The Terrapin Logo Language for the Apple II

TUTORIAL

12345 T5

Congratulations!

You have just purchased the new 3.0 Release of the Terrapin Logo Language for the Apple II family of Computers. Your Logo Language disk contains both 64K and 128K versions. The correct version will be loaded depending on the machine being used. This loading technique is automatic and requires no special input from the user. In addition, loading time is significantly less than in earlier versions.

For those using 128K systems, there have been no functional changes to the Terrapin Logo Language other than the additional memory now available in your workspace. A few points worth mentioning before using the new dual version are as follows:

* You will notice that garbage collection requires more time when 128K is being used due to the increased workspace.

* 128K Logo has approximately three times more storage space available to the user. The error message "NO STORAGE LEFT!" will not appear as frequently, if at all.

* Entering the editor does not affect the contents of the graphics screen.

* Using the Logo command DRAW does not affect the contents of the editor.

New Logo Primitive for Version 3.0: SHOWTEXT

Terrapin has created a new Logo primitive for version 3.0 known as **SHOWTEXT**. This primitive can be used when creating text files in Logo and using Logo as a text editor. Refer to pages A-26 to A-29 in the Appendix and Chapter 7 of the technical manual for further information on creating text files.

SHOWTEXT	Prints the contents of the edit buffer to the current output device, which is normally the video screen. Use OUTDEV to redirect output to a printer.

NOTE: This new primitive is not documented elsewhere in the manual.

The Terrapin Logo Language for the Apple II

TUTORIAL

Written by
Virginia Carter Grammer
and
E. Paul Goldenberg

Edited by
Mark Eckenwiler
and
Peter von Mertens

Please fill this out for your records:

Name _____

Address _____

_____

Telephone ( ) _____

Logo Language Disk # _____

Purchase Date _____

Store Bought _____

Store Telephone Number _____

Salesperson _____

Terrapin, Inc. gratefully acknowledges the writing and editing contributions to this tutorial by

Leigh Klotz, Jr.
J. Sheridan McClees
Nola Sheffer
Patrick G. Sobalvarro
Deborah G. Tatar
Rena Upitis

Designed by Donna Albano and Janet Mumford

Terrapin Logo mascots designed by Virginia Grammer

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IMPORTANT—PLEASE READ

Welcome to Terrapin™ Logo. The Logo language is an exciting way of entering the world of computers. There are all kinds of fun things to do—you can create graphics, play word games, make music and learn how to write fascinating programs.

The items which should be included in this package are listed on page B-1. If you run into a problem, our customer service department is always here to help. Our address is: 222 Third Street, Cambridge, MA 02142. You may call us Monday-Friday between 9:00 AM-4:30 PM EST at: (617) 492-8816. **When contacting our customer service department, always have your language disk serial number available.** However, in the interest of giving Ma Bell and the Post Office less business, **please read these first four pages carefully.** They contain the information most often requested by our users. The third and fourth pages contain helpful information for printing your Logo generated graphics.

Backup and Replacement Policy

The Terrapin Logo language disk is copy-protected. Attempts to duplicate it may result in permanent damage! Company policy allows you, the owner to purchase one backup disk per Logo package. However to obtain a backup, you *must* send in your completed warranty card along with $15.00 to Terrapin. An order form is not necessary—save it for ordering books. Owners of TerraPak 10's and TerraPak 20's are not eligible for backup Language disks.

Your Utilities disk is copyable. Instructions for copying the disk can be found on page B-2 in the tutorial.

Outside the 90-day warranty period, replacement disks are available by returning your damaged disk and $15.00. There will be a higher fee for any major update. Please write your name and address on the disk label. We suggest all disks be sent via registered mail; we are not responsible for disks lost in transit to us.

We cannot stress enough the importance of returning your completed warranty card immediately. This allows us to keep you informed of upgrades and new Terrapin products. It also registers you for the 90-day warranty period, the terms of which are attached to your warranty card.

In addition to offering a quality product and superior customer support, Terrapin also carries a variety of Logo resources to further enhance your use of the language. Several of these publications are difficult to find elsewhere. Please examine the Terrapin price list inserted in the binder's inside pocket. If it is missing, contact us and we'll be happy to send you another.

Versions of Terrapin Logo

These books are compatible with all versions of Terrapin Logo. However, please note that these books may not reflect the changes in our upgraded versions, 2.0 or higher. The version number is printed out on the screen as part of the Welcome message when you start Logo or type Goodbye. Versions 1.0 to 1.3 had disk labels with green lettering on a white background. Version 2.0 has white lettering on a green background.

Differences in Terrapin Logo Versions

A complete list of the modifications appears in the beginning of the Technical Manual. The most important change to be aware of is <CTRL> K has been changed to <CTRL> X. Please remember this because many books on Terrapin Logo still say that <CTRL> K is used to delete a line instead of <CTRL> X.

IMPORTANT PRINTING INFORMATION

The majority of our customers' queries concern printing their Logo graphics. Please realize that it is difficult for Terrapin to keep current with all the new printers and various hardware interfaces that are continually being developed. Your dealer is the best source of information on different printers and interfaces. Answers to some of these most common questions are listed below.

QUESTION: How do I print pictures?

ANSWER: 1. If you have an Epson printer (or similar model printer that receives data from a parallel port) you must have an extra piece of hardware which is compatible with your printer (e.g. Grappler+ card, PKASO, etc.) to print pictures directly from Logo. Printing instructions can be found on pages 16-19 of the Technical Manual included in your Logo package. If you do not have this extra hardware, there are instructions on pages 16-19 for printing pictures from outside of Logo with software only.

2. If you have an Imagewriter or Scribe printer which receives data serially, the above mentioned interface cards will not work. In order to print graphics on these printers you must have a software program. Terrapin has released a new utilities disk—**Utilities II**— which will allow you to dump graphics onto your printer while remaining within Logo.

This feature is only one of 29 new files offered on the **Utilities II** disk. Another file gives you the capability of placing text on the graphics screen. You may obtain the **Utilities II** disk for $19.95 by either contacting your dealer or Terrapin. Complete documentation accompanies this disk.

3. Make sure the OUTDEV command is followed by the number that corresponds with the slot the printer interface card is in. (Slots in the Apple II+ start with slot 0 from left to right—the Apple IIe starts with slot 1 from left to right.)

4. The HC program on page 18 of the Technical Manual is written for Orange Micro's Grappler printer interface card. HC can be used for other printer interfaces if modified slightly. There are too many interfaces being sold for us to list programs for each. However, changing the program to work with your printer interface card is relatively easy. The CHAR 9 and the "G in line two of the program are control characters that tell the Grappler interface card what to do with the screen image. The manual for each interface card will have a list of its own control codes. Use the appropriate control codes for your interface in place of the CHAR 9 and "G. (CHAR is used in Logo to print ASCII characters. CHAR 9 actually means <CTRL> I. There is no way to put double keystroke characters such as <SHIFT> or <CTRL> into a Logo command without using the ASCII representation. If your interface card needs something besides <CTRL> I, there is an ASCII translation table in your Apple Reference Manual.)

QUESTION: I have the **Utilities II** disk but the Imagewriter will not print out pictures. What should I do?

ANSWER: Check all the DIP switches. We have found this to be a common source of people's problems. There are 12 DIP switches on the Imagewriter and 16 DIP switches on the Apple Super Serial Card. Check your manuals for the proper dip switch settings.

QUESTION: Why does my Scribe or Imagewriter printer write over itself when printing out long procedure lines from the editor?

ANSWER: Apple's Super Serial Card has a different default setting than most interface cards and will not do an automatic line feed when it gets to the end of a line. To change this, type:

```
OUTDEV 1
(PRINT1 CHAR 9 "C CHAR 13)
OUTDEV 0
```

This will change the Serial Card setting so that it does the line feed. (OUTDEV 1 assumes that the card is in slot 1.)

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Each school purchasing and putting into use Logo will make the program object code and accompanying manuals and teaching guides, if any, available for inspection by the parents or guardians of the children who will be using Logo in the school.

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All references to "Logo" herein refer to the Logo language, developed at the Massachusetts Institute of Technology.

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BEGINNING IN LOGO

B BEGINNING IN LOGO

Your Terrapin Logo Package

NOTE: This section should be read the first time you use your Logo package. If you have used Terrapin Logo before, or have a resource person or teacher helping you, skip to the next section, titled This Tutorial.

In your Terrapin Logo package, you will find:

1 Logo Language disk
1 Utilities Disk containing demonstration and utility programs
1 Documentation Manual containing
  1 Terrapin Logo Tutorial, which you are now reading, and
  1 Technical Manual

In order to use Logo, you will also need:

An Apple II+ (or Apple II) with 48K of RAM, and a 16K memory card such as the Apple Language Card, Microsoft, MPC, or Davong RamCard
  or
An Apple IIe or IIc
  or
An Apple-compatible computer
One disk drive, with controller

To save your work, you will need a blank disk.

Before using your Utilities Disk, you should make a backup copy because it is possible to damage or erase the Utilities Disk accidentally.

To copy the Utilities Disk, you will need the System Master disk that came with your disk drive and a second blank disk. Use the COPYA program on the DOS 3.3 System Master disk.

It is assumed that your Apple is set up with the disk controller plugged into slot 6 and the memory card (if any) in slot 0.

This Tutorial

This tutorial will teach you how to use Logo. The Technical Manual is a reference document that contains descriptions of Logo primitives with explanations of what they do, and information about assembly language interfaces for Logo and the internal workings of Logo. You need not read it to start using Logo, but you will find it useful when you are ready for new challenges.

Other books you may wish to read include MINDSTORMS: Children, Computers, and Powerful Ideas, by Seymour Papert, LOGO FOR THE APPLE II, by Harold Abelson, which will help you to continue to grow in your use of Logo, TURTLE GEOMETRY, by Harold Abelson and Andrea diSessa, which is awaiting the day that you think you have done all there is to do in Logo, and SPECIAL TECHNOLOGY FOR SPECIAL CHILDREN, by E. Paul Goldenberg, which discusses uses of the computer in special needs environments.

Once you are comfortable with your Apple, use this tutorial to learn the basics of programming in Logo. Type in the examples and problems. Think about what

you are doing; expect to go over some sections more than once.

Logo puts the user in control from the start. In keeping with that philosophy, this tutorial will suggest but not dictate. If you are ever really stuck for an idea, see the Appendix. It contains examples of all the ideas suggested. In fact, after you try things on your own, look through the Appendix for new ideas and tips and tricks.

In this tutorial you will meet three Logo mascots, all drawn with Logo. The elephant marks Things to Remember. The rabbit points out neat tricks, short cuts, and quicker ways of doing things. Go slow and be careful when you see the snail. It calls attention to warnings and possible problems. The procedures that draw the mascots are listed in the Appendix.

We have also put some information between light green bands and shifted them to the right on the page. It is not necessary to read this information your first time through the tutorial, but you will find it helpful when you return and want further explanations of specific sections.

Overview: What Can You Do with Logo?

Logo is a procedural language. Each procedure is a group of one or more instructions which the computer can store for reuse. These instructions can be either Logo commands or procedure names. When you have written a procedure to do a task, you can use it in any other procedure you write, without having to rewrite its instructions in that procedure, or having to chain to it, or link it.

You build a system of procedures the way you build your own knowledge base, new procedures and knowledge using and building on what is already in existence. This leads to clearer, more structured thinking and programming, in contrast to the development of one long, complicated procedure (program) which is common in some other languages.

Logo is what is known as an interpretive language. Logo commands produce immediate results. Logo can either execute a command immediately (called IMMEDIATE Mode) or you can use commands in procedures which can be stored and used as often as you want. Changing or correcting (editing) a procedure is simple in Logo.

If you are familiar with other languages, you will be delighted with the lack of distinction between system commands, Logo primitives, and procedures. This is perhaps the most unusual aspect of Logo, and one of the most powerful, from the user's standpoint. Any command you can type to Logo can be used within a Logo procedure. Logo procedures can even be written to edit themselves, or other procedures.

You can begin to use all of the different types of commands immediately. As you advance in your programming skills, you will gradually discover the vast possibilities this opens to you.

Graphics

Logo graphics allows you to draw lines and turn in any direction. With its simple commands you may create figures and drawings of great complexity. In Logo

you do not have the tedious task of figuring point to point co-ordinates, although Logo can tell you the co-ordinates at any position.

Graphics is first in this tutorial because you need no experience to be able to use it. Pre-schoolers, using the single-letter commands in the INSTANT system, can do Logo graphics. At the other end of the intellectual spectrum, Professors Harold Abelson and Andrea di-Sessa, at M.I.T., use Logo graphics to develop concepts in higher mathematics and physics in their book Turtle Geometry: The Computer as a Medium for Exploring Mathematics.

Computation

In addition to the ordinary mathematical computations all languages can handle, Logo's built-in ability to do recursion, which allows a procedure to use itself as a subprocedure, makes it easy to do computations not possible in languages such as BASIC and FORTRAN. You will meet recursion in each of the areas of Logo described in this overview. For a description of mathematical computation, see the chapter titled Computation: Handling Numbers.

Words and Lists

Logo's facility with words and lists makes it ideal for writing conversational programs, quizzes, pig-Latin translators, programs that teach, and even programs that learn: in short, all programs that need to manipulate lists of information.

Logo's unique list-processing capabilities give you power over words which is impossible to match in non-list-processing languages such as BASIC, FORTRAN, and Pascal. See the chapter titled Words and Lists for what Logo can do and what you can do with it.

Music

Using only the Apple, Logo makes it easy for you to write tunes and pieces of tunes, or play games with pitch, time, and sequencing of phrases. On a more advanced level, you can define your own scales, still working with Logo primitives. See the chapter titled Music for details.

Preparing a Blank Disk for Use

NOTE: It is possible to run Logo without a disk in the disk drive, but you would not be able to save your work. We encourage you to prepare a blank disk for storing the procedures you will be writing.

A blank disk, unlike an audio cassette tape, must be prepared before it can store information. This process is called initializing (or formatting) the disk.

You can use your Logo Utilities Disk briefly to initialize a blank disk.

To initialize a disk on the Apple:

1. Place the Logo Utilities disk in the disk drive and then turn on the Apple. (See the next section, "Starting Logo," if you are not familiar with your computer.)

2. When the red light on the disk drive goes out, remove the Utilities disk from the disk drive and put it away in a safe place for future use.

WARNING: BE SURE THE LOGO UTILITIES DISK IS REMOVED FROM THE DISK DRIVE and replaced with a blank disk before proceeding. When you type INIT HELLO, the disk in the disk drive will be erased. DO NOT TYPE INIT HELLO with your LOGO UTILITIES DISK in the disk drive.

3. The screen will show the following message:

TERRAPIN LOGO FILES DISKETTE

THIS DISKETTE CONTAINS LOGO PROGRAMS. YOU MUST BE RUNNING LOGO ON YOUR APPLE TO USE THESE PROGRAMS.

Insert the blank disk you want to initialize into the disk drive, type

INIT HELLO

and press the <RETURN> key. The disk drive will whir for almost a minute, then the Apple prompt (]) will appear on the screen and the light will go out on the disk drive.

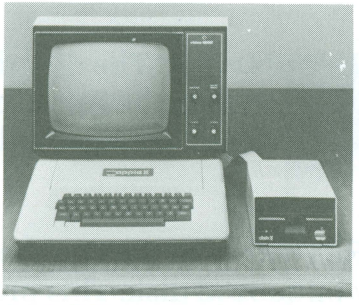
4. Type PR#6 <RETURN> to start up the system using your newly initialized disk. This produces the same results as turning the Apple off and on again. The disk drive should spin and the message shown in step 3 above should appear on the screen. (This checks that the disk really did get initialized.)

Remove this disk from the disk drive, label it immediately, and use it to store your Logo procedures. We will refer to it again in the section When Logo Has Started Up later in this chapter.

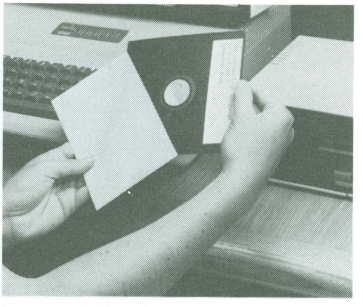
More information about initializing disks is in the Logo Technical Manual in the File System section titled Configuring File Diskettes (page 23) and in the Apple DOS manual, page 13. BASIC programs and Logo procedures can be stored on the same disk.

Starting Logo

One of the disks packaged with your system is called the Language Disk. It is the disk with the Logo interpreter on it. The other disk, labeled Utilities Disk contains some demonstration and utility programs. They are mentioned where appropriate in the tutorial and summarized and cross-referenced in the Appendix.

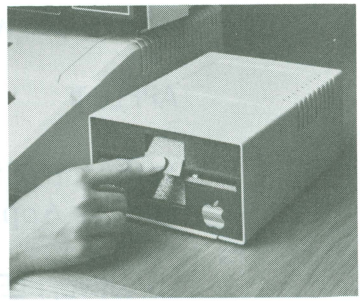


Apple II Plus with Disk Drive and Monitor



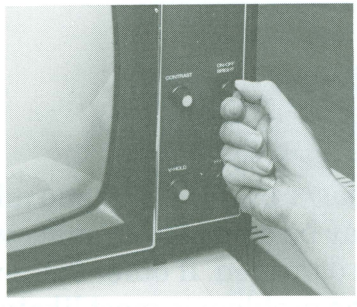
Language Disk

(1)

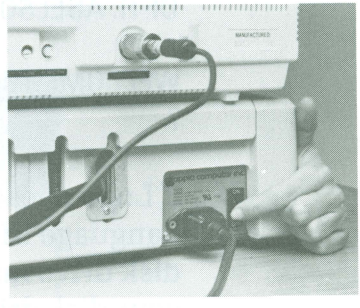


(2)

With the Apple turned off, (1) place the Language Disk in your disk drive with the label facing up and closest to the front. (2) Close the disk drive door firmly. (3) Turn on the monitor. (4) Turn on the Apple. The on-off switch is on the back at the left as you face the machine. (Users of Apple IIs without AutoStart ROM should (A) press <RETURN>, (B) type the number 6, (C) hold down the <CTRL> key and press P, and (D) press the <RETURN> key again.)



(3)



(4)

The Apple will print the message

APPLE][

at the top of its screen, the disk drive light will go on, and the Apple will print

LOADING, PLEASE WAIT...

If this message does not appear, check to be sure that you are using the Language Disk and that the disk drive door is firmly closed.

It takes about 30 seconds to load and start Logo. When it has started, Logo will print this brief message:

```
THE TERRAPIN LOGO LANGUAGE

WRITTEN BY L. KLOTZ, P. SOBALVARRO
AND S. HAIN UNDER THE SUPERVISION
OF H. ABELSON

WELCOME TO LOGO
?
```

If Logo does not start up after about one minute, your Language Disk may be damaged in some way, or your disk drive may be damaged. If other disks work on your disk drive, the problem is most likely with your 16K Memory card or your Language Disk. If you have only 48K instead of the required 64K of memory, you will get a message saying you do not have a language card.

When Logo Has Started Up

Logo will print its WELCOME TO LOGO message and a ? when it is ready for you. The ? is called a prompt, prompting you to respond with a Logo command. The flashing box is called the cursor. It shows you where the next character you type will appear. Whenever the cursor is flashing, Logo is waiting for you to type something.

(This would be a good time to remove the Logo Language Disk from the disk drive, put it in a safe place, and replace it with the blank disk you have initialized and will be using to store your Logo procedures.)

You give Logo directions by typing commands at the Apple keyboard. Logo reads what you have typed when you press the <RETURN> key. Pressing <RETURN> is like saying DO IT. Nothing will happen until you hit <RETURN>.

NOTE ON POINTED BRACKETS: When you see pointed brackets < > around a word, press the key on the keyboard with that word on it. Do not spell out the word. When you see <CTRL> C, hold down the <CTRL> key and type the letter C. (Think of the <CTRL> key as a different kind of <SHIFT> key.)

SPECIAL NOTE: Nothing you type can harm the computer or Logo. Even the worst that can happen is not too bad: pressing the RESET key while using Logo may take you out of Logo and mean the loss of work you

have not yet stored, but it will not harm Logo or the computer. Much of the time you can recover your work after an accidental <RESET> (see below). Don't be afraid to try things.

Recovery Process

To recover, type <CTRL> Y <RETURN>, that is, hold down the <CTRL> key and press the <Y>, then press <RETURN>. (You may have to type <CTRL> G also.) Usually this will put you back into Logo. If it does not, turn the machine off and start Logo according to the four-step summary at the end of this chapter.

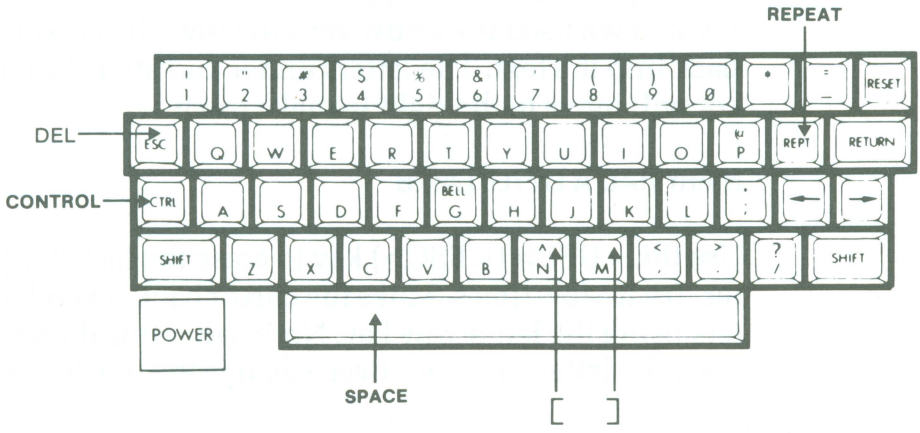
> When Logo does not understand something you have typed, it will try to help you by typing out a message. Most of the time you will have no trouble figuring out what is wrong, but when you do, turn to the list of Error Messages and their explanations (with examples) in the Appendix.

Once in a great while Logo confesses (rightly or wrongly) to a bug and puts you into the Apple monitor, with a line similar to

```
*FFFF- A = 50 X = 02 Y = 4A P = 30 S = 05
```

When this happens, Logo will type out explicit messages and recovery instructions.

KEYBOARD DIAGRAM



The Apple II Keyboard

Using the Keyboard

BEFORE YOU BEGIN: If you have an Apple II or II+, look at the diagram above. You should notice that three keys have special functions. The <ESC> key, which we will call <DEL> from now on, deletes backwards one character. In addition, <SHIFT>N prints a left bracket <[>, and <SHIFT>M prints a right bracket <]>.

If you are using an Apple IIe or IIc, the <ESC> and <DELETE> keys can both be used for deleting backwards. Unlike the Apple II+, the IIe and IIc have their own keys for right and left brackets.

USE THE EDITING KEYS TO CORRECT TYPING ERRORS: The <DEL> key (<ESC>) moves the cursor to the left and erases the character there. Each arrow key moves the cursor in the direction it points on the

keyboard. Any letter, number, or symbol that you type will appear exactly where the cursor is blinking, even if you have used the arrow keys to move the cursor back into the text. The letters under and after the cursor will move to the right to make room.

```
MARY HAD A LITTLE LAMB
```

Use the <DEL> (<ESC>) key to erase the last character. Try it a few times. Move the cursor back several letters using the left-arrow key. Notice that this does not erase the letters it travels over. Change the line to read:

```
GARY HAD A LITTLE LAMB
GARY HAD A LITTLE HAM
GERTA HAD A LITTLE HAM SOUP
GERTA HAD XVP26 A LITTLE HAM SOUP
```

Finally, change it back to

```
MARY HAD A LITTLE LAMB
```

See how typing characters in the middle of the line makes the rest of the line move over to make room? You can never accidentally type on top of other characters and cause them to be erased.

Press <RETURN> now. Logo will try to understand the whole line as a series of commands. Since the words MARY HAD A LITTLE LAMB are not Logo commands, Logo will tell you so. Type MARY again.

Tell Logo to ignore what is typed with <CTRL> G (before you press <RETURN>). To do this, hold down the <CTRL> key and press the <G> key. (Remember, the <CTRL> key is like a special <SHIFT> key which is always used with another key.) Logo will print STOPPED! and a new prompt. Typing <CTRL> G is the usual way to stop whatever Logo is doing.

CAUTION: At any time, you can exit Logo by turning the machine off; however, by doing so, you will lose all your work unless you have saved it on the disk. You are also likely to lose your work if you press the RESET key and have to restart Logo. Use <CTRL> G to stop programs; stay away from the <RESET> key. (An internal switch can be set in your Apple II+ to require one to press <CTRL> <RESET> to activate <RESET>. Doing this can save a lot of grief if you have an itchy <RESET> finger.) But be sure to try the recovery process outlined above if you do press <RESET>.

