right of the base type. The connecting lines help to clarify ancestor and descendant relationships.

Figure 4.3
Viewing the object hierarchy of an application



If your object hierarchy is large, you can choose to not display the descendants of a particular object.

- Using the keyboard, do this:

  1. Select the object.

2. Press the – (minus) key.

- With a mouse, simply click the horizontal line that attaches the object to the hierarchy.

Now the object displays a + (plus sign) next to it and the text is highlighted, indicating that descendants of this object are not displayed.

You can display the descendants of the object again.

- Using the keyboard:

1. Select an object that is prefaced with a + sign.
2. Press the + key.

- With a mouse, click the horizontal line that attaches the object to the hierarchy.

The descendants of the object reappear.

From the object hierarchy, you can view all the symbols declared in a single object. Select the object and press *Enter* or double-click the object.

As you view the symbols declared in an object, you can choose to see different views:

- Click the letter `I` at the top of the ObjectBrowser window or press *Ctrl+I* to display inheritance information for the object you're browsing.
- Click the letter `R` at the top of the window or press *Ctrl+R* to display a list of the program or unit lines where the symbol is referenced.
- Click the letter `S` or press *Ctrl+S* to display the scope of the object.

To find a symbol in a list of displayed symbols, type the first letters of the symbol's name; your cursor then moves to the symbol quickly.

If the ObjectBrowser doesn't find the source file where the symbol is located, it displays a message telling you the position where the symbol is found. You might find that you need to change the path for the Include and unit directories in the Options | Directories dialog so that the Browser can find where your source files are located.

If you modify your source code by adding or deleting program lines after you have opened a browser window, it's best to recompile your program. Although the ObjectBrowser can still track symbol information after you modify the source code, the source code line numbers displayed on the edit window aren't updated unless you recompile your program.

Changing how the ObjectBrowser displays information

You have considerable control as to how the ObjectBrowser displays information.

You can choose which symbols the ObjectBrowser displays:

1. Choose Options | Browser to display the Browser Options dialog box.
2. In the Symbols group, check only the symbols you want to see displayed in the ObjectBrowser. You can also choose to see symbols inherited from an object's ancestors.
3. Choose OK.

   Only the symbols you selected can appear in the ObjectBrowser.

You can also select which symbols appear only in the current browser window. Choose Options on the browser window local menu to display the Local Browser Options dialog box or press *Ctrl+O* when a browser window is displayed.

If you select types, variables, and procedures as the type of symbols you want to see, and then browse through the Location object in the program titled BREAKOUT.PAS (a sample demonstration program in the EXAMPLES\DOS\BREAKOUT directory), you see the following symbol information displayed:

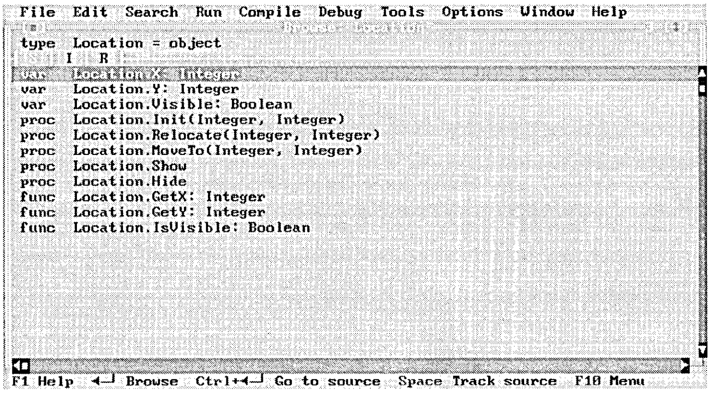


Figure 4.4
Viewing symbol information

The abbreviations to the left of the listed symbols represent the kind of symbol displayed. Note that turning the procedure symbols off also turns functions off.

Symbol	Meaning
const	Constant
func	Function
label	Label
proc	Procedure
type	Type
var	Variable or a typed constant

To display the previous browser window, choose Search | Previous Browser or press *Ctrl+P*.

When you browse a selected symbol, the ObjectBrowser window displays scope information by default. If you prefer to see reference information as the default setting:

1. Choose Options | Browser.
2. Select Reference as the Preferred Pane option.
3. Choose OK.

You won't see fully qualified identifers unless you've checked Inherited in the Browser Options dialog box (Options | Browser).

By default, the ObjectBrowser displays complete declaration information for the symbol being inspected. You can view all fields and methods of records and objects, including fully qualified identifiers. If you don't want to see the identifiers fully qualified:

1. Choose Options | Browser.

2. Uncheck the Qualified Symbols display option.
3. Choose OK.

By default, the ObjectBrowser displays identifiers in the Scope pane in the order they are declared. If you prefer that all identifiers appear in alphabetic order, do this:

1. Choose Options | Browser.
2. Check the Sort Always display option.
3. Choose OK.

   Identifiers will be sorted by name only, not by their fully qualified names. For example, this list of identifiers is considered to be in alphabetical order:

   ```
   THELPFILE.DONE
   TOBJECT.FREE
   THELPFILE.INDEX: PHELP
   ```

When you open a browser window, then browse a symbol listed in it, a new browser window opens, but the previous browser window remains. You can change this behavior so that the new browser window replaces the current one:

1. Choose Options | Browser.
2. Check the Replace Current sub-browsing option.
3. Choose OK.

To have the current browser window remain when you select a symbol listed in it to browse:

1. Choose Options | Browser.
2. Check the New Browser sub-browsing option.
3. Choose OK.

You might prefer to use either the Replace Current or New Browser options most of the time, but occasionally use the other option. You can choose the alternate option very quickly:

1. Hold down the *Shift* key.
2. Select your next browsing action.

   For example, if the New Browser option is in effect, when you hold down the *Shift* key, the next browser window you open replaces the current one.

Tracking and editing line references

When the ObjectBrowser displays reference information, you can choose to edit the program line displayed in a reference or you can track references to a symbol. Tracking means the IDE highlights one program line after another in your source code as you move through the references in the browser window.

To edit the program line displayed in a reference:

1. Select the reference in the browser window.
2. Press *Ctrl+Enter* or press *Ctrl+G.*

   Your cursor jumps to the program line in the source code referenced in the browser window. You can now edit the program line.

   The Close On Go To Source option also affects the Messages window; see page 69.

   By default, the ObjectBrowser window closes when your cursor jumps to the program line in the source code. If you prefer that the browser window remains open, uncheck the Close On Go To Source option in the Preferences dialog box.

To track program lines:

1. In the browser window, select the reference you want to track.
2. Press *Spacebar.*

   The Auto Track Source option also affects the Messages window; see page 69.

   If you always want to track your references in your source code, check Auto Track Source in the Options group of the Preferences dialog box. Then when you scroll through your references, program lines are highlighted in your source code automatically; you don't have to press *Spacebar.*

How program lines referenced in a browser window are tracked depends on how you set tracking options in the Options | Environment | Preferences dialog box: If the referenced file isn't in an edit window, the IDE opens the file and it appears either in a new edit window or in a current edit window.

Source Tracking options also affect the Messages window; see page 69.

- If you want the file to appear in a new edit window, choose New Window as the Source Tracking option.
- If you want the file to replace the current one in the active edit window, choose Current Window as the Source Tracking option.

☞ If the selected unit is stored in Turbo Pascal's run-time library or is one of the standard units, you won't be able to view or edit the source code because these units have been compiled with the symbol information off.

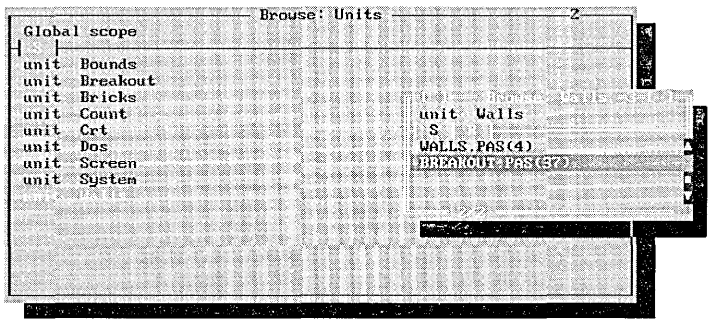
Browsing units

For detailed information about program units, refer to Chapter 6, "Turbo Pascal units."

Search | Units opens a window that displays the units used in your program, listed in alphabetical order. Select a specific unit and press *Enter* or double-click the unit to browse through the symbols declared in the interface section of the unit. Just as you can with objects, you can view scope or reference information for a symbol. As long as the referenced unit isn't one of the standard units that comes with Turbo Pascal, and it has been compiled so that it includes all the necessary integrated debugging/browsing information, you can either track or edit the source code where the unit is referenced.

In the following figure, the unit *Walls* is declared in line 4 of WALLS.PAS and is called on line 37 of BREAKOUT.PAS.

Figure 4.5
Viewing the units in your application

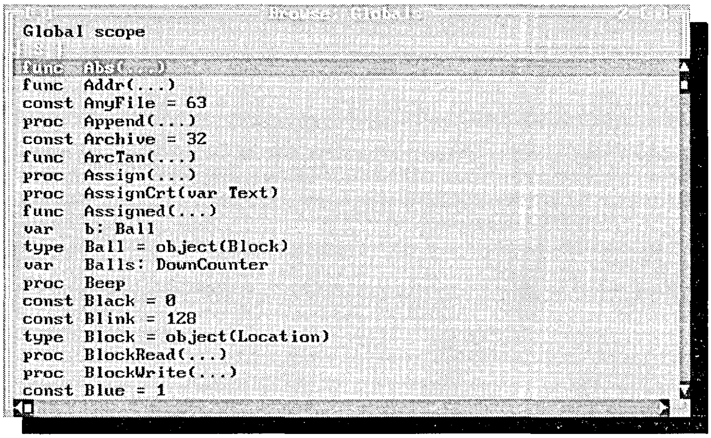


Browsing global symbols

Search | Globals opens a window that displays the global symbols used in your program, listed in alphabetical order. Just as you can with objects, you can open additional ObjectBrowser windows to view program line references to that symbol, the symbol's declarations, and, for objects, the inheritance hierarchy. When reference information is displayed, you can track or edit program lines.

For example, this figure shows a list of the global symbols used in the program BREAKOUT.PAS:

Figure 4.6
Viewing global symbols used in your program



Browsing a symbol in your source code

You can browse a symbol in your source code. Place your cursor on the symbol and choose one of these methods:

- Choose Symbol from the Search menu to display the Browse Symbol dialog box. Accept the symbol listed in the dialog box, or enter another symbol and choose OK.
- Press *Alt+F10* or click your right mouse button to display the edit window local menu, and choose Browse Symbol at Cursor.
- If you've set up your right mouse button to browse symbols (choose Options | Environment | Mouse and select Browse Symbols), hold down the *Ctrl* key and click the right mouse button.

The type of information you see displayed depends on the type of information available for the symbol you selected:

- If the symbol you selected has no scope information available, the ObjectBrowser displays reference information for the symbol. For example, only reference information is available for a simple constant.
- If the symbol you selected does have scope information available, the ObjectBrowser displays scope information for the symbol. It also gives you the option to see reference information.
- If the symbol you selected is a structured type, the ObjectBrowser displays scope information for the type. It also gives you the options to see inheritance and reference

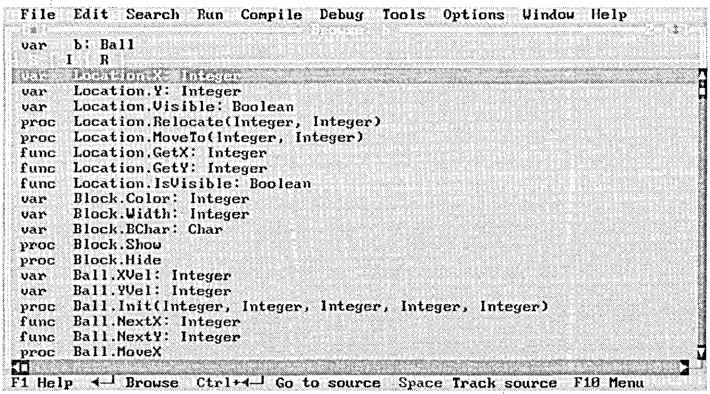
information. If you select to see the inheritance information, you'll see the immediate ancestor of the type and immediate descendants, if any.

If you have selected a structured type to browse, the ObjectBrowser displays fully qualified names if these two conditions are met:

- The Inherited symbol option is checked in the Browser Options dialog box (Options | Browser) or in the Local Browser Options dialog box (browser window local menu | Options.
- The Qualified Symbols option is checked in the Browser Options dialog box (Options | Browser) or in the Local Browser Options dialog box (browser window local menu | Options.

For example, this figure displays the full declaration scope information for the variable *b* of type *Ball*:

Figure 4.7
Viewing full declaration scope information



If the ObjectBrowser displays a message telling you a specific symbol isn't found, check to make sure that you have asked the ObjectBrowser to inspect a legitimate symbol or one within the proper scope. For example, you might have your cursor positioned on a comment when you choose Search | Symbol. Or your cursor might be positioned out of the scope in which the ObjectBrowser can find symbol information. For example, your cursor might be on a formal parameter in a function declaration, not in the function implementation. In this case, the ObjectBrowser won't find the symbol, but if you find the parameter in the function's implementation, you can browse it.

Reviewing ObjectBrowser functions

Table 4.4 lists the keys and menu commands that activate specific ObjectBrowser functions.

Table 4.4
ObjectBrowser functions

To accomplish this:	Do this:
Browse objects	Choose Search | Objects.
Browse units	Choose Search | Units.
Browse global symbols	Choose Search | Globals.
Browse Symbol	Place your cursor on the symbol in your code, choose Search | Symbol, or hold down *Ctrl* and click the right mouse button.
Select Browser Options	Choose Options | Browser.
Select Source Tracking Options	Choose Options | Environment | Preferences.
Select Mouse Options	Choose Options | Environment | Mouse.
Open a Previous browser window	Choose Search | Previous Browser, choose Previous on the browser window local menu, or press *Ctrl+P*.
Select Local Browser Options	Press *Ctrl+O* or choose Options on browser window local menu.
Go to source code	Press *Ctrl+Enter*, press *Ctrl+G*, or choose Goto Source on the browser window local menu.
Track source code	Press *Spacebar* from the ObjectBrowser, press *Ctrl+T*, or choose Track Source on the browser window local menu.
Display reference information	Press *Ctrl+R* from the ObjectBrowser or click the `R` in the window frame.
Display scope information	Press *Ctrl+S* from the ObjectBrowser or click the `S` in the window frame.
Display inheritance information	Press *Ctrl+I* from the ObjectBrowser or click the `I` in the window frame.
Reverse the current Sub-browsing setting	Hold down *Shift* while you select your next browsing action.

Running other programs from the IDE

You can run other programs and utilities without leaving the IDE. When you install the Turbo Pascal package, the IDE is set up to run such programming tools as GREP, Turbo Assembler, Turbo Debugger, and Turbo Profiler.

To run a program from the IDE:

1. Open the Tools menu.

   You'll see the list of programs and utilities you can run.
2. Choose the program you want to run from the Tools menu.

When you choose a program, you transfer control to it. After the program is through running, control is transferred back to the IDE.

Customizing the Tools menu

You can add programs you find useful to the Tools menu and then select them to run from within the IDE.

To add a program to the Tools menu:

1. Choose Options | Tools to display the Tools dialog box.

   In the Program Titles list box, you'll see brief descriptions of the programs already installed and ready to run.
2. Choose New to display the Modify/New Tool dialog box.
3. In the Program Title input box, type the name of the program as you want it to appear on the Tools menu.

   If you want your program to have a keyboard shortcut, type a tilde (~) just before and just after the character you want to be the shortcut. This character will display in bold or in a special color in the Tools menu, and when you press that key, you choose the program. For example, to add Brief to the Tools menu and to make the letter B a keyboard shortcut, type this:

   ```
   ~B~rief
   ```
4. If you want your program to have a hot key associated with it, select one of the Hot Key options. Whenever you press the assigned hot key, the program begins running. For example, hot key *Shift+F2* is assigned to the GREP utility. Any time you want to use GREP, simply press *Shift+F2*.

5. In the Program path input box, type the program name.

   If you don't enter the full path name, only programs in the current directory or programs in your regular DOS path will be found.
6. In the Command Line input box, type any parameters or macro command you want passed to the program.

   See the Turbo Pascal Help system for a complete reference to the macro commands you can use in a Modify/New Tool Command Line box.
7. Choose OK.

To edit an existing Tools menu program:

1. Choose Options | Tools.
2. Select the program you want to edit in the Program Titles list box.
3. Choose Edit.
4. Make your changes to the program title, program path, or command line.
5. Choose OK.

To remove an existing Tools menu program:

1. Choose Options | Tools.
2. Select the program you want to delete.
3. Choose Delete.
4. Choose OK.

Working with the Messages window

Some tools can send program output through a DOS filter, a program that converts the output into a format that can be displayed in the Messages window. See the Help system for more information on using and writing your own DOS filters. One such tool that uses the Messages window is GREP, and its filter is GREP2MSG.EXE. You'll find the source code, GREP2MSG.PAS in the UTILS directory.

When a tool like GREP runs, the Messages window appears and displays the output. You can scroll through the output messages. In the Messages window, you can choose to edit the program line referenced in the message or you can track your messages (highlight one program line after another in your source code as you move through your messages in the Messages window).

To edit the program line referenced in a message,

- If you're using a mouse, double-click the message you're interested in.
- If you're using a keyboard, select the message that references the program line you want to edit and press *Enter.*
- Your cursor jumps to the program line in the source code that is referenced by the message in the Messages window. You can now edit the program line.

The Close On Go To Source option also affects the ObjectBrowser; see page 62.

By default, the Messages window closes when your cursor goes to the program line in the source code. If you prefer that the Messages window remain open, uncheck the Close On Go To Source option in the Preferences dialog box.

To track program lines:

1. In the Messages window, select the message that references the program line you want to track first.
2. Press *Spacebar.*

   The Auto Track Source option also affects the ObjectBrowser; see page 62.

   If you always want to track your messages in your source code, check Auto Track Source in the Options group of the Preferences dialog box. Then when you scroll through your messages, the referenced program lines are highlighted in your source code automatically; you don't have to press *Spacebar.*

How program lines referenced by messages are tracked depends on how you set tracking options in the Options | Environment | Preferences dialog box: If the referenced file isn't in an edit window, the IDE opens the file and it appears either in a new edit window or in a current edit window.

Source Tracking options also affect the ObjectBrowser; see page 62.

- If you want the file to appear in a new edit window, choose New Window as the Source Tracking option.
- If you want the file to replace the current one in the active edit window, choose Current Window as the Source Tracking option.

If the Messages window has been closed, you can display it again with Tools | Messages.

Configuring the IDE

While writing and editing your programs, you'll probably set editing and preference options, select compiler and linker options, or resize and rearrange your edit windows to your liking. The IDE can remember the settings and files you used during a programming session and use them the next time you start a session.

Saving your working environment

You save your working environment with the Auto Save options: Editor Files, Desktop, and Environment in the Options | Environment | Preferences dialog box.