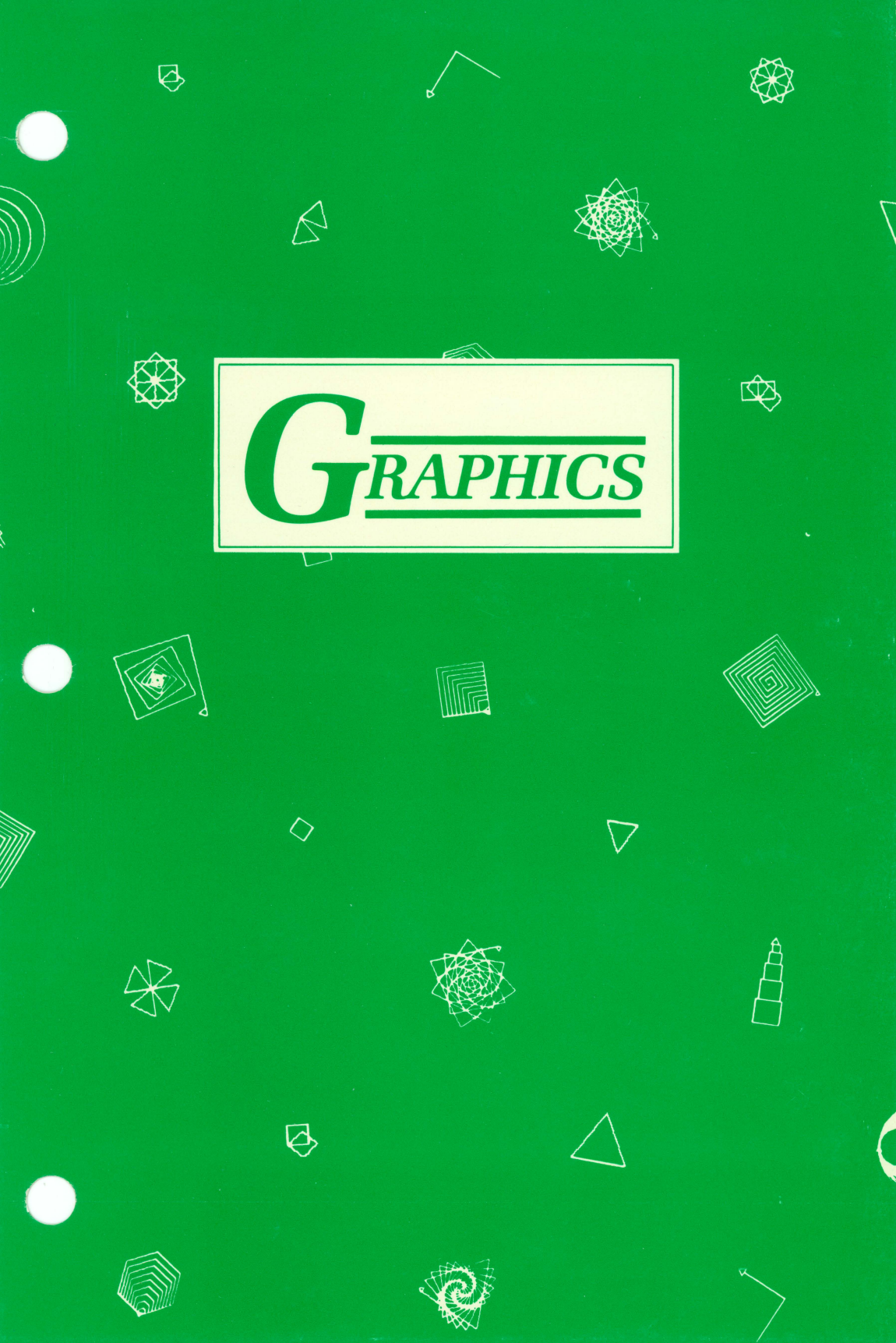
Upper Case and Lower Case

The Apple IIe and IIc, unlike the Apple II and II+, come with the built-in ability to type both upper- and lower-case characters. This feature is especially useful when you are using the TEXTEDIT file on the Utilities Disk.

Generally speaking, however, you will need to type Logo commands in upper case. (Primitives typed in lower case will not be understood.) Be sure to put the <CAPS LOCK> key (in the lower left corner of the keyboard) in the down position.

STARTING LOGO: SUMMARY

1. Place Language Disk in disk drive.
2. Turn on Apple; wait approximately 30 seconds while Logo is loaded.
3. After WELCOME TO LOGO is printed, remove the Language Disk. Insert your storage disk.
4. You are ready to proceed with Logo.


GRAPHICS

G GRAPHICS

> Since this tutorial is written for our reading constituency, we have placed the section describing INSTANT for non-reading users at the end of the Graphics chapter.

Logo puts the user in control from the start. In keeping with that philosophy, this tutorial will suggest but not dictate. If you are ever really stuck for an idea, see the Procedures section of the Appendix. It contains examples of all the ideas suggested. In fact, after you try things on your own, look through the Appendix for new ideas and tips and tricks.

Graphics Mode

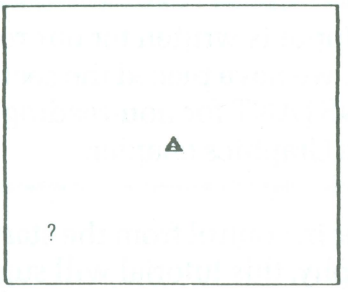
Enter the graphics or DRAW mode by typing DRAW:

```
DRAW
```

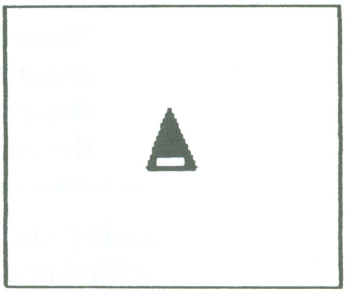
and press the <RETURN> key. (Remember, pointed brackets around a word refer to a key, not a word to be typed.)

A drastic change occurs on the screen; the command you have just typed and all other commands will disappear. A small triangle will appear in the middle of the screen, and the prompt will be in the lower left region of the screen.

Logo is now in DRAW mode. The bottom four lines of the screen are reserved for commands you will type and the rest of the screen is drawing space.



Splitscreen and Turtle

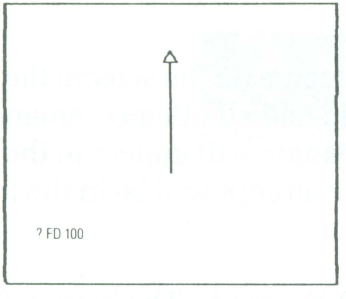


Turtle Enlarged

The small triangle in the middle of your screen is called the turtle. When it first appears, it is pointing upward. You can tell where it is heading by the black bar that runs across its back.

Driving the Turtle: FORWARD (FD), BACK (BK), RIGHT (RT), LEFT (LT)

You move the turtle with turtle commands. The turtle can leave a trail as it moves, allowing you to produce a picture.



FORWARD always moves the turtle in the direction it is pointed. Type

FORWARD 100 <RETURN>

or the short equivalent

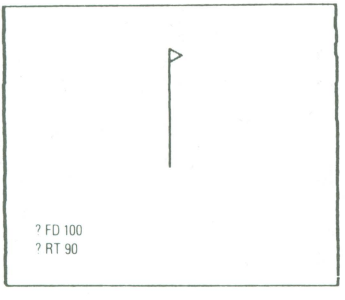
FD 100 <RETURN>

The turtle will move forward one hundred turtle steps. The space between the command and the number is necessary. If omitted, Logo will assume the whole thing to be a procedure name. (Try FD100 without the space.)

If you leave out the number that FORWARD is expecting, or the space, or do something else that Logo does not recognize, Logo will try to help you by printing an error message. These are usually self-explanatory, but if you cannot figure out what is wrong, turn to the Appendix where error messages are interpreted with examples.

To make the turtle turn, type the direction of the turn and the number of degrees:

RIGHT 90 <RETURN> or RT 90 <RETURN>



You told the turtle to turn right 90 degrees (a quarter of a circle). If you type RIGHT 90 again, the turtle will point straight down.

Type

LEFT 90 <RETURN> or LT 90 <RETURN>

From now on, we'll assume you know to press the <RETURN> key after a command.

The turtle will turn in place 90 degrees to its left. Try moving the turtle around yourself. Type BACK (or BK) with a number of steps.

To clear the screen and start over, type DRAW. DRAW erases whatever picture is on the screen and takes the turtle to its starting position. Use DRAW whenever you want to start a new picture.

Play with the turtle some more.
(1) Try some odd distances and turns, such as

```
FD 87
RT 43
FD 26
LT 141
FD 59
```

(2) Draw a square
(3) Try a triangle

Get familiar with the turtle commands. Use the commands or their abbreviations:

Command	Abbreviation
FORWARD	FD
BACK	BK
RIGHT	RT
LEFT	LT

Let Logo Do Your Arithmetic

Whenever Logo expects a number (we call this number its input), you can give it an arithmetic expression to evaluate to get a number. Logo will do the arithmetic for you.

Type	and Logo figures
FD 10*5	FD 50
RT 100/3	RT 33.3333 ...
FD 5 + 5	FD 10

This is useful for both accuracy and precision: the computer will not make a mistake, and the computer will make a division like 100/3 quite precisely.

An Easy Way to Repeat Yourself: <CTRL> P

You can put as many commands on the same line as you want, as long as you separate them with spaces. When you have typed a line and pressed <RETURN>,

Logo will repeat the line for you if you press <CTRL> P. (Hold down the <CTRL> key and press the <P>). Type

```
FD 50 RT 30 FD 20 RT 115<RETURN>
```

Logo draws the line. Type

```
<CTRL> P        Logo types

FD 50 RT 30 FD 20 RT 115
```

You press <RETURN> to do it.

Type <CTRL> P <RETURN> as many times as you wish; each time Logo will print and execute the line.

If you put a space at the end of your original instruction, you may also type

```
<CTRL> P <CTRL> P <RETURN>
```

This will print out two sets of your instructions. You can repeat the <CTRL> P as many times as you wish, up to 129 characters (9 characters more than 3 lines), as long as there are spaces between the commands. If you have no space at the end of the line, and type <CTRL> P twice, you will get

```
FD 50 RT 30 FD 20 RT 115FD 50 RT 30 FD 20 RT 115
```

If there is no space at the end of the line when you type another <CTRL> P (as in the line above), the last com-

mand of the first batch will not be separated from the first command of the second, and Logo will stop and say

```
THERE IS NO PROCEDURE NAMED 115FD
```

You can add a space after you type the <CTRL> P, but an easier way to insure a space is to put it there when you type the line (RT 115 <SPACE> <RETURN>).

The Screen: DRAW, NODRAW (ND), TEXTSCREEN (<CTRL> T), SPLITSCREEN (<CTRL> S), FULLSCREEN (<CTRL> F)

When Logo is in DRAW mode, the Apple displays four lines of text at the bottom of the screen. To see the commands you have typed that have disappeared under the picture, type

```
TEXTSCREEN or <CTRL> T
```

Remember that you must hold the <CTRL> key down while you type the T.

Try typing

```
<CTRL> T
```

To get back the split graphics/text screen, type

```
SPLITSCREEN or <CTRL> S
```

To show off your drawing without the distracting text, type

```
FULLSCREEN or <CTRL> F
```

<CTRL> S will bring back the split screen from either the text or fullscreen.

> To clear the screen and leave DRAW mode, type NODRAW, abbreviated ND. Type ND <RETURN> right now.
> Type DRAW again to do some graphics projects.

Turtle-driving Projects

1. Determine how many turtle steps it takes to get to the top edge of the screen.
2. Determine how many turtle steps from the bottom edge of the screen to the top. From the left edge to the right.
3. (Tricky one) How many steps from the lower left corner of the split screen to the upper right corner?
4. (Trickier still) How many from the lower left corner of the full screen to the upper right?
5. Try each of the commands with a negative number. (Example: FORWARD -100) How else could the turtle make the same move?
6. Can you draw a square? A rectangle?
7. Can you draw your initials?

Color: PENCOLOR (PC) and BACKGROUND (BG)

The turtle has six pencolors and six background colors, plus a switching so-called color that reverses the color it passes over. The colors are numbered from 0 to 6.

Here are the colors and numbers for a black background (BG 0):

Color	Number
Black	0
White	1
Green	2
Violet	3
Orange	4
Blue	5
Reverse	6

The PENCOLOR (or PC) primitive takes the number of the color as input, and sets the turtle's pencolor to that color. Try typing

```
DRAW
PC 4
LT 45
FD 50
RT 90
FD 50
```

To change the background color, type BACKGROUND (or BG) and the number. BG 1 gives a white background. BG 1 PC 0 will give you a black pen on a white background. Try typing

```
BG 5
RT 135
FD 62
```

The Apple computer color system determines the use of background colors. Blue and orange, for instance, do interesting things when exposed to violet and green. Combinations which will work as you expect:

PENCOLOR	on BACKGROUND	draws
4	2	green on green (erases)
4	3	green on violet
5	2	violet on green
5	3	violet on violet (erases)
2	4	orange on orange (erases)
2	5	orange on blue
3	4	blue on orange
3	5	blue on blue (erases)

In addition, changing the background color after a picture is drawn may change some of the lines in peculiar ways. Returning to the original backgound color restores the picture.

To see the effects of the different combinations, set a background color and draw some lines in each of the different colors. Change the background color and do it again.

On a black and white screen, colors 2-5 take on different textures, but black and white remain the same as always.

Logo draws thick lines to obtain clear colors on the Apple. On a black-and-white monitor, for thin white lines on black, use BG 6 and PC 1 through 5. PC 0 is black. (On a color monitor, these lines will not be uniformly white: vertical lines will be red or green, depending on their position.)

The Magic of PENCOLOR 6: Erasing

PC 6 changes black to white and white to black when turtle tracks cross. This means that the turtle can erase a line by going back over it with PC changed to 6. To see how it works, type

```
FD 100
PC 6
BK 100
```

Now is the time to see one of the amazing effects you can create.

Type

```
PC 6
LT 2
FD 3000
```

Vary the turn and the distance forward for different effects. Try starting the turtle at the edge of the screen...

Something to Try After You Read the Procedures Section

To see the effect of PC 6 with a non-stop procedure, choose one that never takes the same track twice. Clear the screen, hide the turtle, set your pencolor to 6, the reversing color, type the name of your procedure, and hit <CTRL> F so you can watch on the full screen:

```
DRAW HT PC 6  (procedure name) <CTRL> F
```

Introduction to Procedure Writing

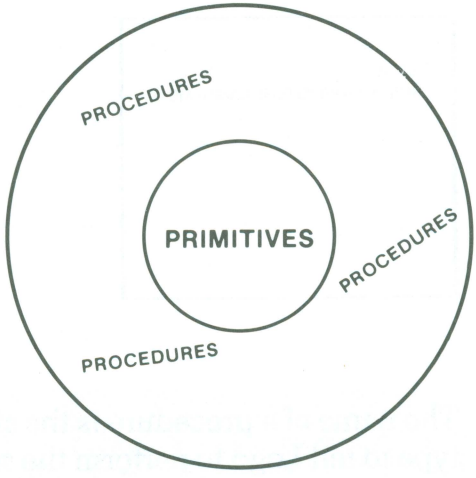
Now that you know how to drive the turtle around and make shapes, we will proceed to giving your shapes names which will become new turtle commands. You will be able to type BOX and get your box picture back, or SQUIGGLE to draw your squiggle.

To do this, you will write procedures.

A procedure is a series of commands which you design to achieve a specific purpose. The commands may be composed of procedures and/or Logo primitives.

LOGO COMMANDS

PRIMITIVE: a command that Logo has already been taught
PROCEDURE: a command that you teach Logo



Think of the PRIMITIVES as the core of the world of PROCEDURES you will write.

FORWARD, BACK, LEFT, RIGHT, DRAW, and NODRAW are Logo primitives. You used the primitives by typing their names, with numbers if they required them. To use a procedure, you do the same.

Naming a Procedure

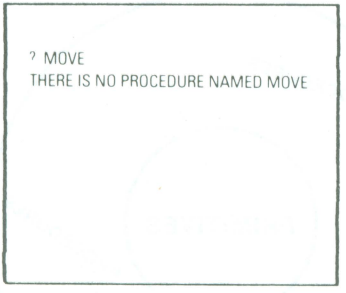
Type

```
MOVE <RETURN>
```

Logo tells you

```
THERE IS NO PROCEDURE NAMED MOVE
```

Logo is saying that it does not recognize the word you typed as either a Logo primitive or a procedure name. It does not know how to do that command.



The name of a procedure is the single word that you type to tell Logo to perform the series of commands in the procedure.

Since you choose the name, select one that

1. Reminds you of what the procedure does
2. Is easy to remember
3. Is easy to type
4. Will not be confused with another name

Writing a Procedure: EDIT Mode: TO, END, <CTRL> C, <CTRL> G

To write a procedure, start with the name. The tutorial will use the name MOVE, but you may use your own.

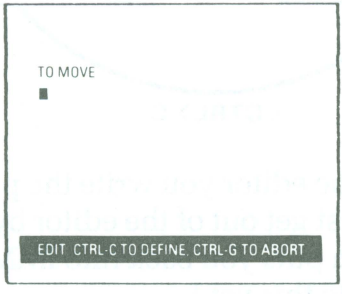
We tell Logo that we're about to write a new procedure by writing TO and the name of the procedure. For example, type:

```
TO MOVE
```

When you press <RETURN>, the screen will change: Logo will clear the screen and print the words

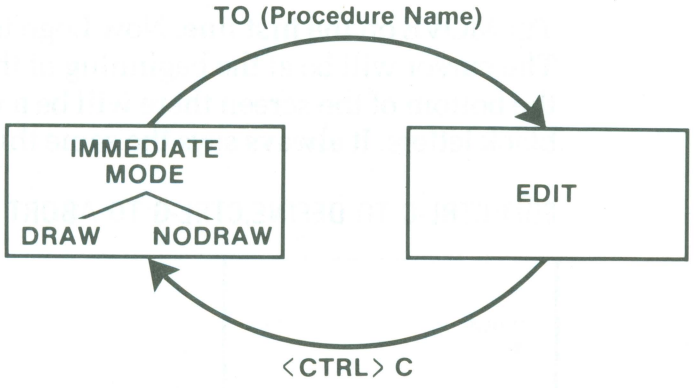
TO MOVE on the first line. Now Logo is in EDIT mode. The cursor will be at the beginning of the next line. At the bottom of the screen there will be a white line with black letters. It always says the same thing:

```
EDIT:CTRL-C TO DEFINE,CTRL-G TO ABORT
```



This reminds you that you are in EDIT mode, and tells you the two ways to get out of it: <CTRL> C to Complete the job and <CTRL> G in which any changes you have made in EDIT are Gone.

EDIT mode is very different from IMMEDIATE mode. In IMMEDIATE mode, Logo does the commands that you type (like FORWARD or RIGHT) as soon as you press the <RETURN> key. In EDIT mode, Logo waits for you to define a whole procedure; that is, to write a series of commands that will constitute the new procedure.



While you are in the editor you write the procedure. To use it, you must first get out of the editor by typing <CTRL> C, which puts you back into IMMEDIATE mode. (But don't do this yet.)

When you are using the editor, you can use the right and left arrows to move the cursor and <DEL> (<ESC>) to erase the character at the left of the cursor, just as you can in IMMEDIATE mode.

Type a line of text to practice. For example, you might type

```
FORWARD 33
RIGHT 55
```

(or their short versions:)

```
FD 33
RT 55
```

Press the

<RETURN>

key. Note that it moved the cursor to the next line. In fact, <RETURN> is just another character to the editor: you can even erase it with the <DEL> (<ESC>) key. Press

<DEL> (<ESC>) and then the
<RETURN>

key again to see this. Press

<DEL> (<ESC>)

until the whole line under TO MOVE goes away. (You can use the <REPT> (repeat) key on the Apple II+ in conjunction with <DEL> (<ESC>) to delete several characters very quickly.)

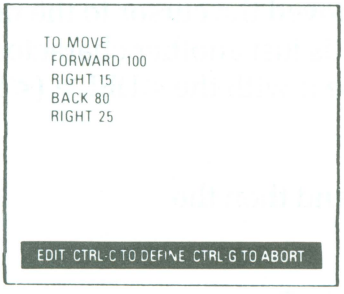
(See the APPENDIX and the Technical Manual for a discussion and summary of some other editing commands.)

Now type a series of commands, alternating FORWARD or BACK with RIGHT or LEFT. Remember to include the number of turtle steps or degrees, and to press <RETURN> after each.

For your first time through this tutorial, type either version of MOVE:

```
TO MOVE
 FORWARD 100
 RIGHT 15
 BACK 80
 RIGHT 25
```

```
TO MOVE
 FD 100
 RT 15
 BK 80
 RT 25
```



Look over your procedure to be sure that
(1) the commands are spelled correctly,
(2) that you have used zeros in your numbers and not the letter O (zeros have slashes through them on the Apple), and
(3) that there are spaces between the commands and the numbers.

Use the arrows and the <DEL> (<ESC>) key to fix errors. Use <REPT> (repeat) with the arrows to move the cursor quickly. When you finish your repairs, leave the cursor where it happens to be. Logo, unlike other languages, does not require the cursor to be at the end of the listing or even at the end of a line when you leave the EDIT mode.

The white line at the very bottom of the screen tells you the two ways of exiting from the editor and returning to IMMEDIATE mode.

Press <CTRL> C.

Logo will Complete your procedure definition: it will return you to IMMEDIATE mode, and will remember your procedure MOVE while you stay in Logo. It will confirm that it has read in your program by saying

```
MOVE DEFINED
```

If instead, you type <CTRL> G, your work done in EDIT mode will be Gone: Logo will return you to IMMEDIATE mode without accepting the work you did in EDIT. <CTRL> G stops Logo, whatever it is doing. Logo will confirm this state of affairs with

```
STOPPED!
?
```

Note above that Logo types PLEASE WAIT... then MOVE DEFINED followed by the prompt ?

(The wait occurs when you write a long procedure. You will not notice the wait with a short procedure like this.)

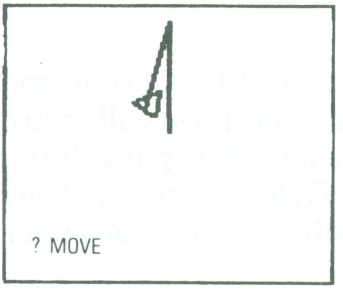
Congratulations! You have written your first procedure. You have taught the turtle a new command. But wait! It's not time for congratulations yet. Does it work? You must try it.

Running a Procedure

Type

```
MOVE<RETURN>
```

Just as typing the name of a primitive makes Logo do it, typing the name of a procedure makes Logo do what that procedure says to do. This is called RUNNING or EXECUTING the procedure.



If you have typed a word incorrectly within your procedure, Logo will try to help you by printing an error message. If you cannot figure out what the problem is, see the Appendix, which explains error messages with examples.

To make a change in your procedure, reenter the EDIT mode by typing TO and the name of your procedure. To change MOVE, type

```
TO MOVE
```

The screen will look as it did just before you left EDIT. Logo confirms that you are again in EDIT mode with the white line at the bottom of the screen.

Make your changes using the arrows and <DEL> (<ESC>) key (don't forget to use the <REPT> (repeat) key to make moving easier), and exit EDIT with <CTRL> C. You are DEBUGGING your procedure (removing errors, called BUGS).

Run your procedure by typing its name. And now... Congratulations! It should look like the picture above.

Type MOVE again. The turtle will begin at the place it finished and will go in the direction it was pointing. You can also add to the shape on the screen by driving the turtle around with individual commands such as RIGHT 12 or FORWARD 55, but these commands will not be included in the procedure.

You may put as many commands on a line as you wish; separate them with spaces and press <RETURN> at the end of the line to run them. If you run over the end of the line, Logo will continue on to the next line. (In EDIT mode, Logo puts an exclamation point to remind you that the line is continued).

CAUTION: In IMMEDIATE mode, Logo will do commands until it sees something it does not recognize. If one of the first commands on a long line of commands is misspelled, it will stop there and you will have to retype the incorrect one and all that came after it.

Planning and Drawing Your Favorite Square

Procedures like MOVE draw somewhat random designs. Drawing a specific shape requires more specific thought about the sequence of commands you will write.

Example: Define a procedure called SQUARE which will draw a square.

Decisions you must make:

The number of
1. steps on a side (your choice)
2. degrees to turn at the corner (Aha!)
3. times to do a side and/or turn (Hmmm)

Things to remember (always):

- Correct spelling of commands
- Space between command and number
- Use zeros in numbers, not the letter O
- Press <RETURN> after each line
- Begin with the name:
  (for this one, type TO SQUARE)
- End your procedure with END

(Logo will put END in for you if you forget it. The only time it is definitely needed is when you define more than one procedure in the editor at the same time.)

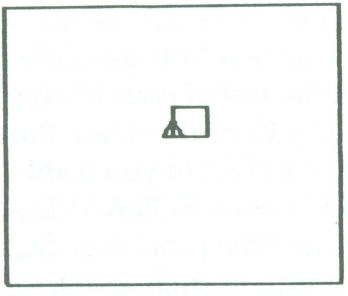
- Exit the editor with <CTRL> C
  (C for Complete)

Analysis:

Decision 1: From your turtle-driving projects, you have a good idea of the size of the screen. Choose a number considerably less than half, so that you can use your square in larger pictures. (Draw your proposed square on the screen with a felt tipped water based pen and make the turtle trace it.)

Decision 2: Only one specific number of degrees will work here; if you don't know what it is, try a few before you begin on SQUARE.

Decision 3: No doubt you know how many times you need to do the side and how many times you need to turn to draw a square. We will discuss other options later on.



SQUARE

Defining SQUARE:

To teach Logo the new command SQUARE, type

```
TO SQUARE
```

You are now in EDIT mode. Type in the commands you need, as you determined above. If you make mistakes in typing, use the arrow keys and <DEL> (<ESC>) to correct them. If the mistake is not on the line with the cursor, you must move the cursor to that line to correct it.

Exit from EDIT mode with <CTRL> C (C for Complete).

(Forgive the repetion of (C for Complete); we just don't want you to lose any of the work you have done in EDIT as you would with <CTRL> G (G for Gone . . .))

Type SQUARE to run it. Move or turn the turtle and run it again, and again. Notice that the turtle draws the square from wherever it happens to be, and starts off on the first side in whatever direction it is heading.

Now for a trick or two. You certainly don't want to spend the rest of your life typing SQUARE when you could obtain the same results typing SQ. (Would you want to have to type the whole word FORWARD all the time?) You created the procedure SQUARE using Logo primitives such as FD, BK, LT, and RT. Now you can create a procedure SQ using the new Logo command, the procedure name SQUARE.

Using the editing techniques you have learned, write a procedure SQ that looks like this:

```
TO SQ
 SQUARE
END
```

Clear the screen with DRAW and run SQ. Clear it again with DRAW and run SQUARE. You should get the same results with both. Now any time you want to draw a square, type either SQ or SQUARE.

SQ and SQUARE can also be used in procedures any time you wish, and as many times as you wish, just like the Logo primitives.

Projects: Simple Procedures

Write several of your own procedures. Choose appropriate names, but do not use the name MOVE as we will be using that again later.

What goes Into a Procedure

Any command you can type at the keyboard, as well as any procedure you have written, can be used in a procedure. Some commands have two versions: one is a word spelled out at the keyboard and the other uses the <CTRL> key plus a letter. Use the word in a procedure; the <CTRL> version is only for convenience at the keyboard.

SUMMARY OF COMMANDS USED SO FAR THAT HAVE A CONVENIENT KEYBOARD VERSION

Procedure Version	Keyboard Version
TEXTSCREEN	<CTRL> T
SPLITSCREEN	<CTRL> S
FULLSCREEN	<CTRL> F

More Primitives: REPEAT, CLEARSCREEN (CS), HOME, PENUP (PU), PENDOWN (PD)

The Logo command REPEAT saves you the work of typing a command or series of commands more than once. You tell Logo the number of times you wish to repeat, and enclose the command(s) to be repeated in square brackets.

Try these examples:

```
REPEAT 4 [FD 23]
REPEAT 3 [FD 30 RT 60]
REPEAT 8 [FD 65 RT 135]
REPEAT 20 [RT 50 FD 15 RT 60 FD 10]
```

As you will recall, when you type <CTRL> P, Logo will retype the previous line for you. You press <RETURN>, and Logo will execute it.

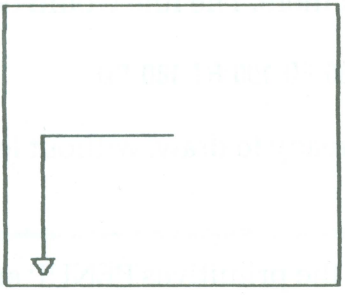
To repeat MOVE 24 times, type

```
REPEAT 24 [MOVE]
```

If the turtle starts in the middle of the screen, the design created by repeating MOVE will go off the edge (and appear on the opposite side). To avoid this, move the turtle before starting the design. 100 steps to the left and 100 steps down turn out to be a good starting point for MOVE, determined by examination and experimentation. Find a good starting point for your procedure.

To walk the turtle to its starting point for MOVE, type

```
LT 90 FD 100 LT 90 FD 100
```



The turtle is there, but it is pointing down. To head it in the right direction to start MOVE, type RT 180.

Now, what about the track it left? (If you type DRAW to get rid of the track, you will also send the turtle home.) To keep it where it is as Logo clears the screen, type CLEARSCREEN (or CS). Now try that REPEAT line with MOVE.

DRAW is a combination of CLEARSCREEN, SHOWTURTLE (explained later), and HOME, the command that moves the turtle to the center of the screen and turns it to point straight up. Walk the turtle around some, then type HOME to see what happens.

There is another way to move the turtle without leaving a trace. Tell it to pick up its pen with PENUP (PU) before you start, and to put it down with PENDOWN (PD) when you get there. The line would be

```
PU LT 90 FD 100 LT 90 FD 100 RT 180 PD
```

The turtle arrives ready to draw, without leaving tracks.

> The names of the primitives PENUP and PENDOWN come from the robot floor turtle which has the ability to pull its pen up and not draw or put it down and draw.

Procedure Projects

1. Write a setup procedure to move the turtle to its starting point without leaving a track.
2. Write a procedure using REPEAT which draws a design with MOVE.
3. Write a procedure to draw a four-sided figure.
4. Write a procedure to draw a rectangle.
5. Use your setup and rectangle procedures to draw a rectangle where MOVE began.
6. Write a procedure using REPEAT that repeats the sequence of drawing a shape with one of your shape procedures and then turns the turtle (then draws the shape and turns . . .)

Saving Procedures: CATALOG, SAVE, POTS

You have created a procedure which Logo will remember as long as you do not exit Logo or turn off your Apple. To be able to turn the computer off without losing your work, so that you may be able to use these procedures another day, you must ask Logo to SAVE them on a Logo file disk. Use a file disk prepared according to the instructions in the section titled Preparing a Blank Disk.

When you use the SAVE command, every procedure in your workspace is saved in a file on your disk. Your workspace is like your desktop. You do your work here, sometimes creating new material, sometimes bringing copies of files out of the drawers. When you finish for the day, you go to the copying machine, make a copy for the file, and file the copy away. Everything you are currently working on is on your desktop (in your workspace). This may include many procedures. When you want to save the contents of your workspace (desktop), use SAVE to transfer a copy of it to the disk (desk drawer).

You can use and change procedures only when they are in your workspace, not on the disk. When you are happy with your changes, or finished for the session, you store a copy of the workspace contents back as a file on the disk.

The SAVE command copies the entire contents of your workspace into a file on the disk. Just as your procedures have names, the collection of procedures in your workspace, which will be saved in a file, must have a name too, to distinguish it from your other files. Since

you choose the name for the group of procedures in the file, it is a smart idea to choose a file name that tells you what they are. The file name SHAPES might be useful for the first group of procedures you will be writing as you go through this chapter.

Type

```
SAVE "SHAPES
```

The double-quote character immediately preceding the word is a crucial part of the file name. You cannot omit it. If you try to store your workspace without it, nothing will be saved, because Logo does not recognize it as a file name without the quote character. If you try to read a file without it, Logo will not find the file.

The quote distinguishes other types of names from procedure names. There is no space between the quote character and the word.

WARNING: You can have only one file per file name. Therefore, for the time being, use a new file name each time you save your workspace (such as SHAPES, SHAPES1, SHAPES2). (The Appendix includes more details about saving procedures.) If you had already had a file called SHAPES, the contents of the old file would be erased, replaced by the present contents of your workspace.

If you had nothing in your workspace (which is the case every time you turn on the computer, before you read a file or write a procedure) and typed SAVE "SHAPES, Logo will print out a message telling you there is nothing to save. But if you had one item in

your workspace, Logo would still save the entire contents of your workspace, even though it is almost empty, and the file "SHAPES would be replaced by a copy of the almost empty workspace. The old file "SHAPES on the disk would be gone.

This would be like taking a blank book with only a title page to the copying machine, copying it, and replacing your old files in the drawer with the copies of the blankpaper.

To see the names of the files you have saved on your disk, type

```
CATALOG
```

Everything on the disk will be listed, including the HELLO file which was put there during the initialization process, which must stay there although you will never need to use it again. Each Logo file will have your file name followed by .LOGO. For example, the new entry SHAPES.LOGO will appear on the list.

To print out the titles of your procedures in your workspace, type

```
POTS
```

To print out the commands in a procedure, type PO (procedure name) i.e.

```
PO BOX
```

SUMMARY

Command	Purpose: Lists	Example
CATALOG	Files on disk	CATALOG
POTS	Procedure titles	POTS
PRINTOUT or PO	Procedure commands	PO BOX

Clearing the Workspace, Reloading Procedures: READ, GOODBYE, ERASE (ER), ERASE ALL (ER ALL), ERASEFILE

You may reload procedures into your workspace at any time. The most usual time might be when you begin a new session with Logo, but there will be times when you wish to add the contents of another file to what is already in your workspace. To list on the screen the files which are saved on your disk, type CATALOG, as before. To reload the procedures from your file SHAPES.LOGO, type

```
READ "SHAPES
```

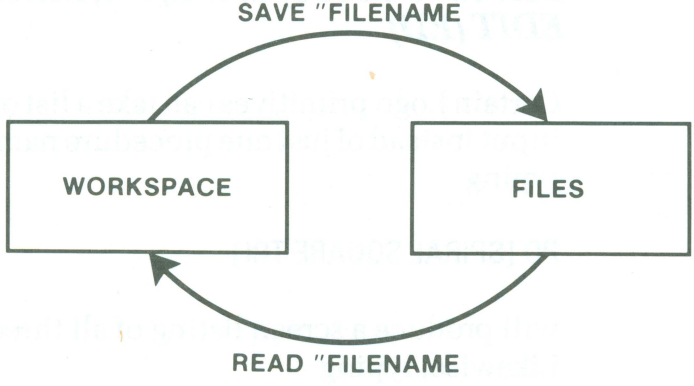
The red light on the disk drive will go on, the disk will whirr, and the computer will print out the name of each of your procedures in your file SHAPES and confirm that it has been read into your workspace by printing DEFINED. For instance,

```
MOVE DEFINED
```

A word of warning: if you have changed MOVE in your workspace, the version read in from the disk will wipe out the one in your workspace. If you want to keep both versions, rename the one in your workspace using EDIT, before you read in the file. You can change the name in EDIT mode just as you change a command.

To store them all back in SHAPES, type

```
SAVE "SHAPES
```



There will be times when you want to clear your workspace, particularly when you want to shift gears and read in another file. If you want to save your current work, save it first.

To clear your workspace, type

```
ERASE ALL
```

It is always possible to erase whole files from a disk. The command which does this is ERASEFILE. For example, to permanently delete a file called JUNK, type

```
ERASEFILE "JUNK
```

to Logo. Always double-check to see that you're not erasing a file you want to keep.

Selective Uses of SAVE, PO, ERASE (ER), and EDIT (ED)

Certain Logo primitives can take a list of procedures as input instead of just one procedure name. For instance, typing

```
PO [SPIRAL SQUARE TRI]
```

will produce a screen listing of all three procedures. Likewise, typing

```
ER [TRI SQ CIR]
```

will erase all three procedures. In this case, the option of giving ERASE a list as its input is convenient but not crucial; the same effect could be achieved by typing

```
ER TRI ER SQ ER CIR
```

Using an extra input list with SAVE or EDIT is a bit more powerful, as it allows you to do things not otherwise possible.

Suppose you had two similar procedures, TRI and TRI2, and wanted to edit them together. You could type ED ALL, but then every procedure would appear in the editor; also, TRI and TRI2 might not be together. A simpler approach would be to type

```
ED [TRI TRI2]
```

SAVE normally puts all existing procedures into a new file. However, by using an input list you can save a selected list of procedures. If you have several procedures in your workspace and want to SAVE only a few of them, you can type something like

```
(SAVE "FIGURES [SQ TRI STAR])
```

The parentheses are necessary in order to tell Logo to expect an extra input.

Saving, Reading and Erasing Pictures: SAVEPICT, READPICT, ERASEPICT

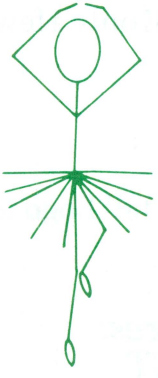
Logo can store complicated pictures on your disk and read them back in much less time than it takes the procedure to draw them. However, there is a tradeoff in disk space. The procedure might take 1 block of disk storage space. The picture will occupy 34 blocks. Only you can decide when this is worthwhile.

To save a picture (whatever is on the drawing part of the screen at the time), assign it a name. We shall use DANCER. To save the

picture part of the screen on the disk under the name DANCER, type

```
SAVEPICT "DANCER
```

The name you choose can be any name you care to give it. It does not have to be the same name as the procedure that drew it, but it could be. The picture can be the result of running one or several procedures (without clearing the screen between), or driving the turtle around, or a combination. Everything on the picture part of the screen except the turtle is stored with SAVEPICT.



To recall a stored picture (remember, this one will be listed on the disk as DANCER.PICT), type

```
READPICT "DANCER
```

To remove the picture from the disk forever (not just from the workspace), type

```
ERASEPICT "DANCER
```

In each case, use the double-quote character before the first character of the name.

The Invisible Turtle: HIDETURTLE (HT), SHOWTURTLE (ST)

There are two situations in which you might want the turtle to become invisible.

1. To get it out of the way of your picture either during the drawing or after the picture is completed.
2. To speed up the drawing of a picture (the invisible turtle draws faster).

To tell the turtle to become invisible, type

HT (or its long form) HIDETURTLE

To tell it to reappear, type

ST or SHOWTURTLE

Except for being invisible, the hidden turtle works exactly the same as the visible turtle. In particular, it draws when its pen is down and leaves no trace when its pen is up.

Summary of Logo Commands Used So Far

TURTLE COMMANDS

Command	Abbreviation
FORWARD	FD
BACK	BK
LEFT	LT
RIGHT	RT
HOME	
PENUP	PU
PENDOWN	PD
HIDETURTLE	HT
SHOWTURTLE	ST
PENCOLOR	PC
BACKGROUND	BG

SCREEN COMMANDS

Command	Abbreviation
CLEARSCREEN	CS
DRAW	
NODRAW	ND
TEXTSCREEN	<CTRL> T
SPLITSCREEN	<CTRL> S
FULLSCREEN	<CTRL> F

FILE COMMANDS

READ
SAVE
SAVEPICT
READPICT
ERASEPICT
ERASEFILE

PENCOLORS on BG 0

PC 0	Black
PC 1	White
PC 2	Green
PC 3	Violet
PC 4	Orange
PC 5	Blue
PC 6	Reverse

Commands used in all Logo domains (Graphics, Music, Computation, etc.):

TO ...
END

READ
SAVE

REPEAT
<CTRL> P

EDIT
<CTRL> C
<CTRL> G

CATALOG
POTS
ERASE
PO

<CTRL> P, <CTRL> C, and <CTRL> G are keyboard instructions which cannot be used in procedures.

More About the Editor: <CTRL> P, <CTRL> N, <CTRL> O, <CTRL> A, <CTRL>E, <CTRL>D, <CTRL>K, <CTRL>Y

In EDIT mode you must often move the cursor from one line to another. One way to do this is to use an arrow key and the <REPT> (repeat) key.

It is faster to type

<CTRL> P
to go to the Previous line (Up on the screen),

<CTRL> N
to move the cursor to the Next line (Down on the screen).

If you are using an Apple IIe, the up and down arrow keys can be used instead of <CTRL>P and <CTRL>N.

To Open up a space to insert a new line, type

<CTRL> O (letter O)

No matter where the cursor is on the line, the rest of the line will be moved down to the next line, but the cursor will stay put.

To move the cursor to the beginning of the line, type

<CTRL> A

To move the cursor to the End of the line, type

<CTRL> E

To Delete the character under the cursor, type

<CTRL> D

Note that this is the opposite of the <DEL> key which deletes to the left of the cursor.

To kill a line from the cursor to the end, type

<CTRL>X

To Yank back the last line killed, type

<CTRL>Y

Other editing commands are described in the APPENDIX and Chapter 2 in the Technical Manual.

SUMMARY OF EDITING COMMANDS

	MOVING BACKWARD	MOVING FORWARD
1 character	Left arrow	Right arrow
End of line	<CTRL> A	<CTRL> E
Adjacent line	<CTRL> P or Up arrow	<CTRL> N or Down arrow
	DELETING BACKWARD	**DELETING FORWARD**
1 character	<DEL> (<ESC>)	<CTRL> D
Line	— —	<CTRL>X
	FOR EASY INSERTION OF A LINE	
Open line	<CTRL> O	
	RESTORING DELETED TEXT	
Line	<CTRL>Y	

Projects Using Shapes

1. Write a procedure (using SQ or SQUARE) that puts a square in each corner of the screen. (Hint: remember PENUP?)(Don't forget PENDOWN)
2. Write a procedure that draws a row of squares.
3. Write a procedure that draws a tower of squares. (Hint: use your row of squares procedure in it)
4. Write a procedure that draws a leaning tower of squares. (use your tower procedure)
5. How about a window with four panes?
6. Write a different procedure to draw the same size square as SQUARE.
7. Using the same sort of analysis used in developing the SQUARE procedure, figure out how you would draw a triangle whose turns are all the same size, then write the procedure.
8. Try #1-4 using triangles.
9. Write procedures to use your 4-sided (not a square) figure to make designs.
10. How about a window with 6 triangular panes?
11. Write a different procedure to draw the same size triangle.

Since all your new procedures (and old) are in your workspace, you can safely save them all in SHAPES by typing SAVE "SHAPES.

Listing a Procedure: PRINTOUT (PO), <CTRL> W

Just as you can print out titles using POTS, you can also PRINTOUT the list of commands in any procedure. Type

PO (procedure name)

to list the commands in any procedure in your workspace. Type

PO (procedure name)

to list any other procedure in your workspace. PO provides a handy, quick way to check on a procedure, but to make changes in it, you must get into EDIT mode as described before. Type

PO ALL

to scroll by the listings of all the procedures in your workspace. Use

<CTRL> W (W for Wait)

to stop the scrolling; each <CTRL> W you press after you stop the scrolling will move one line onto the screen. You may inspect the titles one by one with more <CTRL> Ws, or resume the scrolling by pressing another key.

To printout a selected list of procedures, type

PO [PROC1 PROC2 . . .]

SUMMARY OF LISTING COMMANDS

Command	Result
CATALOG	Lists names of files on disk in disk drive
POTS	Lists names of procedures in workspace
PO	(procedure name) Lists commands in named procedure
PO ALL	Lists entire contents of workspace
<CTRL> W	Wait: computer waits for another key to be pressed: press <CTRL> W again for line by line inspection, or any key to resume scrolling.

Heading: A Matter of State

It is possible that when you closed your square and triangle, you finished your procedure with FD and did not follow it with a turn. This left the turtle heading in the direction the last side required. This makes it handy to draw successive figures in new positions, but it leads to confusion when you want to use the shape in another procedure.

It is generally good programming practice to leave the turtle in the same state in which you found it. The state of the turtle is its position and heading. It is already in the original position, since you closed the figure. All that is required is to turn the turtle so that it is heading in the original direction. This means one more turn, the same size as the other turns.

Consider these three procedures:

```
TO SQ          TO SUPER
 FD 30          REPEAT 8 [SQ RT 45]
 RT 90         END
 FD 30
 RT 90         TO STRANGE
 FD 30          REPEAT 4 [SQ]
 RT 90          RT 45
 FD 30          REPEAT 4 [SQ]
END            END
```

Both SUPER and STRANGE draw the same design (although they draw the parts of the design in a different order).

Note that the last turn in SQ, the one that would turn the turtle back to its original heading, is omitted.

If you edit SQ now to add a RT 90 at the end, SUPER will still draw the same design (in yet a new order), but STRANGE will not.

This may seem odd at first because we have not changed STRANGE. However, we DID change the procedure STRANGE uses.

To counteract the effect of adding the RT 90 at the end of SQ, we would have to insert a LT 90 immediately after SQ in each procedure that uses it.

This kind of fix is not always so easy. For example, if the newly introduced extra was a line instead of a turn, it would be harder (in some contexts, impossible) to counteract its effect.

So it is best to leave the turtle heading as it started. This will eliminate many interface bugs (puzzling things that must be fixed in order to use one procedure after another).

Copying a Procedure

Your procedures SQUARE and TRIANGLE may now need another command added to them to turn the turtle to its original heading. But you have used SQUARE and TRIANGLE in other procedures; changing them now would spoil the procedures that use them. Take heart; change SQUARE, but give the new version a new name, such as SQUARE1. While in EDIT, change the name slightly (it can be edited like any other part of the procedure), then move down and add the new command. Voila. You now have your original procedure plus a slightly altered copy under a new name.

A Magic Number

Now for a rather basic question: how far around did the turtle turn when it drew the square that left it in the same state that it started from (same position and heading)? (Add up the turns.) How far around did the turtle turn when it drew the triangle that left it in its original state?

You have just discovered a great truth: the turtle will turn the same amount to get back to its original heading, no matter how it goes. The total amount of the turn, adding the turns in one direction and subtracting if it turns the other way, will be the magic number you just discovered. (Of course, if it goes one way and then cancels the turn out completely by going the other way, the total turn will be 0, but it will not have traveled completely AROUND anything, either.) This is called The Total Turtle Trip Theorem: if the turtle travels around an area, no matter what shape, and ends in the same place that it started, heading in the same direction, it always turns the same amount.

You can use the magic number to make shapes with any number of sides. To see the relationship between the magic number and the turns you made in the square, divide the magic number by the number of turns. Let Logo do it for you. On the computer, where we cannot type one character above another on a single line, we use the slash (/) (on same key as the ?) for division. To divide 10 by 5, type

```
10/5
```

Logo will reply

```
RESULT: 2
```

Remember, when Logo requires a number, it can use the result of an arithmetic operation, so you can also use this division as the number required by the Logo primitives FD, BK, LT, and RT. For example,

Command	Equivalent
FD 100/2	FD 50
RT 300/30	RT 10
BK 200/4	BK 50
LT 360/4	LT 90

Projects: More Shapes

1. Using REPEAT and division in your turn command, write another procedure that draws a square.
2. Using REPEAT and division in your turn command, write another procedure that draws a triangle.
3. Using REPEAT and division in your turn command, write a procedure that draws a 5-sided figure.
4. Write a procedure that draws a 6-sided figure.
5. Write a procedure that draws a 7-sided figure.
6. How about a 15-sided figure?

Introduction to Variables: Procedures That Take Inputs

DRAW does the same thing each time it is used. FORWARD is more flexible; it moves the turtle different distances depending on its input.

INPUT is the specific term for the number required by commands like FD, BK, LT, and RT. (Later you will also see INPUTS which are not numbers.)

So far your procedures have always done the same thing each time they were used, but it is possible to write procedures which use some input to tell them, for example, how much to move the turtle.

It would be nice to have a BOX procedure which draws different sized squares, just as we have a line procedure (FORWARD) which draws different lengths of line.

We would expect BOX 10 to produce a small box and BOX 100 to produce a larger box. To describe what happens more fully, we might say:

To draw a box of some dimension,
 we go forward that dimension,
 turn right 90 degrees,
 go forward that dimension,
 turn right 90,
 forward that dimension,
 right 90,
 forward dimension,
 right 90
and that's it.

The Logo translation of the English is very similar:

```
TO BOX :DIMENSION
 FD :DIMENSION
 RT 90
 FD :DIMENSION
 RT 90
 FD :DIMENSION
 RT 90
 FD :DIMENSION
 RT 90
END
```

Or, we could have said:

To draw a box of some dimension,
we must, 4 times, go forward that dimension
and turn right 90 degrees.

which translates into Logo as

```
TO BOX :DIMENSION
 REPEAT 4 [ FD :DIMENSION RT 90 ]
END
```

NOTE:

1. The : that appears in the procedure must be there every time an input variable is used, attached directly to the variable name without a space between. The dots distinguish the name of a variable from the name of a procedure. We call the colon (:) DOTS because it is more descriptive. Read :DIMENSION as DOTS DIMENSION.
2. Variable names are just as much your choice as procedure names. We could have written

   ```
   TO BOX :WIDTH or
       TO BOX :DIST or even
           TO BOX :X
   ```

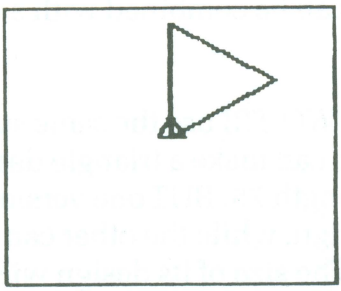
   Of course, the name you choose in the title line must also be the one used within the procedure, so those procedures would have had

   ```
   FD :WIDTH  FD :DIST  and  FD :X
   ```

3. Note where the variable-number name must go, in the same place in which you previously put the

constant number. In the procedure TRI, for example, FD 100 becomes FD :LENGTH. To pass the number into the procedure for FORWARD to use, the title now must become TO TRI :LENGTH.
The two procedures look like this:

```
TO TRI
 REPEAT 3 [FD 100 RT 120]
END

TO TRI :LENGTH
 REPEAT 3 [FD :LENGTH RT 120]
END
```



TRI

This TRI procedure is very much like the Logo primitives you have been using. For a triangle of any size, you type TRI and the length of the side.

Try a few triangles of different sizes.

Try typing TRI without a number. Now that TRI is defined with a variable input, Logo looks for that input, just as it does when you type FD or RT. To recall just what inputs a procedure is expecting, type either POTS, to print out the titles of all the procedures in your workspace, or PO (procedure name), to print out the one procedure (for instance PO TRI).

You have a choice now when you want to use TRI in another procedure. You can specify the size of the triangle in the procedure (TRI 75), or you can choose to decide on the size when you run the superprocedure it is in. You must pass the number in to TRI if you do not specify it inside the procedure. For example:

```
TO TWO.TRI          TO TWO.TRI2 :LENGTH
 TRI 75              TRI :LENGTH
 RT 90               RT 90
 TRI 75              TRI :LENGTH
END                 END
```

Note: Two words can be combined with a dot to make a title.

Both versions of TWO.TRI use the same subprocedure TRI. Both versions can make a triangle design with triangle sides of length 75. BUT one version can only draw a size 75 design, while the other can draw designs of any size. The size of its design will depend on the number you give it when you run it.

The variable name :LENGTH may be used in any number of procedures. You are allowed to have only one procedure named SQUARE or TRIANGLE, but both may use the variable name :LENGTH. :LENGTH is what is called a local variable, local to its procedure. A name used in one procedure will not interfere with the same name used in another.

This also means that TWO.TRI2 could have used a different name for the variable than was used internally by TRI.

Projects: Sizable Shapes

1. Write a procedure SQV with variable input and use it in a new procedure SQUARE4 to draw a series of squares of different sizes, all starting at the same place. (Hint: you can add to a picture; you don't have to clear the screen with DRAW everytime you want to draw something more.)
2. Add another set of squares beside the first.
3. Write a procedure that uses a specific size square in it.
4. (Here's a toughie) Write a procedure that draws 4 squares, each 25 steps bigger than the last, and which receives as input the size of the first square when the procedure is run.

From SQUARE to POLY

SQUARE4 (if you did project 1) now has a variable input for the length of the side, but it still has two other numbers, the size of the turn and the number of times the sequence is repeated. Either or both of these numbers could also become variables. (However, if we change either one, it would not draw a square.)

You know from your experiments that 360 is the magic number that takes the turtle all the way around and back to the same heading, no matter what shape it is going around. You also know that the amount of the turn at each corner is 360 divided by the number of turns. Remember too that Logo will do all the work of dividing for you. You may use 360/4 as the input for your turn in SQUARE4, for instance.

In other words, the SQUARE4 procedure could be written

```
TO SQUARE4 :LENGTH
 REPEAT 4 [FD :LENGTH RT 360/4]
END
```

The 4 in both places is the number of turns. SQUARE4 now has a variable input for the length of the side and one other number that might be changed, the number of turns or sides. What if we made that number a variable, too?The procedure would repeat the side-and-turn sequence that number of times, and would divide 360 by the number for the turn. Sounds all right, but it wouldn't draw a square. It would draw a many-sided figure, (called a polygon) with the number of sides you chose when you ran it. Call it POLY.

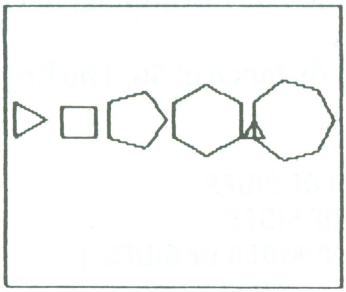
POLY will need two names for the variable inputs, and they should clearly describe what they are for.

:LENGTH would be fine for the length of the side again, and you could use :TURNS for the number of turns (or sides).

Both variable names must appear in the title, to pass the numbers in to where they are used in the procedure. Choose the order you will remember best. They do not have to appear in the title in the order in which they are used in the procedure, but, when you run POLY, the numbers must be typed in the same order as the variables which represent them in the title. POLY 100 4 will be very different from POLY 4 100.

So POLY could look like this:

```
TO POLY :LEN :TURNS
 REPEAT :TURNS [FD :LEN RT 360/:TURNS]
END
```



POLY

Projects: Regular Polygons

Experiment with different inputs to POLY. Write down the ones you like.