- If the Editor Files option is on, the IDE saves all modified files open in edit windows whenever you exit the IDE, choose File | Dos Shell, or run or debug a program.
- If the Desktop option is on, the IDE saves the name of the files you were working with in a desktop file whenever you exit the IDE, choose File | Dos Shell, or run or debug a program.
- If the Environment option is on, the IDE saves all editing, compiling, linking, and preference options you selected in a configuration file whenever you exit the IDE, choose File | DOS Shell, or run or debug a program.

Using the configuration file

A configuration file keeps track of all the options set with the Options menu, all the settings selected in the Find Text dialog box, all merged Help files, and the name of the primary file, if any. If the Auto Save Environment option is checked in the Options | Environment | Preferences dialog box, each time you exit the IDE, choose File | DOS Shell, or run or debug a program, the current configuration file is updated. The default configuration file name is TPX.TP if you're using TPX.EXE, and TURBO.TP if you're using TURBO.EXE.

To learn how to use a configuration file to manage a programming project, see page 72.

To create a new configuration file for a different project:

1. Choose Options | Save As.
2. Type a new name in the Options File Name input box.
3. Choose OK.

To change to another existing configuration file:

1. Choose Options | Open.
2. Specify the name of an existing configuration file.
3. Choose OK.

To modify your existing configuration:

1. Change the options you want.
2. Choose Options | Save.

   The IDE saves all your changes in the current configuration file.

Using the desktop file

If you check the Auto Save Desktop option in the Options | Environment | Preferences dialog box, the IDE updates a *desktop file* each time you exit the IDE, choose File | DOS Shell, or run or debug a program. A desktop file keeps track of the files you opened and the files you worked on but closed during a programming session (except NONAMExx.PAS files). When you start a new session, your edit windows appear just as you left them. When you open the File menu, you see a list of closed files that you opened earlier. As long as you use the same desktop file, the list of closed files on the File menu continues to grow, up to a maximum of five files.

How do you determine which desktop file to use? You can't select a new desktop file directly, but every time you create a new configuration file, the IDE creates a new desktop file. The file name is the same, except a desktop file has a .DSK extension instead of a .TP extension. For example, if your configuration file is named MY.TP, then the desktop file is MY.DSK.

By default, the IDE saves a desktop file in the same directory as the current configuration file. If you prefer, you can choose to save desktop files in the current directory:

1. Choose Options | Environment | Preferences.
2. In the Desktop File group, select Current Directory.

At times you might want to keep your current configuration settings but clear your desktop so the IDE "forgets" the list of files you have been working with, clears all history lists, and closes all windows. Do this:

1. Choose Options | Environment | Preferences.

2. In the Preferences dialog box, make sure Desktop is on and Environment is off.
3. Choose File | Exit to exit the IDE.
4. Restart the IDE.

   The IDE closes all your windows and remembers your current settings, but your desktop, history lists, and closed files list are cleared.

Preserving symbols across sessions

You can choose to save symbol reference information in a symbol file (a file with a .PSM extension) at the same time you save a desktop file. Then the next time you start the IDE, the symbol information generated during your last compilation will be available to you so that you can immediately browse and debug.

To preserve symbols across sessions:

1. Choose Options | Environment | Preferences.
2. In the Desktop File Options group, select Desktop and Symbols.
3. Check to be sure the Auto Save Desktop option is on.
4. Choose OK.

Managing a project

If you want to make your programming project modular and easier to control, use a *primary file*. Specify your main program file as the primary file and have it use several unit or Include files where you keep large chunks of your code.

To specify which file is your primary file, follow these steps:

1. Choose Compile | Primary File.
2. In the dialog box that appears, type in the name of your file or select it from the Files list box.
3. Choose OK.

Now when you use Compile | Make or Build, the primary file compiles, even if it's not the file in your active edit window.

Each project you work on in the IDE has unique requirements. For example, each project has a different primary file and different directories where your files are located. You can customize the IDE to your project.

Manage multiple projects with a configuration file for each.

The secret to project management in the IDE is to use a different configuration file for each project. When you begin a new project, create a new configuration file:

1. Set all options the way you want them to be for the new project.
2. Specify a primary file.
3. Use Options | Directories to specify the directories the compiler will look in to find your files for this project.
4. Choose Save As from the Options menu.

   A dialog box prompts you for a new configuration file name.
5. Specify a new configuration file name.
6. Choose OK.

If you exit the IDE at this point and the Desktop and Environment Auto Save options are on, the IDE will use the new configuration file the next time you start a new session. The files you were working with will be readily available to you, either in an edit window or in the closed files listing on the File menu, because a new desktop file has also been created for your project.

☞ If you keep each of your Pascal projects in separate directories, here is a tip to make managing a project more convenient. When you have set all the options as you want them to be for the project and specified a primary file, if any, do this:

1. Choose Save As from the Options menu.
2. Specify a new configuration file name including the full path the project directory.
   - If you're using TPX.EXE, specify TPX.TP as the new configuration file name.
   - If you're using TURBO.EXE, specify TURBO.TP as the new configuration file name.
3. Choose OK.

   By saving TPX.TP or TURBO.TP in the project's directory, you can go to the project directory, start the IDE, and the IDE automatically loads the configuration file in that directory.

If you no longer want a file specified as a primary file, you can use two methods to *clear* a primary file:

- Choose Compile | Clear Primary File.
- Choose Primary File and choose Clear in the Primary File dialog box.

If you want to work on a different project, you can load its configuration file with Options | Open.

C H A P T E R

5

Debugging in the IDE

The Turbo Pascal integrated development environment (IDE) includes a number of features to facilitate program development: automatic project management, program modularity, high-speed compilation, and easy-to-use overlays. But with all that, your program can still have *bugs*, or errors, that keep it from working correctly.

Turbo Pascal's IDE gives you tools for *debugging* your programs, that is, finding and removing the errors. This chapter outlines the tools and procedures for debugging your programs in the IDE, including the following topics:

- Overview of bugs and debugging
- Controlling program execution
- Watching program output
- Examining values
- Breaking into an executing program

This chapter applies to the integrated debugger in the IDE. All the tasks described also apply to Turbo Debugger, although menu names and keystrokes vary.

What is debugging?

Debugging is the process of locating and fixing program errors that prevent your programs from operating correctly. Before we delve into the specific tools in the Turbo Pascal IDE that help you in debugging, here's an overview of the kinds of bugs you might be looking for and the kinds of operations you'll be using to find them.

What kinds of bugs are there?

There are three basic kinds of program bugs: compile-time errors, run-time errors, and logic errors. If you already have a good grasp of those concepts, you can skip to the next section on debugging techniques.

Compile-time errors

Compile-time errors, or *syntax* errors, occur when your code violates a rule of Pascal syntax. Turbo Pascal can't compile your program unless the program contains valid Pascal statements. When the compiler comes to a statement it can't understand, it stops compiling, brings the offending file into an editor window, positions the cursor at the spot it doesn't understand, and displays an error message.

The command-line compiler also gives the same kind of information. When it finds a syntax error, it displays the line containing the error, with the line number and error message.

The most common causes of compile-time errors are typographical errors, omitted semicolons, references to variables that haven't been declared, passing the wrong number (or type) of parameters to a procedure or function, and assigning values of the wrong type to a variable.

After you correct the error, you can restart the compilation. Once you have eliminated all the syntax errors and your program compiles successfully, you are ready to run the program and look for run-time errors and logic errors.

Run-time errors

Run-time errors, or *semantic* errors, happen when you compile a complete program that does something illegal when you execute it. That is, the program contains legal Pascal statements, but executing the statements does something wrong. For example, your program might be trying to open a nonexistent file for input or to divide by zero.

When a Turbo Pascal program encounters such an error, it terminates and prints a message like this:

```
Run-time error ## at seg:ofs
```

If you're running the program from the IDE, Turbo Pascal automatically locates the statement that caused the error, just as it does with syntax errors. If you're running the program outside the IDE, you can start the IDE and use Search | Find Error, giving it the seg:ofs address, to locate the statement that caused the error. If you're using the command-line compiler, you can use the **/F** option to find the error.

Logic errors

Logic errors are errors in design and implementation. That is, your Pascal statements are perfectly valid and they do *something*, but what they do is not what you intended. These errors are often hard to track down, because the IDE can't find them automatically as it can with syntax and semantic errors. Fortunately the IDE includes debugging features that can help you locate logic errors.

Logic errors are to blame when variables have incorrect or unexpected values, graphic images don't look right, or code isn't executed when you expect it. The rest of this chapter discusses techniques for tracking down these logic errors.

Debugging techniques

Sometimes when a program does something you didn't expect, the reason is readily apparent, and you can quickly correct the code. But other errors are more subtle or involve interactions with different parts of the program. In these cases, it is most helpful to stop your program at a given point, walk through it step-by-step, and look at the state of variables and expressions. This controlled execution is the key to debugging.

This section briefly describes the various debugging capabilities of the Turbo Pascal IDE.

Stepping and tracing

The Step Over and Trace Into options on the Run menu give you the ability to execute your program one line at a time. The only difference between stepping and tracing is the way they deal with procedure and function calls. Stepping over a procedure or function treats the call as a simple statement, and returns control to you at the next line, after the subprogram finishes. Tracing into the routine loads the code for that routine and continues stepping through it line-by-line.

Breaking

There are two ways to tell the IDE to run your program to a certain point and then stop. The first and simplest way is to locate the position in your program where you want to stop, then choose Go to Cursor from the Run menu. Your program executes as usual until it reaches the statement where you told it to stop, at which point you can examine values and continue running either continuously or step-by-step.

The second way to stop your program at a certain point is to set a *breakpoint* where you want the program to stop. When you run the program, it stops before executing the statement at the breakpoint. Breakpoints are more flexible than using the Go to Cursor method because you can have several breakpoints throughout your program.

Watching and modifying

While you step through a program, you can watch the program output in several ways. The first is to swap screens as needed. The second is to use a second monitor. Third, you can open a window in the IDE that holds the program's output.

In addition to showing program output, the integrated debugger lets you watch the values of variables, expressions, and data structures. You can add or remove items to watch in the Watches window using the Watches command in the Debug menu.

If you want to change the value of a variable, rather than just watch it, you can bring up a dialog box using the Evaluate/Modify command on the Debug menu. In that dialog box, you can examine variables and expressions and change the values of any variables, including strings, pointers, array elements, and record fields, to test how your code reacts to different conditions.

Finding

If you need to find procedure and function declarations or object definitions in your code, you can locate them easily with the ObjectBrowser. Bring up the appropriate browser window using the Search menu and choose Objects, Globals, Units, or Symbols. See page 55 in Chapter 4, "Programming in the IDE" for more about browsing through your code.

While tracing, you can scroll back through the function calls that got you to where you are by looking at the Call Stack window

(Debug | Call Stack). This window shows each procedure and function call along with its parameters.

Generating debugging information

Before you can debug a program, you have to tell the compiler to generate some extra information so it can keep track of which lines in your source code correspond to particular parts of the executing program. This extra information is called *debugging information*. You turn it on by either checking the appropriate box in the IDE's Compiler Options (Options | Compiler) dialog box or by inserting a compiler directive into your code.

When you compile a Turbo Pascal program, the compiler always keeps a list of the identifiers used, called the *symbol table*. This list tracks all variables, constants, types, and procedure and function names. For debugging purposes, it also has to track line numbers in your source code files for all these identifiers. By checking Debug Information in the Compiler Options dialog box or by using the **$D+** compiler directive, you tell the compiler to add line-number information to the symbol table.

Integrated vs. standalone

In the Debugger Options (Options | Debugger) dialog box, you can tell the compiler whether to generate debugging information for use in the integrated debugger, for use by a standalone debugger such as Turbo Debugger, or for both. The Integrated option, which is checked by default, must be checked if you want to use the integrated debugger.

Information in units

If you're writing a large program that uses units and your debugging information gets too large, you can cut down the amount of information generated for particular units by using the **$L-** compiler directive in individual units, or by unchecking Local Symbols in the Compiler Options dialog box.

If you turn off the generation of information on a unit's local symbols, debugging information for that unit excludes all identifiers declared in the unit's implementation section. Full information is still generated for all identifiers in the interface section, so you can still debug using those.

Controlling execution

The most basic part of using the integrated debugger is controlling execution. By managing the stage when each instruction is executed, you can more easily determine which part of your program is causing a problem. The debugger provides five basic tools for controlling the execution of a program, enabling you to

- Step through instructions
- Trace into instructions
- Run to a certain spot
- Find a certain spot
- Reset the program

By itself, stepping through code might not be very helpful, except for locating a spot where things go completely awry. But controlled execution gives you a chance to examine the state of the program and its data, such as watching output and variables, as described elsewhere in this chapter.

What is a step?

When you debug a program, the smallest unit of execution is the *line*. That means you can control the rate of debugging to the level of a single line of source code. So, if you string several Pascal statements together on one line, you can't debug those statements individually. On the other hand, you can spread a statement out over multiple lines for debugging purposes, and it will still execute as a single step.

All execution in the debugger, including stepping, tracing, and breaking, is based on lines. The integrated debugger always tells you which line it will execute next by highlighting it with an *execution bar*. The execution bar is a different color than your normal text so you can easily see where you're going.

Stepping through code

Stepping is the simplest way to move through your code a little bit at a time. Choosing Run | Step Over or pressing *F8* causes the debugger to execute all the code in the statement indicated by the execution bar, including any procedures or functions it might call, before returning control to you. The execution bar then indicates the next complete statement.

For example, take the simple program shown in Listing 5.1:

Listing 5.1
A simple program to step through

```
program StepTest;

  function Negate(X: Integer): Integer;
  begin
    Negate := -X;
  end;

var
  I: Integer;

begin
  for I := 1 to 10 do Writeln(Negate(I));
end.
```

If you bring up *StepTest* in the edit window and press *F8*, the execution bar moves to the **begin** at the start of the main loop, because that's the first thing to be executed in the program. Pressing *F8* a second time executes **begin** and moves the execution bar down to the **for** statement on the next line. Pressing *F8* now causes the entire **for** loop to execute; the numbers –1 to –10 are printed on the user screen, and the execution bar moves to **end**. Pressing *F8* a final time executes **end**, terminating the program.

Although the function *Negate* is called 10 times, the execution bar never moves through it. Stepping tells the debugger not to show the details of any calls made by a single line. Of course, stepping executed the entire **for** loop at once, so you couldn't see changes as the loop progressed. If you want to see the details of a loop, make this simple change to the main loop of the program in Listing 5.1:

Listing 5.2
Code reformatted for better stepping

```
begin
  for I := 1 to 10 do
    Writeln(Negate(I));
end.
```

Because Pascal statements can span more than one line, this program is exactly equivalent to the earlier version, and the code generated is identical. But because the *Writeln* statement now has its own line, the debugger can treat it separately. Now if you press *F8* repeatedly, you'll find that the execution bar returns to the *Writeln* statement 10 times, once for each time through the loop.

Tracing into code

Tracing into code is very much like stepping through code, with the sole exception that when you come to a statement that calls a procedure or function, tracing into the code steps through the procedures or functions, but stepping returns control to you *after* those subprograms finish.

For example, trace through the code in Listing 5.1: Load the file, then choose Run | Trace Into or press *F7*. The first time you do this, the execution bar moves to **begin** in the main program. Pressing *F7* again moves the bar to the **for** statement. Pressing *F7* now traces into the call to the *Negate* function—the execution bar moves to the **begin** statement in the function block. If you continue to press *F7*, the execution bar steps through the function, then when you execute **end**, returns to the calling statement.

The format of your code affects the behavior of the execution bar when tracing, although not to the degree it does when stepping. With the code formatted as in Listing 5.1, tracing into the **for** statement follows the execution of the *Negate* function 10 times. If you break the **for** statement into two lines, as in Listing 5.2, tracing the **end** of the function returns the execution bar to the line in the main program that will execute next. The first nine times, that's the function call again. The tenth time, the execution bar moves to the program's **end**.

Stepping vs. tracing

Stepping and tracing perform exactly the same action, except when a call occurs to a procedure or function in the line under the execution bar, or when you execute **begin** at the beginning of a program or unit that uses other units.

Units and their initialization sections are explained in Chapter 6, "Turbo Pascal units."

Executing **begin** in a program's main **begin..end** block calls the initialization code for any units used by the program, in the order they appear in the program's **uses** clause. In the same way, executing **begin** at the start of a unit's initialization section calls the initialization code for any other units used by that unit. Stepping and tracing work in these cases as you might expect—stepping over **begin** executes all the initializations, returning control at the next statement only after all have finished; tracing traces into the units' initialization code.

Stepping and tracing object methods

If you use objects in your programs, the debugger treats their methods exactly as it would treat ordinary procedures and functions. Stepping over a method call treats the method as a single step, returning control to the debugger after the method completes running. Tracing into a method loads and displays the method's code and traces through its statements.

Stepping and tracing external code

If you link external code into your program using the {**$L** file name} compiler directive, you can step over or trace into that code if the .OBJ file you link in contains debugging information. Turbo Pascal won't know anything about the code you're debugging in these modules, but it will show you the appropriate lines in the source code.

The requirements for external code are explained in Chapter 23 of the Language Guide.

You can debug external code written in any language, including C, C++, and assembly language. As long as the code meets all the requirements for external linking and contains full standard debugging information, the IDE's debugger can step or trace through it.

Taking big steps

Sometimes, of course, you don't want to step through *all* your code, just to get to some part that's causing problems. Fortunately, the debugger gives you the ability to step over large amounts of code and regain control at the point where you want to start stepping slowly.

Use Run | Go To Cursor (or the *F4* key) to specify a spot in your program where you want to run, and then stop. (You're telling the debugger you don't want to go step-by-step until you get to a certain point.) Position the cursor at the line where you want to resume debugging control, then press *F4*. Note that you can do this either as a way to start your debugging session or after you've already been stepping and tracing.

Finding a certain spot

The IDE provides two ways to locate a certain spot in your code. The simplest is the Find Procedure command on the Search menu. Find Procedure asks you for the name of a procedure or function, then finds the proper line in the file where that routine is defined. This approach is useful in general editing, of course, but you can also combine it with the ability to run to a certain spot to execute up to the section of code you want to debug.

Navigating backward

Sometimes in the middle of debugging, it's helpful to know how you got where you are. The Call Stack window shows you the sequence of procedure and function calls that brought you to your current state, up to 128 levels deep. Use Debug | Call Stack to bring up the Call Stack window.

The Call Stack window is particularly useful if you accidentally traced into code you wanted to step over. You can move up the call stack to the call you started tracing into by mistake, then choose Run to Cursor to step over the rest of the call.

Starting over

In the middle of a debugging session, you might want to start over from the beginning. Choose the Run | Reset Program command or press *Ctrl+F2*. This resets all debugging, so running, stepping, or tracing begins at the start of the main program.

Watching program output

When stepping or tracing through your program, it's often helpful to be able to look at the program's output, called the *user screen*. Turbo Pascal has several ways you can look at your program's user screen.

Swapping screens

At any time during a debugging session, you can move back and forth between the IDE's display and the user screen. To display the user screen, press *Alt+F5*. To return to the IDE, press any key or click the mouse.

The debugger can also swap screens automatically while you step through a program. You can control when swapping takes place using the Display Swapping options in the Debugger dialog box. The default setting is for *smart* swapping, meaning that the user screen is shown only if the executed statement performs screen output or calls a procedure (even if the procedure performs no output). As soon as the output finishes, the screen swaps back to the IDE.

You can also tell the debugger to swap screens for every line, regardless of output, or to not swap screens at all. Swapping screens for every line is useful if your program sends output directly to the screen, which could overwrite the IDE.