1. What is the difference between POLY 100 4 and POLY 4 100? Try them both.
2. Try POLY with the same :LENGTH input and a lot of different numbers for :TURNS.
3. Keep :TURNS the same and try a lot of different numbers for :LENGTH.
4. Make a design using POLY twice, with a different number of sides (:TURNS) each time.
5. Use POLY to make a triangle.
6. What is the largest number you can use for turns? (Hint: hide the turtle for a quicker trip.)

Another View of POLY

Look back at the procedures in which you used division to help you draw 3, 4, 5, 6, and 7-sided figures.

They probably look a lot alike. In English you might describe them this way:

To draw a shape of some specified number of sides, repeat for each side: go forward some distance and turn right 360 divided by the number of sides

Let's use a forward distance of 50. The English translates to Logo:

```
TO SHAPE :NUMBER.OF.SIDES
REPEAT :NUMBER.OF.SIDES
   [ FD 50 RT 360/:NUMBER.OF.SIDES ]
END
```

Type as one line

(Note that the REPEAT statement must be typed on one line.) Type in SHAPE and try it with various inputs. Try

```
SHAPE 3
SHAPE 4
```

We can also make shapes of various sizes by making the forward distance a variable. Replace the 50 with the variable :DIST and add it to the title:

```
TO SHAPE :NUMBER.OF.SIDES :DIST
REPEAT :NUMBER.OF.SIDES
   [FD :DIST RT 360/:NUMBER.OF.SIDES]
END
```

Type as one line

Try

SHAPE 3 50 and SHAPE 50 3

It is important to remember the order of the variables in the title.

This procedure produces the same design as POLY (above). The number of sides will be the same as the number of turns.

Circles

So far we have drawn only straight lines. How does the turtle draw curves? When you consider that all it can do is step and turn, then it must be some combination of steps and turns in curves as well as in straight-sided figures. Experiment with small steps and small turns. Use REPEAT with your little steps and turns to avoid exhaustion. Try some combinations in IMMEDIATE mode, then make procedures of the combinations you like.

Some things to remember:

- the turtle draws faster when hidden (HT)
- <CTRL> G stops the turtle, whatever it is doing
- you know how far the turtle must turn to finish back where it started

Projects: Curves

Try these first, then make procedures of the ones you would like to be able to use. Give your procedures descriptive names, for instance, a 6th-of-a-circle arc to the right might be ARCR6.

1. Use REPEAT to draw a circle, then without clearing the screen, draw another circle with steps twice as big as in the first one. Draw another with the turn twice as big.

2. Draw a circle to the right and an identical one to the left.
3. Figure out the diameter (distance across) of the last circle.
4. Draw a quarter-circle arc to the right.
5. Draw another quarter-circle arc with steps twice as big as the one in #4.
6. Draw a 6th-of-a-circle arc to the left, then a 6th-of-a-circle arc to the right. (Hint: use division, and let Logo do it for you)
7. Write a procedure that uses an arc procedure and straight lines to draw a picture or design.
8. Do these projects using variable inputs for the step size and the number of degrees.

See the section on Procedures for a way to develop an arc procedure. There are also several demonstration arc and circle procedures on the Utilities Disk. See the Utilities Disk section.

Using Subprocedures

A procedure used as a command in another procedure is called a subprocedure. The procedure which uses it is a superprocedure. You have already used SQUARE as a subprocedure when you called it in the superprocedure SQ, and, if you did the projects, you used procedures as subprocedures to draw towers, windows, and a design with arcs and lines.

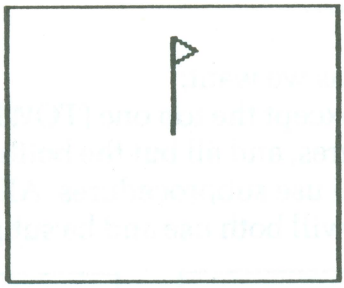
A subprocedure is useful when you want to use a procedure as a new primitive in a variety of procedures, or several times in one procedure. You could write a procedure to do one side of a square (such as FD 73) and

one turn (RT 90). If you called it SQUARESIDE, then your square procedure would look like this:

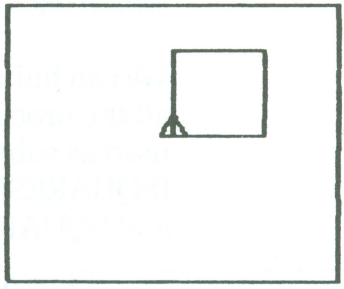
```
TO SQUARE2
 SQUARESIDE
 SQUARESIDE
 SQUARESIDE
 SQUARESIDE
END
```

(or perhaps)

```
TO SQUARE2
 REPEAT 4 [SQUARESIDE]
END
```



SQUARESIDE



SQUARE2

Any Logo procedure can be a subprocedure. In addition, subprocedures may have subprocedures of their own.

For example:

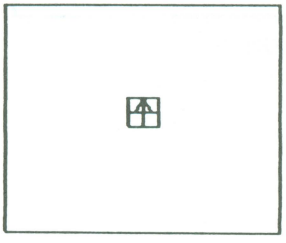
SQUARE2 uses SQUARESIDE as a subprocedure.

We write WINDOW which uses SQUARE2 as a subprocedure.

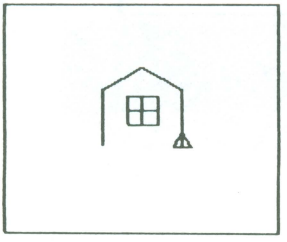
SQUARE2, which has SQUARESIDE as a subprocedure, is now also a subprocedure.

We write HOUSE, which uses WINDOW, and TOWN, which uses HOUSE...

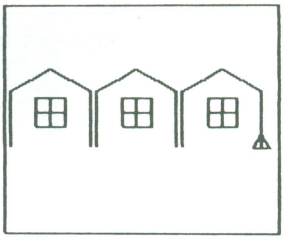
We can build as far as we want;
all the procedures except the top one (TOWN) will be used as subprocedures, and all but the bottom one (SQUARESIDE) will use subprocedures. All but TOWN and SQUARESIDE will both use and be subprocedures.



WINDOW



HOUSE



TOWN

The point of this exercise is to show that even now you are writing procedures you can use later on. As you write your way through the tutorial, note the procedures that may be particularly useful to you as subprocedures. You might even want to file them separately

after a while, in a file called NEW.PRIMITIVES (Logo allows you to use periods in your procedure and file names to connect words.) Your arc procedures are good examples of useful primitive-like subprocedures.

Non-stop Procedures: Introduction to Recursion

Your procedures up to now have been very well-behaved and have stopped when you told them to. Now let's try a type of procedure that simply doesn't know when to stop.

As you know, a Logo procedure can use any Logo command, whether it is a primitive or a procedure. This includes a procedure being able to use itself.

The ability of a procedure to call itself is called recursion. We shall work up to the power of recursion with some simple examples. What happens when you tell a procedure to do itself? Let's try it with a square program:

```
TO SQUARE3 :LENGTH
 FD :LENGTH
 RT 90                (Stop me with <CTRL> G)
 SQUARE3 :LENGTH
END
```

What have we told SQUARE3 to do?

1. Draw a side and do a turn
2. Do SQUARE3
    1. Draw a side and do a turn
    2. Do SQUARE3
        1. ...

Only a <CTRL> G typed at the keyboard will stop this runaway square. It will go over and over the same track until you stop it. Not very interesting.

But what would happen if there was a side and a turn that made a design which would not go over itself? Change the amount of the turn. Try a little more or less than the 90 used for a square. Try, for example,

```
FD :LENGTH
RT 87
```

Projects: Simple Recursion

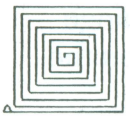
1. Write a recursive procedure that draws a little figure then calls itself.
2. Write a recursive procedure that uses arcs and lines.
3. Use your triangle procedure in a recursive procedure.
4. Write a recursive procedure to draw a star.

Recursion: Changing the Input WRAP, NOWRAP, CONTINUE (CO)

Another interesting possibility is that of changing the length of the side each time it is drawn. Remember, wherever Logo requires a number, there are several ways to give it one. We have tried actual values (100 for instance) and right now we are using a variable (:LENGTH). The next kind of number to try is a number which Logo will produce for us by doing some arithmetic, for instance, :LENGTH + 3.

```
TO SQUARAL :LENGTH
 FD :LENGTH
 RT 90
 SQUARAL :LENGTH + 3
END
```

When SQUARAL calls SQUARAL, it uses a little bigger number for the length of the side. Now, even with a turn of 90, the design will not repeat itself on the same path.



SQUARAL

What happens when you run this procedure: Type

```
SQUARAL 5
```

1. The turtle moves FD 5 for the first side and turns right.
2. Logo runs SQUARAL 5 + 3.

```
SQUARAL 8
```

1. The turtle moves FD 8, 3 steps more than the first side and turns.
2. Logo runs SQUARAL 8 + 3.

```
SQUARAL 11
```

1. The turtle moves FD 11 and turns.
2. Logo runs SQUARAL 11 + 3.
   and so on.

The second side, and each side after it, will be 3 steps longer than the previous side, and the picture will clearly not be a square.

Before long, the line spills off the edge and reappears on the other side of the screen. Logo is in WRAP mode, where the lines wrap around the screen rather than stopping at the edge. This can make interesting effects, particularly with PENCOLOR 6, which reverses the color when lines cross.

Remember, you can use FULLSCREEN or <CTRL> F, SPLITSCREEN or <CTRL> S, and TEXTSCREEN or <CTRL> T to change the amount of drawing space showing on the screen.

To make Logo stop the procedure when the line threatens to get out of bounds, type NOWRAP to put Logo into NOWRAP mode. Now, no matter where the turtle is when you run the procedure, when the design gets too big for the screen, Logo will stop it. (There are more elegant ways to stop recursive procedures mentioned later on. See Stopping With Style.)

The commands WRAP and NOWRAP, like all other Logo commands, can also be used in procedures. Whenever they are used, each stays in effect until the other is used, or until you exit DRAW mode.

Projects: Changing Inputs

Make the changes suggested below and give each changed version a new name. Run each version with several different inputs, large and small (SQUARE 10, SQUARE 100 for instance)

1. Change the amount added to :LENGTH in SQUARAL make it large; make it very small.
2. Subtract an amount from :LENGTH in SQUARAL instead of adding to it.
3. Change the size of the turn a little bit.
4. Multiply :LENGTH by a number. Keep trying until you find one you like. Remember, use the star (*) for multiplication. (Hint: you can use decimals such as 1.1 or 1.5)
5. Try all of your procedures in WRAP mode and NO-WRAP mode.
6. In WRAP mode, try your procedures with PENCOLOR 6 (PC 6).
7. Write a procedure which takes a variable input and draws one square. (Hint: use REPEAT) Then write a recursive procedure that uses the square procedure as a subprocedure and draws a series of squares which get bigger and bigger.

Stopping With Style: IF-THEN, STOP

Logo can make choices based on what you tell it to do. You can write IF (something) is true, THEN (do something else) (STOP for instance). (If it is not true, it will go directly to the next line. If it IS true, and the instruction is not STOP, it will execute the instruction and THEN go to the next line.)

For example, you would like to be able to specify the number of times a recursive procedure executes, and specify a different number every time you run it. Make the procedure count down from the number you give it, and test the count each time it executes with

```
IF :TIMES = 0 THEN STOP
```

Here is a procedure that draws a square, turns the turtle a little, and does it again.

```
TO DESIGN :TIMES
 IF :TIMES = 0 THEN STOP
 SQUARE 100
 RT 45
 DESIGN :TIMES-1
END
```

This is what happens when you type

☐ `DESIGN 4`

1. Logo tests :TIMES (4) to see if it is zero.
2. Logo runs SQUARE and turns the turtle
3. Logo calls DESIGN 4—1 or DESIGN 3

DESIGN 3

1. Logo tests :TIMES (3) to see if it is 0
2. Logo runs SQUARE and turns the turtle
3. Logo calls DESIGN 3—1 or DESIGN 2

DESIGN 2

1. 1. Logo tests :TIMES (2) to see if it is 0
2. Logo runs SQUARE and turns the turtle
3. Logo calls DESIGN 2—1 or DESIGN 1

DESIGN

DESIGN 1

1. tests :TIMES (1) to see if it is 0
2. runs SQUARE and turns the turtle
3. calls DESIGN 1—1 or DESIGN 0

DESIGN 0

1. Logo tests :TIMES (0) to see if it is zero and stops. :TIMES = 0 is finally true.

Control is passed back to each level in turn and the procedure is done. This aspect of recursion will be covered in the next section.

What happens when your friend tries to be funny and runs DESIGN with a negative number?(Ah, you tried it ... Well, remember <CTRL> G.)You will be pleased to know that you can test for that also. In fact, you can put as many tests as you wish in your procedure. You can test for that negative number by using one of the two other conditions, less than (<) or greater than (>).

To cover both situations, your negative friend and the normal ending of the procedure, change your test:

```
TO DESIGN :TIMES
 IF :TIMES < 1 THEN STOP
 SQUARE 100
 RT 45
 DESIGN :TIMES-1
END
```

Now DESIGN will stop when :TIMES gets to 0 and will never start if :TIMES is less than 0.

The procedure can still have variable inputs for other values, such as the length of the side of the square:

```
TO DESIGN :TIMES :LENGTH
 IF :TIMES < 1 THEN STOP
 SQUARE :LENGTH
 RT 45
 DESIGN :TIMES-1 :LENGTH
END
```

You can even change the length each time it is called if you wish by incrementing it as it is in SQUARAL.

NOTE: Be sure the variable you test in your procedure will eventually reach the test value. For example, in our first version of DESIGN, :TIMES would never have reached 0 if it had started out negative. The first one, in fact, will also fail with a decimal such as 10.3.

If you don't happen to think of this possibility, the procedure may go on and on and on and you won't know why.

This is a common problem in writing procedures: the computer always does what you TELL it to do, whether or not it's what you want it to do. BUGS creep into the procedures of the best of programmers.

Bugs can be fun. You can learn from them, and sometimes what the computer does is more interesting than what you had intended.

Projects: Testing and Stopping

1. Try replacing the 45 in RT 45 with something that depends on :TIMES, such as 4 * :TIMES.
2. Write a procedure to draw a tower of smaller and smaller squares, choosing the number of squares when you run it.
3. In DESIGN, change the input for RT to a variable. (Remember to add the variable name to the procedure title)

Using the Full Power of Recursion

> To see Logo execute procedures step by step, use TRACE, described in the section on debugging in this chapter, the Appendix, and in the Technical Manual.

The results of the recursive procedures shown so far could have been achieved with non-recursive procedures. Each one so far has done something and then called itself to do essentially the same thing again. Except for DESIGN, the procedures did not stop by themselves, so they never had the chance to return to the top level.

The power of recursion, and what makes it different from iteration (repetition), is its ability to come back from the last call to itself (called the deepest or lowest level), finishing a job at each level as it returns.

This will be a new concept to many. Logo is one of the few computer languages with this capability.

The following comparison will illustrate this:

```
TO COUNTER :NUMBER
 IF :NUMBER > 2 STOP
 PRINT :NUMBER
 COUNTER  :NUMBER + 1
END

TO COUNT.PLUS :NUMBER
 IF :NUMBER > 2 STOP
 PRINT :NUMBER
 COUNT.PLUS :NUMBER + 1
 PRINT :NUMBER
END
```

Small numbers are used to permit full step-wise explanation.

COUNTER works in the same way as DESIGN. Type

COUNTER 1 and Logo will respond

```
1
2
```

COUNT.PLUS, as its name suggests, does more. This is what happens when you type

COUNT.PLUS 1

1. Logo tests to see if :NUMBER (1) greater than 2.
2. Logo prints :NUMBER (1).
3. Logo calls COUNT.PLUS :NUMBER + 1 (2).
4. (The last statement, PRINT :NUMBER, is not executed.)

COUNT.PLUS 2

1. Logo tests to see if :NUMBER (2) > 2.
2. Logo prints :NUMBER (2).
3. Logo calls COUNT.PLUS :NUMBER + 1 (3).
4. (The last statement, PRINT :NUMBER, is not executed.)

COUNT.PLUS 3

1. Logo tests to see if :NUMBER (3) > 2.
2. Logo stops and returns control to the procedure that called COUNT.PLUS 3, which was COUNT.PLUS 2.

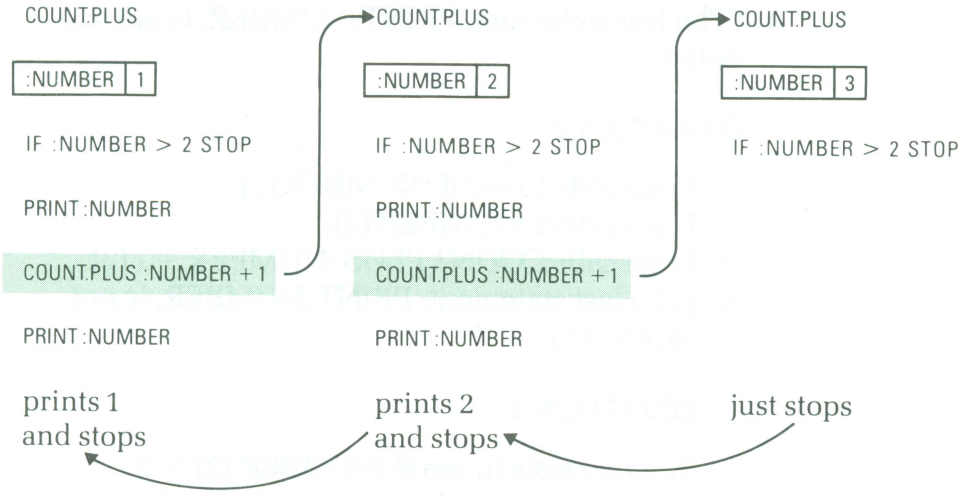
COUNT.PLUS 2

5. Logo executes the next statement in COUNT-.PLUS 2, which is PRINT :NUMBER. Prints 2.
6. Logo stops and returns control to the procedure that called COUNT.PLUS 2, which was COUNT-.PLUS 1.

COUNT.PLUS 1

5. Logo executes the next statement in COUNT.PLUS 1, which is PRINT :NUMBER. Prints 1.
6. Logo stops and returns control to the procedure that called COUNT.PLUS 1, which was the main Logo command level.

The diagram shows how all copies of COUNT.PLUS exist at once, each with its own private value for :NUMBER.



The process of recursion is based on one idea:

When a procedure (A) calls another procedure (B), the calling procedure (A) puts on hold any instructions which come after the call. When the procedure (B) which is called stops, the calling procedure (A) continues with the rest of its instructions after the call to (B).

What makes recursion so powerful is that this idea applies also to (B) and any procedure (B) calls, and any procedure that THAT procedure calls...

And all of these copies of the procedure co-exist, each with its private portfolio of values. All copies are used and exist as if they were completely different procedures.

An excellent example is the procedure SQS which produces squares with half-size squares on the corners:

```
TO SQS :LENGTH
 IF :LENGTH < 5 STOP
 REPEAT 4 [FD :LENGTH SQS :LENGTH/2 RIGHT 90]
END

TO SQR :LENGTH
 IF :LENGTH < 5 STOP
 REPEAT 4 [FD :LENGTH  RT 90]
 SQR :LENGTH/2
END
```

Note the difference the placement of the recursive call makes in SQR and SQS.

The procedure EXPONENT in the Computation chapter and the procedure TET on the Utilities disk (see the APPENDIX) are two other examples of good recursive procedures. See also Recursion in Music in the music chapter.

See chapter 2 in LOGO FOR THE APPLE II, by Professor Harold Abelson, M.I.T., for a further discussion of recursion.

Recursion Projects

1. Write a set of procedures which draw successively smaller houses. Use subprocedures for the parts of the house.
2. Write a procedure to draw a binary tree. A binary tree is a v-shaped tree with a smaller v-shaped tree on each tip. Develop the procedure for the basic V, then determine where in the procedure you would insert a recursive call to itself to draw a smaller tree.

To stop the procedure, use a test similar to the one used in SQS.

3. Write a procedure that draws a series of successively larger fish, each totally within the next larger.

Special Effects and New Utilities

Remember that PC 6 changes black to white and white to black when turtle tracks cross. Try it with SQUARE3 and SQUARAL.

```
TO SQUARE3 :LEN
 FD :LEN
 RT 90
 SQUARE3 :LEN
END
```

```
TO SQUARAL :LEN
 FD :LEN
 RT 90
 SQUARAL :LEN + 3
END
```

Clear the screen, hide the turtle, set your pencolor to 6 (the reversing color), type SQUARE3, and hit <CTRL> F so you can watch on the full screen:

```
DRAW HT PC 6 SQUARE3 <CTRL> F
```

If you like the effect, write a procedure which will do it for you at the stroke of a single name. Give the procedure a name and the commands in the line above (use the word FULLSCREEN for the <CTRL> F):

```
TO SUPERSQ
 DRAW HT PC 6 FULLSCREEN SQUARE3
END
```

Type SUPERSQ and sit back.

You could also make a separate procedure of the SETUP part. Make this one of your own utility procedures.

```
TO SETUP
 DRAW
 HT
 PC 6
 FULLSCREEN
END
```

```
TO SUPERSQ
 SETUP
 SQUARE3
END
```

Since Logo lets you use primitives and procedures the same way, you can build your own file of new primitives, utility procedures that do the special things that you want to do. This might even include procedures like C which has the single command CATALOG, simply to save typing...

If you can change a color once, you can change it again, both background and pencolor. You can make the change once in a great while, or you can flash from one to another.

Here's a flashy example (NOTSQ is not quite a square)

```
TO NOTSQ
 REPEAT 4 [FD 85 RT 85]
END

TO FLASH.NOTSQ
 PC 6
 BG 0 NOTSQ
 BG 1 NOTSQ
 BG 2 NOTSQ
 FLASH.NOTSQ
END
```

FLASH.NOTSQ sets the pencolor to 6 (reversing), the background to black, and runs NOTSQ, four lines that

don't quite meet. The background changes to white, four more lines are drawn, the background changes to a color, four more lines, then the whole procedure repeats endlessly. Each time a line crosses a line, the color of that spot is reversed.

RANDOM Numbers, Numbers from Arithmetic Operations, Inputs, Outputs

The Logo primitive RANDOM will give you a number, chosen at random from the group you specify. You specify the group from 0 to your number by giving RANDOM the next higher number. For instance, RANDOM 7 will choose a number from 0 to 6 (just what PC and BG need).

The number RANDOM chooses is called its OUTPUT. If you type RANDOM 7 at the keyboard, Logo will respond with RESULT: 4 (or some other number from 0 to 6), just as it printed RESULT: 90 when you typed 360/4. Both RANDOM and the arithmetic operation produce a result, that is, they each put out a number, which is called an OUTPUT.

The number RANDOM uses is its INPUT. You can never leave out an input: the command needs it to work. On the other hand, in IMMEDIATE mode, Logo will print an output as a RESULT sometimes. However, any time Logo expects to go on, as in a procedure or a REPEAT command, it needs to know what to do with that output. Try typing

```
REPEAT 4 [RANDOM 8]
```

and Logo will complain.

This is equivalent to typing

```
REPEAT 4 [5]
```

Give RANDOM's OUTPUT to something that requires an INPUT (such as FORWARD or PRINT), and you are in business:

```
REPEAT 4 [FORWARD RANDOM 8]
```

Ooh la la... it works.

To make the turtle's pen or the background take on a random color, use RANDOM 7 instead of the number. FLASH.NOTSQ could now be

```
TO FLASH.NOTSQ
 PC 6
 BG RANDOM 7
 NOTSQ
 FLASH.NOTSQ
END
```

(You have the choice of editing the old FLASH.NOTSQ or typing ERASE (or ER) FLASH.NOTSQ and typing the new version.)

Here FLASH.NOTSQ sets the pencolor to reverse, picks a random background color, runs NOTSQ, then does the same three steps again and again until you stop it.

To avoid using the reversing (eraser) color #6, use RANDOM 6, which will select numbers from 0 to 5. To

avoid using black as well (color #0), use 1 + RANDOM 5. This gives you a random number from 1 to 5 because 1 is always added to a random number from 0 to 4.

Try adding one of these lines to one of your procedures:

```
PC 1 + RANDOM 5
BG 1 + RANDOM 5
```

Note that the number used with PC (PENCOLOR) and BG (BACKGROUND) is the result of an arithmetic operation again, addition this time. Recall that some of the turns in your shape procedures were calculated by division.

Any time a number is required in Logo, it can be given as the result of an arithmetic operation. In Logo, use + and − for addition and subtraction (as usual), the slash (/) for division, and the star (*) (or asterisk) for multiplication. There are rules you need to know if you use more than one operator (+−/*) at a time; see the COMPUTATION chapter for details on that.

Projects Using Random

1. Substitute FORWARD RANDOM 100 for the side in SQUARE3.
2. Write a REPEAT statement using a FORWARD command and a random turn from 0 to 360 degrees.
3. Write a recursive procedure using a FD command and a random turn between 90 and 180 degrees.
4. Try some other ranges for turns; choose the most interesting to keep as a procedure.

Debugging by printing values: PRINT (PR)

Logo is one of the easier computer languages to debug (get rid of the errors, called bugs) because large programs are composed of small procedures. It is a lot easier to debug a small procedure than a long, complicated program. Always make sure your procedures are debugged (run correctly by themselves) before you use them in other procedures.

```
TO DESIGN :TIMES :LENGTH
 IF :TIMES = 0 THEN STOP
 SQUARE :LENGTH
 RT 45
 DESIGN :TIMES-1 :LENGTH
END
```

In DESIGN, if you type

```
DESIGN 6.5 100
```

the procedure will never stop.

To find out why, we want to check out :TIMES. It would be nice to print it out each time around.

Use the Logo PRINT (PR) command to check on the value of :TIMES. Type

```
TO DESIGN
```

and add this line (in EDIT mode) just before the test (before IF...):

```
PR :TIMES
```

(You can remove it after you have debugged the procedure.)

DESIGN now looks like this:

```
TO DESIGN :TIMES :LENGTH
 PR :TIMES
 IF :TIMES = 0 THEN STOP
 SQUARE :LENGTH
 RT 45
 DESIGN :TIMES-1 :LENGTH
END
```

Type <CTRL> C to leave EDIT mode, then type

```
DESIGN 6.5 100
```

As it runs DESIGN, Logo will draw the design in the graphics part of the split-screen, and will print the values of :TIMES on the four lines of the text part of the screen.

Because the values are not whole numbers, if you look quickly, you will see them get smaller and smaller and then become negative and get larger and larger. In other words, :TIMES has passed zero and skipped the test because :TIMES was never exactly zero.

Now you know that the bug is in the test that failed to account for this possibility. You can either change the test or add another test. The best thing to do is change the test, since two tests are not really necessary. However, when you change the test, be sure to try out DESIGN with every possibility you can think of. ALWAYS test your procedures using all of the possibilities you can think of.

Debugging Using PAUSE: <CTRL> Z CONTINUE (CO)

PAUSE or <CTRL> Z stops a procedure in such a way that you can start it again. While it is stopped, you can find out where the (hidden) turtle is by typing SHOWTURTLE (or ST), hide the turtle with HT, print the procedure out with PO, PRINT variable values, or do a number of other things. To resume running the procedure, type CONTINUE (or CO).

Negative Inputs

There is also another possibility: remember that friend of yours who likes negative inputs? What happens to DESIGN if :LENGTH is negative? What happens to :TIMES? What happens to the friend?

Well, if :LENGTH is negative, the turtle just backs around in the opposite direction. Logo knows all about negative lengths.

And the friend? Unless he knows how to give that negative input, Logo will give him a (no doubt helpful) error message.

A negative input for the second variable must be in parentheses to show that it is an input and not a number to be subtracted from the first variable, for, as you will recall, inputs can be the results of arithmetic operations. Type

```
DESIGN 5 (-100)
```

Let's set up a situation where the size of the turn between squares depends on the number of :TIMES the

square is drawn, so we can have a complete design. To do this, we replace the 45 with 360 / :TIMES.

```
TO DESIGN :TIMES :LENGTH
 IF :TIMES < 1 THEN STOP
 SQUARE :LENGTH
 RT 360/:TIMES
 DESIGN :TIMES-1 :LENGTH
END
```

Now we have two things which depend on :TIMES, :TIMES itself, which must always be positive, and the turn between squares, which could be either positive or negative. A negative turn just goes around in the other direction.

How can we fix it so a negative number for :TIMES will give us a positive value for :TIMES, but keep the negative turn?

To do this, we must write a procedure to test :TIMES, then call DESIGN with the appropriate values. We also need to use a variable for the turn, so we can keep it negative when :TIMES changes to positive. DESIGN becomes

```
TO DESIGN :TIMES :LENGTH :TURN
 IF :TIMES < 1 THEN STOP
 SQUARE :LENGTH
 RT :TURN
 DESIGN :TIMES-1 :LENGTH :TURN
END
```

COMPLETE.DESIGN is the procedure which handles the details:

Type as one line

```
TO COMPLETE.DESIGN :TIMES :LENGTH
IF :TIMES < 0 THEN
    DESIGN -:TIMES :LENGTH 360/:TIMES
    ELSE
    DESIGN :TIMES :LENGTH 360/:TIMES
END
```

This is a one-line procedure, shown here on several lines for clarity. It must be typed as one line.

This says that if :TIMES is negative, change it to positive when you call DESIGN, otherwise leave it alone. In both cases, :TURN uses :TIMES directly, so if :TIMES is negative, :TURN is negative; if :TIMES is positive, :TURN is positive.

More on Debugging: TRACE, NOTRACE

Logo provides a detective system to trace through the procedure with you as the procedure is executed. Logo prints each line on the screen, you press <RETURN>, and Logo executes the line. Type TRACE to activate TRACE mode, NOTRACE to get out of it. See the Appendix for a full description of TRACE and NOTRACE.

More About the Turtle: TURTLESTATE (TS), HEADING, SETHEADING (SETH), TOWARDS

Logo primitives which give information about the turtle are useful for testing.TURTLESTATE is a good example, giving a list of four pieces of information.

Type

```
TURTLESTATE and Logo will reply
RESULT: [TRUE TRUE 0 1]
```

if 1. It is TRUE that the pen is down
2. It is TRUE that the turtle is visible
3. Background color is 0 (black)
4. Pencolor is 1 (white)

Refer to the chapter on Words and Lists for how to test against a member of a list. You can also print the information, i.e. PRINT TURTLESTATE.

Logo uses HEADING for the direction the turtle is pointing. Type

```
HEADING and Logo will reply
RESULT: 45.007
```

or whatever number of degrees the turtle has turned to the right (clockwise) from facing up.

PRINT HEADING, whether used in a procedure or not, will print the number alone. You can use HEADING to stop a procedure after a turn. Example:

```
IF HEADING < 45 STOP
```

Use SETHEADING (SETH) to tell Logo what direction you want the turtle to face:

```
SETHEADING 45
```

turns the turtle as if it had turned 45 degrees to the right from facing straight up.

To change the turtle's heading by a specific amount, use both:

```
SETHEADING HEADING + 5
```

will turn the turtle 5 degrees to the right.

TOWARDS turns the turtle to face a point designated by its coordinates:

```
SETHEADING TOWARDS 100 (-100)
```

turns the turtle to face a point 100 turtle steps to the right (x = 100) and 100 turtle steps down (y = −100) from the center of the screen. Note that here, too, the negative input is in parentheses to avoid confusion with subtraction. Another way to write a negative second input is to write it as zero minus the number. Example:

```
SETHEADING TOWARDS 100 0-100
```

Position When You Want It: XCOR, YCOR, SETX, SETY, SETXY

The graphics screen can be thought of as a grid, with X going across and Y going up and down. At the HOME position in the center of the screen, X and Y are zero. X gets larger to the right; Y increases as you go up. X is negative to the left of HOME, and Y is negative below it.

XCOR and YCOR give the X and Y coordinates of the turtle's position on this grid. Type XCOR, YCOR,

PRINT XCOR, or PRINT YCOR and Logo will print the X or Y coordinate. You may also test against either:

```
IF XCOR = 150 STOP
```

To move the turtle to a specific coordinate position, use SETX, SETY, or SETXY. Only the position will change; the turtle will not change its heading. Type:

```
SETX 100
```
to move the turtle across to x = 100

```
SETY 100
```
to move the turtle up or down to y = 100

```
SETXY 100 100
```
to move the turtle to the point x = 100, y = 100

```
SETXY 100 (-100)
```
to move the turtle to x = 100, y = −100

Use these commands together to move the turtle a specific distance:

```
SETX XCOR + 5
```

moves the turtle 5 steps to the right without changing its heading.

```
SETXY XCOR + 5 YCOR − 5
```

moves the turtle 5 steps to the right and 5 steps down, keeping the same heading.

SETXY is used in the Computation chapter to draw curves using their equations. To see how to use SETXY with joysticks and paddles, see PADDLE in the Technical Manual.

INSTANT: Logo Turtle Graphics for the Non-reader

Your Logo system disk contains a collection of procedures which makes Logo turtle graphics accessible to young children. The INSTANT system uses single character commands which are equivalent to longer Logo commands. You can use colored stickers to identify the appropriate keys for use with INSTANT.

To use INSTANT, turn on the Apple with the Logo Language disk in the disk drive. When Logo is loaded and displaying the question-mark prompt (?), put the Utilities Disk in the disk drive and type

READ "INSTANT (with the ")

Logo will read in the file of procedures used by INSTANT, identifying each as defined. Type

INSTANT (without the ")

The screen will display the commands used in INSTANT as follows:

```
F  MOVES THE TURTLE FORWARD
R  TURNS IT RIGHT
L  TURNS IT LEFT
D  DRAW (CLEARS THE SCREEN)
U  UNDO (ERASES LAST COMMAND)
N  NAMES THE PICTURE
P  SHOWS A PICTURE, ASKS FOR ITS NAME.
?  GIVES HELP

PRESS ANY KEY TO CONTINUE.
```

When you press a key, the list goes away, the turtle appears, and the blinking cursor moves to the lower left portion of the screen.

Type F to move the turtle forward.Turn the turtle with either R or L.

D restores the screen to its original condition, erasing the whole picture.

To erase just the last command, type U. Logo will re-draw the picture without the most recent command.

Animation Of A Sort

U makes it possible to do some interesting animation, since every motion of the turtle is relived in the re-drawing, even though it is not visible in the finished drawing. For a Lively Line, try typing

```
FRLLR   FRLLR   FRLLR   U
```

The idea is to wave the turtle back and forth every once in a while, perhaps turn it completely around; let it be indecisive about making a turn... It all comes out again when you type the U.

To name a picture, type N and the name. (Names do not have to be single letters; they can be of any length.) INSTANT will create a Logo procedure which has that name and contains all the steps used in drawing the picture.

To get a picture back, type P and its name. When the picture-drawing procedure is called using P, it is added to the current list of commands and becomes part of a new procedure when N is next used. Using N and P in this way, you can do structured programming in INSTANT.

The following INSTANT session demonstrates this feature. Although the single-letter INSTANT commands do not print out when you type them, they are shown here for convenience. The computer's responses appear in italics.

```
F
F
R
R
N
WHAT DO YOU WANT TO CALL THIS PICTURE?
SIDE
P
WHAT PICTURE DO YOU WANT TO SHOW?
SIDE
P
WHAT PICTURE DO YOU WANT TO SHOW?
SIDE
P
WHAT PICTURE DO YOU WANT TO SHOW?
SIDE
P
WHAT PICTURE DO YOU WANT TO SHOW?
SIDE
N
WHAT DO YOU WANT TO CALL THIS PICTURE?
BOX
```

If you leave INSTANT and print out the procedures SIDE and BOX, you can see that they are basically the same procedures developed in the beginning of this chapter, with minor differences such as three RIGHT 30 commands being used instead of RIGHT 90.

To save a picture on the disk, return to Logo with <CTRL> G and type SAVEPICT " and the name you want for your picture. Example:

```
SAVEPICT "PUPPY
```

will save the picture on the screen under the name PUPPY on the disk.

Type

```
INSTANT
```

to return to the INSTANT system.

For disk storage of procedures created using INSTANT, you must leave INSTANT and return to Logo:

1. Type <CTRL> G to return to Logo.
2. Type <CTRL> T for the full screen of text (TEXT mode)
3. Type POTS to list the procedures you have created (plus the system procedures you saw defined as they were read in)
4. To write all of the listed procedures to your disk, put your procedure-storage disk in the disk drive, and type

```
SAVE "INSTANT
```

All the procedures listed will be written to your disk. In subsequent sessions using INSTANT, READ "INSTANT from your own disk instead of the Utilities disk. You will have everything you need to run INSTANT as well as all previously written original procedures.

If you want only the procedures created by INSTANT, you can use SAVE with two inputs: a filename and a list of procedures. See the earlier section on Saving Procedures.

Modifying INSTANT

Like many of the programs on the Utilities Disk, INSTANT can be expanded or modified to include more complex commands. To add new single-letter commands, edit the COMMAND procedure.

COMPUTATION: HANDLING NUMBERS

C COMPUTATION: HANDLING NUMBERS

Perhaps you've begun to wonder if Logo can do anything but draw pictures. Have no fear! Like any other full computer language, Logo can perform a variety of numerical operations

Logo uses integers (whole numbers like 4, 67, 1918) and real numbers (numbers with a decimal part like 4.55, 3.14159) without distinguishing between them. 7/2 (7 divided by 2) is always 3.5 in Logo.

Logo also recognizes "floating point" numbers, which use a form of scientific notation. For instance, 5000 can be represented as 5E3 (5 times ten to the exponent 3); likewise, 0.005 can be represented as 5N3 (5 times ten to the exponent -3). Floating point notation is useful primarily in representing extremely large numbers. See page 83 of the Technical Manual for more details.

Arithmetic Operations

When you use a computer, you must type everything on one line. For the operations of addition, subtraction, multiplication, and division, Logo uses the following operators:

		as in	
Addition	+	7 + 5	(12)
Subtraction	−	7 − 5	(2)
Multiplication	*	7 * 5	(35)
Division	/	7 / 5	(1.4)

The star (or asterisk *) is used for multiplication to avoid confusion with the letter x. The slash (/) is used to keep division on one line.

Raising to powers (exponentiation) uses the procedure EXPONENT, described below.

Logo will do the arithmetic for you when you give it an operation for its input. When you type:

`FD 26 + 42` Logo will move the turtle 68 steps forward;

`PRINT 76 * 42` Logo will print 3192;

`RT 360/5` Logo will turn the turtle 72.

Hierarchy of Operations

Doing arithmetic on a line does present some problems, however. There must be rules about which operation is done first. Try these:

```
PRINT (7 + 5)/ 2
PRINT  7 + 5  / 2
```

In the first, the 7 and 5 are added, to make 12, then the 12 is divided by 2, which gives 6. In the second, the 5 is divided by 2 first, with the result of 2.5, then the 2.5 is added to the 7, giving 9.5.

RULES THE COMPUTER PLAYS BY

1. Parentheses are the first thing the computer looks for in evaluating an arithmetic expression. It does whatever is in the parentheses first, according to the rest of the rules.

2. Multiplication and division are done next, from left to right.

3. Addition and subtraction are done last, also from left to right.

Examples:

1.

	4	*	3	+	6	/	3	−	2	*	(3	+	2)
Step 1	4	*	3	+	6	/	3	−	2	*		5	
Step 2		12		+		2		−		10			
Step 3				14				−		10			
Step 4								4					

2.

	4	*	(3	+	6)	/	(3	−	2)	*	3	+	2
Step 1	4	*		9		/		1		*	3	+	2
Step 2		36				/		1		*	3	+	2
Step 3						36				*	3	+	2
Step 4										108		+	2
Step 5												110	

3.

	4	*	(3	+	6)	/	((3	−	2)	*	3	+	2)
Step 1	4	*	(	9	)	/	((	1	)	*	3	+	2)
Step 2	4	*	(	9	)	/	(			3		+	2)
Step 3		36				/	(					5	)
Step 4						7.2							

So you see, the order in which the operations are done can make a considerable difference.

Outputs, Integer Operators, Functions: RANDOM, RANDOMIZE, ROUND, INTEGER, QUOTIENT, REMAINDER, SQRT, SIN, COS

Arithmetic operations give a result, called an output. When you type an operation at the keyboard, Logo will tell you that result. Type

```
24/3
RESULT: 8
```

and Logo will type

RANDOM is another Logo operation which gives a result. It chooses a random number in the group you select. You specify the group by giving RANDOM the next higher number.

Type	Logo will output
RANDOM 10	a number between 0 and 9;
RANDOM 501	a number between 0 and 500.

(Type RANDOMIZE before using RANDOM to avoid identical sequences of random numbers every time you turn on the computer.)

The other integer operators also output. ROUND rounds off a real number to the closest integer:

ROUND 6.4	outputs 6
ROUND 2.7	outputs 3
ROUND −6.4	outputs −6
ROUND −2.7	outputs −3
ROUND 6.5	outputs 7

INTEGER gives the integer portion of a real number:

```
INTEGER 4.3          outputs 4
INTEGER 4.9          outputs 4
INTEGER -4.3         outputs -4
INTEGER -4.9         outputs -4
INTEGER 7/2          outputs 3
```

QUOTIENT gives the integer part of the quotient of two numbers:

```
QUOTIENT 7 2         outputs 3
```
(the same as INTEGER 7/2)
```
QUOTIENT 1 2         outputs 0
QUOTIENT -7 2        outputs -3
```

REMAINDER outputs what is left over from the integer division:

```
REMAINDER 7 2        outputs 1
REMAINDER 2 3        outputs 2
```

When you use real numbers with QUOTIENT or REMAINDER, they are ROUNDed to integers before the division takes place.

SQRT produces the square root of the positive number you give it:

```
SQRT 160             outputs 12.6491
SQRT 16              outputs 4
```

SIN and COS output the sine and cosine of the number given in degrees:

```
SIN 0                    outputs 0
SIN 90                   outputs 1
COS 0                    outputs 1
COS 90                   outputs 0
```

In a procedure you must do something with an output. If you don't, Logo complains that you don't say what to do with it.You might PRINT it, assign it to a variable name, or use it in a graphics command:

```
RT 360/4                 the turtle turns right 90
MAKE "A 360/4            the value of A becomes 90
PRINT :A                 Logo prints 90
PRINT QUOTIENT 5 2       Logo prints 2
MAKE "B REMAINDER 5 2    :B becomes 1
PRINT :B                 Logo prints 1
```

Variables, Global and Local: MAKE

In Logo, you may use a variable anywhere you can use a number.

Variable names in Logo may be of any length, made up of any combination of letters, numbers, or the special characters !,"#$.%&? which leave out only the operators, brackets and parentheses, and the single quote.

The name of the variable is preceded by the single set of double quotes ("). The value of the variable is preceded by dots (: also known as colon).

Global Variables:

The Logo primitive MAKE gives a value to a variable which the variable keeps until it is changed with another MAKE command. MAKE can be used either in IMMEDIATE mode or in a procedure. The value assigned is used in any procedure in which the variable is used; the value is also stored when a copy of the workspace is saved onto a disk. Variables created with MAKE are called Global Variables. Examples:

MAKE "PI 3.14159 gives the variable :PI the value 3.14159

PRINT :PI prints 3.14159

MAKE "MINE "MINK gives :MINE the value MINK

PRINT :MINE prints MINK

MAKE "A :PI gives :A the VALUE of :PI (3.14159)

PRINT :A prints 3.14159

Local Variables:

Local variables are used only in procedures. When a procedure is running, its local variable(s) have a value. When the procedure stops, the variable ceases to exist until the next time the procedure is run. An input to a procedure behaves as a local variable.

You can also make a variable local to the current procedure with the LOCAL command (added in version 2.0). Any time MAKE is used after the command LOCAL, the variable is treated as a local and not a global variable.

Local variables are important because they keep the workspace from becoming cluttered. Using global variables when local variables will do wastes memory space that could be used for other purposes. Also, you can have several local variables with the same name in different procedures, but only one global variable with a given name.

Procedures: TO, END

Any command you can type at the keyboard can be used in a Logo procedure. To define a procedure, type TO and the name you have chosen. For example, type:

```
TO CUBE
```
(to obtain a number multiplied by itself 3 times)

The screen will clear, with the procedure title TO CUBE at the top and a white line at the bottom which tells you that you are in EDIT mode and should use <CTRL> C to complete the definition of your procedure. (<CTRL> G means gone.) (To do a <CTRL> C, hold down the <CTRL> key and press the <C> key.)

Type in the rest of the procedure below, and press <CTRL> C. (See the APPENDIX for a discussion of commands used in EDIT mode.)

```
TO CUBE
 PRINT 4 * 4 * 4
END
```

Type

```
CUBE                    Logo will print 64
```

You can use a variable to extend the usefulness of this procedure. Make it print the cube of whatever number is given it, instead of printing the cube of 4 all the time. Replace each 4 with the variable name and add it to the title, so the value of the variable may be brought into the procedure. You may choose any name for your variable; a descriptive one is most helpful.

```
TO CUBE :NUMBER
 PRINT :NUMBER✳:NUMBER✳ :NUMBER
END
```

CUBE now expects a number. This means that you may not type CUBE by itself any more. When you do, Logo will tell you that you forgot the input (:NUMBER).

Now when we type CUBE with a number, Logo will print the cube of that number.

Type	Logo will print
CUBE 3	27
CUBE 33	35937
CUBE 333	36926037

After CUBE is run, Logo forgets the value of :NUMBER. Try typing

```
PRINT :NUMBER
```

:NUMBER is a local variable and has value only within the procedure in which it is used. :NUMBER could be used in a variety of procedures and have a different value in every one.

Interactive Procedures: LOCAL, REQUEST (RQ)

LOCAL is convenient when you don't want to give a procedure input immediately, but still want to use a local variable. This is frequently the case with interactive procedures, especially if the procedure requires the user to input more than one variable.

An interactive procedure is one that requires user input from the keyboard while the procedure is running. As an example of this, we start with a procedure which randomly picks two numbers and prints their product.

```
TO MULTIPLY
  LOCAL "X LOCAL "Y
  MAKE "X RANDOM 10
  MAKE "Y RANDOM 10
  (PRINT :X [TIMES] :Y [IS] :X * :Y )
END
```

LOCAL specifies that its input (in this case X and Y) be treated as local variable for the rest of the procedure. In the procedure shown, RANDOM is used to pick values for the variables. The last line then prints the variables and their product as part of a sentence.

Note that X and Y do not have values until MAKE is used. To see this, put PRINT :X between the LOCAL and MAKE statements.

> PRINT usually takes one input which can be a word, a list, or a number. In this case it has five inputs, so parentheses must be used to tell Logo to expect more than the usual number of inputs.

To make the procedure continue to pick variables and print answers, add MULTIPLY as the last line in the procedure (but before END). Use <CTRL>G to stop it.

Now you have a procedure that is good at picking numbers and telling you the product, but this isn't an interactive procedure. There is no way for you to do anything while the procedure is running. Let's change things so that you have to type the answer to a question. The line with PRINT will become

```
(PRINT [HOW MUCH IS] :X [TIMES] :Y [?])
```

Of course, you'll want Logo to tell you whether the answer you give is right or wrong. The following procedure will do just that.

```
TO TESTANSWER :ANSWER
 IF :ANSWER = :X * :Y PRINT [CORRECT] STOP
 PRINT [INCORRECT]
END
```

This procedure looks to see if the value of ANSWER equals :X * :Y. If this is TRUE, the procedure prints CORRECT and stops; otherwise, it prints INCORRECT.

How should you combine the two procedures? If you add TESTANSWER :ANSWER as the line after the PRINT command in MULTIPLY, where does :ANSWER come from?

To allow user input, use REQUEST. This primitive takes input from the keyboard and makes it into a list when <RETURN> is hit.

```
TO MULTIPLY
  LOCAL "X LOCAL "Y
  MAKE "X RANDOM 10
  MAKE "Y RANDOM 10
  (PRINT [HOW MUCH IS] :X [TIMES] :Y [?] )
  TESTANSWER FIRST REQUEST
END
```

REQUEST takes what you type and gives it to TESTANSWER as input. The command FIRST is needed because REQUEST makes a list; if FIRST were omitted, the first line of TESTANSWER would compare a number with a list containing a number, and the procedure would print INCORRECT. What we need is the first (in this case, the only) item in the list, which is the number you typed in.

Note that TESTANSWER uses X and Y even though they were not declared in its title line. A subprocedure always has access to the variables in the calling procedure(s).

So far MULTIPLY and TESTANSWER could have been written as one procedure. But what if we wanted to make the program keep asking for an answer until it got the right one? To do this, we need a recursive call to TESTANSWER so it will keep calling itself until you type the correct answer.

What happens if you add TESTANSWER :ANSWER as the last line of TESTANSWER? Obviously this doesn't work! (Try it to see why.) We need to change :ANSWER in the last line to something else. Hint: look at MULTIPLY.

Why all this fuss about local variables, whether created by LOCAL or declared as procedure inputs in the title line? Global variables take up space. Unless you have a particular need for a variable that stays around in the workspace, use a local variable.

Bringing Values Out of Procedures: OUTPUT (OP)

When the results of running a procedure are to be used by another procedure, which often happens when the purpose of a procedure is doing a computation, those results must be brought out of the procedure for use.

There are two ways of getting values out of a procedure:

1. Create a global variable (described above).
2. Use the Logo primitive OUTPUT.

The Logo primitive OUTPUT returns values from the procedure in which it occurs. The values are returned to the procedure which called that procedure.

If you run a procedure which uses OUTPUT, the procedure will print the OUTPUT on the screen.

If you run a procedure which calls a procedure which uses OUTPUT, only the procedure you ran will receive the information from OUTPUT. It will not be printed unless there is a PRINT statement.

This is similar to what happens when you do arithmetic operations. Type

```
3 + 5
```

and Logo will print

```
RESULT: 8
```

Type

```
FORWARD 3 + 5
```

and the result 8 only goes to the FORWARD

The turtle moves, but the 8 is not printed on the screen.

We can change the PRINT statement in CUBE to OUTPUT to show this:

```
TO CUBE1 :NUMBER
 OUTPUT :NUMBER * :NUMBER * :NUMBER
END
```

Now if you type

```
CUBE1 3
```

Logo will print

```
RESULT: 27
```

However, if you type

```
FORWARD CUBE1 3
```

the graphics turtle will move forward 27 steps.

Example of OUTPUT and Recursion: A Procedure to Do Exponentiation

A recursive procedure is a procedure which calls itself as a subprocedure. The procedure EXPONENT, shown below, uses recursion to raise :X to the power of :Y.

```
TO EXPONENT :X :Y
 IF :Y = 0 THEN OUTPUT 1
 OUTPUT :X * (EXPONENT :X :Y-1)
END
```

In the procedure, Y is used as a counter to make sure that X is multiplied together the correct number of times.

How EXPONENT works:

1. Tests for the finish, i.e. Y = 0
2. Multiplies :X by the result of running EXPONENT with the counter decremented.
   1. Tests for the finish
   2. Multiplies :X by the result of running EXPONENT with the counter decremented, and so on until :Y is decremented to 0.

Example:

```
EXPONENT 3 4
```

We shall follow the recursion down through all its levels and then trace OUTPUT on its way back up.

Going down, each level is put on hold pending the appearance of a number needed to complete the computation. Coming back up, each number is output to the level above and each computation completed.

Going down:

```
EXPONENT 3 4
```

1. Check to see if :Y (4) is 0
2. OUTPUT 3 ✳ the result output by EXPONENT 3 3

Logo must figure out the value of EXPONENT 3 3.

```
EXPONENT 3 3
```

1. Check to see if :Y (3) is 0
2. OUTPUT 3 ✳ the output of EXPONENT 3 2

Logo must figure out the value of EXPONENT 3 2.

```
EXPONENT 3 2
```

1. Check to see if :Y (2) is 0
2. OUTPUT 3 ✳ the output of EXPONENT 3 1

Logo must figure out the value of EXPONENT 3 1.

```
EXPONENT 3 1
```

1. Check to see if :Y (1) is 0
2. Output 3 ✳ the output of EXPONENT 3 0

Logo must figure out the value of EXPONENT 3 0.

```
EXPONENT 3 0
```

1. Check to see if :Y (0) is 0; if it is, OUTPUT 1. OUTPUT stops the procedure and outputs the value 1.

Going back up:

The 1 is output to the procedure which called EXPONENT 3 0, which was EXPONENT 3 1. This completes the evaluation in EXPONENT 3 1, which is output to the procedure which called EXPONENT 3 1, which was EXPONENT 3 2. The process is repeated until the top level is reached.