The Output window

The IDE provides a window onto the user screen, called the *Output window*. By choosing the Debug | Output menu command, you open (or bring to the front) an active window containing your program's output. You can move or resize this window just as you would an edit window.

Dual monitors

The IDE gives you the option of using a second monitor for debugging purposes. The monitor must be a monochrome display (because it uses different memory than a color display), and you need to start the IDE with the **/D** command-line option. In dual-monitor mode, the IDE's screen displays on the monochrome screen, your program's output displays on the color screen, and no screen swapping occurs.

Examining values

Stepping and tracing through your code can help you find problems in program flow, but you'll usually want to watch what happens to the values of variables while you step. For example, as you step through a **for** loop, it's helpful to know the value of the index variable. The Turbo Pascal IDE has two tools to help you examine the contents of your program's variables: the Watches window and the Evaluate and Modify dialog box.

What's an expression?

Both watching and evaluating operate at the level of *expressions*, so it's important to define just what we mean by expression. An expression consists of constants, variables, and data structures combined with operators and most built-in functions. Almost anything you can use as the right side of an assignment statement can be used as a debugging expression. The exact specifications are shown in Table 5.1.

Table 5.1
Elements of debugger expressions

Expression element	Acceptable values
Constants	All normal types: *Boolean, Byte, Char,* enumerated, *Integer, Longint, Real, Shortint,* string, and *Word.*
Variables	All types, including user-defined
integer-type	Any integer expression within the variable's range bounds
floating-point	Any floating-point or integer expression within the variable's exponent range; excess significant digits are dropped
Char	Any character expression, including printable characters in single quotes, integer expressions typecast to *Char,* and ASCII constants (#*xx*)
Boolean	*True, False,* or any Boolean expression
enumerated	Any compatible enumerated constant or in-range integer expressions typecast to a compatible enumerated type
Pointer	Any compatible pointer or typecast expression; the function *Ptr* with appropriate parameters
string	Any string constant (text in single quotes); string variables; string expressions consisting of concatenated string constants and variables
set	Any set constant; any compatible set expression using set operators +, –, and *
Typecasts	Following standard Pascal rules
Operators	All Turbo Pascal operators
Built-in functions	All functions legal in constant declarations
Arrays	Turbo Pascal arrays *Mem, MemL,* and *MemW*

Watching expressions

If you want to keep track of the value of a variable or expression while you step through your code, you can open a *Watches window.* This IDE window shows variables and their values at any given time.

To open the Watches window, choose Window | Watch. The IDE opens an active Watches window with no active entries. If you choose a variable to watch, the IDE automatically opens a Watches window if you haven't already done so.

Adding a watch

To add a variable to the Watches window, you choose Debug | Watch | Add Watch or press *Ctrl+F7*. If the Watches window is the active window, you can add a watch by pressing *Ins*. The debugger opens a dialog box, prompting you to type in a watch expression. The default expression is the word at the cursor in the current edit window. A history list keeps track of expressions you've watched before.

Tracking the current watch

The watch expression most recently added or modified is the *current* watch expression, indicated by a bullet in the left margin. If the Watches window is active, the current watch expression is affected by keystrokes.

Deleting a watch

To delete the current watch expression, choose Debug | Watch | Delete Watch. If the Watches window is active, you can also delete the current watch expression by pressing *Del* or *Ctrl+Y*. To remove all watch expressions, choose Debug | Watch | Remove All Watches.

Editing a watch

To edit a watch expression, either double-click the expression you want to edit or make that expression the current one, then press *Enter* or choose Debug | Watch | Edit Watch. The debugger opens a dialog box much like the one for adding a watch expression, allowing you to edit the current expression. When you click OK or press *Enter*, the edited expression replaces the original.

Formatting watch expressions

The Watches window enables you to format your watch expressions a number of ways by adding a comma and one or more format specifiers. For example, although integer values normally display in decimal form, you can specify that an expression be displayed as hexadecimal by putting **,H** after it. Table 5.2 shows all the legal format specifiers and their effects.

Table 5.2
Format specifiers for debugger expressions

Character	Types affected	Function
$, H, or X	integers	**Hexadecimal**. Shows integer values in hexadecimal with the $ prefix, including those in data structures.
C	*Char*, strings	**Character**. Shows special display characters for ASCII 0..31. By default, such characters show as #*xx* values.

Table 5.2: Format specifiers for debugger expressions (continued)

D	integers	**Decimal**. Shows integer values in decimal form, including those in data structures.
F*n*	floating point	**Floating point**. Shows *n* significant digits (where *n* is in the range 2..18, and 11 is the default).
*n*M	all	**Memory dump**. Shows *n* bytes starting at the address of the indicated expression. If *n* is not specified, it defaults to the size in bytes of the type of the variable. By default, each byte shows as two hex digits. The $, C, D, H, S, and X specifiers can be used with M to change the byte formatting.
P	pointers	**Pointer**. Shows pointers as *seg:ofs* instead of the default *Ptr(seg:ofs)*.
R	records, objects	**Record**. Shows field names such as (*X*:1;*Y*:10;*Z*:5) instead of (1,10,5).
S	*Char*, strings	**String**. Shows ASCII 0..31 as #*xx*. Use only to modify memory dumps (see nM above).

Evaluating and modifying

In addition to watching variables as your program executes, the debugger has a facility to let you evaluate expressions at any given moment and change the values of variables at run time.

Evaluating expressions

To evaluate an expression, choose Debug | Evaluate/Modify or press *Ctrl+F4*. The debugger displays an Evaluate and Modify dialog box. By default, the word at the cursor position in the current edit window displays highlighted in the Expression field. You can edit that expression, type in another, or choose one from the history list of expressions you evaluated previously.

The current value of the expression in the Expression field shows in the Result field when you press *Enter* or click Evaluate.

The rules for legal expressions are the same for evaluating as they are for watching; all of the rules shown in Table 5.1 apply. The format specifiers in Table 5.2 also work for specifying the display format for evaluated expression results.

Modifying variables

You can change the value of a variable while debugging by using the Evaluate and Modify dialog box. Enter the variable in the Expression field, then type the new value in the New Value field.

Keep these points in mind when you change the values of variables:

- You can only change individual variables, or elements of arrays or records that are not themselves arrays or records.
- Expressions in the New Value field must meet the restrictions for expressions listed in Table 5.1.
- The expression in the New Value field must evaluate to a result that is assignment-compatible with the variable you want to assign it to. A good rule of thumb is that if the assignment would cause a compile-time or run-time error, it is not a legal modification value.
- You can't directly modify untyped parameters passed into a procedure or function, but you can typecast them and then assign new values.
- Modifying values, and especially pointer values and array indexes, can have undesirable effects and cause you to overwrite other variables and data structures. Be careful.

Using breakpoints

Turbo Pascal gives you the ability to set *breakpoints* in your code for debugging purposes. A breakpoint is a designated position in the code where you want the program to stop executing and return control to the debugger. In a sense, a breakpoint works much like the Go to Cursor command, in that the program runs at full speed until it reaches a certain point. The main differences are that you can have multiple breakpoints and breakpoints that don't break all the time.

Setting breakpoints

To set a breakpoint in your code, move the cursor to the line where you want to break. The line needs to contain executable code — it can't be a comment, a blank, or a declaration. Choosing Toggle Breakpoint on the edit window local menu or pressing

Ctrl+F8 sets the line as a breakpoint, which is indicated by highlighting the entire line.

Breakpoints only exist during your debugging session; they aren't saved in your .EXE file.

Now when you run your program from the IDE it will stop whenever it reaches that line, but *before* it executes the line. The line containing the breakpoint shows in the edit window, with the execution bar on it. At that point, you can do any other debugging actions such as stepping, tracing, watching, and evaluating.

Clearing breakpoints

To clear a breakpoint, move the cursor to the line containing the breakpoint and choose Toggle Breakpoint from the edit window local menu or press *Ctrl+F8*.

Modifying breakpoints

The IDE keeps track of all your breakpoints during a debugging session. Rather than making you chase through your source code files looking for your breakpoints, it enables you to maintain all your breakpoints from a single dialog box. Choose View | Breakpoints to bring up the Breakpoints dialog box. From this dialog box, you can set, remove, edit, and view your breakpoints.

The buttons in the Breakpoints dialog box work as follows:

- To add a new breakpoint, highlight a blank line in the list and choose Edit.
- To clear a breakpoint, highlight it and choose Delete.
- To modify an existing breakpoint, highlight it and choose Edit.
- To find a breakpoint in your code, highlight it and choose View.
- To remove all breakpoints, choose Clear All.

Making conditional breakpoints

The breakpoints added by Toggle Breakpoint are unconditional: any time you get to that line, the debugger stops. When you're editing a new or existing breakpoint, however, you have two extra options in the Edit Breakpoint dialog box that let you create *conditional* breakpoints. You can put two kinds of conditions on breakpoints: *pass counts* and *Boolean conditions*.

Counting passes

Setting a pass count on a breakpoint tells the debugger not to break every time it reaches that point, but instead only to break the *n*th time. That is, if the pass count is 3, the debugger only breaks the third time it reaches that line.

Testing conditions

You can also enter a Boolean expression as a condition for a breakpoint. For example, you might test if a variable falls in a certain range, or if some flag has been set. You can condition your breakpoints to any Boolean expression that follows the guidelines in Table 5.1.

Breaking without breakpoints

Even if you don't set breakpoints, you can still "break" into the debugger when you run your program from the IDE. At any time when your program is running, press *Ctrl+Break*, and the debugger locates the position in the source code where you interrupted the program. As with a breakpoint, you can then step, trace, watch, or evaluate.

C H A P T E R

6

Turbo Pascal units

This chapter explains what a unit is, how you use it, what predefined units are available, how to go about writing your own units, and how to compile them.

What is a unit?

Turbo Pascal gives you access to a large number of predefined constants, data types, variables, procedures, and functions. Because they are numerous and you seldom use them all in a given program, they are split into related groups called *units*. You can then use only the units your program needs.

A unit is a library of declarations you can pull into your program that allows your program to be split up and separately compiled. It is a collection of constants, data types, variables, procedures, and functions. Each unit is almost like a separate Pascal program—it can have a main body that is called before your program starts and does whatever initialization is necessary.

All the declarations within a unit are usually related to one another. For example, the *Strings* unit contains all the declarations for null-terminated string-handling routines.

Turbo Pascal provides standard units for your use: *System*, *Crt*, *Dos*, *Printer*, *Graph*, and *Overlay*. They provide support for your Turbo Pascal programs and are all stored in TURBO.TPL, the run-time library. Your program can use any of the procedures or functions in these units; you don't have to write them from scratch yourself. Although not in TURBO.TPL, the *Strings*, *WinDos*, *Graph3*, and *Turbo3* units are provided separately and your programs can use these units also.

A unit's structure

A unit's structure is not unlike that of a program, but there are some significant differences.

```
unit <identifier>;
interface
uses <list of units>;    { Optional }
  { public declarations }
implementation
uses <list of units>;    { Optional }
  { private declarations }
  { implementation of procedures and functions }
begin
  { initialization code }
end.
```

The unit header starts with the reserved word **unit**, followed by the unit's name (an identifier), much the way a program begins. The next item in a unit is the keyword **interface**. This signals the start of the interface section of the unit—the section visible to any other units or programs that use this unit.

A unit can use other units by specifying them in a **uses** clause. The **uses** clause can appear in two places. First, it can appear immediately after the keyword **interface**. In this case, any constants or data types declared in the interfaces of those units can be used in any of the declarations in this unit's interface section.

Second, it can appear immediately after the keyword **implementation**. In this case, any declarations from those units can be used only within the implementation section.

Interface section

The interface portion—the "public" part—of a unit starts at the reserved word **interface**, which appears after the unit header and ends when the reserved word **implementation** is encountered. The interface determines what is "visible" to any program (or other unit) using that unit; any program using the unit has access to these "visible" items.

In the unit interface, you can declare constants, data types, variables, procedures, and functions. As with a program, these sections can be arranged in any order, and they can repeat themselves. For example, your program might have a **var** section followed by a **const** section, and then have another **var** section.

The procedures and functions visible to any program using the unit are declared here, but their actual bodies—their implementations—are found in the implementation section. You won't need to use **forward** declarations and they aren't allowed. The interface section lists all the procedure and function headers; the implementation section contains the coded logic of the procedures and functions.

The bodies of all the regular procedures and functions are held in the implementation section after all the procedure and function headers have been listed in the interface section.

A **uses** clause may appear in the interface section. If present, **uses** must immediately follow the keyword **interface**.

Implementation section

The implementation section—the "private" part—starts at the reserved word **implementation**. Everything declared in the interface portion is visible in the implementation: constants, types, variables, procedures, and functions. Furthermore, the implementation can have additional declarations of its own, although these are not visible to any programs using the unit. The program doesn't know they exist and can't reference or call them. However, these hidden items can be (and usually are) used by the "visible" procedures and functions—those routines whose headers appear in the interface section.

A **uses** clause may appear in the implementation. If present, **uses** must immediately follow the keyword implementation.

The normal procedures and functions declared in the interface—those that are not inline—must reappear in the implementation. The **procedure/function** header that appears in the implementation should either be identical to that which appears in the interface or should be in the short form. For the short form, type in the keyword (**procedure** or **function**), followed by the routine's name (identifier). The routine will then contain all its local declarations (labels, constants, types, variables, and nested procedures and functions), followed by the main body of the routine itself. Say the following declarations appear in the interface of your unit:

```
procedure ISwap(var V1,V2: Integer);
function IMax(V1,V2: Integer): Integer;
```

The implementation could look like this:

```
procedure ISwap;
var
  Temp: Integer;
begin
  Temp := V1; V1 := V2; V2 := Temp;
end; { of proc ISwap }
function IMax(V1, V2: Integer): Integer;
begin
  if V1 > V2 then IMax := V1
  else IMax := V2;
end; { of func IMax }
```

Routines local to the implementation (that is, not declared in the interface section) must have their complete **procedure/function** header intact.

Initialization section

The entire implementation portion of the unit is normally bracketed within the reserved words **implementation** and **end**. If you put the reserved word **begin** before **end** with statements between the two, however, the resulting compound statement, which looks very much like the main body of a program, becomes the **initialization** section of the unit.

Use the initialization section to initialize any data structures (variables) that the unit uses or makes available through the interface section to the program using it. You can use it to open files for the program to use later.

When a program using that unit is executed, the unit's initialization section is called before the program's main body is run. If the program uses more than one unit, each unit's initialization section is called before the program's main body is executed.

How are units used?

The units your program uses are separately compiled and stored as machine code, not Pascal source code; they are not Include files. Even the interface section is stored in the special binary symbol table format that Turbo Pascal uses. Also, certain standard units are stored in a special file (TURBO.TPL, the run-time library) and are automatically loaded into memory along with Turbo Pascal itself.

As a result, using a unit or several units usually adds less than a second to the length of your program's compilation.

As stated earlier, to use a specific unit or collection of units, you must place a **uses** clause at the start of your program, followed by a list of the unit names you want to use, separated by commas:

```
program MyProg;
uses thisUnit, thatUnit, theOtherUnit;
```

When the compiler sees this **uses** clause, it adds the interface information in each unit to the symbol table and links the machine code that is the implementation to the program itself.

The ordering of units in the **uses** clause is not important. If *thisUnit* uses *thatUnit* or vice versa, you can declare them in either order, and the compiler determines which unit must be linked into *MyProg* first. In fact, if *thisUnit* uses *thatUnit* but *MyProg* doesn't need to directly call any of the routines in *thatUnit*, you can "hide" the routines in *thatUnit* by omitting it from the **uses** clause:

```
unit thisUnit;
uses thatUnit;
   ⋮
program MyProg;
uses thisUnit, theOtherUnit;
   ⋮
```

In this example, *thisUnit* can call any of the routines in *thatUnit*, and *MyProg* can call any of the routines in *thisUnit* or *theOtherUnit*. *MyProg* can't call any of the routines in *thatUnit*, because *thatUnit* doesn't appear in *MyProg*'s **uses** clause.

If you don't put a **uses** clause in your program, Turbo Pascal links in the *System* standard unit anyway. This unit provides some of the standard Pascal routines as well as a number of Turbo Pascal-specific routines.

Referencing unit declarations

Once you include a unit in your program, all the constants, data types, variables, procedures, and functions declared in that unit's interface become available to you. For example, suppose the following unit existed:

```
unit MyStuff;
interface
const
  MyValue  = 915;
type
  MyStars  = (Deneb, Antares, Betelgeuse);
var
  MyWord: string[20];
procedure SetMyWord(Star: MyStars);
function  TheAnswer: Integer;
implementation
    :
end.
```

What you see here is the unit's interface, the portion that is visible to and used by your program. Given this, you might write the following program:

```
program TestStuff;
uses MyStuff;
var
  I: Integer;
  AStar: MyStars;
begin
  Writeln(MyValue);
  AStar := Deneb;
  SetMyWord(AStar);
  Writeln(MyWord);
  I := TheAnswer;
  Writeln(I);
end.
```

Now that you have included the **uses** *MyStuff* statement in your program, you can refer to all the identifiers declared in the interface section of *MyStuff* (*MyWord*, *MyValue*, and so on). But consider the following situation:

```
program TestStuff;
uses MyStuff;
const
  MyValue = 22;
var
  I: Integer;
  AStar: MyStars;

function TheAnswer: Integer;
begin
  TheAnswer := -1;
end;

begin
  Writeln(MyValue);
  AStar := Deneb;
  SetMyWord(AStar);
  Writeln(MyWord);
  I := TheAnswer;
  Writeln(I);
end.
```

This program redefines some of the identifiers declared in *MyStuff*. It compiles and runs, but uses its own definitions for *MyValue* and *TheAnswer*, because those were declared more recently than the ones in *MyStuff*.

You can still continue to refer to the identifiers in *MyStuff* by prefacing each one with the identifier *MyStuff* and a period (.). For example, here's yet another version of the earlier program:

```
program TestStuff;
uses MyStuff;
const
  MyValue = 22;
var
  I: Integer;
  AStar: MyStars;

function TheAnswer: Integer;
begin
  TheAnswer := -1;
end;

begin
  Writeln(MyStuff.MyValue);
  AStar := Deneb;
  SetMyWord(AStar);
  Writeln(MyWord);
```

```
  I := MyStuff.TheAnswer;
  Writeln(I);
end.
```

This program gives you the same answers as the first one, even though you've redefined *MyValue* and *TheAnswer*. Indeed, it would have been perfectly legal, although rather wordy, to write the first program as follows:

```
program TestStuff;
uses MyStuff;
var
  I: Integer;
  AStar: MyStuff.MyStars;
begin
  Writeln(MyStuff.MyValue);
  AStar := MyStuff.Deneb;
  MyStuff.SetMyWord(AStar);
  Writeln(MyStuff.MyWord);
  I := MyStuff.TheAnswer;
  Writeln(I);
end.
```

Note that you can preface any identifier—constant, data type, variable, or subprogram—with the unit name.

Implementation section uses clause

Turbo Pascal allows you to place an optional **uses** clause in a unit's implementation section. If it's present, the **uses** clause must immediately follow the **implementation** keyword, just like a **uses** clause in the interface section must immediately follow the **interface** keyword.

A **uses** clause in the implementation section allows you to further hide the inner details of a unit, because units used in the implementation section aren't visible to users of the unit. It also enables you to construct mutually dependent units.

Because units in Turbo Pascal don't need to be strictly hierarchical, you can make circular unit references. To learn more about circular unit references, see Chapter 10 in the *Language Guide*.

The standard units

See Chapter 11 in the Language Guide for information about each unit in the run-time library.

The units in Turbo Pascal's run-time libraries are loaded into memory with Borland Pascal; they're always readily available to you. Usually you'll keep the file TURBO.TPL in the same directory as TPX.EXE, TURBO.EXE, or TPC.EXE.

Writing your own units

If you want to write a unit that has some useful routines and you want to use these routines in your programs, write the unit and save it with the name you specified in the unit header. Turbo Pascal saves the file with a .PAS extension just as it does any file created in the Turbo Pascal editor. You can have only one unit in a source file.

Compiling your unit

You have two options for compiling your unit. You may

- Compile the unit with Compile | Compile. Instead of creating an .EXE file, Turbo Pascal creates a .TPU, a Turbo Pascal unit file. For example, if your unit was named MYUNIT.PAS, it will compile to MYUNIT.TPU.
- Compile the unit when you compile a program that includes the unit with the **uses** clause with Compile | Make or Compile | Build. Turbo Pascal creates a .TPU file.

See the next section to learn how to use the uses statement.

Making your unit available to your program

Copy your new .TPU file to the unit directory you specified in the Options | Directories dialog box.

If you place the unit in the specified unit directory, you can reference the unit even if it's not in the current directory or in the run-time library, TURBO.TPL.

Include the **uses** clause in any program you want to use your new unit. For example, if your new unit is named INTLIB.TPU, enter the **uses** clause like this:

```
uses IntLib;
```

To learn about putting your units in the run-time libraries, see page 104.

To find the unit named in a **uses** clause, Turbo Pascal checks to see if it is in the run-time library that is loaded into memory at startup.

If it's not in TURBO.TPL, the compiler searches for it on disk, first in the current work directory, and then in the directories specified as unit directories (Options | Directories). The compiler assumes the name of the file is the unit name with a .TPU extension.

If you use the Make or Build command, Turbo Pascal searches for the source files specified in a **uses** clause in the same order as for .TPU files. The compiler assumes the source file will be the unit name with a .PAS extension.

An example

Let's write a small unit. We'll call it *IntLib* and put in two simple integer routines—a procedure and a function:

```
unit IntLib;

interface
procedure ISwap(var I,J: Integer);
function  IMax(I,J: Integer): Integer;

implementation
procedure ISwap;
var
  Temp: Integer;
begin
  Temp := I; I := J; J := Temp;
end;  { of proc ISwap }

function IMax;
begin
  if I > J then
    IMax := I
  else IMax := J;
end;  { of func IMax }
end.  { of unit IntLib }
```

Type this in, save it as the file INTLIB.PAS, then compile it. The resulting unit code file is INTLIB.TPU. Move it to your unit directory or leave it in the same directory as the program that follows. This next program uses the unit *IntLib*:

```
program IntTest;
uses IntLib;
var
  A, B: Integer;
begin
  Write('Enter two integer values:  ');
  Readln(A, B);
  ISwap(A, B);
  Writeln('A = ', A, ' B = ', B);
  Writeln('The max is ', IMax(A, B));
end.  { of program IntTest }
```

Units and large programs

So far we've only talked about units only as libraries—collections of useful routines to be shared by several programs. Another function of a unit, however, is to break up a large program into modules.

Two aspects of Turbo Pascal make this modular functionality of units work:

- Its tremendous speed in compiling and linking
- Its ability to manage several code files simultaneously, such as a program and several units.

Usually a large program is divided into units that group procedures by their function. For instance, an editor application could be divided into initialization, printing, reading and writing files, formatting, and so on. Also, there could be a "global" unit—one used by all other units, as well as the main program—that defines global constants, data types, variables, procedures, and functions.

The skeleton of a large editor program might look like this:

```
program Editor;
uses
  Strings,                             { Standard units from TURBO.TPL }
  EditGlobals,                                  { User-written units }
  EditInit,
  EditPrint,
  EditRead, EditWrite,
  EditFormat;

{ Program's declarations, procedures, and functions }
begin  { main program }
end.  { of program Editor }
```

Note that the units in this program could either be in TURBO.TPL or in their own individual .TPU files. If the latter is true, then Turbo Pascal manages your project for you. This means when you recompile program *Editor* using the compiler's built-in make facility, Turbo Pascal compares the dates of each .PAS and .TPU file and recompile modules whose source has been modified.

See page 72 in Chapter 4, "Programming in the IDE," for more information about managing large programming projects.

Another reason to use units in large programs involves code segment limitations. The 8086 (and related) processors limit the size of a given chunk, or segment, of code to 64K. This means that the main program and any given segment can't exceed a 64K size. Turbo Pascal handles this by making each unit a separate code segment. Without units, you're limited to 64K of code for your program.

The TPUMOVER utility

Suppose you want to add a well-designed and thoroughly debugged unit to the run-time library so that it's automatically loaded into memory when you run the compiler. You can do so by using the TPUMOVER.EXE utility.

You'll find instructions on how to use TPUMOVER in Turbo Pascal's online Help system.

You can also use TPUMOVER to remove units from the Turbo Pascal standard unit library file, reducing its size and the amount of memory it takes up when loaded.

As you've seen, it's really quite simple to write your own units. A well-designed, well-implemented unit simplifies program development; you solve the problems only once, not for each new program. Best of all, a unit provides a clean, simple mechanism for writing very large programs.

C H A P T E R

7

Using Pointers

A *pointer* is a reference to data or code in your program. It's literally the address in memory of the item pointed to. Using pointers enables you to write larger and more flexible programs, and it's especially helpful when you start writing object-oriented programs.

This chapter is designed to help you make better use of pointers, whether you're just starting out with Pascal or you've been programming in Pascal for years but never needed pointers before. It covers these topics:

- Why and when to use pointers
- What is a pointer
- How to use pointers
- Managing pointers effectively

Why use pointers?

Sooner or later, every Pascal programmer runs into a situation that requires the use of pointers. You need to use pointers for these reasons:

- If your program handles large amounts of data (more than 64K total)
- If your program uses data of unknown size at compile time
- If your program uses temporary data buffers

- If your program handles multiple data types
- If your program uses linked lists of records or objects

Let's look at each reason to use pointers.

Handling large amounts of data

As programs get larger and more complex and need to handle more data, the 64K area Turbo Pascal sets aside for data might not be large enough to hold all the data your program needs. Pointers let you get around this.

Local variables don't go in the data segment, so they don't count against the 64K limit.

When you declare global variables in Turbo Pascal, the compiler allocates space for them in an area called the *data segment*. The data segment has a maximum size of 64K, meaning that all your global variables can total only 64K. For many programs, this limit doesn't matter, but there are times when you might need more.

For example, suppose you have a program that requires an array of 400 strings, each of them holding up to 100 characters. That array would take up roughly 40K bytes, which is less than the maximum 64K. An array of this size is not a problem, assuming your other variables fit in the remaining 24K.

But what if you need two such arrays at the same time? That would require about 80K, which won't fit in the 64K data segment. To handle larger amounts of data, you need to use the *heap*. Your program can allocate the 80K on the heap, keeping a pointer as a reference to the location of the data. The pointer takes up only 4 bytes in the data segment.

What is the heap?

The heap is all the memory your operating system makes available that isn't being used by your program code, its data segment, and its stack. You can control the amount of heap space available by using the **$M** compiler directive.

Usually in Turbo Pascal you can set aside space on the heap, access it through a pointer, and then release the space again. For details about how to allocate space on the heap for your data, see the section "How do you use pointers?" starting on page 111.

Handling data of unknown size

Some Turbo Pascal data items (particularly strings and arrays) need to have their sizes specified at compile time, even though they might not need all the allocated space when the program runs. A simple example would be a program that reads a string from the user, such as the user's name. To store that name in a regular string variable, you would have to set aside enough space to handle the largest possible string, even if the name typed is only a few letters. If you wait to allocate that variable on the heap at run time, you can allocate just the number of bytes needed to hold the actual string data.

This is a trivial example, but in an application with hundreds or thousands of such data items (such as multiple windows or lists read from files), allocating only as much space as needed can mean the difference between running successfully and running out of memory.

Handling temporary data buffers

Pointers and the heap are extremely handy for situations when you need memory allocated temporarily, but don't want to commit that memory for the entire duration of the program. For example, a file editor usually needs a data buffer for every file being edited. Rather than declaring at compilation time that you'll have a certain number of buffers of a certain size always allocated for files, you can allocate only as many as you need at any given time, making memory available for other purposes.

Another common example of temporary memory use is sorting. Usually when you sort a large array of data, you make a copy of the array, sort the copy, and then copy the sorted data back into the original array. This protects the integrity of your data. But it also requires that you have two copies of your data while you're sorting. If you allocate the sorting array on the heap, you can sort it and copy it back into the original, then dispose of the sorting array, freeing that memory for other uses.

Managing multiple data types

*Untyped **var** parameters are explained in Chapter 9, "Procedures and functions," in the Language Guide.*

One less common use of pointers is to point to variable data structures—that is, records or arrays that might not always have the same structure. For instance, you might have a block of memory set aside to hold a "history list" of different-length string items typed into a data-entry field. To read the history list, a routine would scan through the block looking for individual strings. You could use a simple pointer to indicate where the block begins. In this case, the pointer works much the same way as passing an untyped **var** parameter to a procedure or function—you simply want to tell *where* something is, without specifying *what* it is.

Linked lists

For an example of using linked lists, see "Managing a linked list," on page 118.

One common use of pointers is to tie together *linked lists* of records. In many simple database-type applications, you can hold data records in arrays or typed files, but sometimes you need something more flexible than an array, which has a fixed size. By allocating dynamic records so that each record has a field that points to the next record, you can construct a list that contains as many elements as you need.

What is a pointer?

A pointer is an address of something in your computer's memory. It could be the address of a variable, a data record, or a procedure or function. Normally, you don't care *where* something resides in memory. You just refer to it by name, and Turbo Pascal knows where to look.

That's exactly what happens when you declare a variable. For example, if your program includes the following code, you've told the compiler to set aside an area in memory you'll refer to as *SomeNumber*.

```
var SomeNumber: Integer;
```

You won't need to worry about where *SomeNumber* resides in memory; that's why you gave it a name.

You can find out the memory address of *SomeNumber* using the @ operator. *@SomeNumber* is the address of your integer variable. You can assign that address to a *pointer variable,* which is a variable that holds an address of data or code in memory.

Pointer types

You need a pointer variable to hold a pointer, and to create pointer variables, you must have *pointer types*. The simplest pointer type is a standard type called *Pointer*. A variable of type *Pointer* is a generic (or *untyped*) pointer—that is, it's just an address. It has no information about what kind of thing it points to.

So, to use the same *SomeNumber* example, you can assign its address to a pointer variable:

```
var
  SomeNumber: Integer;
  SomeAddress: Pointer;

begin
  SomeNumber := 17;                       { give SomeNumber a value }
  SomeAddress := @SomeNumber;    { assign the address to SomeAddress }
  SomeAddress := Addr(SomeNumber);  { another way to get the address }
end.
```

Untyped pointers aren't used much in Pascal because they are very limited. They are most useful when the item pointed to will vary, because an untyped pointer is compatible with any other pointer. Typed pointers are much more useful, and they are safer, as you'll see in the next section.

Typed pointers

Usually you'll define pointer types that point to a particular kind of item, such as an integer or a data record. As you'll see shortly, you can take advantage of the fact that a pointer knows what it's pointing to. To define a typed pointer, you declare a new type, defined by a caret (^) followed by any other type identifier. For example, to define a pointer to an *Integer*, you could do this:

```
type PInteger = ^Integer;
```

You can now declare variables of type *PInteger*. If you're not going to use the pointer type often, you can simply declare variables as pointers to an already-defined type. For example, given that you've defined *PInteger* as *^Integer*, the following variable declarations are equivalent:

```
var
  X: ^Integer;
  Y: PInteger;
```

Dereferencing pointers

So far you've seen how to assign values to pointers, but that's not much use if you can't get the values back. You can treat a typed pointer exactly as if it were a variable of the type it points to by *dereferencing* it. To dereference a pointer, you put a caret (^) after the pointer's identifier.

Listing 7.1 shows some examples of dereferencing pointers:

Listing 7.1
Simple examples of pointer dereferencing.

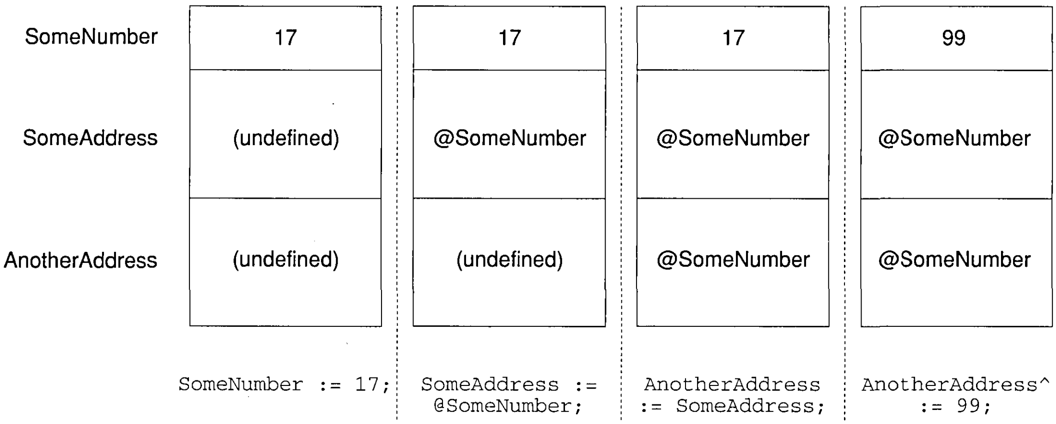
```
type PInteger = ^Integer;

var
  SomeNumber: Integer;
  SomeAddress, AnotherAddress: PInteger;

begin
  SomeNumber := 17;                          { assign 17 to SomeNumber }
  SomeAddress := @SomeNumber;     { SomeAddress points to SomeNumber }
  Writeln(SomeNumber);                                   { prints 17 }
  Writeln(SomeAddress);               { illegal; can't print pointers }
  Writeln(SomeAddress^);                                 { prints 17 }
  AnotherAddress := SomeAddress;        { also points to SomeNumber }
  AnotherAddress^ := 99;                 { new value for SomeNumber }
  Writeln(SomeNumber);                                   { prints 99 }
end.
```

The most critical lines in Listing 7.1 are these:

```
  AnotherAddress := SomeAddress;        { also points to SomeNumber }
  AnotherAddress^ := 99;                 { new value for SomeNumber }
```

If you understand the difference between these two statements, you understand the basics of pointers. The first statement assigns an address to *AnotherAddress*; it tells it where to point. The second statement assigns a new value to the item pointed to by *AnotherAddress*. Figure 7.1 shows this graphically.

Figure 7.1: Dereferencing a pointer yields a value.



How do you use pointers?

By now you should have a pretty good idea of the kinds of situations in which you'd use pointers, so it's time to look at how you actually go about using them. This section covers these topics:

- Allocating dynamic variables
- Deallocating dynamic variables
- Allocating and deallocating specific amounts
- Checking available heap space

Turbo Pascal provides two pairs of procedures for allocating and deallocating dynamic variables. *New* and *Dispose* should meet your needs most of the time. *GetMem* and *FreeMem* perform the same jobs, but at a lower level.

Allocating dynamic variables

One of the primary uses of pointers is allocating dynamic variables on the heap. Turbo Pascal provides two ways to allocate heap memory to a pointer: the *New* procedure and the *GetMem* procedure.

Using New as a procedure

New is a very simple procedure. Once you've declared a pointer variable, you can call *New* to allocate space on the heap for the item pointed to by the variable. Listing 7.2 is an example:

Listing 7.2
Dynamic variable allocation with New

```
var
  IntPointer: ^Integer;
  StringPointer: ^String;

begin
  New(IntPointer);                { allocates two bytes on the heap }
  New(StringPointer);             { allocates 256 bytes on the heap }
   :
end.
```

Once you've called *New*, the pointer variable points to the space allocated on the heap. In this example, *IntPointer* points to the two-byte area allocated by *New*, and *IntPointer^* is a valid integer variable (although that integer's value hasn't been defined yet). Similarly, *StringPointer* points to the 256-byte block allocated for a string, and dereferencing it produces a usable string variable.

Using New as a function

In addition to allocating memory to a particular dynamic variable, you can use *New* as a function that returns a pointer of a particular type. For example, if *PInteger* is a type defined as *^Integer* and IntPointer is of type *PInteger*, these two statements are equivalent:

```
New(IntPointer);
IntPointer := New(PInteger);
```

This is particularly useful in cases where the pointer variable might need to be assigned items of different types. At times you might want to allocate a dynamic variable without explicitly assigning the resulting pointer to a particular variable. You would probably do this only to create a parameter for a procedure or function:

```
SomeProcedure(New(PointerType));
```

In this case, *SomeProcedure* would probably add the passed pointer to some sort of list. Otherwise the memory allocated would be lost. Borland's *Turbo Vision* library uses this technique extensively in assigning dynamic objects to lists.

Using New with objects

Objects and their constructors are explained in Chapter 8, "Object-oriented programming."

When you use *New* as a function or procedure to allocate a dynamic object, you can add an optional second parameter that specifies the constructor used to initialize the object. For example, in Listing 7.3, the first call to *New* allocates space for an object but doesn't initialize that object in any way. The second call allocates the space and then calls the constructor *Init* to set up the object.

Listing 7.3 Constructing dynamic objects

```
type
  PMyObject = ^TMyObject;
  TMyObject = object
    constructor Init;
  end;

var
  MyObject, YourObject: PMyObject;

begin
  New(MyObject);                        { object is not initialized }
  New(YourObject, Init);             { calls Init to initialize object }
end.
```

Deallocating dynamic variables

Variables allocated with *New* must be deallocated when you're finished with them to make the heap space available for other dynamic variables. To deallocate a dynamic variable, you call the *Dispose* procedure. For the example in Listing 7.2, you'd add the following:

```
Dispose(StringPointer);
Dispose(IntPointer);
```

Remember that if you allocate dynamic variables with *New*, you must deallocate them with *Dispose* as soon as you're finished with them.

GetMem and FreeMem

Sometimes you don't want to allocate memory the way *New* does. You might want to allocate more or less memory than *New* allocates by default, or you might not know until run time just how much memory you need to use. Turbo Pascal handles such allocations using the *GetMem* procedure.

GetMem takes two parameters: a pointer variable to which you want to allocate memory and a number of bytes to be allocated.

Dynamic string allocation

For example, you might have an application that reads 1,000 strings from a file and stores them in dynamic memory. You can't be sure how long any of the strings will be, so you need to declare a string type long enough to accommodate the longest possible string. Assuming that not all the strings take up the maximum length, you have space wasted on unused characters.