The evaluation of EXPONENT 3 4 on the way down looks like this:

```
EXPONENT 3 4 = 3 *(EXPONENT 3 3)
             = 3 *(3 *(EXPONENT 3 2)
             = 3 *(3 *(3 * EXPONENT 3 1))
             = 3 *(3 *(3 *(3 * EXPONENT 3 0)))
```

Since the value output by EXPONENT 3 0 is 1, going back up this becomes

```
EXPONENT 3 4 = 3 * (3 * (3 * (3 * (1))))
                EXPONENT 3 0 outputs 1
             = 3 * (3 * (3 * (3 * 1)))
           EXPONENT 3 1 outputs 3
             = 3 * (3 * (3 * 3)
      EXPONENT 3 2 outputs 9
             = 3 * (3 * 9)
  EXPONENT 3 3 outputs 27
             = 3 * 27
EXPONENT 3 4 outputs 81
```

The 3 is multiplied by itself 4 times, just as prescribed.

Note the use of :Y as a counter which makes sure that EXPONENT is called exactly 4 times, that is, 3 is multiplied by itself 4 times, or raised to the power of 4.

Graphing Functions: Sine, Cosine, Tangent, Parabola, Ellipse, SETXY, HOME, DRAW, HT

It is easy to graph functions of the form Y = f(X) using the Logo primitive SETXY, which takes as its inputs the :X and :Y positions on the Logo screen.

The heart of each procedure is the evaluation of :Y and the positioning of the turtle (f(:X) is whatever the function calls for):

```
MAKE "Y f(:X)
SETXY :X :Y
```

This is more elegantly accomplished by combining the two operations. For example:

```
SETXY :X f(:X)
```

Principal considerations include

1. Keeping the curve on the screen
2. Positioning the curve
3. Scaling for visibility

To position the start of the curve, we might want to move :X to the left by the amount :C. Our statement becomes:

```
SETXY :X-:C  f(:X)
```

To see :Y if it is very small, we might want to multiply it by a visibility factor :D:

```
SETXY :X-:C   f(:X) * :D
```

SINE FUNCTION: Y = SIN X

We would like to begin the sine wave at the left edge of the screen (−140), make it large enough to be visible, and stop at the right edge of the screen (+140).

To begin drawing at the left edge and yet have :X start at 0 for the evaluation of :Y, the X position becomes :X−140.

To see :Y, which will vary between 0 and 1, multiply by 100 (actually anything up to 120, the vertical limits of the screen).

The procedure starts out as

```
TO GRAPH.SIN :X
 SETXY   :X - 140     100 * SIN :X
END
```

This computes one point and moves the turtle to it. To continue the curve, increment :X by calling GRAPH.SIN with an incremented value:

```
TO GRAPH.SIN :X
 SETXY   :X - 140     100 * SIN :X
 GRAPH.SIN   :X + 5
END
```

To stop the curve at the right edge of the screen, insert a test for the X positon (:X–140):

```
TO GRAPH.SIN :X
 IF :X – 140 > 140 STOP
 SETXY :X – 140     100 * SIN :X
 GRAPH.SIN   :X + 5
END
```

To draw a sine wave starting at X = 0, type

```
GRAPH.SIN 0
```

An axis would improve the graph (DRAW clears the screen and moves the turtle to the center, HT hides the turtle):

```
TO AXIS
 DRAW
 HT
 SETXY 140 0
 HOME
 SETXY –140 0
END
```

Now to draw a sine wave with an X-axis, type

```
AXIS
GRAPH.SIN 0
```

The final improvement for the sine wave is writing a procedure to do that typing for us:

```
TO SINE
 AXIS
 GRAPH.SIN 0
END
```

Finally, to draw a sine wave, type

```
SINE
```

COSINE FUNCTION: Y = COS X

Substitute COS for SIN in the GRAPH.SIN procedure, changing its name to GRAPH.COS. Write a superprocedure COSINE to call it with AXIS. The easiest way to do this is to edit GRAPH.SIN and SINE. See the editing sections of the Graphics chapter and the APPENDIX.

TANGENT FUNCTION: Y = (SIN X) / (COS X)

The tangent procedure has some different problems.

Note how :X is incremented slightly if COS :X = 0, to avoid dividing by 0. Since we don't want to stop the procedure in the middle of the screen, PU (PENUP) is used to stop the turtle from drawing when it is simply wrapping around the screen to get to the off-screen points. (When the line goes off the edge of the screen, it continues by entering on the opposite side of the screen. This is called wrapping.) Using PU requires adding PD (PENDOWN) to start drawing again.

```
TO GRAPH.TAN :X
 IF COS :X = 0 THEN MAKE "X :X + 1
 IF :X - 140 > 140 STOP
 MAKE "Y (SIN :X) / (COS :X)
 IF 100 * :Y > 115 PU
 IF 100 * :Y < -115 PU
 SETXY  :X-140 :Y * 100
 PD
 GRAPH.TAN :X + 5
END
```

Here Y is evaluated separately because it must be tested before the drawing step.

PARABOLA: Y = (X * X) / (4 * A)

The vertex of this parabola is at 0,0; the axis is vertical. A is the distance from the vertex to the focus. Increasing A makes a wider parabola; decreasing it makes a narrower one.

The general formula for this parabola is

$$(X-H) * (X-H) = 4 * A * (Y-K)$$

where H is the X co-ordinate and K is the Y co-ordinate. H and K are 0 in this example.

In the drawing of the parabola, add PU after AXIS to avoid leaving a trail to the beginning of the curve. (This is the same AXIS procedure that is used in the sine procedure.)

Determine the beginning point in the superprocedure PARABOLA, using the equation again, with 118 the value for Y (about the largest possible value for Y).

```
TO PARABOLA :A
 AXIS
 PU
 GRAPH.P (SQRT (118 * 4 * :A)) :A
END

TO GRAPH.P :X :A
 MAKE "Y (:X * :X) / (4 * :A)
 IF :Y > 124 STOP
 SETXY  :X  :Y
 PD
 GRAPH.P :X + 5 :A
END
```

With a positive value for :A, this will draw a parabola above the X axis. To allow use of a negative :A, which would draw a parabola below the X axis, we must use the absolute value of :A (:A without its sign) in calculating the starting position of X, since we cannot take the squareroot of a negative number. We write the procedure ABS to figure the absolute value for us:

```
TO ABS :X
 IF :X < 0 THEN OUTPUT (-:X)
 OUTPUT :X
END
```

OUTPUT stops after it outputs. So if X is negative, it will change it to positive; if it is positive it will output it directly. PARABOLA becomes:

```
TO PARABOLA :A
 AXIS
 PU
 GRAPH.P (-SQRT(118 * 4 * ABS :A)) :A
END
```

Since it is a test for Y that stops the procedure, we must revise the test to allow for a negative Y:

```
TO GRAPH.P :X :A
 MAKE "Y (:X * :X) / (4 * :A)
 IF ANYOF (:Y > 124) (:Y < -124) STOP
 SETXY  :X  :Y
 PD
 GRAPH.P :X + 5:A
END
```

To make a family of parabolas, add a recursive call to PARABOLA (taking care to pick up the pen in between):

```
TO PARABOLA :A
 AXIS
 PU
 GRAPH.P (-SQRT(118 * 4 * ABS :A)) :A
 PU
 PARABOLA :A + 1
END
```

ELLIPSE FUNCTION:
Y = B * SQRT (1-(X * X) / (A * A))

The center of this ellipse is at 0,0. A is half of the horizontal axis, B is half of the vertical axis.

The general formula for an ellipse is

$$(X-H) * (X-H) / (A * A) + (Y-K) * (Y-K) / (B * B) = 1$$

where H,K are the X and Y co-ordinates of the center, (0,0) in this example.

The ellipse procedure must solve the problem of Y becoming negative as X returns to its original value. Changing the sign of the increment takes care of it.

```
TO GRAPH.ELLIPSE :X :A :B :INC
 IF (:X * :X) > (:A * :A) STOP
 IF :X = :A THEN MAKE "INC (-1)
 SETXY :X  :INC * :B * SQRT (1-(:X * :X) / (:A * :A))
 PD
 GRAPH.ELLIPSE :X + :INC :A :B :INC
END
```

The SETXY command must be typed as one line. Use the same AXIS program as you used with the sine procedure.

```
TO ELLIPSE :A :B
 AXIS
 PU
 GRAPH.ELLIPSE -:A :A :B 1
END
```

WORDS & LISTS

WORDS & LISTS

INTRODUCTION

So far, all of the procedures that we have described or encouraged you to write have been non-interactive. That is, once you started them, they did what they were designed to do without consulting you further. The most you might ever have done was press <CTRL> G to stop them.

Interactive programs are perhaps the most fun of all, precisely because they interact. They are also potentially the most complex. The reason for this is that while they are underway, they must account for the unpredictable behavior of the person with whom they are interacting.

Interactive movement forms the basis for a variety of video games and simulations. Interactive language adds attractive features to these games, but it can also open up a whole new interest area: mad-libs, quizzes, word games, conversational programs that construct grammatical sentences and "understand" limited amounts of natural language, even foreign languages.

There are two ways you can approach this chapter. You may prefer to go quickly through, skipping all of the indented text, or you may wish to study those portions as you work your way through the chapter. As in other chapters, the indented portions add depth and detail to the presentation.

The procedures you are asked to type in are used throughout the chapter, so be sure to save them on your disk when you decide to take a break, and be sure to read them back in when you start to work on the chap-

ter again. (CHAPTERW would be an appropriate file name, so you can type SAVE "CHAPTERW and READ "CHAPTERW.)

In the graphics chapter, you learned about procedures which had an immediate and visible effect. FD moved the turtle (and left a trace on the screen if the pen was down), DRAW cleared the screen, and so on.

This meant that even without writing procedures, you were able to give Logo several commands in succession and see what their combined effect was. You may even have forgotten what commands you used, but the screen "remembered" their effect.

Procedures spared you considerable typing. They also gave you a way of recording the instructions for your designs. But the designs themselves didn't depend on the procedures. They would have grown just as surely on the screen if you had typed each turtle command line by line.

In this chapter, you will be learning about primitives that manipulate Logo "objects." The effects of these primitives are not graphic and do not accumulate unless you explicitly instruct them to.

These primitives can be explained and used one by one, but their real power is most apparent in combination. As a result, the focus of this chapter must be on building procedures which combine these primitives in different and varied ways.

Even though there are only roughly a dozen important new primitives, and even though only about half are

used with much frequency, there are many, many combinations which can be used in creating sophisticated and interesting programs.

Here are some of the programs that you will learn how to write in this chapter:

—Interactive video programs
—Quiz programs
—Programs that write and "understand" language
—Programs that play games
—Programs that learn

Logo's facility with words and lists makes it ideal for writing conversational programs, quizzes, pig Latin translators, programs that teach, and even programs that learn: in short, all programs that need to manipulate lists of information.

The chapter is divided into three sections. The first is devoted entirely to interactive video programs, but introduces some procedures and techniques used in the remainder of the chapter.

The second section is devoted to programs that manipulate language (quizzes, sentence generators, etc.) and programs that build and manipulate knowledge bases.

The third section is devoted to building and manipulating more complex knowledge bases, and includes programs that play games and that learn.

Interactive Graphics: READCHARACTER (RC), TOPLEVEL, STOP

Let's create a program to control the turtle with single key-presses at the keyboard. The initial design will provide only four turtle behaviors, FD, RT, LT, and DRAW, and will control them with F, R, L, and D, respectively.

> Projects at the end of this section suggest some additional behaviors to control. Further additions will become possible with techniques that you will learn later in this chapter.
>
> The procedures that you will be developing are similar to those in the INSTANT program on your utilities disk. This program is explained further in this guide and in LOGO FOR THE APPLE II, by H. Abelson (published by Byte Books, 1982, and available from Terrapin).

In this design, the turtle will be moved Forward 10 steps each time the F is pressed. Each time R or L is pressed, the turtle will turn Right or Left 15 degrees. (You may choose any amount, of course, not just what is suggested here.) Pressing D executes DRAW.

The first task is to create a procedure that takes a single character as input and controls the turtle on the basis of that character. Its title line might be:

```
TO EASYDRAW :CHARACTER
```

or to save typing

```
TO EASY :CHTR
```

The logic is quite simple. If the character is an F, then perform FD 10. In Logo, this is:

```
IF :CHTR = "F FD 10
```

If you prefer, you can add the word THEN, and write

```
IF :CHTR = "F THEN FD 10
```

Some people find it easier to read a program that has the extra word in it. Others find it more cluttered that way. We will leave it out in this chapter.

Similarly, if the character is an R, perform RT 15.

```
IF :CHTR = "R RT 15
```

There should be some way of telling the program when we want to quit drawing to do something else. The letter Q (for Quit) can be used. If that character is the input, the procedure will perform NODRAW and TOPLEVEL.

NODRAW gets out of draw mode and clears the text screen. TOPLEVEL is the Logo primitive that tells Logo to stop executing a program and return to immediate mode to wait for a new command.

It is important to know the difference between TOPLEVEL and STOP. STOP stops the execution of the procedure in which it is found, but does not stop other procedures that may also be running. TOPLEVEL stops an entire program. Every procedure that Logo was running stops, and Logo returns control to the user.

The whole procedure might look like this:

```
TO EASY :CHTR
  IF :CHTR = "F FD 10
  IF :CHTR = "R RT 15
  IF :CHTR = "L LT 15
  IF :CHTR = "D DRAW
  IF :CHTR = "Q NODRAW TOPLEVEL
END
```

Define this procedure. Type carefully, making certain that no spaces are left between the : and the word CHTR, or between the double-quote character and the single letter that follows it. Notice also that there is only one double-quote character on each line.

We will explain in greater detail later, but provide this brief version for the curious. The words

"F in IF :CHTR = "F FD 10 and
"CHAPTERW in SAVE "CHAPTERW

are quoted in order to tell Logo not to treat them as procedures. The words FD and SAVE are executed by Logo, but we want "F to be just plain F, literally, and not have Logo try to execute it as an instruction. Similarly, we want "CHAPTERW to be the name of a file — just a name, not something to do. The quoted word ends at the next blank space, so no final quote is needed.

Do not add a final quote, since Logo will then assume you mean to say something like: If the character is an F followed by a double-quote-mark, then . . . This is not at all what you want. To demonstrate this, type

```
PR "A"
```

After the procedure is defined — remember to type <CTRL>C — you can try it out by typing

```
EASY "F
EASY "R
EASY "Q
```

This is definitely not an improvement over typing FD 10 RT 15 ND, but it contains all the logic for the program we intended to create. Now what is needed is another procedure — let's call it QUICKDRAW — whose sole purpose is to wait for a key to be pressed at the keyboard and to give that character to EASY as an input.

QUICKDRAW will use the Logo primitive READCHARACTER, abbreviated RC, to report what key has been pressed at the keyboard. To make QUICKDRAW continue endlessly (until a Q is pressed), QUICKDRAW calls itself as a subprocedure and looks like this:

```
TO QUICKDRAW
  EASY RC
  QUICKDRAW
END
```

The line EASY RC in QUICKDRAW tells Logo to read a character typed by the person using the computer and to use that character as the input to EASY. EASY figures out what action to perform based on what character it receives. If it gets an R, it performs a RT 15.

Even though all five lines of EASY are executed each time EASY is called, at most one action will be taken, because only one of the IF tests will be true.

Projects with RC: Extending QUICKDRAW

1. By using the same logic you can add other commands to EASY. Teach the procedure how to control the pen (PU or PD) in a single keystroke. (You might assign U to the command PU and P to the command PD, or you might choose D for PD, in which case you would need something else for DRAW.)

2. Add SHOWTURTLE (ST) and HIDETURTLE (HT).

3. Teach EASY to change the pen color with two keystrokes. The first keystroke (C, for Color) will run a procedure that waits for a second keystroke. If that second keystroke is a 0 through 6, the pen will be set to that color. If any other key is pressed, nothing happens.

The job could, of course, be done with one keystroke, representing each pen color with a different key. You might use the number keys directly, or use letters that represent the color names (for example, W for White, G for Green, etc.).

A disadvantage of using the numbers is that it would be nice to have them available for use as "multipliers" to multiply the effect of the next command. You will learn a technique for doing this in the next section. Choosing letters for each color is acceptable, although it requires that a person remember codes for each color.

4. Use the same technique to change background color.

Changing the Value of a Variable: MAKE, PRINT (PR)

We must take a short detour from the QUICKDRAW program. When you return to it, you will be able to write procedures which allow multiples of the single key commands in EASY. For example, 3F will make the turtle go forward 3 * 10 or 30 turtle steps.

The Logo primitive MAKE is used in several ways. In this section, we will illustrate one way, and in another section of this chapter, when we define words, lists, variables, input, and output more carefully, you will learn more of the subtleties of MAKE.

A metaphor for MAKE: When you say

```
MAKE "NUM 7 or
MAKE "PERSON [MARGARET TRUMAN]
```

it is as though you are creating locations or boxes called NUM and PERSON and tossing a 7 into the first and the list [MARGARET TRUMAN] into the second. To find out what is in a particular box called NUM, the Logo command is THING "NUM or, more commonly, just :NUM, meaning the thing or value that is in the box named NUM.

Of course, you have been using names to refer to values all along. We will use the new metaphor to translate a procedure in a new way.

```
TO SHAPE :LENGTH :SIDES
 REPEAT :SIDES [FD :LENGTH RT 360/:SIDES]
END
```

This procedure tells the turtle how to draw a SHAPE whose features will be found in boxes that the procedure refers to as LENGTH and SIDES. The procedure's first instruction is to look in its SIDES box for a number, and REPEAT the following list of commands that number of times — go FORWARD the dimension found in its LENGTH box, and turn RIGHT however many degrees is equal to 360 divided by the number it found in the box named SIDES.

At the moment that you type

```
SHAPE 73 4 or SHAPE 15 6
```

Logo puts the 73 or 15 in a location (think of it as a box) that the SHAPE procedure refers to as LENGTH and puts the 4 or 6 into another location that SHAPE refers to as SIDES.

It is important to remember that LENGTH and SIDES are names that SHAPE uses to keep track of these numbers, and that no other procedure knows what SHAPE keeps in the boxes or even that the boxes exist! Further, those boxes cease to exist after SHAPE finishes its work.

> Please note, however, that if SHAPE had called any subprocedures during its execution, those subprocedures would also have had access to the values in SHAPE's boxes.

Before getting back to MAKE, define SHAPE as shown above and then type

```
SHAPE 50 5
```

While SHAPE is operating, it executes the command FD :LENGTH, telling FD to move the turtle forward 50 turtle steps, the number of steps in the box LENGTH. If the 50 is still left in the box after SHAPE has finished drawing its pentagon, you should still be able to use it.

Try typing FD :LENGTH to see what Logo will do. Your screen should look like this:

```
FD :LENGTH
THERE IS NO NAME LENGTH
```

Now back to MAKE. MAKE can assign a value to a box or change the value that is in the box, and it can do it equally well in or out of a procedure.

Type MAKE "LENGTH 10 to create a box named LENGTH and place a 10 in it. Type DRAW to clear the screen, and then type FD :LENGTH. The turtle will move forward 10 turtle steps. Type

```
RT 144
FD :LENGTH
```

This box did not disappear. It still exists and still has a 10 in it. Type

```
PRINT :LENGTH
```

Logo should print 10.

> This kind of variable, defined outside of a procedure, is called a Global variable. See the explanation of global and local variables in the chapter titled Computation.

Since there is already a box called LENGTH with a 10 in it, you might think that you could now type just SHAPE 4 to get a four-sided shape with a size of 10.

If you try that, Logo will complain that SHAPE needs more inputs. Because SHAPE was defined to take two inputs, it must always be given two inputs.

Type

```
SHAPE 50 4
```

When it executed FD :LENGTH, how far did the turtle move? Not 10, but 50. And now that the square is drawn, type

```
FD :LENGTH
```

How far did the turtle move this time? Not 50, but 10. Type PRINT :LENGTH to Logo. Again Logo should print 10.

A summary of what happened: You told Logo to MAKE "LENGTH 10. Both before and after running SHAPE (with its own variable of the same name set to 50), you were able to show that LENGTH really did have the value 10. Whether you typed PRINT :LENGTH or FD :LENGTH, LENGTH represented 10.

However, SHAPE, even though it had a variable of the same name, did not seem to know about the 10 and did not change it to 50, even though that is what SHAPE considered LENGTH to be.

Until you have had a chance to write enough procedures and have had more experience with variables and values, they tend to remain confusing, but remembering one principle may help.

When a procedure has variables in its title line, the values of those variables inside the procedure depend entirely on the values given to the procedure as inputs. This is true regardless of the existence or values of variables with the same names that may be found elsewhere in a program.

One more experiment with variables and MAKE before returning to QUICKDRAW. Type

```
PRINT :NUM
```

It should reply:

THERE IS NO NAME NUM

(If it prints something different from that, type

```
ERNAME "NUM
```

and start again!)

Now type

```
MAKE "NUM 5
```

and on the next line type

```
PR :NUM
```

(PR is the abbreviation for PRINT.) Now it should reply by printing a 5.

Define these two very similar procedures:

```
TO FOO
 PR :NUM
 MAKE "NUM 2 * :NUM
 PR :NUM
END

TO FOOL :NUM
 PR :NUM
 MAKE "NUM 2 * :NUM
 PR :NUM
END
```

After you have defined them and before you run them, type PR :NUM again. Logo will still reply 5.

Now, in order and one at a time, type the following commands to Logo. We will explain the mystery afterward.

```
FOO
PR :NUM
FOOL 4
PR :NUM
FOO
PR :NUM
FOOL 3
PR :NUM
```

What's happening?! FOO and FOOL have absolutely identical insides, and yet their behavior is so very different. You printed the value that is inside the box named NUM before and after running each procedure.

FOO knew about what was in that box and also changed it, but FOOL did neither. Before and after FOOL, the value in NUM remained the same — even though it appears to have two completely different values inside FOOL.

The explanation is in the title line. As mentioned earlier, when a procedure's title line contains a variable name in it, that name refers to a totally private box created just for that procedure.

So FOO could use the value of NUM that was lying around at the time, and could also change it. But FOOL

had access only to its private box, which happened to have the same name, but is altogether a different box.

Whenever the name NUM was used inside FOOL, FOOL took it to mean its own box of that name. It was not the public box named NUM that FOOL printed and changed, but only FOOL's NUM. As soon as FOOL stopped running, it took its NUM with it.

When you then typed PR :NUM again, you had no access to FOOL's private box; instead, you referred to everyone's public box named NUM. The private variable is called a local variable, and the public one is a global variable.

Logo version 2.0 includes the command LOCAL, which allows you to create local variables without declaring them in the title line. An example:

```
TO DEMO.LOCAL
  LOCAL "VALUE
  MAKE "VALUE RC
  PR :VALUE
END
```

Consult page C-7 for a full discussion of LOCAL.

Admonition: Unless you really intend to make a variable public and available for everybody to use and change, don't make global variables. They are troublemakers (in large programs) precisely because anybody is free to fool around with them.

On the other hand, the great virtue of global variables is that they survive even after a procedure is finished. When you need to have a value remembered even after the procedure that created it is finished working, use a global variable.

Otherwise avoid global variables. It is almost never good style to use MAKE when passing a variable to a procedure in the title line can be done easily.

Projects with MAKE: More Extensions to QUICKDRAW

5. Teach EASY to recognize digits and use them to multiply the effect of the very next keypress. For example, the effect of typing 3F, should be either FD 30 or REPEAT 3 [FD 10]. You decide which.

If the character 3 is typed to RC, RC's output, which EASY knows as CHTR, can be used both in tests such as IF :CHTR = 3 and in numerical expressions such as :CHTR + 5. You may also find the Logo primitive NUMBER? useful. The test NUMBER? :CHTR is true for all characters 0 through 9.

Project 5 is a reasonable use of MAKE because it requires remembering a number from one execution of EASY to the next. A command like MAKE "MULTIPLE :CHTR will put the current value of CHTR into a box named MULTIPLE.

The contents of the CHTR box will be forgotten when EASY stops, but since MULTIPLE will be a global variable, the value in that box will not be forgotten and can be used until it is changed.

6. Type MAKE "PENPOS [DOWN] and then define and experiment with the following procedure.

```
TO PEN
 IF :PENPOS = [DOWN] PU MAKE "PENPOS [UP]
                ELSE PD MAKE "PENPOS [DOWN]
 PRINT SENTENCE [THE TURTLE'S PEN IS NOW] :PENPOS
END
```

The procedure contains at least one primitive (SENTENCE) that you have not seen before, and an interesting use of a global variable. When you understand how this procedure works, include it in EASY.

7. Write a similar procedure for ST and HT.

Programs that Interact without Waiting: RC?

Until some key has been pressed, RC cannot output a message saying which key. That is why QUICKDRAW always waits until a character is typed. Every time it runs RC, RC waits until it has something to report back to EASY.

Sometimes, though, you want the program to keep going while waiting for the user to type something. For example, in video-action-games, objects are supposed to keep moving on the screen whether or not the player touches the keys or twiddles the knobs.

Let's design a program in which we drive the turtle like a car. The turtle will always be moving, but we can increase or decrease its speed and can change its direction. In order to have it moving constantly, we will need a loop something like this:

```
TO LOOP
 FD :DIST
 LOOP
END
```

Make DIST have some small initial value, like 1 or 2, by typing MAKE "DIST 2. Then run LOOP. The turtle will slowly crawl across the screen.

To be more flexible, LOOP should check to see if the person has typed anything, and, if so, should take some action before moving the turtle again. RC? is the primitive that checks to see if a character has been typed.

The logic is this: If the person has typed a character,

```
IF RC?
```

then read the character, and control the turtle accordingly:

```
EASY RC
```

So the completed LOOP would look like this:

```
TO LOOP
 IF RC? EASY RC
 FD :DIST
 LOOP
END
```

Define LOOP and experiment with it using your EASY just as it is. How does LOOP behave differently from QUICKDRAW?

As it is written, EASY does not give sensitive control over the speed of the turtle. Pressing F does give a burst of distance, but the turtle settles back to the same slow crawl immediately afterward.

Look at LOOP to see what determines the turtle's speed. Now study EASY to see why it does not alter that speed. Even though EASY is not quite what is needed for this program, still it provides a number of features that are just as appropriate for LOOP as they are for QUICKDRAW.

So that you can make changes to an EASY-like procedure without changing EASY itself (which is just fine for QUICKDRAW), make a copy of EASY using a different title. To do this, edit EASY and change the title in the editor to ACTION. Then, when you define the procedure, it will be named ACTION.