To get around this, you could read each string into a buffer, then allocate only enough space to store the actual information in the string. Listing 7.4 shows an example of this:

Listing 7.4
Dynamically allocating string space

```
type PString = ^String;

var
  ReadBuffer: String;
  LinesRead: array[1..1000] of PString;
  TheFile: Text;
  LineNumber: Integer;

begin
  Assign(TheFile, 'FOO.TXT');
  Reset(TheFile);
  for LineNumber := 1 to 1000 do
  begin
    Readln(ReadBuffer);
    GetMem(LinesRead[LineNumber], Length(ReadBuffer) + 1);
    LinesRead[LineNumber]^ := ReadBuffer;
  end;
end.
```

Instead of allocating 256K for the lines (256 characters per string times 1000 lines), you allocate 4K (4 bytes per pointer times 1000 lines) plus whatever is actually taken up by the text.

Freeing allocated memory

Just as you have to dispose of memory allocated with *New*, you need to free the memory you allocate with *GetMem*. The procedure that handles this is called *FreeMem*. Again, just as you pair each call to *New* with a call to *Dispose*, each call to *GetMem* should have a corresponding call to *FreeMem*.

Like *GetMem*, *FreeMem* needs two parameters: the variable to free and the amount of memory to be freed. It is critical that the amount freed be exactly the same as the amount allocated. *New* and *Dispose* always know how many bytes to allocate or free, based on the type of the pointer, but with *GetMem* and *FreeMem* the amount is entirely under your control.

If you free fewer bytes than you allocated, the remaining bytes are lost (a form of heap leak). If you free more bytes than you allocated, you might be releasing memory allocated to another variable, which will probably lead to corrupted data.

For example, suppose you are going to allocate memory for one or more data records of type *TCheck*, defined in Listing 7.5:

Listing 7.5
A simple record type

```
type
  PCheck = ^TCheck;
  TCheck = record
    Amount: Real;
    Month: 1..12;
    Day: 1..31;
    Year: 1990..2000;
    Payee: string[39];
  end;
```

Each record of type *TCheck* takes up 50 bytes, so if you have a variable *ThisCheck* of type *PCheck*, you could allocate a dynamic check record using this:

```
GetMem(ThisCheck, 50);
```

You could release it later with this:

```
FreeMem(ThisCheck, 50);
```

Using SizeOf with GetMem

Making sure you allocate and free the same amount every time is not enough, however. You also must ensure that you allocate the right amount of memory. Suppose you change the definition of *TCheck*. For example, if you redefined *TCheck.Payee* to be a 50-character string instead of a 39-character string, you would not be getting and freeing enough memory. The safest way to code something like this is to use *SizeOf*:

```
GetMem(ThisCheck, SizeOf(TCheck));
   ⋮
FreeMem(ThisCheck, SizeOf(TCheck));
```

This not only ensures that you allocate and free the same amount, but also guarantees that if you change the size of the type, your code still allocates all the memory you need.

Checking available heap space

Turbo Pascal defines two functions that return important information about the heap: *MemAvail* and *MaxAvail*.

MemAvail returns the total number of bytes available for allocation on the heap. Before you allocate a large amount of heap space, it's a good idea to make sure that much space is available.

MaxAvail returns the size of the largest available block of contiguous memory on the heap. When you first run a program, *MaxAvail* is equal to *MemAvail*, because the whole heap is available and contiguous. Once you allocate and free a few blocks, it's likely that the available space on the heap will be *fragmented*, meaning there are blocks of allocated space between the free spaces. *MaxAvail* returns the size of the largest of these free blocks.

The details of how Turbo Pascal manages the heap vary depending on the operating system. If you need to know more details, read Chapter 19, "Memory issues," in the *Language Guide*.

Common pointer problems

Pointers enable you to do some important things in Pascal, but there are a couple of common problems you should watch out for when using pointers. The most common pointer problems are

- Dereferencing uninitialized pointers
- Losing heap memory ("heap leaks")

Dereferencing invalid pointers

One common source of errors with pointers is dereferencing a pointer that hasn't been assigned. Like all Pascal variables, a pointer variable's value is undefined until you assign it a value, so it could point anywhere in memory.

☞ *Always* assign values to pointers before using them. If you dereference a pointer that you haven't assigned a value to, the data you read from it could be random bits, and assigning a value to the item pointed to could overwrite other data, your program, or even the operating system. This sounds a little ominous, but with a little discipline it's easy to manage.

Using the nil pointer

To keep from dereferencing pointers that don't point to anything meaningful, you need some way of telling that a pointer is invalid. Pascal provides the reserved word **nil** that you can use as a consistent value for pointers that don't currently point to anything. A **nil** pointer is valid, but unattached. You should check to make sure a pointer is non-**nil** before dereferencing it.

For example, suppose you have a function that returns a pointer to some item in memory. You can indicate that such a function failed to find the item by returning **nil**:

```
var ItemPointer: Pointer;

function FindItem: Pointer;
begin
   :
        { search for item, return pointer to it or nil if not found }
end;

begin
  ItemPointer := nil;                          { start by assuming nil }
  ItemPointer := FindItem;                         { call the function }
  if ItemPointer <> nil then ...   { safe to dereference ItemPointer }
end.
```

☞ Usually it's a good idea to initialize pointers to **nil** if you're not going to assign them some other value right away, then check to make sure such pointers are non-**nil** before dereferencing them.

Losing heap memory

A common problem when using dynamic variables is known as a *heap leak*. A heap leak is a situation where space is allocated on the heap and then lost—for some reason your pointer no longer points to the allocated area, so you can't deallocate the space.

A common cause of heap leaks is reassigning dynamic variables without disposing of previous ones. The simplest case of this is the following:

Listing 7.6
A simple heap leak

```
var IntPointer: ^Integer;

begin
  New(IntPointer);
  New(IntPointer);
end.
```

The first call to *New* allocates eight bytes on the heap and sets *IntPointer* to point to them. The second call to *New* allocates yet another eight bytes, and sets *IntPointer* to point to *them*. Now you have no pointer to the first eight bytes allocated, so there is no way to deallocate them—those eight bytes are lost, as far as this program is concerned.

Of course, a heap leak is usually not as obvious as the one in Listing 7.6. The allocations are almost never consecutive statements, but might be in separate procedures or widely separated portions of the same routine. In any case, the best way to keep track of dynamic variables is to make sure you set them to **nil** when you deallocate them, and then make sure pointer variables are **nil** before you try to allocate them again:

```
var IntPointer: ^Integer;

begin
  New(IntPointer);
   :
  Dispose(IntPointer);
  IntPointer := nil;
   :
  if IntPointer = nil then New(IntPointer);
end.
```

Managing a linked list

Suppose you want to write a program to manage your personal checking account. You can store all the check data in records such as the *TCheck* type defined in Listing 7.5. But it's hard to know when you're writing the program just how many checks you might eventually need to handle. One solution is to create a huge array of check records, but that's wasteful of memory. A more elegant and flexible solution is to expand the record definition to include a pointer to a the next record in a list, forming a linked list, as shown in Listing 7.7.

Listing 7.7
A record type for a linked list

```
type
  PCheck = ^TCheck;
  TCheck = record
    Amount: Real;
    Month: 1..12;
    Day: 1..31;
    Year: 1990..2000;
```

```
    Payee: string[39];
    Next: PCheck;                   { points to the next check record }
  end;
```

Now you can read each check record from a file and allocate space for it. The *Next* field should be **nil** if the record is the end of the list. Your program only needs to keep track of two pointers: the first check in the list and the "current" check.

Building the list

Listing 7.8 shows a procedure that builds a linked list of records read from a file. The code assumes that you've opened a file of *TCheck* records called *CheckFile* that contains at least one record.

Listing 7.8
Building a linked list

```
var ListOfChecks, CurrentCheck: PCheck;

procedure ReadChecks;
begin
  New(ListOfChecks);              { allocate memory for first record }
  Read(CheckFile, ListOfChecks^);                { read first record }
  CurrentCheck := ListOfChecks;          { make first record current }
  while not Eof(CheckFile) do
  begin
    New(CurrentCheck^.Next);       { allocate memory for next record }
    Read(CheckFile, CurrentCheck^.Next^);         { read next record }
    CurrentCheck := CurrentCheck^.Next;   { make next record current }
  end;
  CurrentCheck^.Next := nil;    { no next record after last one read }
end;
```

Moving through the list

Once you have the list, you can easily search through the list for a particular record. Listing 7.9 shows a function that locates the first check with a particular amount and returns a pointer to it.

Listing 7.9
Searching through a linked list

```
function FindCheckByAmount(AnAmount: Real): PCheck;
var Check: PCheck;
begin
  TempCheck := ListOfChecks;                   { point to first record }
  while (Check^.Amount <> AnAmount) and (Check^.Next <> nil) do
    Check := Check^.Next;
  if Check^.Amount = AnAmount then
    FindCheckByAmount := Check       { return pointer to found record }
  else FindCheckByAmount := nil;             { or nil if none matched }
end;
```

Disposing of the list

When you're through with the list, you go through the items, disposing of each, as shown in the *DisposeChecks* procedure in Listing 7.10.

Listing 7.10
Disposing of a linked list

```
procedure DisposeChecks;
var Temp: PCheck;
begin
  CurrentCheck := ListOfChecks;                  { point to first record }
  while CurrentCheck <> nil do
  begin
    Temp := CurrentCheck^.Next;                    { store Next pointer }
    Dispose(CurrentCheck);                     { dispose of current record }
    CurrentCheck := Temp;                     { make stored record current }
  end;
end;
```

C H A P T E R

8

Object-oriented programming

Object-oriented programming (OOP) is a method of programming that closely mimics the way all of us get things done. It is a natural evolution from earlier innovations to programming language design: It is more structured than previous attempts at structured programming; and it is more modular and abstract than previous attempts at data abstraction and detail hiding. Three main properties characterize an object-oriented programming language:

- *Encapsulation*: Combining a record with the procedures and functions that manipulate it to form a new data type—an object.
- *Inheritance*: Defining an object and then using it to build a hierarchy of descendant objects, with each descendant inheriting access to all its ancestors' code and data.
- *Polymorphism*: Giving an action one name that is shared up and down an object hierarchy, with each object in the hierarchy implementing the action in a way appropriate to itself.

Turbo Pascal's language extensions give you the full power of object-oriented programming: more structure and modularity, more abstraction, and reusability built right into the language. All these features add up to code that is more structured, extensible, and easy to maintain.

The challenge of object-oriented programming is that it requires you to set aside habits and ways of thinking about programming that have been standard for many years. Once you do that, however, OOP is a simple, straightforward, superior tool for solving many of the problems that plague traditional programs.

A note to you who have done object-oriented programming in other languages: Put aside your previous impressions of OOP and learn Turbo Pascal's object-oriented features on their own terms. OOP is not one single way of programming; it is a continuum of ideas. In its object philosophy, Turbo Pascal is more like C++ than Smalltalk. Smalltalk is an interpreter, while from the beginning, Turbo Pascal has been a pure native code compiler. Native code compilers do things differently (and far more quickly) than interpreters.

And a note to you who haven't any notion at all what OOP is about: That's just as well. Too much hype, too much confusion, and too many people talking about something they don't understand have greatly muddied the waters in recent years. Strive to forget what people have told you about OOP. The best way (in fact, the *only* way) to learn anything useful about OOP is to do what you're about to do: Sit down and try it yourself.

Objects?

Yes, objects. Look around you...there's one: the apple you brought in for lunch. Suppose you were going to describe an apple in software terms. The first thing you might be tempted to do is pull it apart: Let *S* represent the area of the skin; let *J* represent the fluid volume of juice it contains; let *F* represent the weight of fruit inside; let *D* represent the number of seeds....

Don't think that way. Think like a painter. You see an apple, and you paint an apple. The picture of an apple is not an apple; it's just a symbol on a flat surface. But it hasn't been abstracted into seven numbers, all standing alone and independent in a data segment somewhere. Its components remain together, in their essential relationships to one another.

Objects model the characteristics and behavior of the elements of the world we live in. They are the ultimate data abstraction so far.

Objects keep all their characteristics and behavior together.

An apple can be pulled apart, but once it's been pulled apart it's not an apple anymore. The relationships of the parts to the whole and to one another are plainer when everything is kept together in one wrapper. This is called *encapsulation*, and it's very important. We'll return to encapsulation in a little while.

Equally important, objects can *inherit* characteristics and behavior from what are called *ancestor objects*. This is an intuitive leap; inheritance is perhaps the single biggest difference between object-oriented Turbo Pascal and Standard Pascal programming today.

Inheritance

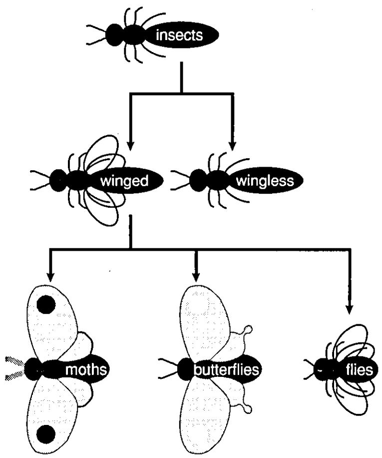
The goal of science is to describe the workings of the universe. Much of the work of science, in furthering that goal, is simply the creation of family trees. When entomologists return from the Amazon with a previously unknown insect in a jar, their fundamental concern is working out where that insect fits into the giant chart upon which the scientific names of all other insects are gathered. There are similar charts of plants, fish, mammals, reptiles, chemical elements, subatomic particles, and external galaxies. They all look like family trees: a single overall category at the top, with an increasing number of categories beneath that single category, fanning out to the limits of diversity.

Within the category *insect*, for example, there are two divisions: insects with visible wings, and insects with hidden wings or no wings at all. Under winged insects is a larger number of categories: moths, butterflies, flies, and so on. Each category has numerous subcategories, and beneath those subcategories are even more subcategories (see Figure 8.1).

This classification process is called *taxonomy*. It's a good starting metaphor for the inheritance mechanism of object-oriented programming.

The questions a scientist asks in trying to classify a new animal or object are these: *How is it similar to the others of its general class? How is it different?* Each different class has a set of behaviors and characteristics that define it. A scientist begins at the top of a specimen's family tree and starts descending the branches, asking those questions along the way. The highest levels are the most general, and the questions the simplest: Wings or no wings? Each level is more specific than the one before it, and less general. Eventually the scientist gets to the point of counting hairs on the third segment of the insect's hind legs—specific indeed.

Figure 8.1
A partial taxonomy chart of insects



The important point to remember is that once a characteristic is defined, all the categories *beneath* that definition *include* that characteristic. So once you identify an insect as a member of the order *diptera* (flies), you needn't make the point that a fly has one pair of wings. The species of insect called *flies* inherits that characteristic.

As you'll learn shortly, object-oriented programming is the process of building family trees for data structures. One of the important things object-oriented programming adds to traditional languages like Pascal is a mechanism by which data types inherit characteristics from simpler, more general types. This mechanism is inheritance.

Objects: records that inherit

In Pascal terms, an object is very much like a record, which is a wrapper for joining several related elements of data together under one name. Suppose you want to develop a payroll program that produces a report showing how much each employee gets paid each payday. You might lay out a record like this:

We start all our type names with the letter T. This is a convention you may want to follow.

```
TEmployee = record
  Name: string[25];
  Title: string[25];
  Rate: Real;
end;
```

TEmployee here is a *record type*; that is, it's a template that the compiler uses to create record variables. A variable of type *TEmployee* is an instance of type *TEmployee*. The term *instance* is used now and then in Pascal circles, but it is used all the time by OOP people, and you'll do well to start thinking in terms of types and instances of those types.

With type *TEmployee* you have it both ways: You can think of the *Name*, *Title*, and *Rate* fields separately, or when you need to think of the fields working together to describe a particular worker, you can think of them collectively as *TEmployee*.

Suppose you have several types of employees working in your company. Some are paid hourly, some are salaried, some are commissioned, and so on. Your payroll program needs to accommodate all these types. You might develop a different record type for each type of employee. For example, to figure out how much an hourly employee gets paid, you need to know how many hours the employee worked. You could design a *THourly* record like this:

```
THourly = record
  Name: string[25];
  Title: string[25];
  Rate: Real;
  Time: Integer;
end;
```

You might also be a little more clever and retain record type *TEmployee* by creating a field of type *TEmployee* within type *THourly*:

```
THourly = record
  Worker: TEmployee;
  Time: Integer;
end;
```

This works, and Pascal programmers do it all the time. One thing this method doesn't do is force you to think about the nature of what you're manipulating in your software. You need to ask questions like, "How does an hourly employee differ from other employees?" The answer is this: An hourly employee is an employee who is paid for the number of hours the employee works. Think back on the first part of that statement: An *hourly* employee is an *employee*....

There you have it!

An *hourly* employee record must have all the fields that exist in the *employee* record. Type *THourly* is a descendant type of type *TEmployee*. *THourly* inherits everything *TEmployee* has, and adds whatever is new about *THourly* to make *THourly* unique.

This process by which one type inherits the characteristics of another type is called *inheritance*. The inheritor is called a *descendant type*; the type that the descendant type inherits from is an *ancestor type*.

The familiar Pascal record types cannot inherit. Turbo Pascal, however, extends the Pascal language to support inheritance. One of these extensions is a new category of data structure, related to records but far more powerful. Data types in this new category are defined with a new reserved word: **object**. An object type can be defined as a complete, stand-alone type in the fashion of Pascal records, or it can be defined as a descendant of an existing object type by placing the name of the ancestor type in parentheses after the reserved word **object**.

In the payroll example you just looked at, the two related object types would be defined this way:

Note the use of parentheses here to denote inheritance.

```
type
  TEmployee = object
    Name: string[25];
    Title: string[25];
    Rate: Real;
  end;

  THourly = object(TEmployee)
    Time: Integer;
  end;
```

Here, *TEmployee* is the ancestor type, and *THourly* is the descendant type. As you'll see a little later, the process can continue indefinitely: You can define descendants of type *THourly*, and descendants of *THourly*'s descendant type, and so on. A large part of designing an object-oriented application lies in building this *object hierarchy* expressing the family tree of the objects in the application.

All the types eventually inheriting from *TEmployee* are called *TEmployee*'s descendant types, but *THourly* is one of *TEmployee*'s *immediate descendants*. Conversely, *TEmployee* is *THourly*'s *immediate ancestor*. An object type (just like a DOS subdirectory) can have any number of immediate descendants, but only one immediate ancestor.

Objects are closely related to records, as these definitions show. The new reserved word **object** is the most obvious difference, but there are numerous other differences, some of them quite subtle, as you'll see later.

For example, the *Name*, *Title*, and *Rate* fields of *TEmployee* are not explicitly written into type *THourly*, but *THourly* has them anyway, by virtue of inheritance. You can speak about *THourly*'s *Name* value, just as you can speak about *TEmployee*'s *Name* value.

Instances of object types

Instances of object types are declared just as any variables are declared in Pascal, either as static variables or as pointer referents allocated on the heap:

```
type
  PHourly = ^THourly;

var
  StatHourly: THourly;   { Ready to go! }
  DynaHourly: PHourly;   { Must allocate with New before use }
```

An object's fields

You access an object's data fields just as you access the fields of an ordinary record, either through the **with** statement or by *dotting*; for example,

```
AnHourly.Rate := 9.45;

with AnHourly do
begin
  Name  := 'Sanderson, Arthur';
  Title := 'Word processor';
end;
```

Don't forget: An object's inherited fields are not treated specially simply because they are inherited.

You just have to remember at first (eventually it comes naturally) that inherited fields are just as accessible as fields declared within a given object type. For example, even though *Name*, *Title*, and *Rate* are not part of *THourly*'s declaration (they are inherited from type *TEmployee*), you can specify them just as though they were declared within *THourly*:

```
AnHourly.Name := 'Arthur Sanderson';
```

Good practice and bad practice

Turbo Pascal actually lets you make an object's fields and methods private; for more on this, refer to page 134.

Even though you can access an object's fields directly, it's not an especially good idea to do so. Object-oriented programming principles require that an object's fields be left alone as much as possible. This restriction might seem arbitrary and rigid at first, but it's part of the big picture of OOP that is being built in this chapter. In time you'll see the sense behind this new definition of good programming practice, though there's some ground to cover before it all comes together. For now, take it on faith: Avoid accessing object data fields directly.

So—how are object fields accessed? What sets them and reads them?

An object's data fields are what an object knows; its methods are what an object does.

The answer is that an object's *methods* are used to access an object's data fields whenever possible. A *method* is a procedure or function declared *within* an object and tightly bonded to that object.

Methods

Methods are one of object-oriented programming's most striking attributes, and they take some getting used to. Start by harkening back to that fond old necessity of structured programming, initializing data structures. Consider the task of initializing a record with this definition:

```
TEmployee = record
  Name: string[25];
  Title: string[25];
  Rate: Real;
end;
```

Most programmers would use a **with** statement to assign initial values to the *Name*, *Title*, and *Rate* fields:

```
var
  MyEmployee: TEmployee;

with MyEmployee do
begin
  Name := 'Arthur Sanderson';
  Title := 'Word processor';
  Rate := 9.45;
end;
```

This works well, but it's tightly bound to one specific record instance, *MyEmployee*. If more than one *TEmployee* record needs to be initialized, you'll need more **with** statements that do essentially the same thing. The natural next step is to build an initialization procedure that generalizes the **with** statement to encompass any instance of a *TEmployee* type passed as a parameter:

```
procedure InitTEmployee(var Worker: TEmployee; AName,
  ATitle: String; ARate: Real);
begin
  with Worker do
  begin
    Name  := AName;
    Title := ATitle;
    Rate  := ARate;
  end;
end;
```

This does the job, all right—but if you're getting the feeling that it's a little more fooling around than it ought to be, you're feeling the same thing that object-oriented programming's early proponents felt.

It's a feeling that implies that, well, you've designed procedure *InitTEmployee* specifically to serve type *TEmployee*. Why, then, must you keep specifying what record type and instance *InitTEmployee* acts upon? There should be some way of welding together the record type and the code that serves it into one seamless whole.

Now there is. It's called a *method*. A method is a procedure or function welded so tightly to a given type that the method is surrounded by an invisible **with** statement, making instances of that type accessible from within the method. The type definition includes the header of the method. The full definition of the method is qualified with the name of the type. Object type and object method are the two faces of this new species of structure called an object:

```
type
  TEmployee = object
    Name, Title: string[25];
    Rate: Real;
    procedure Init(NewName, NewTitle: string[25];
      NewRate: Real);
  end;

procedure TEmployee.Init(NewName, NewTitle: string[25]; NewRate:
  Real);
begin
  Name  := NewName;  { The Name field of an TEmployee object }
  Title := NewTitle; { The Title field of an TEmployee object }
  Rate  := NewRate;  { The Rate field of an TEmployee object }
end;
```

Now, to initialize an instance of type *TEmployee*, you simply call its method as though the method were a field of a record, which in one very real sense it is:

```
var
  AnEmployee: TEmployee;

AnEmployee.Init('Sara Adams, Account manager, 15000');  { Easy, no? }
```

Code and data together

One of the most important tenets of object-oriented programming is that the programmer should think of code and data *together* during program design. Neither code nor data exists in a vacuum. Data directs the flow of code, and code manipulates the shape and values of data.

When your data and code are separate entities, there's always the danger of calling the right procedure with the wrong data or the wrong procedure with the right data. Matching the two is the programmer's job, and while Pascal's strong typing does help, at best it can only say what *doesn't* go together.

Pascal says nothing, anywhere, about what *does* go together. If it's not in a comment or in your head, you take your chances.

By bundling code and data declarations together, an object helps keep them in sync. Typically, to get the value of one of an object's fields, you call a method belonging to that object that returns the value of the desired field. To set the value of a field, you call a method that assigns a new value to that field.

See "Private section" on page 134 for details on how to do this.

Like many aspects of object-oriented programming, respect for encapsulated data is a discipline you should always observe. It's better to access an object's data by using the methods it provides, instead of reading the data directly. Turbo Pascal lets you enforce encapsulation through the use of a **private** declaration in an object's declaration.

Defining methods

The process of defining an object's methods is reminiscent of Turbo Pascal units. Inside an object, a method is defined by the header of the function or procedure acting as a method:

All data fields must be declared before the first method declaration.

```
type
  TEmployee = object
    Name, Title: string[25];
    Rate: Real;
    procedure Init(AName, ATitle: String; ARate: Real);
    function GetName : String
    function GetTitle: String;
    function GetRate : Real;
  end;
```

As with procedure and function declarations in a unit's **interface** section, method declarations within an object tell *what* a method does, but not *how*.

The *how* is defined *outside* the object definition, in a separate procedure or function declaration. When methods are fully defined outside the object, the name of the object type that owns the method, followed by a period, must precede the method name:

```
procedure TEmployee.Init(AName, ATitle: String;
  ARate: Real);
begin
  Name  := AName;
  Title := ATitle;
  Rate  := ARate;
end;

function TEmployee.GetName: String;
  GetName := Name;
end;
```

```
function TEmployee.GetTitle: String;
begin
  GetTitle := Title;
end;

function TEmployee.GetRate: Real;
begin
  GetRate := Rate;
end;
```

Method definition follows the intuitive dotting method of specifying a record field. In addition to having a definition of *TEmployee.GetName*, it would be completely legal to define a procedure named *GetName* without the identifier *TEmployee* preceding it. However, the "outside" *GetName* would have no connection to the object type *TEmployee* and would probably confuse the sense of the program as well.

Method scope and the Self parameter

Notice that nowhere inside a method is there an explicit `with object do...` construct. The data fields of an object are freely available to that object's methods. Although they are separated in the source code, the method bodies and the object's data fields really share the same scope.

This is why one of *TEmployee*'s methods can contain the statement `GetTitle := Title` without any qualifier to *Title*. It's because *Title belongs to the object that called the method.* When an object calls a method, there is an implicit statement to the effect `with myself do method` linking the object and its method in scope.

This implicit **with** statement is accomplished by the passing of an invisible parameter to the method each time any method is called. This parameter is called *Self*, and is actually a full 32-bit pointer to the object instance making the method call. The *GetRate* method belonging to *TEmployee* is roughly equivalent to the following:

This example is not fully correct syntactically; it's here simply to give you a fuller appreciation for the special link between an object and its methods.

```
function TEmployee.GetRate(var Self: TEmployee): Integer;
begin
  GetRate := Self.Rate;
end;
```

Is it important for you to be aware of *Self*? Ordinarily, no: Turbo Pascal's generated code handles it automatically in virtually all cases. There are a few circumstances, however, when you might have to intervene inside a method and make explicit use of the *Self* parameter.

For more details on method call stack frames, see Chapter 20 in the Language Guide.

The *Self* parameter is part of the physical stack frame for all method calls. Methods implemented as externals in assembly language must take *Self* into account when they access method parameters on the stack.

Object data fields and method formal parameters

One consequence of the fact that methods and their objects share the same scope is that a method's formal parameters cannot be identical to any of the object's data fields. This is not some new restriction imposed by object-oriented programming, but rather the same old scoping rule that Pascal has always had. It's the same as not allowing the formal parameters of a procedure to be identical to the procedure's local variables:

```
procedure CrunchIt(Crunchee: MyDataRec; Crunchby, ErrorCode:
  Integer);
var
  A, B: Char;
  ErrorCode: Integer; { This declaration causes an error! }
begin
    :
```

A procedure's local variables and its formal parameters share the same scope and thus cannot be identical. You'll get "Error 4: Duplicate identifier" if you try to compile something like this; the same error occurs if you attempt to give a method a formal parameter identical to any field in the object that owns the method.

The circumstances are a little different, since having procedure headers inside a data structure is a wrinkle new to Turbo Pascal, but the guiding principles of Pascal scoping have not changed at all.

Objects exported by units

It makes good sense to define objects in units, with the object type declaration in the interface section of the unit and the procedure bodies of the object type's methods defined in the implementation section.

By "exported" we mean "defined within the interface section of a unit."

Units can have their own private object type definitions in the implementation section, and such types are subject to the same restrictions as any types defined in a unit implementation section. An object type defined in the interface section of a unit can have descendant object types defined in the implementation section of the unit. In a case where unit *B* uses unit *A*, unit *B* can also define descendant types of any object type exported by unit *A*.

The object types and methods described earlier can be defined within a unit as shown in WORKERS.PAS on your disk. To make use of the object types and methods defined in unit *Workers*, you simply use the unit in your own program, and declare an instance of type *THourly* in the **var** section of your program:

```
program HourRpt;

uses WinCrt, Workers;

var
  AnHourly: THourly;
   :
```

To create and print the hourly employee's name, title, and amount of pay represented by *AnHourly*, you simply call *AnHourly*'s methods, using the dot syntax:

```
AnHourly.Init('Sara Adams', 'Account manager', 1400);
                        { Initializes an instance of THourly with }
                        { employee data for Sara Adams }
AnHourly.Show;          { Writes name, title, and pay amount }
```

Objects can also be typed constants.

Objects, being very similar to records, can also be used inside **with** statements. In that case, naming the object that owns the method isn't necessary:

```
with AnHourly do
begin
  Init('Sara Adams', 'Account manager', 1400);
  Show;
end;
```

Just as with records, objects can be passed to procedures as parameters and (as you'll see later on) can also be allocated on the heap.

Private section

In some circumstances you may have parts of an object declaration that you don't want to export. For example, you may want to provide objects for other programmers to use without letting them manipulate the object's data directly. To make it easy for you, Turbo Pascal allows you to specify private fields and methods within objects.

Private fields and methods are accessible only within the unit in which the object is declared. In the previous example, if the type

THourly had private fields, they could only be accessed by code within the *THourly* unit. Even though other parts of *THourly* would be exported, the parts declared as private would be inaccessible.

Private fields and methods are declared just after regular fields and methods, following the optional **private** reserved word. Thus, the full syntax for an object declaration is

```
type
  NewObject = object(ancestor)
    fields; { these are public }
    methods; { these are public }
  private
    fields; { these are private }
    methods; { these are private }
  end;
```

Programming in the active voice

Most of what's been said about objects so far has been from a comfortable, Turbo Pascal-ish perspective, since that's most likely where you are coming from. This is about to change, as you move on to OOP concepts with fewer precedents in standard Pascal programming. Object-oriented programming has its own particular mindset, due in part to OOP's origins in the (somewhat insular) research community, but also because the concept is truly and radically different.

Object-oriented languages were once called "actor languages" with this metaphor in mind.

One often amusing outgrowth of this is that OOP fanatics anthropomorphize their objects. Data structures are no longer passive buckets that you toss values into. In the new view of things, an object is looked upon as an actor on a stage, with a set of lines (methods) memorized. When you (the director) give the word, the actor recites from the script.

It can be helpful to think of the function *AnHourly.GetPayAmount* as giving an order to object *AnHourly*, saying "Calculate the amount of your pay check." The object is the central concept here. Both the list of methods and the list of data fields contained by the object serve the object. Neither code nor data is boss.

Objects aren't being described as actors on a stage just to be cute. The object-oriented programming paradigm tries very hard to model the components of a problem as components, and not as logical abstractions. The odds and ends that fill our lives, from toasters to telephones to terry towels, all have characteristics (data) and behaviors (methods). A toaster's characteristics might include the voltage it requires, the number of slices it can toast at once, the setting of the light/dark lever, its color, its brand, and so on. Its behaviors include accepting slices of bread, toasting slices of bread, and popping toasted slices back up again.

If you wanted to write a kitchen simulation program, what better way to do it than to model the various appliances as objects, with their characteristics and behaviors encoded into data fields and methods? It's been done, in fact; the very first object-oriented language (Simula-67) was created as a language for writing such simulations.

This is the reason that object-oriented programming is so firmly linked in conventional wisdom to graphics-oriented environments. Objects in Turbo Pascal should model components of the problem you're trying to solve. Keep that in mind as you further explore Turbo Pascal's object-oriented extensions.

Encapsulation

Declaring fields as private allows you to enforce access to those fields only through methods.

The welding of code and data together into objects is called *encapsulation*. If you're thorough, you can provide enough methods so that a user of the object never has to access its fields directly. Like Smalltalk and other programming languages, Turbo Pascal lets you enforce encapsulation through the use of a **private** directive. In this example, we won't specify a **private** section for fields and methods, but instead we will restrict ourselves to using methods in order to access the data we want.

TEmployee and *THourly* are written such that it is completely unnecessary to access any of their internal data fields directly:

```
type
  TEmployee = object
    Name, Title: string[25];
    Rate: Real;
    procedure Init(AName, ATitle: String; ARate: Real);
    function GetName: String;
    function GetTitle: String;
    function GetRate: Real;
    function GetPayAmount: Real;
  end;
```

```
THourly = object(TEmployee)
  Time: Integer;
  procedure Init(AName, ATitle: String; ARate: Real; ATime:
    Integer);
  function GetPayAmount: Real;
end;
```

There are only four data fields here: *Name, Title, Rate,* and *Time.* The *ShowName* and *ShowTitle* methods print an employee's name and title respectively. *GetPayAmount* uses *Rate,* and, in the case of an *THourly* employee, *Time,* to calculate the employee's pay check amount. There is no further need to access these data fields directly.

Assuming an instance of type *THourly* called *AnHourly,* you would use this suite of methods to manipulate *AnHourly*'s data fields indirectly, like this:

```
with AnHourly do
begin
  Init('Allison Karlon', 'Fork lift operator', 12.95, 62);
  Show;             { Writes name, title, and pay amount to screen }
end;
```

Note that the object's fields are not accessed at all except by the object's methods.

Methods: no downside

Adding these methods bulks up *THourly* a little in source form, but the Turbo Pascal smart linker strips out any method code that is never called in a program. You therefore shouldn't hang back from giving an object type a method that might or might not be used in every program that uses the object type. Unused methods cost you nothing in performance or .EXE file size—if they're not used, they're simply not there.

About data abstraction

☞ There are powerful advantages to being able to completely decouple *THourly* from global references. If nothing outside the object "knows" the representation of its internal data, the programmer who controls the object can alter the details of the internal data representation—as long as the method headers remain the same.

Within some object, data might be represented as an array, but later on (perhaps as the scope of the application grows and its data volume expands), a binary tree might be recognized as a more efficient representation. If the object is completely encapsulated, a change in data representation from an array to a binary tree *does not alter the object's use at all.* The interface to the object remains completely the same, allowing the programmer to fine-tune an object's performance without breaking any code that uses the object.

Extending objects

People who first encounter Pascal often take for granted the flexibility of the standard procedure *Writeln,* which allows a single procedure to handle parameters of many different types:

```
Writeln(CharVar);        { Outputs a character value }
Writeln(IntegerVar);     { Outputs an integer value }
Writeln(RealVar);        { Outputs a floating-point value }
```

Unfortunately, standard Pascal has no provision for letting you create equally flexible procedures of your own.

Object-oriented programming solves this problem through inheritance: When a descendant type is defined, the methods of the ancestor type are inherited, but they can also be overridden if desired. To override an inherited method, simply define a new method with the same name as the inherited method, but with a different body and (if necessary) a different set of parameters.

A simple example should make both the process and the implications clear. We have already defined a descendant type to *TEmployee* that represents an employee that is paid hourly wages:

```
const
  PayPeriods = 26;          { per annum }
  OvertimeThreshold = 80;   { per pay period }
  OvertimeFactor = 1.5;     { times normal hourly rate }

type
  THourly = object(TEmployee)
    Time: Integer;
    procedure Init(AName, ATitle: String; ARate: Real; ATime:
       Integer);
    function GetPayAmount: Real;
  end;

procedure THourly.Init(AName, ATitle: String; ARate: Real;
    ATime: Integer);
begin
  TEmployee.Init(AName, ATitle, ARate);
  Time := ATime;
end;
```

```
function THourly.GetPayAmount: Real;
var
  Overtime: Integer;
begin
  Overtime := Time - OvertimeThreshold;
  if Overtime > 0 then
     GetPayAmount := RoundPay(OvertimeThreshold * Rate
       + OverTime * OvertimeFactor * Rate)
  else
     GetPayAmount := RoundPay(Time * Rate);
end;
```

A person who is paid hourly wages is still an employee: That person has everything we used to define the *TEmployee* object (name, title, rate of pay) except that the amount of money an hourly employee is paid depends on how many hours that employee has worked during a pay period. Therefore, *THourly* requires another field, *Time.*

Since *THourly* defines a new field, *Time*, initializing it requires a new *Init* method that initializes *Time* as well as the inherited fields. Rather than directly assigning values to inherited fields like *Name*, *Title* and *Rate*, why not reuse *TEmployee*'s initialization method (illustrated by *THourly.Init*'s first statement)? The syntax for calling an inherited method is *Ancestor.Method*, where *Ancestor* is the type identifier of an ancestral object type, and *Method* is a method identifier of that type.

Note that calling the method you override is not merely good style; it's entirely possible that *TEmployee.Init* performs some important, hidden initialization. By calling the overridden method, you ensure that the descendant object type includes its ancestor's functionality. In addition, any changes made to the ancestor's method automatically affects all its descendants.

After calling *TEmployee.Init*, *THourly.Init* can then perform its own initialization, which in this case consists only of assigning *Time* the value passed in *ATime.*

The *THourly.GetPayAmount* function, which calculates the amount an hourly employee is paid, is another example of an overriding method. In fact, each type of employee object has its own *GetPayAmount* method, because how the employee's pay amount is calculated differs depending on the employee type. The *THourly.GetPayAmount* method must consider how many hours the employee worked, if the employee worked overtime, what the overtime pay factor is, and so on. The *TSalaried.GetPayAmount* method needs only to divide an employee's rate of pay by the number of pay periods per year (26 in our example).

```
unit Workers;

interface

const
  PayPeriods = 26;              { per annum }
  OvertimeThreshold = 80;       { per pay period }
  OvertimeFactor = 1.5;         { times normal hourly rate }

type
  TEmployee = object
    Name: string[25];
    Title: string[25];
    Rate: Real;
    procedure Init(AName, ATitle: String; ARate: Real);
    function GetName: String;
    function GetTitle: String;
    function GetPayAmount: Real;
  end;

  THourly = object(TEmployee)
    Time: Integer;
    procedure Init(AName, ATitle: String; ARate: Real; ATime:
      Integer);
    function GetPayAmount: Real;
    function GetTime: Integer;
  end;

  TSalaried = object(TEmployee)
    function GetPayAmount: Real;
  end;

  TCommissioned = object(TSalaried)
    Commission: Real;
    SalesAmount: Real;
    procedure Init(AName, ATitle: String; ARate, ACommission,
      ASalesAmount: Real);
    function GetPayAmount: Real;
  end;

implementation

function RoundPay(Wages: Real): Real;
{ Round pay amount to ignore any pay less than 1 penny }
begin
  RoundPay := Trunc(Wages * 100) / 100;
end;
  ⋮
```

TEmployee is at the top of our object hierarchy and it contains the first *GetPayAmount* method.

```
function TEmployee.GetPayAmount: Real;
begin
  RunError(211);          { Give runtime error }
end;
```

You may wonder why all this method does is give you a run-time error. If *TEmployee.GetPayAmount* is called, an error exists in your program. Why? Because *TEmployee* is just the top of our object hierarchy and doesn't define a real worker; therefore, none of the *TEmployee* methods will be called specifically, although they may be inherited. All our employees are either hourly, salaried, or commissioned. The *RunTime* error terminates your program and displays "211", the Call to abstract method error message, if your program mistakenly calls *TEmployee.GetPayAmount*.