EASY is still around, as before, but a new copy titled ACTION now exists also. If you have been doing the projects, your copy of EASY (and, therefore, ACTION) will no longer look like the original. But if it did, it would look like this:

```
TO ACTION :CHTR
  IF :CHTR = "F FD 10
  IF :CHTR = "R RT 15
  IF :CHTR = "L LT 15
  IF :CHTR = "D DRAW
  IF :CHTR = "Q NODRAW TOPLEVEL
END
```

Do you see that although ACTION controls the turtle's movement, it does not change :DIST, and therefore does not affect the turtle's speed?

Instead of having F move the turtle directly, it could increase the distance that the turtle moves each time through LOOP. The logic might be like this — If the character typed is F

```
IF :CHTR = "F
```

make the distance to travel 2 greater than it was the last time.

```
MAKE "DIST :DIST + 2
```

If F stood for Faster, S could stand for Slower and decrease DIST.

A working version of ACTION might look like this:

```
TO ACTION :CHTR
  IF :CHTR = "R RT 15
  IF :CHTR = "L LT 15
  IF :CHTR = "F MAKE "DIST :DIST + 2 ; FASTER
  IF :CHTR = "S MAKE "DIST :DIST - 2 ; SLOWER
  IF :CHTR = "D DRAW
END
```

When you press the F key, the distance that the turtle will move during each loop increases by 2 steps. The S key decreases the number of steps per loop.

Define ACTION in one of the ways suggested above, and write a START procedure like this one:

```
TO START
  MAKE "DIST 0
  LOOP
END
```

Remember to edit LOOP so that it uses ACTION in place of EASY.

Now type START and experiment with controlling the turtle. With practice, you can learn to control it well enough to draw even complicated figures.

Projects with RC, RC?: Extensions to LOOP

8. By changing LOOP so that both the turtle's position and heading are updated each time through the loop, the turtle can then draw curves. Here is how LOOP would look:

```
TO LOOP
 IF RC? ACTION RC
 FD :DIST
 RT :ANG
 LOOP
END
```

Design and make some changes to ACTION and START to take advantage of the new capabilities of LOOP.

9. Add a feature to stop the turtle. Experiment also with three new commands, one of which does MAKE "DIST (- :DIST), another of which does the same for ANG, and the third of which makes both DIST and ANG negative. Try to gain enough skill at controlling the turtle to get it to write your name in cursive script.

INTERACTIVE LANGUAGE

Don't Skip This Section! MEMBER?, EMPTY?

Right now, please define two procedures, MEMBER? and EMPTY?, that will be used throughout the remainder of the chapter. (If you have Terrapin Logo Version 2.0 or beyond, these are already provided as primitives, so you need not define them yourself and may skip to the next section.)

Type carefully. Make certain that you leave no space between : and the word that follows it, and that you do not leave out the question marks in the procedure titles.

```
TO MEMBER? :ELEMENT :OBJECT
 IF EMPTY? :OBJECT OUTPUT "FALSE
 IF :ELEMENT = FIRST :OBJECT OUTPUT "TRUE
 OUTPUT MEMBER? :ELEMENT BUTFIRST :OBJECT
END

TO EMPTY? :OBJECT
 OUTPUT ANYOF :OBJECT = [] :OBJECT = "
END
```

It is worth the effort to save these procedures in their own separate file as well as with the work you are doing in this chapter. That will allow you to read them into your workspace whenever you need them without reading in everything else you have ever worked on.

For now, these procedures will be explained only as if they were primitives; we will show how they are to be used, but not how they work. Later in the chapter, both will be explained in greater detail.

MEMBER? takes two inputs — a word and a list — and outputs the value "TRUE if the word is an element of the list. (You can also give MEMBER? a character and a word, and it will return "TRUE if the character is part of the word.)

EMPTY? takes one input and outputs "TRUE if the input is the empty list or the empty word. We will explain this in greater detail later on.

To see what MEMBER? does, try the following commands.

```
MEMBER? "DOG [THE DOG BARKED]
MEMBER? "CAT [THE DOG BARKED]
MEMBER? "U "AEIOU
MEMBER? "G "AEIOU
MEMBER? "4 "1234XYZ
```

Your screen should look like this:

```
MEMBER? "DOG [THE DOG BARKED]
RESULT: TRUE
MEMBER? "CAT [THE DOG BARKED]
RESULT: FALSE
MEMBER? "U "AEIOU
RESULT: TRUE
MEMBER? "G "AEIOU
RESULT: FALSE
MEMBER? "4 "1234XYZ
RESULT: TRUE
```

If these are not the results you get, check the procedures carefully, character by character, to make certain that they are exactly as shown above. After you have checked, save the procedures.

Some Friendly Introductions: SENTENCE (SE), REQUEST (RQ), LPUT, FPUT

If you did project 6 above, you have already seen the Logo primitive SENTENCE used to combine two pieces of text into a single sentence. In the procedure in project 6 the line read

```
PRINT SENTENCE [THE TURTLE'S PEN IS NOW] :PENPOS
```

When PENPOS was [DOWN], the effect of that line was to print

THE TURTLE'S PEN IS NOW DOWN

When PENPOS was [UP], the effect of that line was to print

THE TURTLE'S PEN IS NOW UP

Define the procedure GREET. You may wish to spell out PRINT and SENTENCE fully or to abbreviate them. Both forms of the procedure are shown.

Fully spelled out:

```
TO GREET :PERSON
  PRINT SENTENCE [NICE TO MEET YOU,] :PERSON
END
```

or abbreviated:

```
TO GREET :PERSON
 PR SE [NICE TO MEET YOU,] :PERSON
END
```

Run the procedure GREET, giving it a person's name as input. For example:

```
GREET [GEORGE]
GREET [GEORGE WASHINGTON]
```

GREET has a simple behavior. Whatever its input, GREET prints a sentence composed of the words NICE TO MEET YOU (with a comma at the end) and that input.

Now we will create a procedure which uses GREET in a brief friendly conversation. The behavior of the new procedure will be a bit more complex. It will start up with no information at all (no input), and will ask the person to type his or her name. Then it will use GREET to greet the person. To do this, it must give GREET an input consisting of whatever the person typed.

Let's write the procedure as we review its behavior. It needs no inputs, so its title line could be TO FRIENDLY. It asks the person it meets to type a name: PR [WHAT'S YOUR NAME?]. It then gives GREET an input consisting of whatever the person types: GREET REQUEST.

REQUEST (abbreviated RQ) is a Logo primitive that tells a procedure 1) to wait for a person to type a line and press <RETURN> and 2) to output that line as a list that can be used by a procedure.

Here, REQUEST's output is used as GREET's input. Define FRIENDLY.

```
TO FRIENDLY
  PR [WHAT'S YOUR NAME?]
  GREET REQUEST
END
```

To run it, type FRIENDLY (remember, no input!) and press <RETURN>. When it asks, type your name (and press <RETURN>). You do not need to type brackets or other special decorations; just your name will do. Run it again, but this time, when it asks for your name, press <RETURN> without typing anything at all. Your screen will now look something like this:

```
FRIENDLY
WHAT'S YOUR NAME?
HANNIBAL THE TURTLE
NICE TO MEET YOU, HANNIBAL THE TURTLE
FRIENDLY
WHAT'S YOUR NAME?

NICE TO MEET YOU,
```

REQUEST can return an empty list, indicating that the person typed nothing, but GREET is not smart enough to know what to do about that. It would be nicer if GREET could recognize an empty input and respond differently.

Here's a version of GREET that does that. We will use the command EMPTY? to check for bashful typists.

```
TO GREET :PERSON
  IF EMPTY? :PERSON PR [OH! YOU MUST BE QUITE SHY.] STOP
  PR SE [NICE TO MEET YOU,] :PERSON
END
```

Edit GREET to insert the new line and try it again, as you did before.

```
FRIENDLY
WHAT'S YOUR NAME?
HANNIBAL THE TURTLE
NICE TO MEET YOU, HANNIBAL THE TURTLE
FRIENDLY
WHAT'S YOUR NAME?

OH! YOU MUST BE QUITE SHY.
```

This time GREET is better about handling the blank response, but it apparently has a terrible memory! After all, it has already met HANNIBAL THE TURTLE, and should have said something more like GOOD TO SEE YOU AGAIN rather than NICE TO MEET YOU.

Helping the computer remember names brings in a whole new idea. For GREET to remember, it must be a learning program. It must keep a list of the people it has already met, and, when it gets a person's name, it must be able to check to see whether that name is on its list. If the person is a member of the list of known people

```
IF MEMBER? :PERSON :KNOWN
```

then GREET should print some appropriate response and then stop.

```
PR SE [GOOD TO SEE YOU AGAIN] :PERSON STOP
```

If the person is not a member of that list, then GREET should say what it did before. It should also stick the person's name at the end of the list of known people. That is accomplished by taking the list out of the box named KNOWN, tacking the person's name at the end of it, and placing the result back in the box.

```
MAKE "KNOWN LPUT :PERSON :KNOWN
```

LPUT takes two inputs, an object (in this case PERSON) and a list (in this case KNOWN), and puts the object in the list as the last element. LPUT abbreviates LastPUT, but there is no fully spelled out name of the primitive. (Its companion FPUT, for FirstPUT, will put in an appearance later on.)

Here is GREET as it is now designed.

```
TO GREET :PERSON
  IF EMPTY? :PERSON PR [OH! YOU MUST BE QUITE SHY.] STOP
  IF MEMBER? :PERSON :KNOWN PR SE [GOOD TO SEE
       YOU AGAIN] :PERSON STOP
  PR SE [NICE TO MEET YOU,] :PERSON
  MAKE "KNOWN LPUT :PERSON :KNOWN
END
```

Edit it to include the new changes, and when it is defined, type

```
FRIENDLY
```

What happens? Ah! Logo complains that there is no list of known people.

Before GREET has met any people, the list may have no names in it, but it must still exist in order to be checked. That is why Logo said

THERE IS NO NAME KNOWN

This problem is solved by typing

```
MAKE "KNOWN []
```

Type

```
PRINT :KNOWN
```

and notice that just an empty line is printed. Now type

```
FRIENDLY
```

again. After it finishes greeting you, type

```
PRINT :KNOWN
```

again and note what you see. Play with it for a while, perhaps by typing

```
REPEAT 10 [FRIENDLY]
```

Introduce new people and reintroduce old people. Type

```
PRINT :KNOWN
```

to see what its memory contains. (If the program is not being friendly, check for errors.)

Finally, some fine points. When the person has been too shy to type a name, let GREET be a bit pushier. Instead of just stopping, it can ask again. How? By running FRIENDLY before stopping. The line might look like

```
IF EMPTY? :PERSON PRINT [DON'T BE SHY. PLEASE TELL
    ME.] FRIENDLY STOP
```

Edit GREET again, making this last change, and experiment with it. Notice that even after you have edited GREET it remembers the people it had met earlier. Any time you want to, you can make it forget everybody by typing

```
MAKE "KNOWN []
```

to empty out its list. You can also type

```
EDIT NAMES
```

and change the contents of the name KNOWN at will. When you do that, make sure when you are finished that all of the left and right brackets match up properly!

There are two more features that would make GREET seem really like an intelligent program. Try typing I DON'T WANT TO TELL YOU, or NONE OF YOUR BUSINESS, or even MY NAME IS PAUL when FRIENDLY asks your name. GREET should certainly not say NICE TO MEET YOU, NONE OF YOUR BUSINESS.

It would be nice if GREET could be given enough knowledge of English to recognize at least these cases and respond properly. Also, it would be nice if both GREET and FRIENDLY had a bit more variety in what they said. You will be able to make both of these improvements by the end of this chapter.

First you must learn some new primitives and programming techniques.

Interlude: Clearing the Text Screen with CLEARTEXT

Type CLEARTEXT to Logo. While working on this chapter you will often need to clear the text screen. CLEARTEXT has no abbreviation, so you might want to define an abbreviation.

```
TO CT
 CLEARTEXT
END
```

After defining CT, and without typing any graphics commands, mess up the text screen some. Typing the following lines should create plenty of mess:

```
ABC
+
:
```

Messy enough? Now type CT. Ah, if only all cleaning up were that easy.

Objects: Producing RESULTs as Output, and Using Them as Input

The best way to come to understand Logo objects well is to use them in a variety of contexts. A formal definition will come later, but some experiments are needed now.

Type

```
5 <RETURN>
[APPLES AND ORANGES] <RETURN>
"BEEP <RETURN>
```

(Don't forget the double-quote at the beginning of "BEEP.)

In each case Logo responds RESULT: followed by the object you typed.

```
5
RESULT: 5
[APPLES AND ORANGES]
RESULT: [APPLES AND ORANGES]
"BEEP
RESULT: BEEP
```

In two of the cases Logo typed exactly what you typed. But in the third case, Logo typed the word BEEP without a double-quote mark.

Here is the explanation. The object you typed was the word BEEP. The double-quote mark was merely to tell Logo that you were typing an object and not the name of a procedure.

Typing "FRIENDLY (with the quote-mark) will have the same effect. Typing FRIENDLY (without the quote-mark) will run the procedure that you wrote in the last section.

The double-quote is not part of the object; it is just a marker. Neither numbers nor lists can be procedure titles, so Logo does not need any special markers to help it recognize those as objects.

Also, words that are already inside lists, like APPLES or AND, need no special markers. Logo will not try to run them unless you explicitly tell it to.

If an object is "given to" Logo in immediate mode, Logo announces it with the word RESULT:. If an object is "given to" PRINT as an input, PRINT prints the object on the screen.

PRINT, too, changes the appearance of what you type slightly. Using the same three examples, PRINT 5, PRINT [APPLES AND ORANGES], and PRINT "BEEP, both of the last two are printed without their punctuation.

PRINT doesn't show the marker or the outer brackets that surround a list, but merely the object and the list elements themselves.

Even though we have been playing with a number (5), a list ([APPLES AND ORANGES]), and a word (BEEP) — all abstractions — we think of these very concretely,

as if they were solid objects that can be tossed back and forth among players in a game.

This metaphor is very useful in Logo programming. Procedures are the players. You make up the rules of the game, deciding what the behavior of each procedure will be, what object (if any) a procedure should create, and who should receive the object after it is made.

There are ways of giving objects to Logo in immediate command mode other than by placing them there yourself. You can let a procedure create them and place them there.

At the beginning of the section, you typed MEMBER? "G "AEIOU and Logo announced that the object FALSE was given to it as a result. Here are some other ways of getting procedures to hand objects to Logo.

```
RANDOM 100
FIRST :KNOWN
```

The primitive RANDOM outputs a random number from 0 up to (but not including) its input. FIRST outputs the first element of the object that is its input. (In this case, the object is a list from the box named KNOWN that you created earlier in the chapter.)

In the next two lines are two other primitives that output objects. It may be harder to recognize the primitives this time, because you are probably not used to thinking of them as primitives.

```
5 + 6
:KNOWN
```

The first primitive is the +. It takes two inputs, one on each side of it, and outputs their sum if they are numbers.

The second primitive is the : (which is a special kind of abbreviation for THING). It takes one input, attached to it on the right, and outputs the object that is found in the box of that name. (The box, KNOWN, was created earlier as part of the FRIENDLY program.)

There are only two ways of creating objects. You can put them there, yourself, or a procedure or primitive can create them.

Some primitives create objects as output and others don't. For example, if you type FIRST 37, Logo announces the object that FIRST outputs. (What is it?) But if you type PRINT 37, the object simply appears on the screen and cannot be used by other commands.

Some primitives require objects as input and others don't. If a primitive does need an object as input, it does not care whether that input is put there by you, or is the result of running another primitive.

So, in the command PRINT FIRST :KNOWN, the object that PRINT needs as its input is created by FIRST and supplied as its output.

Writing Procedures that Create and Output Objects: OUTPUT

Except for the two procedures MEMBER? and EMPTY? with which we began this section, you have never written a procedure that creates an object and outputs it for another procedure to work with. Such a

procedure is vastly more powerful and flexible than anything we have discussed up to now.

To begin, let's define the procedures TEN and DOUBLE.

```
TO TEN
 OP 7 + 3
END

TO DOUBLE :NUMBER
 OP 2 * :NUMBER
END
```

Now, typing TEN to Logo gets the response RESULT: 10. TEN can be used in computations.

Type

```
PRINT DOUBLE TEN
```

The OUTPUT command (or its abbreviation, OP) tells these procedures to stop and "output an object" or "return a value" or "produce a result." To see what all this means, try the following experiments by typing these lines to Logo:

```
10
TEN
DOUBLE 5
5 * DOUBLE 1
```

When you typed the number 10, you were handing Logo the object 10 directly. The object 10 has the value 10 or results in a 10 lying around. Logo announces that with the message, RESULT: 10.

When you typed the procedure name TEN, it computed a value and then it handed the value (the object 10) to Logo. Similarly, when you typed the procedure name DOUBLE, you handed it the object 5 to work with. It computed the value 10, and handed that back as the result.

In both of these cases, you may think of the procedures as having replaced themselves by the value they output. That makes the last line especially clear. If DOUBLE 1 replaces itself with the value 2, then the line becomes 5 * 2.

We often use the word "object" to refer equally to words (including such things as numbers and letters) and lists (including simple sentences or complex data structures).

We do this because Logo can easily combine words and lists to make other words and lists, break words and lists into pieces, or pass words and lists back and forth between procedures as if they were concrete, solid objects.

When we need to specify what kind of object, we refer to "numbers" or "words" or "lists," but the word "object" refers to them all.

The word "value" sometimes sounds more natural than "object" when we are referring to the result of some computation, but there is really no important difference between the words.

Here is a more useful application of the same sorts of procedures.

```
TO PI
 OUTPUT 3.14159
END
```

```
TO CIRCUMF :DIAMETER
 OP PI * :DIAMETER
END
```

Having a procedure that figures out the circumference of a circle, given its diameter, has a practical application in Logo. Among other jobs, it can be used in a graphics procedure to draw circles of a given size.

All circles in Logo are drawn by drawing short line segments, turning a little, and repeating the process until the circle closes. The smaller the line segments, of course, the smaller the circle.

But how do we determine the length of the segments if we want a circle of a very specific size? If the circle is composed of twenty segments, then each one is one-twentieth of the circumference. If it is drawn with twelve segments, then each is one-twelfth of the circumference.

Clearly, then, to draw a circle of a specific diameter, we must first know the circumference. Then we can divide it into equal parts, and repeatedly draw one of these parts and turn the appropriate amount.

```
TO CIRCLE :DIAMETER
 ARC 20 ( CIRCUMF :DIAMETER ) / 20
END

TO ARC :SEGMENTS :CHORD
 REPEAT :SEGMENTS [FD :CHORD RT 18]
END
```

Try

```
CIRCLE 40 RT 180 CIRCLE 40
```

The following definition of ARC gives a slightly more symmetrical placement of the circles on a vertical line. Figure out why.

```
TO ARC :SEGMENTS :CHORD
 FD :CHORD/2
 RT 18
 REPEAT :SEGMENTS - 1 [FD :CHORD RT 18]
 FD :CHORD/2
END
```

It is useful to have a definition of CIRCLE that curves to the left as well as this one that turns to the right. You can also define half- and quarter-circles using the same ARC procedure.

The objects these procedures manipulated were all words -- in fact, only numbers. Now back to lists. Define these two procedures.

```
TO PEOPLE
 OUTPUT [SANDY CHRIS [THE TURTLE] DANA LEE
     PAT DALE]
END

TO ACTIONS
 OUTPUT [LOVES [DREAMS ABOUT] KISSED
     HATES [CAN'T STAND] LIKES]
END
```

We have chosen the names PEOPLE and ACTIONS as good descriptions of the nature of the procedures. You will be using these procedures often, so you might like to choose names that are shorter or easier to type, like PPL and ACTS, or NOUNS and VERBS, or just N and V.

As you develop more complex programs, it will become especially important that you choose procedure titles and variable names that help you remember what their purpose is. The best policy is to choose names that are easy in two ways: easy to type and easy to remember.

These procedures contain instruction lines that are too long to fit neatly on the screen, but you should continue typing normally, without pressing <RETURN> when you get to the edge of the screen. Logo will place a ! at the end of the screen to indicate that your line continues past there, but will continue to show the rest of your typing on the next line.

Type these procedures accurately, being particularly careful about getting the left and right brackets in the correct places. (Notice that they are the square brackets, and not parentheses! The brackets are typed as SHIFT-N and SHIFT-M on the Apple II and Apple II+.)

Once you are in the editor, you can type any number of procedures before pressing CTRL-C to define them. (But remember you must type END after each procedure before

starting the next one.) In this case it makes little difference whether you define the procedures one by one or both together. Sometimes, though, you will find it very convenient to be able to look at one procedure while you are defining another.

The only behavior of these procedures is to output a list. PEOPLE outputs a list of seven names. Six of those names are words, but one of them, THE TURTLE, is itself a list of two words.

ACTIONS also outputs a list. That list contains only six elements, four of which are single words and two of which are lists of two words each.

To demonstrate that these procedures output objects, type PEOPLE to Logo. Then type PRINT ACTIONS. Your screen should look something like this.

```
PEOPLE
RESULT: [SANDY CHRIS [THE TURTLE] DANA L
EE PAT DALE]
PRINT ACTIONS
LOVES [DREAMS ABOUT] KISSED HATES [CAN'T
STAND] LIKES
```

When Logo cannot fit everything onto one line, it breaks the line where it must, and continues on the next line. (Note that a ! does not appear at the end of the first line in immediate mode, unlike in edit mode.)

Making One Procedure's Output into Another Procedure's Input: OUTPUT (OP), FIRST, BUTFIRST (BF), LAST, BUTLAST (BL), SENTENCE (SE), WORD

Clear the text screen.

What object does FIRST PEOPLE output? (Type FIRST PEOPLE to check if you want to.)

Logo also has a procedure BUTFIRST which outputs all but the first element of its input. Type BUTFIRST PEOPLE to see the object it outputs. And what is the FIRST of that object? Type FIRST BUTFIRST PEOPLE to see.

What object would BUTFIRST output if its input is the object created by BUTFIRST PEOPLE. (In other words, what object is created by BF PEOPLE, and what is the BF of that?) Type BF BF PEOPLE or BUTFIRST BUTFIRST PEOPLE to check.

And what is the FIRST of that object? Type FIRST BF BF PEOPLE to see.

Remember to clear the text screen whenever it will help you see what you are doing.

Here are some more experiments to do with PEOPLE and ACTIONS. They are all to get you familiar with some new primitives and passing objects between them. You may type abbreviated forms such as PR, SE, and BF, or fully spelled out forms, whichever you prefer, but don't just sight-read these experiments. Do each of them and compare the results you get to the comments written before or after the experiments.

Logo can copy an object from either end of a list,

```
FIRST ACTIONS
LAST ACTIONS
```

and from either end of a word

```
PR FIRST "CAT
PR LAST "CAT
```

When FIRST or LAST receive a word as input, they output the corresponding (first or last) letter of the word. When they receive a list as input, they output the corresponding element of the list.

BUTFIRST (BF) and BUTLAST (BL) output all but what FIRST and LAST output. It is important to remember (and a common source of bugs for those who forget) that the BF or BL of a list is always a list. Thus, the BUTFIRST of [FD 30] is not 30, but [30].

FIRST of ACTIONS produced an object, a result. Logo can manipulate that object, taking its FIRST or LAST element, just as it can manipulate any other object.

```
PR FIRST FIRST ACTIONS
PR LAST FIRST ACTIONS
```

Since FIRST ACTIONS is LOVES, its FIRST is L and its LAST is S.

Type:

```
PR SENTENCE PEOPLE ACTIONS
PR SE FIRST PEOPLE FIRST ACTIONS
```

SENTENCE (abbreviated SE) glues any two objects together into a sentence. The sentence of the lists output by PEOPLE and ACTIONS is a long one. The sentence of the first elements of those lists is SANDY LOVES.

Type:

```
PR (SE LAST PEOPLE LAST ACTIONS FIRST PEOPLE)
```

By surrounding SENTENCE and its inputs with parentheses, you can force SENTENCE to take more (or fewer) than two inputs. This is often very important in interactive language programs.

The next series of experiments is particularly important as it forms the basis for the vast majority of the procedures you will use most in manipulating words and lists. It is, for example, at the heart of the MEMBER? procedure that you defined at the very beginning of this chapter. Clear the text screen. Do each experiment and note its behavior.

```
PEOPLE
BF PEOPLE or BUTFIRST PEOPLE
BF BF PEOPLE
BF BF BF PEOPLE
```

Be certain you see the pattern in the results of the previous four experiments before going on. Now predict the results of each of these experiments and then check your prediction by running the experiment.

```
FIRST PEOPLE
FIRST BF PEOPLE
FIRST BF BF PEOPLE
FIRST BF BF BF PEOPLE
```

Similar patterns hold for LAST and BUTLAST (BL).

```
PR BUTLAST ACTIONS or PR BL ACTIONS
PR LAST BL ACTIONS
```

Finally, you can combine a whole bunch of these operations into one command.

```
PR (SE FIRST BF BF PEOPLE LAST BL ACTIONS [ME])
```

SENTENCE glues parts together to make a sentence. We added [ME] to try to add some interest.

Logo also provides the primitive WORD, which glues parts together to make a word. Try this:

```
PR WORD "C BF "SANDY
```

Here are some more complicated expressions using WORD.

```
PR WORD BL FIRST PEOPLE "WICH
PR WORD BL FIRST ACTIONS LAST BL PEOPLE
```

Subprocedures for Cleaner Programming

The primitives that Logo provides give immediate access to the first or last element of a list, or to the first or last character of a word, but what about the second, third, or other elements?

One set of procedures to output the SECOND, THIRD, FOURTH, and FIFTH elements of an object is based on the experiments you tried above. Type these in, and try them out with the projects suggested.

```
TO SECOND :OBJ
 OP FIRST BF :OBJ
END

TO THIRD :OBJ
 OP FIRST BF BF :OBJ
END

TO FOURTH :OBJ
 OP FIRST BF BF BF :OBJ
END

TO FIFTH :OBJ
 OP FIRST BF BF BF BF :OBJ
END

PR (SE FOURTH PEOPLE THIRD ACTIONS THIRD PEOPLE)
PR (SE SECOND PEOPLE FIFTH ACTIONS THIRD PEOPLE)
```

The new procedures allow you to write equivalent commands in different ways. For example, the two following commands have the exactly the same effect:

```
PR (SE FOURTH PEOPLE SECOND ACTIONS FIFTH PEOPLE)
PR (SE FIRST BF BF BF PEOPLE FIRST BF ACTIONS FIRST BF
    BF BF BF PEOPLE)
```

. . . but there are important differences. Not only is the first shorter to type, but it is also much more understandable. Writing understandable programs is a mark of good programming.