Next is the *THourly.GetPayAmount* method considers such things as overtime pay, the number of hours worked, and so on.

```
function THourly.GetPayAmount: Real;
var
  OverTime: Integer;
begin
  Overtime := Time - OvertimeThreshold;
  if Overtime > 0 then
    GetPayAmount := RoundPay(OvertimeThreshold * Rate +
      OverTime * OvertimeFactor * Rate)
  else
    GetPayAmount := RoundPay(Time * Rate);
end;
```

The *TSalaried.GetPayAmount* method is much simpler; it divides the rate of pay by the number of pay periods.

```
function TSalaried.GetPayAmount: Real;
begin
  GetPayAmount := RoundPay(Rate / PayPeriods);
end;
```

If you look at the *TCommissioned.GetPayAmount* method, you'll see it calls *TSalaried.GetPayAmount*, calculates a commission, and adds it to the amount returned by *TSalaried.GetPayAmount*.

```
function TCommissioned.GetPayAmount: Real;
begin
  GetPayAmount := RoundPay(TSalaried.GetPayAmount + Commission *
     SalesAmount);
end;
```

Important! Whereas methods can be overridden, data fields cannot. Once you define a data field in an object hierarchy, no descendant type can define a data field with precisely the same identifier.

Inheriting static methods

All the methods shown so far in connection with the *TEmployee*, *THourly*, *TSalaried*, and *TCommissioned* object types are static methods. There is a problem inherent with static methods, however.

To understand the problem, let's leave our payroll example, and consider another simplistic and unrealistic, but instructional example. Let's go back to talking about insects. Suppose you want to build a program that will draw different types of flying insects on your screen. You decide to start with a *TWinged* object at the top of your hierarchy. You plan to build new flying insect object types as descendants of *TWinged*. For example, you might create a *TBee* object type, which differs only from a generic winged insect in that a bee has a stinger and stripes. Of course, a bee has other distinguishing characteristics, but for our example, this is how it might look:

```
type
  TWinged = object(Insect)
    procedure Init(AX, AY: Integer)   { initializes an instance }
    procedure Show;       { displays winged insect on the screen }
    procedure Hide;       { erases the winged insect }
    procedure MoveTo(NewX, NewY: Integer);  { moves winged insect }
  end;

type
  TBee = object(TWinged)
   :
    procedure Init(AX, AY: Integer) { initializes instance of TBee }
    procedure Show;                 { displays a bee on the screen }
    procedure Hide;                 { erases the bee }
    procedure MoveTo(NewX, NewY: Integer;   { moves the bee }
  end;
```

Both *TWinged* and *TBee* have four methods. *TWinged.Init* and *TBee.Init* initialize an instance of their respective objects. The

TWinged.Show method knows how to draw a winged insect on the screen; the *TBee.Show* methods knows how to draw a TBee on the screen (a winged insect with stripes and a stinger). The *TWinged.Hide* method knows how to erase a winged insect; *TBee.Hide* knows how to erase a bee. The two *Show* methods differ, as do the two *Hide* methods.

The *TWinged.MoveTo* and the *TBee.MoveTo* methods are exactly the same, however. In our example, *X* and *Y* define a location on the screen.

```
procedure TWinged.MoveTo(NewX, NewY: Integer);
begin
  Hide;
  X := NewX;          { new X coordinate on the screen }
  Y := NewY:          { new Y coordinate on the screen }
  Show;
end;

procedure TBee.MoveTo(NewX, NewY: Integer);
begin
  Hide;
  X := NewX;           { new X coordinate on the screen }
  Y := NewY:           { new Y coordinate on the screen }
  Show;
end;
```

Nothing was changed other than to copy the routine and give it *TBee*'s qualifier in front of the *MoveTo* identifier. Since the methods are identical, why bother to put *MoveTo* into *TBee*? After all, *TBee* automatically inherits *MoveTo* from *TWinged*. There seems to be no need to override *TWinged*'s *MoveTo* method, but this is where the problem with static methods appears.

The term *static* was chosen to describe methods that are not *virtual*. (You will learn about virtual methods shortly.) Virtual methods are in fact the solution to this problem, but in order to understand the solution you must first understand the problem.

The symptoms of the problem are these: Unless a copy of the *MoveTo* method is placed in *TBee*'s scope to override *TWinged*'s *MoveTo*, the method does not work correctly when it is called from an object of type *TBee*. If *TBee* invokes *TWinged*'s *MoveTo* method, what is moved on the screen is a winged insect rather than a bee. Only when *TBee* calls a copy of the *MoveTo* method defined in its own scope are bees hidden and drawn by the nested calls to *Show* and *Hide*.

Why so? It has to do with the way the compiler resolves method calls. When the compiler compiles *TBee*'s methods, it first encounters *TWinged.Show* and *TWinged.Hide* and compiles code for both into the code segment. A little later down the file it encounters *TWinged.MoveTo*, which calls both *TWinged.Show* and *TWinged.Hide*. As with any procedure call, the compiler replaces the source code references to *TWinged.Show* and *TWinged.Hide* with the addresses of their generated code in the code segment. Thus, when the code for *TWinged.MoveTo* is called, it in turn calls the code for *TWinged.Show* and *TWinged.Hide* and everything's in phase.

So far, this scenario is all classic Turbo Pascal and would have been true (except for the nomenclature) since Turbo Pascal first appeared on the market in 1983. Things change, however, when you get into inheritance. When *TBee* inherits a method from *TWinged*, *TBee* uses the method exactly as it was compiled.

Look again at what *TBee* would inherit if it inherited *TWinged.MoveTo*:

```
procedure TWinged.MoveTo(NewX, NewY: Integer);
begin
  Hide;        { Calls TWinged.Hide }
  X := NewX;
  Y := NewY;
  Show;        { Calls TWinged.Show }
end;
```

The comments were added to drive home the fact that when *TBee* calls *TWinged.MoveTo*, it also calls *TWinged.Show* and *TWinged.Hide*, not *TBee.Show* and *TBee.Hide*. *TWinged.Show* draws a winged insect, not a bee. As long as *TWinged.MoveTo* calls *TWinged.Show* and *TWinged.Hide*, *TWinged.MoveTo* can't be inherited. Instead, it must be overridden by a second copy of itself that calls the copies of *Show* and *Hide* defined within its scope; that is, *TBee.Show* and *TBee.Hide*.

The compiler's logic in resolving method calls works like this: When a method is called, the compiler first looks for a method of that name defined within the object type. The *TBee* type defines methods named *Init*, *Show*, *Hide*, and *MoveTo*. If a *TBee* method were to call one of those four methods, the compiler would replace the call with the address of one of *TBee*'s own methods.

If no method by a name is defined within an object type, the compiler goes up to the immediate ancestor type, and looks within that type for a method of the name called. If a method by that name is found, the address of the ancestor's method replaces the name in the descendant's method's source code. If no method by that name is found, the compiler continues up to the next ancestor, looking for the named method. If the compiler hits the very first (top) object type, it issues an error message indicating that no such method is defined.

But when a static inherited method is found and used, you must remember that the method called is the method exactly as it was defined *and compiled* for the ancestor type. If the ancestor's method calls other methods, the methods called are the ancestor's methods, even if the descendant has methods that override the ancestor's methods.

Virtual methods and polymorphism

The methods discussed so far are static methods. They are static for the same reason that static variables are static: The compiler allocates them and resolves all references to them *at compile time*. As you've seen, objects and static methods can be powerful tools for organizing a program's complexity.

Sometimes, however, they are not the best way to handle methods.

Problems like the one described in the previous section are due to the compile-time resolution of method references. The way out is to be dynamic—and resolve such references at run time. Certain special mechanisms must be in place for this to be possible, but Turbo Pascal provides those mechanisms in its support of virtual methods.

Important! ☞

Virtual methods implement an extremely powerful tool for generalization called polymorphism. *Polymorphism* is Greek for "many shapes," and it is just that: A way of giving an action one name that is shared up and down an object hierarchy, with each object in the hierarchy implementing the action in a way appropriate to itself.

The simplistic hierarchy of winged insects already described provides a good example of polymorphism in action, implemented through virtual methods.

Each object type in our hierarchy represents a different type of figure onscreen: a winged insect or a bee. It certainly makes sense to say that you can show a point on the screen, or show a circle.

Later on, if you were to define objects to represent other types of winged insects such as moths, dragonflies, butterflies, and so on, you could write a method for each that would display that object onscreen. In the new way of object-oriented thinking, you could say that all these insect types types had the ability to show themselves on the screen. That much they all have in common.

What is different for each object type is the *way* it must show itself to the screen. A bee requires stripes be drawn on its body, for example. Any winged insect type can be shown, but the mechanism by which each is shown is specific to each type. One word, "Show," is used to show (literally) many winged insects. Likewise, if we return to our payroll example, the word "GetPayAmount" calculates the amount of pay for several types of employees.

These are examples of what polymorphism is, and virtual methods are how it is done in Turbo Pascal.

Early binding vs. late binding

The difference between a static method call and a virtual method call is the difference between a decision made now and a decision delayed. When you code a static method call, you are in essence telling the compiler, "You know what I want. Go call it." Making a virtual method call, on the other hand, is like telling the compiler, "You don't know what I want—yet. When the time comes, ask the instance."

Think of this metaphor in terms of the *MoveTo* problem mentioned in the previous section. A call to *TBee.MoveTo* can go to only one place: the closest implementation of *MoveTo* up the object hierarchy. In that case, *TBee.MoveTo* would still call *TWinged's* definition of *MoveTo*, since *TWinged* is the closest up the hierarchy from *TBee*. Assuming that no descendant type defined its own *MoveTo* to override *TWinged's MoveTo*, any descendant type of *TWinged* would still call the same implementation of *MoveTo*. The decision can be made at compile time and that's all that needs to be done.

When *MoveTo* calls *Show*, however, it's a different story. Every figure type has its own implementation of *Show*, so which implementation of *Show* is called by *MoveTo* should depend entirely on what object instance originally called *MoveTo*. This is why the call to the *Show* method within the implementation of *MoveTo* must be a delayed decision: When the code for *MoveTo* is compiled, no decision as to which *Show* to call can be made. The information isn't available at compile time, so the decision has to be deferred until run time, when the object instance calling *MoveTo* can be queried.

The process by which static method calls are resolved unambiguously to a single method by the compiler at compile time is *early binding*. In early binding, the caller and the callee are connected (bound) at the earliest opportunity, that is, at compile time. With *late binding*, the caller and the callee cannot be bound at compile time, so a mechanism is put into place to bind the two later on, when the call is actually made.

The nature of the mechanism is interesting and subtle, and you'll see how it works a little later.

Object type compatibility

Inheritance somewhat changes Turbo Pascal's type compatibility rules. In addition to everything else, a descendant type inherits type compatibility with all its ancestor types. This extended type compatibility takes three forms:

- Between object instances
- Between pointers to object instances
- Between formal and actual parameters

In all three forms, however, it is critical to remember that type compatibility extends *only* from descendant to ancestor. In other words, descendant types can be freely used in place of ancestor types, but not vice versa.

In WORKERS.PAS, *TSalaried* is a descendant of *TEmployee*, and *TCommissioned* is a descendant of *TSalaried*. With this in mind, consider these declarations:

```
type
  PEmployee = ^TEmployee;
  PSalaried = ^TSalaried;
  PCommissioned = ^TCommissioned;

var
  AnEmployee: TEmployee;
  ASalaried: TSalaried;
  ACommissioned: TCommissioned;
  TEmployeePtr: PEmployee;
  TSalariedPtr: PSalaried;
  TCommissionedPtr: PCommissioned;
```

With these declarations, the following assignments are legal:

An ancestor object can be assigned an instance of any of its descendant types.

```
AnEmployee := ASalaried;
ASalaried := ACommissioned;
AnEmployee := ACommissioned;
```

The reverse assignments are not legal.

This is a concept new to Pascal, and it might be a little hard to remember, at first, which way the type compatibility goes. Think of it this way: *The source must be able to completely fill the destination.* Descendant types contain everything their ancestor types contain by virtue of inheritance. Therefore a descendant type is either exactly the same size or (usually) larger than its ancestors, but never smaller. Assigning an ancestor object to a descendant object could leave some of the descendant's fields undefined after the assignment, which is dangerous and therefore illegal.

In an assignment statement, only the fields that the two types have in common are copied from the source to the destination. In the assignment statement

```
AnEmployee := ACommissioned;
```

only the *Name*, *Title*, and *Rate* fields of *ACommissioned* are copied to *AnEmployee*, since *Name*, *Title*, and *Rate* are all that types *TCommissioned* and *TEmployee* have in common.

Type compatibility also operates between pointers to object types, under the same rule as for instances of object types: Pointers to descendants can be assigned to pointers to ancestors. These pointer assignments are also legal:

```
TSalariedPtr := TCommissionedPtr;
TEmployeePtr := TSalariedPtr;
TEmployeePtr := TCommissionedPtr;
```

Again, the reverse assignments are not legal.

A formal parameter (either value or **var**) of a given object type can take as an actual parameter an object of its own, or any descendant type. Given this procedure header,

```
procedure CalcFedTax(Victim: TSalaried);
```

actual parameters could legally be of type *TSalaried* or *TCommissioned*, but not type *TEmployee*. *Victim* could also be a **var** parameter; the same type compatibility rule applies.

Warning! ☞ However, keep in mind that there's a drastic difference between a value parameter and a **var** parameter: A **var** parameter is a pointer to the actual object passed as a parameter, whereas a value parameter is only a *copy* of the actual parameter. That copy, moreover, only includes the fields and methods included in the formal value parameter's type. This means the actual parameter is literally translated to the type of the formal parameter. A **var** parameter is more similar to a typecast, in that the actual parameter remains unaltered.

Similarly, if a formal parameter is a pointer to an object type, the actual parameter can be a pointer to that object type or a pointer to any of that object's descendant types. Given this procedure header,

```
procedure Worker.Add(AWorker: PSalaried);
```

actual parameters could legally be of type *PSalaried* or *PCommissioned*, but not type *PEmployee*.

Polymorphic objects

In reading the previous section, you might have asked yourself: If any descendant type of a parameter's type can be passed in the parameter, how does the user of the parameter know which object type it is receiving? In fact, the user does not know, not directly. The exact type of the actual parameter is unknown at compile time. It could be any one of the object types descended from the **var** parameter type and is thus called a *polymorphic object*.

Now, exactly what are polymorphic objects good for? Primarily, this: *Polymorphic objects allow the processing of objects whose type is not known at compile time.* This whole notion is so new to the Pascal way of thinking that an example might not occur to you immediately. (You'll be surprised, in time, at how natural it begins to seem.)

Suppose you've written a toolbox that draws numerous types of winged insects: butterflies, bees, moths, and so on. You want to write a routine that drags insects around the screen with the mouse pointer.

The old way would have been to write a separate drag procedure for each type of insect. You would have had to write *DragButterfly*, *DragBee*, *DragMoth*, and so on. Even if the strong typing of Pascal allowed it (and don't forget, there are always

ways to circumvent strong typing), the differences between the types of insects would seem to prevent a truly general dragging routine from being written.

After all, a bee has stripes and a stinger, a butterfly has large, colorful wings, a dragonfly has iridescent colors, arrgh....

At this point, clever Turbo Pascal hackers will step forth and say, do it this way: Pass the winged insect record to procedure *DragIt* as the referent of a generic pointer. Inside *DragIt*, examine a tag field at a fixed offset inside the winged insect record to determine what sort of insect it is, and then branch using a **case** statement:

```
case FigureIDTag of
  TBee          : DragBee;
  TButterfly    : DragButterfly;
  TDragonfly    : DragDragonfly;
  TMosquito     : DragMosquito;
   :
```

Well, placing seventeen small suitcases inside one enormous suitcase is a slight step forward, but what's the real problem with this way of doing things?

What if the user of your toolbox defines some new winged insect type?

What indeed? What if the user wants to work with Mediterranean fruitflies? Your program does not have a *TFruitfly* type, so *DragIt* would not have a *TFruitfly* label in its **case** statement, and would therefore refuse to drag the new *TFruitfly* figure. If it were presented to *DragIt*, *TFruitfly* would fall out in the **case** statement's **else** clause as an "unrecognized insect."

Plainly, building a toolbox of routines for sale without source code suffers from this problem: The toolbox can only work on data types that it "knows," that is, that are defined by the designers of the toolbox. The user of the toolbox is powerless to extend the function of the toolbox in directions unanticipated by the toolbox designers. What the user buys is what the user gets. Period.

The way out is to use Turbo Pascal's extended type compatibility rules for objects and design your application to use polymorphic objects and virtual methods. If a toolbox *DragIt* procedure is set up to work with polymorphic objects, it works with any objects defined within the toolbox—and any descendant objects that you define yourself. If the toolbox object types use virtual methods, the toolbox objects and routines can work with your custom winged insects figures *on the figures' own terms*. A virtual method you define today is callable by a toolbox .TPU unit file that was written and compiled a year ago. Object-oriented programming makes it possible, and virtual methods are the key.

Understanding how virtual methods make such polymorphic method calls possible requires a little background on how virtual methods are declared and used.

Virtual methods

A method is made virtual by following its declaration in the object type with the new reserved word **virtual**. Remember that if you declare a method in an ancestor type **virtual**, all methods of the same name in any descendant must also be declared **virtual** to avoid a compiler error.

Here are the employee objects you have seen in the previous payroll example, properly virtualized:

```
type
  PEmployee = ^TEmployee;
  TEmployee = object
    Name: string[25];
    Title: string[25];
    Rate: Real;
    constructor Init(AName, ATitle: String; ARate: Real);
    function GetPayAmount: Real; virtual;
    function GetName: String;
    function GetTitle: String;
    function GetRate: Real;
    procedure Show; virtual;
  end;

  PHourly = ^THourly;
  THourly = object(TEmployee)
    Time: Integer;
    constructor Init(AName, ATitle: String; ARate: Real; ATime:
      Integer);
    function GetPayAmount: Real; virtual;
    function GetTime: Integer;
  end;

  PSalaried = ^TSalaried;
  TSalaried = object(TEmployee)
    function GetPayAmount: Real; virtual;
  end;
```

```
PCommissioned = ^TCommissioned;
TCommissioned = object(TSalaried)
  Commission: Real;
  SalesAmount: Real;
  constructor Init(AName, ATitle: String;
    ARate, ACommission, ASalesAmount: Real);
  function GetPayAmount: Real; virtual;
end;
```

And here is the insect example, complete with virtual methods:

```
type
  TWinged = object(Insect)
    constructor Init(AX, AY: Integer)
    procedure Show; virtual;
    procedure Hide; virtual;
    procedure MoveTo(NewX, NewY: Integer);
  end;

type
  TBee=object(TWinged)
    constructor Init(AX, AY: Integer)
    procedure Show; virtual;
    procedure Hide; virtual;
  end;
```

Notice first of all that the *MoveTo* method shown of type *TBee* is gone from *Bee's* type definition. *TBee* no longer needs to override *TWinged's* *MoveTo* method with an unmodified copy compiled within its own scope. Instead, *MoveTo* can now be inherited from *TWinged*, with all *MoveTo's* nested method calls going to *TBee's* methods rather than *TWinged's*, as happens in an all-static object hierarchy.

We suggest the use of the identifier Init for object constructors.

Also, notice the new reserved word **constructor** replacing the reserved word **procedure** for *TWinged.Init* and *TBee.Init*. A constructor is a special type of method that does some of the setup work for the machinery of virtual methods.

Warning! *Every object type that has virtual methods must have a constructor.*

☞ The constructor must be called before any virtual method is called. Calling a virtual method without previously calling the constructor can cause system lockup, and the compiler has no way to check the order in which methods are called.

☞ Each individual instance of an object must be initialized by a separate constructor call. It is not sufficient to initialize one instance of an object and then assign that instance to additional instances. The additional instances, while they might contain correct data, are not initialized by the assignment statements, and lock up the system if their virtual methods are called. For example

```
var
  FBee, GBee: TBee;                    { create two instances of TBee }

begin
  FBee.Init(5, 9);                     { call constructor for FBee }
  GBee := FBee;                               { GBee is not valid! }
end.
```

What do constructors construct? Every object type has something called a *virtual method table* (VMT) in the data segment. The VMT contains the object type's size and, for each of its virtual methods, a pointer to the code implementing that method. What the constructor does is establish a link between the instance calling the constructor and the object type's VMT.

That's important to remember: There is only one virtual method table for each object type. Individual instances of an object type (that is, variables of that type) contain a link to the VMT—they do not contain the VMT itself. The constructor sets the value of that link to the VMT—which is why you can launch execution into nowhere by calling a virtual method before calling the constructor.

Range checking virtual method calls

The default state of $R is inactive, {$R-}.

During program development, you might wish to take advantage of a safety net that Turbo Pascal places beneath virtual method calls. If the **$R** toggle is in its active state, {**$R+**}, all virtual method calls are checked for the initialization status of the instance making the call. If the instance making the call has not been initialized by its constructor, a range check run-time error occurs.

Once you've shaken out a program and are certain that no method calls from uninitialized instances are present, you can speed your code up somewhat by setting the **$R** toggle to its inactive state, {**$R-**}. Method calls from uninitialized instances will no longer be checked for, and will probably lock up your system if they're found.

Once virtual, always virtual

Notice that both *TWinged* and *TBee* have methods named *Show* and *Hide*. All method headers for *Show* and *Hide* are tagged as virtual methods with the reserved word **virtual**. Once an ancestor object type tags a method as **virtual**, all its descendant types that implement a method of that name must tag that method **virtual** as well. In other words, a static method can never override a virtual method. If you try, a compiler error results.

You should also keep in mind that the method heading cannot change in *any* way downward in an object hierarchy once the method is made virtual. You might think of each definition of a virtual method as a gateway to *all* of them. For this reason, the headers for all implementations of the same virtual method must be identical, right down to the number and type of parameters. This is not the case for static methods; a static method overriding another can have different numbers and types of parameters as necessary.

It's a whole new world.

Object extensibility

The important thing to notice about units like WORKERS.PAS is that the object types and methods defined in the unit can be distributed to users in linkable .TPU form only, without source code. (Only a listing of the interface portion of the unit need be released.) Using polymorphic objects and virtual methods, the users of the .TPU file can still add features to it to suit their needs.

This novel notion of taking someone else's program code and adding functionality to it *without benefit of source code* is called *extensibility*. Extensibility is a natural outgrowth of inheritance: You inherit everything that all your ancestor types have, and then you add what new capability you need. Late binding lets the new meld with the old at run time, so the extension of the existing code is seamless and costs you no more in performance than a quick trip through the virtual method table.

Static or virtual methods

In general, you should make methods virtual. Use static methods only when you want to optimize for speed and memory efficiency. The tradeoff, as you've seen, is in extensibility.

Let's say you are declaring an object named *Ancestor*, and within *Ancestor* you are declaring a method named *Action*. How do you decide whether *Action* should be virtual or static? Here's the rule of thumb: Make *Action* virtual if there is a possibility that some future descendant of *Ancestor* will override *Action*, and you want that future code to be accessible to *Ancestor*.

On the other hand, remember that if an object has any virtual methods, a VMT is created for that object type in the data segment and every object instance has a link to the VMT. Every call to a virtual method must pass through the VMT, while static methods are called directly. Though the VMT lookup is very efficient, calling a method that is static is still a little faster than calling a virtual one. And if there are no virtual methods in your object, then there is no VMT in the data segment and—more significantly—no link to the VMT in every object instance.

The added speed and memory efficiency of static methods must be balanced against the flexibility that virtual methods allow: extension of existing code long after that code is compiled. Keep in mind that users of your object type might think of ways to use it that you never dreamed of, which is, after all, the whole point.

Dynamic objects

All the object examples shown so far have had static instances of object types that were named in a **var** declaration and allocated in the data segment and on the stack.

The use of the word static here does not relate in any way to static methods.

```
var
  ASalaried: TSalaried;
```

Objects can be allocated on the heap and manipulated with pointers, just as the closely related record types have always been in Pascal. Turbo Pascal includes some powerful extensions to make dynamic allocation and deallocation of objects easier and more efficient.

Objects can be allocated as pointer referents with the *New* procedure:

```
var
  CurrentPay: Real;
  P: ^TSalaried;

New(P);
```

As with record types, *New* allocates enough space on the heap to contain an instance of the pointer's base type, and returns the address of that space in the pointer.

If the dynamic object contains virtual methods, it must then be initialized with a constructor call before any calls are made to its methods:

```
P^.Init('Sara Adams', 'Account manager', 2400);
```

Method calls can then be made normally, using the pointer name and the reference symbol ^ (a caret) in place of the instance name that would be used in a call to a statically allocated object:

```
CurrentPay := P^.GetPayAmount;
```

Allocation and initialization with New

Turbo Pascal extends the syntax of *New* to allow a more compact and convenient means of allocating space for an object on the heap and initializing the object with one operation. *New* can now be invoked with two parameters: the pointer name as the first parameter, and the constructor invocation as the second parameter:

```
New(P, Init('Sara Adams', 'Account manager', 2400));
```

When you use this extended syntax for *New*, the constructor *Init* actually performs the dynamic allocation, using special entry code generated as part of a constructor's compilation. The instance name cannot precede *Init*, since at the time *New* is called, the instance being initialized with *Init* does not yet exist. The compiler identifies the correct *Init* method to call through the type of the pointer passed as the first parameter.

New has also been extended to allow it to act as a function returning a pointer value. The parameter passed to *New* is the *type* of the pointer to the object rather than the pointer variable itself:

```
type
  PSalaried = ^TSalaried;

var
  P: PSalaried;

P := New(PSalaried);
```

Note that with this version, the function-form extension to *New* applies to *all* data types, not only to object types.

The function form of *New*, like the procedure form, can also take the object type's constructor as a second parameter:

Fail helps you do error recovery in constructors; see the section "Constructor error recovery" in Chapter 9 of the Language Guide.

```
P := New(PSalaried, Init('Sara Adams', 'Account manager',
  2400));
```

A parallel extension to *Dispose* has been defined for Turbo Pascal, as fully explained in the following sections.

Disposing dynamic of objects

Just like traditional Pascal records, objects allocated on the heap can be deallocated with *Dispose* when they are no longer needed:

```
Dispose(P);
```

There can be more to getting rid of an unneeded dynamic object than just releasing its heap space, however. An object can contain pointers to dynamic structures or objects that need to be released or "cleaned up" in a particular order, especially when elaborate dynamic data structures are involved. Whatever needs to be done to clean up a dynamic object in an orderly fashion should be gathered together in a single method so that the object can be eliminated with one method call:

```
MyComplexObject.Done;
```

We suggest the identifier Done for cleanup methods that "close up shop" once an object is no longer needed.

The *Done* method should encapsulate all the details of cleaning up its object and all the data structures and objects nested within it.

It is legal and often useful to define multiple cleanup methods for a given object type. Complex objects might need to be cleaned up in different ways depending on how they were allocated or used, or depending on what mode or state the object was in when it was cleaned up.

Destructors

Turbo Pascal provides a special type of method called a *destructor* for cleaning up and disposing of dynamically allocated objects. A destructor combines the heap deallocation step with whatever other tasks are necessary for a given object type. As with any method, multiple destructors can be defined for a single object type.

A destructor is defined with all the object's other methods in the object type definition:

```
type
  TEmployee = object
    Name: string[25];
    Title: string[25];
    Rate: Real;
    constructor Init(AName, ATitle: String; ARate: Real);
    destructor Done; virtual;
    function GetName: String;
    function GetTitle: String;
    function GetRate: Rate; virtual;
    function GetPayAmount: Real; virtual;
  end;
```

Destructors can be inherited, and they can be either static or virtual. Because different shutdown tasks are usually required for different object types, it is a good idea *always* to make destructors virtual, so that in every case the correct destructor is executed for its object type.

Keep in mind that the reserved word **destructor** is not needed for every cleanup method, even if the object type definition contains virtual methods. Destructors really operate only on dynamically allocated objects. In cleaning up a dynamically allocated object, the destructor performs a special service: It guarantees that the correct number of bytes of heap memory are always released. There is, however, no harm in using destructors with statically allocated objects; in fact, by not giving an object type a destructor, you prevent objects of that type from getting the full benefit of Turbo Pascal's dynamic memory management.

Destructors really come into their own when polymorphic objects must be cleaned up and their heap allocation released. A polymorphic object is an object that has been assigned to an ancestor type by virtue of Turbo Pascal's extended type compatibility rules. An instance of object type *THourly* assigned to a variable of type *TEmployee* is an example of a polymorphic object. These rules govern pointers to objects as well; a pointer to *THourly* can be freely assigned to a pointer to type *TEmployee*, and the referent of that pointer is also a polymorphic object.

The term *polymorphic* is appropriate because the code using the object doesn't know at compile time precisely what type of object is on the end of the string—only that the object is one of a hierarchy of objects descended from the specified type.

The size of object types differ, obviously. So when it comes time to clean up a polymorphic object allocated on the heap, how does

Dispose know how many bytes of heap space to release? No information on the size of the object can be gleaned from a polymorphic object at compile time.

The destructor solves the problem by going to the place where the information *is* stored: in the instance variable's VMT. In every object type's VMT is the size in bytes of the object type. The VMT for any object is available through the invisible *Self* parameter passed to the method on any method call. A destructor is just a special kind of method, and it receives a copy of *Self* on the stack when an object calls it. So while an object might be polymorphic at *compile time,* it is never polymorphic at run time, thanks to late binding.

To perform this late-bound memory deallocation, the destructor must be called as part of the extended syntax for the *Dispose* procedure:

```
Dispose(P, Done);
```

(Calling a destructor outside of a *Dispose* call does no automatic deallocation at all.) What happens here is that the destructor of the object pointed to by *P* is executed as a normal method call. As the last thing it does, however, the destructor looks up the size of its instance type in the instance's VMT, and passes the size to *Dispose*. *Dispose* completes the shutdown by deallocating the correct number of bytes of heap space that had previously belonged to *P^*. The number of bytes released is correct whether *P* points to an instance of type *TSalaried* or to one of *TSalaried*'s descendant types like *TCommissioned*.

Note that the destructor method itself can be empty and still perform this service:

```
destructor AnObject.Done;
begin
end;
```

What performs the useful work in this destructor is not the method body but the epilog code generated by the compiler in response to the reserved word **destructor**. In this, it is similar to a unit that exports nothing, but performs some "invisible" service by executing an initialization section before program startup. The action is all behind the scenes.

An example of dynamic object allocation

The WORKLIST.PAS example program that came on your distribution diskettes provides some practice in the use of objects allocated on the heap, including the use of destructors for object deallocation. The program shows how a linked list of worker objects might be created on the heap and cleaned up using destructor calls when they are no longer required.

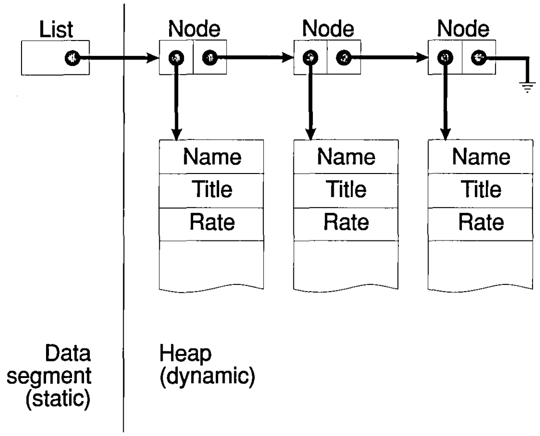
Building a linked list of objects requires that each object contain a pointer to the next object in the list. Type *TEmployee* contains no such pointer. The easy way out would be to add a pointer to *TEmployee*, and in doing so ensure that all *TEmployee*'s descendant types also inherit the pointer. However, adding anything to *TEmployee* requires that you have the source code for *TEmployee*, and as said earlier, one advantage of object-oriented programming is the ability to extend existing objects without necessarily being able to recompile them.

The solution that requires no changes to *TEmployee* creates a new object type not descended from *TEmployee*. Type *TStaffList* is a very simple object whose purpose is to head up a list of *TEmployee* objects. Because *TEmployee* contains no pointer to the next object in the list, a simple record type, *TNode*, provides that service. *TNode* is even simpler than *TStaffList*, in that it is not an object, has no methods, and contains no data except a pointer to type *TEmployee* and a pointer to the next node in the list.

TStaffList has a method that allows it to add new workers to its linked list of *TNode* records by inserting a new instance of *TNode* immediately after itself, as a referent to its TNodes pointer field. The *Add* method takes a pointer to an *TEmployee* object, rather than an *TEmployee* object itself. Because of Turbo Pascal's extended type compatibility, pointers to any type descended from *TEmployee* can also be passed in the *Item* parameter to *TStaffList.Add*.

Program *WorkList* declares a static variable, *Staff*, of type *TStaffList*, and builds a linked list with five nodes. Each node points to a worker object that is one of *TEmployee*'s descendants. The number of bytes of free heap space is reported before any of the dynamic objects are created, and then again after all have been created. Finally, the whole structure, including the five *TNode* records and the five *TEmployee* objects, are cleaned up and removed from the heap with a single destructor call to the static *TStaffList* object, *Staff*.

Figure 8.2
Layout of program WorkList's data structures



Disposing of a complex data structure on the heap

This destructor, *Staff.Done*, is worth a close look. Shutting down a *TStaffList* object involves disposing of three different kinds of structures: the polymorphic worker objects in the list, the *TNode* records that hold the list together, and (if it is allocated on the heap) the *TStaffList* object that heads up the list. The whole process is invoked by a single call to *TStaffList*'s destructor:

```
Staff.Done;
```

The code for the destructor merits examination:

```
destructor TStaffList.Done;
var
  N: TNodePtr;
begin
  while TNodes <> nil do
  begin
    N := TNodes;
    Dispose(N^.Item, Done);
    TNodes := N^.Next;
    Dispose(N);
  end;
end;
```

The list is cleaned up from the list head by the "hand-over-hand" algorithm, metaphorically similar to pulling in the string of a kite: Two pointers, the *TNodes* pointer within *Staff* and a working pointer *N*, alternate their grasp on the list while the first item in the list is disposed of. A dispose call deallocates storage for the first *TEmployee* object in the list (*Item^*); then *TNodes* is advanced to the next *TNode* record in the list by the statement `TNodes := N^.Next`; the *TNode* record itself is deallocated; and the process repeats until the list is gone.

The important thing to note in the destructor *Done* is the way the *TEmployee* objects in the list are deallocated:

```
Dispose(N^.Item,Done);
```

Here, *N^.Item* is the first *TEmployee* object in the list, and the *Done* method called is its destructor. Keep in mind that the actual type of *N^.Item^* is not necessarily *TEmployee*, but could as well be any descendant type of *TEmployee*. The object being cleaned up is a polymorphic object, and no assumptions can be made about its actual size or exact type at compile time. In the earlier call to *Dispose*, once *Done* has executed all the statements it contains, the "invisible" epilog code in *Done* looks up the size of the object instance being cleaned up in the object's VMT. *Done* passes that size to *Dispose*, which then releases the exact amount of heap space the polymorphic object actually occupied.

Remember that polymorphic objects must be cleaned up this way, through a destructor call passed to *Dispose*, if the correct amount of heap space is to be reliably released.

In the example program, *Staff* is declared as a static variable in the data segment. *Staff* could as easily have been itself allocated on the heap, and anchored to reality by a pointer of type *TStaffListPtr*. If the head of the list had been a dynamic object too, disposing of the structure would have been done by a destructor call executed within *Dispose*:

```
var
  Staff: TStaffListPtr;
   ⋮
Dispose(Staff, Done);
```

Here, *Dispose* calls the destructor method *Done* to clean up the structure on the heap. Then, once *Done* is finished, *Dispose* deallocates storage for *Staff*'s referent, removing the head of the list from the heap as well.

WORKLIST.PAS (on your disk) uses the same WORKERS.PAS unit described on page 154. It creates a *List* object heading up a linked list of five polymorphic objects compatible with *TEmployee*, produces a payroll report, and then disposes of the whole dynamic data structure with a single destructor call to *Staff.Done*.

Where to now?

As with any aspect of computer programming, you don't get better at object-oriented programming by reading about it; you get better at it by doing it. Most people, on first exposure to object-oriented programming, are heard to mutter "I don't get it" under their breath. The "Aha!" comes later, when in the midst of putting their own objects in place, the whole concept comes together in the sort of perfect moment we used to call an epiphany. Like the face of woman emerging from a Rorschach inkblot, what was obscure before at once becomes obvious, and from then on it's easy.

The best thing to do for your first object-oriented project is to take the WORKERS.PAS unit (you have it on disk) and extend it. Once you've had your "Aha!," start building object-oriented concepts into your everyday programming chores. Take some existing utilities you use every day and rethink them in object-oriented terms. Take another look at your hodgepodge of procedure libraries and try to see the objects in them—then rewrite the procedures in object form. You'll find that libraries of objects are much easier to reuse in future projects. Very little of your initial investment in programming effort will ever be wasted. You will rarely have to rewrite an object from scratch. If it will serve as is, use it. If it lacks something, extend it. But if it works well, there's no reason to throw away any of what's there.

Conclusion

Object-oriented programming is a direct response to the complexity of modern applications, complexity that has often made many programmers throw up their hands in despair. Inheritance and encapsulation are extremely effective means for managing complexity. (It's the difference between having ten thousand insects classified in a taxonomy chart, and ten thousand insects all buzzing around your ears.) Far more than structured programming, object-orientation imposes a rational order on software structures that, like a taxonomy chart, imposes order without imposing limits.

Add to that the promise of the extensibility and reusability of existing code, and the whole thing begins to sound almost too good to be true. Impossible, you think?

Hey, this is Turbo Pascal. "Impossible" is undefined.

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