A Generalization Using Recursion: ITEM

Although these new procedures vastly simplify both the look and the typing of some list manipulations, they have some drawbacks. The most obvious is that in order to get PAT out of the PEOPLE list, we'd need a procedure SIXTH, and even if we wrote that, there would always be some list that was even longer.

What we really need is one single procedure that can retrieve any member of a list. (If you have version 2.0, you can use the primitive ITEM to do this. Don't skip ahead, though.)

As a first step toward figuring out how to write it, let us carefully describe its behavior in English. Let us call this procedure NTH (as in fourTH, sixTH, sevenTH). We need to tell NTH two things: what number element to find, and what object to choose it from. Perhaps the whole title line will look something like this:

```
TO NTH :N :OBJECT
```

If N is 1, the procedure should just output the first element of the object. That instruction would look like this in Logo.

```
IF :N = 1 OUTPUT FIRST :OBJECT
```

and the whole procedure, so far, would look like this:

```
TO NTH :N :OBJECT
 IF :N = 1 OUTPUT FIRST :OBJECT
END
```

Create this procedure. At this stage you can use the procedure to get the first (but only the first) element of an object. Try typing PR NTH 1 PEOPLE, and make sure it prints SANDY.

That is the simplest situation. To come up with a good way of describing the other situations, let us examine them one by one. If N is 2 then we want NTH to output the first element of the next shorter object (the BUTFIRST of the object). The first element of an object is something NTH knows how to output, so it can do the job itself. In Logo, that might be translated this way:

```
IF :N = 2 OUTPUT NTH 1 BF :OBJECT
```

It will turn out that there is a neater way of doing things, but, for now, add that line to your procedure, too, and check to see that PR NTH 2 PEOPLE causes Logo to print CHRIS. You might also check PR NTH 1 ACTIONS and PR NTH 2 ACTIONS.

What if N is 3? NTH already knows how to find the second element of an object. To find the third element, we could simply find the second element in the BUTFIRST of the object. In Logo, this is translated:

```
IF :N = 3 OUTPUT NTH 2 BF :OBJECT
```

If we continued in this way, we might add a bunch of instructions that look like this:

```
IF :N = 4 OUTPUT NTH 3 BF :OBJECT
IF :N = 5 OUTPUT NTH 4 BF :OBJECT
IF :N = 6 OUTPUT NTH 5 BF :OBJECT
IF :N = 7 OUTPUT NTH 6 BF :OBJECT
```

But this does not solve the original problem. N might still be some number larger than we account for. Fortunately, there is a generalization we can make. In all of the cases where N is not 1, the procedure figures out what to do by looking for element N-1 in the BUTFIRST of the object.

We will repeat the logic:

TO output the NTH element of an object we need to know N and the OBJECT.

```
TO NTH :N :OBJECT
```

If N = 1, we want to OUTPUT the FIRST of the OBJECT.

```
IF :N = 1 OP FIRST :OBJECT
```

In every other case, we want to OUTPUT the N-1 element (found by using NTH with an input of N-1) of the BUTFIRST of the OBJECT.

```
OP NTH :N - 1 BF :OBJECT
```

Thus, the procedure might look like this (with OUTPUT abbreviated as OP):

```
TO NTH :N :OBJECT
 IF :N = 1 OP FIRST :OBJECT
 OP NTH :N - 1 BF :OBJECT
END
```

Edit NTH to make your copy look like this new version and try it out with values of N ranging from 1 to 7 and the PEOPLE list, or with values ranging from 1 to 6 and the ACTIONS list. It even works on words.

Remember that ITEM, which does the same thing as NTH, is provided as a primitive in Terrapin Logo version 2.0.

Projects

10. Write a procedure that takes a number from 1 to 26 as input and outputs the corresponding letter of the alphabet.

11. Using the procedure you wrote in project 10, write a new procedure that takes a list containing a number from 1 to 26 and again outputs the corresponding letter of the alphabet.

12. Using the procedure you wrote in project 11, write a new procedure that takes a list of exactly two numbers ranging from 1 to 26 and outputs a two-letter word with the corresponding letters of the alphabet.

13. Using the procedure you wrote in project 12, write a new procedure that takes a list of exactly three numbers ranging from 1 to 26 and outputs a three-letter word with the corresponding letters of the alphabet.

14. Using the reasoning suggested in this chapter, write a new procedure that takes an arbitrary length list of numbers ranging from 1 to 26 and outputs the word composed of the corresponding letters of the alphabet.

15. Using PEOPLE, ACTIONS, NTH (or ITEM), and Logo primitives PR, SE, and RANDOM, write a procedure that prints random sentences. (Write subprocedures that do parts of the job and then combine them.)

Some Important Primitives Used in this Chapter

The following summary gives a brief synopsis of some commonly used primitives. It is by no means an exhaustive listing. If you don't find what you want, consult the Technical Manual.

The primitives that manipulate Logo objects can be classified into four categories:

1) Those that assemble objects
2) Those that decompose objects
3) Those that determine the nature of objects (i.e. Predicates)
4) Those that pass objects back and forth among procedures, to and from variable names, and between the user and the procedure.

Primitives that assemble Logo objects:

WORD — Creates a word (a set of contiguous characters) from two inputs. Inputs may be words, characters, or procedures that output words/characters.

SENTENCE (SE) — Creates a list from two inputs. Inputs may be words, lists, or procedures which output words/lists. Unlike LIST, SENTENCE returns a list containing no sub-lists.

LIST — Like SENTENCE, creates a list from two inputs. If either input is a list, it will appear as a sub-list in the newly created list.

FPUT — Creates a list from two inputs, the second of which must be a list. The new list created by FPUT consists of the first input (a word or list) followed by the elements of the second input.

LPUT — Same as FPUT, except that LPUT creates a list consisting of the elements of the second input followed by the first input.

Primitives that decompose Logo objects:

FIRST — Outputs the first element of its input. If the input is a word, FIRST outputs a character; if the input is a list, FIRST outputs the first element of the list.

BUTFIRST (BF) — Takes one input and outputs all but the first element.

LAST, BUTLAST (BL) — Corresponding operations for last element of input.

COUNT — Takes a single input, a word or a list. Outputs the number of characters in the word, or the number of elements in the list. (Remember that Logo treats a sub-list as a single element of the larger list.)

ITEM — Takes two inputs; the first input must be a number, and the second must be a word or list. Outputs the nth element of the second input.

Note that COUNT and ITEM are not primitives in Logo versions prior to version 2.0.

Primitives that determine the nature of an object:

WORD? — Outputs "TRUE if the input is a word; otherwise, outputs "FALSE.

LIST? — Outputs "TRUE if the input is a list; otherwise, outputs "FALSE.

NUMBER? — Outputs "TRUE if the input is a number; otherwise, outputs "FALSE.

EMPTY? — Outputs "TRUE if the input is the empty list or the empty word ([] or "); otherwise, outputs "FALSE.

MEMBER? — Takes two inputs. Outputs "TRUE if the first input is an element of the second input; otherwise, outputs "FALSE.

Note that MEMBER? and EMPTY? are not primitives in Logo versions prior to version 2.0.

Primitive that passes an object from one procedure to another:

OUTPUT (OP) — Causes a procedure to STOP and output an object to another procedure or primitive.

Primitives that pass objects to and from variable names:

MAKE — Takes two inputs. The first input becomes the name associated with the value of the second input.

THING — Takes a variable name as an input. Outputs the value associated with the name. A colon (:) prefixed directly to a name is the abbreviation for THING. Thus, THING "A is the same as :A.

Primitives that pass objects to and from the user:

REQUEST (RQ) — Waits for the user to type an input line followed by <RETURN>. Outputs the input line as a list to the calling procedure.

READCHARACTER (RC) — Takes a character typed at the key board and outputs it as a word to the calling procedure. (Remember that RC does not wait for you to type <RETURN>.)

RC? — Outputs "TRUE if a keyboard character is pending; otherwise, outputs "FALSE.

PRINT (PR) — Prints its input on the screen (or on the printer, if specified) followed by <RETURN>. Input may be a word or a list. Notice that PRINT strips away all brackets and single-quotes.

PRINT1 — Prints its input on the screen without <RETURN>. Otherwise, exactly like PRINT.

Also, note that certain Logo primitives can take extra inputs if the entire command is enclosed in parentheses, e.g. (PRINT :LENGTH :HEIGHT :WIDTH). The primitives are LIST, WORD, SENTENCE, PRINT, and PRINT1. In this situation, LIST and SENTENCE may also take one input instead of two.

When using parentheses to indicate extra inputs, be sure to put a space before the closing parenthesis. Otherwise, Logo may assume that the parenthesis is part of the last input and complain that

```
(primitive) NEEDS MORE INPUTS
```

Definitions of Words and Lists
CHAR

We have not yet carefully defined Logo's two types of objects, words and lists. A word, the simplest data object, consists of any continuous string of characters. You've seen several already; here are some other examples:

```
90
3.1416
HI
ANTIDISESTABLISHMENTARIANISM
HENRY.THE.8TH
XYZ
R2D2
```

As you can see, numbers are Logo words, long and short English words are Logo words, and even arbitrarily spelled symbols can be Logo words. Experience has already taught you that when you type several Logo words, spaces separate them instead of becoming part of them.

If you need words that contain odd characters like <SPACE> in them, you can surround them with single-quotes. In the experiment that follows, type carefully, remembering to put in all the double-quote

characters and single-quote characters just as they are shown and to type a space between the first A and the B. Clear the text screen and type

```
"'A BC'
PRINT "'A BC'
[A BC]
PRINT [A BC]
LAST "'A BC' and LAST [A BC]
```

Your screen should look like this:

```
"'A BC'
RESULT: 'A BC'
PRINT "'A BC'
A BC
[A BC]
RESULT: [A BC]
PRINT [A BC]
A BC
LAST "'A BC'
RESULT: C
LAST [A BC]
RESULT: BC
```

Notice that PRINT and other primitives (except OUTPUT) strip away brackets and single-quotes.

The following procedure ODDWORD creates a word of three other words, two of which have spaces in them. Define the procedure, typing carefully. Be sure to type a space before the second parenthesis. (See the preceding glossary if you're not sure why.)

```
TO ODDWORD
  OP ( WORD "'A BA' "'BY B' "OY )
END
```

Now try these experiments with the odd word that ODDWORD outputs.

```
PR ODDWORD
PR NTH 1 ODDWORD
PR NTH 2 ODDWORD
PR NTH 3 ODDWORD
PR NTH 10 ODDWORD
PR LAST ODDWORD
PR WORD NTH 2 ODDWORD ODDWORD
PR WORD "'<space><space><space>' ODDWORD
```

Even though the word that ODDWORD outputs contains spaces, it is a word. Even though it looks like a list when printed, it behaves like a word. The LAST of it is the letter Y, not the word BOY.

A space can be typed, and the single-quote character allows you to insert that space inside a word, but there are some characters that cannot be typed into a procedure at all. An example is the <CTRL> G character. If you were to try typing

```
PR "'<CTRL> G'
```

to Logo, it would say STOPPED! before you reached the second single-quote. But there is a way to include even strange characters like that in a word. The Logo primitive CHAR outputs the character which corresponds to the ASCII code it is given.

The ASCII codes for <CTRL> A through <CTRL> Z are 1 through 26. The codes for capital A through capital Z are 65 through 90, or 64 larger. Thus, you will get the same effect if you type

```
PR CHAR 65 or PR "A
```

Empty words — words that contain no characters at all, not even a space — also exist. When typing a command to Logo, one way to indicate you are referring to the empty word is by following a " with a <SPACE> or <RETURN>. (The <SPACE> separates the word from what follows, and is not part of the word.)

See, for example, the procedure EMPTY?, which tests to see if its input OBJECT is either the empty word or the empty list.

A list is an ordered collection of Logo objects. Its elements can be words or other lists. Here are some examples of lists:

```
[COLORS [BLUE GREEN YELLOW RED] SIZES [LARGE
    SMALL]]
[555-2561 617-4436 918-9961]
[[FD 70] [RT 120] [FD 70] [RT 120] [FD 70] [RT 120]]
[]
```

The matched left and right square-brackets show the scope of a list. The first list contains four elements, the second and fourth of which are lists themselves and thus are grouped together with the square-brackets.

The second list contains three elements, each a word denoting a telephone number. The third list contains six sublists, each of which contains a Logo command. The fourth list is empty; it contains no elements at all.

Spaces separate elements of the list. The number of spaces signifies nothing, and in fact, more than one space between two elements will be ignored by Logo.

Some Details of Programming in Logo: Variables, Passing Objects, Logo's Way of Understanding Commands, and Logo's Messages When It Doesn't Understand

Type this operation to Logo:

```
WORD "CAT "S
```

As has happened frequently in this chapter, we have suggested you type somehing to Logo that caused it to respond with the word "RESULT: " followed by the result of the operation. Logo includes the message RESULT: to remind you that it has computed a result, but you have not told it what to do with the result. Compare the effect of this command:

```
PR WORD "CAT "S
```

Both times, the word CATS appeared, but the second time you told Logo what to do with the result (to print it) and so that is what it did.

You can predict the result of these operations:

```
WORD "HORSE "S
WORD "DOG "S
```

In each case, you typed

```
WORD somethingorother "S
```

suggesting a procedure that might look a bit like this:

```
TO PLURAL :SOMETHINGOROTHER
  WORD :SOMETHINGOROTHER "S
END
```

Of course, since names of procedures and variables are arbitrary, you could choose names that are easier to type. NOUN, or IT might be good choices for the variable name.

```
TO PLURAL :NOUN
  WORD :NOUN "S
END
```

Why did we switch from quote CAT and quote DOG and quote HORSE to colon NOUN? When you typed

```
WORD "CAT "S
```

CAT was the word you wanted to attach the S to. In the procedure, the word NOUN only stands for the word you want to attach the S to, but it is not the real word. You still want the procedure to work on words like CAT, DOG, and HORSE.

Remember the tiresome joke?

> Dale: Bet you've never heard of the word "antidisestablishmentarianism!"
> Dana: Of course I have.
> Dale: Pooh! I bet you can't even spell it.

Dana: Of course I can.
Dale: Go ahead. Let's see if you can spell it.
Dana: A, n, t, i, d, i . . .
Dale: Hah! Wrong already! "It" is spelled "i t."

Dale is playing with the confusion between what a word is and what it stands for. When you speak, you change your tone of voice when you need to make that clear. Consider, for example, how you might say the words

"Please say your name"

to Dale if you really wanted Dale to answer "your name" instead of "Dale"? When you write, you use quotation marks to help make your meaning clear. And when you program in Logo, the quotation marks again mean "take this word literally" as they do in written English.

However, Logo's rule is different from the rule in English: in Logo no quotation mark is placed after the quoted word and that one quotation mark applies to only one word. When you need to indicate that more than one word is to be taken literally, you must either separately quote each word, this way

```
"YOUR "NAME
```

or enclose all of the words in square brackets, this way

```
[YOUR NAME]
```

Now type in the procedure:

```
TO PLURAL :NOUN
 WORD :NOUN "S
END
```

To run it, type PLURAL followed by a quoted word like this:

```
PLURAL "CAT
PLURAL "HORSE
```

Your screen will look like this:

```
PLURAL "CAT
YOU DON'T SAY WHAT TO DO WITH CATS, IN LINE
     WORD :NOUN "S
     AT LEVEL 1 OF PLURAL
```

Inside the procedure PLURAL, Logo has created an object and does not know what to do with that object. It is telling you what problem it was having and exactly where it encountered the problem.

Logo tells which of your procedures confused it (in this case, only one of your procedures, PLURAL, was involved, but there might have been more).

It tells the line in which it got stuck. And it tells the "level" at which it got stuck — how many procedures it was already trying to execute when the error occurred.

To see the meaning of level, create another procedure that runs PLURAL.

```
TO TRYLEV
  PLURAL "CAT
END
```

Try it.

```
TRYLEV
YOU DON'T SAY WHAT TO DO WITH CATS, IN LINE
        WORD :NOUN "S
        AT LEVEL 2 OF PLURAL
```

Note that the level is now 2. TRYLEV is the first level, the command you typed to the "top level" of Logo. Since PLURAL is "within" TRYLEV, its level is 2. Level can be useful information when debugging complex programs.

Before you can tell Logo what to do with the object it creates inside PLURAL, you have to decide that for yourself. You know how to tell Logo to PRINT the result immediately, but perhaps you want to do something more complicated with the plural word before printing it.

Suppose, for example, you want to create a procedure that brags about your pet like this:

```
I LIKE some-pet-or-otherS.
some-pet-or-otherS ARE GREAT,
BUT MY some-pet-or-other IS THE BEST!
```

In the second sentence, we want the plural to be tucked into the sentence before it is printed, and in the first sentence we need to do two things before printing — attach a period to the plural and then stick the whole thing at the end of the sentence.

Since we want to use the object that PLURAL creates in different ways, it would be nice if PLURAL would hand the object back to us to manipulate further as we wish. This is accomplished by telling it to OUTPUT the object.

Edit PLURAL to insert the word OUTPUT (or its abbreviation OP) in the proper place. The procedure will now look like this:

```
TO PLURAL :NOUN
  OUTPUT WORD :NOUN "S
  PRINT [DONE]
END
```

Now run it again as you did before.

```
PLURAL "CAT
PLURAL "HORSE
```

This time, your screen should say:

```
PLURAL "CAT
RESULT: CATS
PLURAL "HORSE
RESULT: HORSES
```

That is precisely what we want. PLURAL has computed the result, and we are still free to decide what to do with it.

But what became of the DONE that we told PLURAL to print? OUTPUT tells a procedure not only to return a value, but to stop immediately. If it is important that PLURAL announce when it is done, it must print DONE before it is done. (It can't do anything after it is done!)

However, if PLURAL is to be used inside another procedure, perhaps one that brags about pets, PLURAL probably should not print anything anyway. It should do its job quietly, and let the superprocedure that uses it decide what to print and when.

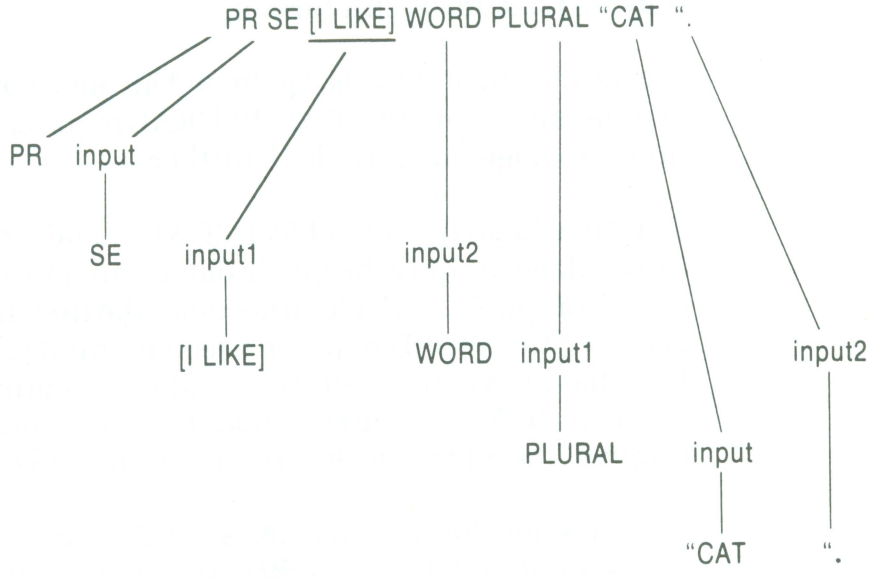
Edit PLURAL again to remove the useless line PRINT [DONE].

Try to predict what each of these commands will do, and then type them to see how each works:

```
PR SE [I LIKE] PLURAL "CAT
PR WORD "TOM PLURAL "CAT
PR WORD PLURAL "CAT ".
PR SE [I LIKE] WORD PLURAL "CAT ".
```

How Logo Interprets a Command

It is worth spending a moment to understand how Logo interprets a command as complex as the last one.



Logo reads from left to right, but as you will see by following the diagram above and the discussion below, PLURAL is the first operation to be executed.

First Logo sees the word PR. That means that it will have to print whatever follows. So before executing PR, Logo must read further to see what follows. PR must wait.

Instead of finding an object, Logo encounters another operation, SE. Furthermore, this primitive requires two inputs of its own, so again Logo must read on to find them. PR waits for SE and SE waits for its inputs.

Logo finds the object [I LIKE] as a first input to SE. But SE needs another, so Logo reads further.

Next it finds WORD. Again, this is not an object but an operation. As before, this primitive requires two inputs, so Logo reads still further.

The next thing it finds is, again, not an object but another operation, PLURAL. PLURAL requires one input, so Logo must still look further.

This time Logo finds an object, "CAT — and since PLURAL needs only the one input, it can now execute. It outputs CATS which becomes the first input to WORD. Still, WORD requires a second input which Logo has not yet seen. So, now — after executing PLURAL "CAT — Logo continues to read through the original line and finds the object ". at the end of it.

Logo has now found two objects — CATS and . — to use as inputs to WORD. WORD can now execute, outputting CATS., which becomes the second input to SE. SE can now execute, outputting [I LIKE CATS.] which becomes the input to PR. PR can now execute, printing (not outputting!)

```
I LIKE CATS.
```

This left-to-right reading but (seemingly) right-to-left execution can be confusing sometimes. Both of the following command lines will cause Logo to complain. Try them out to see when and where the complaint occurs, and then use an analysis like the one given above to understand what Logo was doing when it had to stop.

```
PR SE [I LIKE] WORD PLURAL [CAT] ".
PR SE [I LIKE] WORD PLURAL "CAT [.]
```

Sometimes the complexity of a line makes it difficult to understand even by the person who first wrote it. Before reading on, try to predict what the following Logo command will do. Then type it in to try it, and read on.

```
PR SE WORD LAST PLURAL "CAT "CAT "CAT
```

When you write complex Logo commands — especially if you are writing them for other people to understand, but often even for yourself — it can be a good idea to use parentheses to help group the parts of the command. Logo will interpret the command according to its rules equally easily with or without the parentheses, but people find the added punctuation helpful.

You should decide for yourself how much parenthesizing to do. Sometimes, using the maximum is best. At times, the maximum looks too cluttered, and just a few are better. The choice is entirely a matter of taste. For example, that last command might be parenthesized in the following ways. Which way makes it visually clearest to you what the command does?

```
PR (SE (WORD (LAST (PLURAL "CAT )) "CAT ) "CAT )
PR SE (WORD LAST (PLURAL "CAT ) "CAT ) "CAT
PR SE (WORD (LAST PLURAL "CAT ) "CAT ) "CAT
```

Be sure to type a space between "CAT and) — otherwise, Logo will read the parenthesis as part of the word and will complain that the primitive needs more inputs, i.e. Logo can't find a matching right parenthesis.

Using Logo Predicates and Creating New Ones: LIST?, WORD?, MEMBER?, and the Structure of IF, THEN, and ELSE

All along, we've been using IF without any explanation of its structure. The IF statement has three parts:

1) The IF itself

2) A condition which may be either TRUE or FALSE. (In this case, the condition is LIST? :NOUN which tells whether it is TRUE or FALSE that NOUN is a list.) The condition may include modifiers such as NOT, ALLOF, and ANYOF, either individually or in combination.

3) The THEN clause: an action to perform if the condition is TRUE.

An IF statement can also have an additional two parts when desired.

1) The word ELSE and

2) An action to perform if the condition is FALSE

Finally, as mentioned earlier, the word THEN can be used optionally between the condition and the action-if-true.

Thus, an IF statement can take the following four forms.

IF condition action-if-true
IF condition THEN action-if-true
IF condition action-if-true ELSE action-if-false
IF condition THEN action-if-true ELSE action-if-false

The condition always contains a "predicate," a Logo primitive or user procedure that answers a True-False question by outputting TRUE or FALSE.

In the case of LIST? :NOUN, the True-False question is "NOUN is a list! True or false?" If the statement is false, LIST? outputs FALSE. If the statement is true, LIST? outputs TRUE.

You will often need to create your own predicates, so it is important to become familiar with their behavior. Type these expressions to Logo:

```
LIST? PEOPLE
LIST? FIRST PEOPLE
LIST? NTH 3 PEOPLE
```

Each time, Logo should announce a result, showing that LIST? output a word, either TRUE or FALSE, depending on whether the input was a list or not.

You have used several other predicates. When you used NUMBER? :CHTR in the EASY procedure for QUICKDRAW in project 5, it output TRUE or FALSE depending on the truth of the statement "CHTR is a number."

In GREET, you used the expression EMPTY? :PERSON. It worked the same way.

And, in the expression IF :CHTR = "F, the equal sign also outputs TRUE or FALSE depending on the truth of the statement that CHTR equals "F. (The =, like the +, comes between its inputs.)

The RC? primitive (which takes no inputs), the WORD? primitive (which takes one input), and the procedure MEMBER? (which takes two inputs) are also predicates.

When you first defined MEMBER? and EMPTY? we postponed explaining how they work. You are now probably ready for that explanation.

Look first at the procedure EMPTY?.

```
TO EMPTY? :OBJECT
 OUTPUT ANYOF :OBJECT = [] :OBJECT = "
END
```

There are two equal-signs in the procedure. Each one outputs TRUE or FALSE.

The first one outputs TRUE if OBJECT is the empty list (and FALSE otherwise). The second outputs TRUE if OBJECT is the empty word (and FALSE otherwise).

ANYOF takes two (or more) inputs, and it outputs TRUE if *any* of them is TRUE.

Finally, the purpose of the command OUTPUT in the procedure is to tell EMPTY? to output whatever ANYOF outputs. Thus, EMPTY? outputs TRUE if any of these conditions is true:

the OBJECT is [], the empty list
the OBJECT is " , the empty word

Otherwise, EMPTY? outputs FALSE.

Now look at the procedure MEMBER?.

```
TO MEMBER? :ELEMENT :OBJECT
 IF EMPTY? :OBJECT OUTPUT "FALSE
 IF :ELEMENT = FIRST :OBJECT OUTPUT "TRUE
 OUTPUT MEMBER? :ELEMENT BUTFIRST :OBJECT
END
```

Surely ELEMENT cannot be a member of OBJECT if OBJECT has no members! So, if OBJECT is empty, MEMBER? should output FALSE.

```
IF EMPTY? :OBJECT OUTPUT "FALSE
```

If ELEMENT is the first member of OBJECT, the procedure need check no further. It can already answer TRUE that ELEMENT is a member of OBJECT.

```
IF :ELEMENT = FIRST :OBJECT OUTPUT "TRUE
```

Now, the recursive step. If there are more elements in OBJECT (because OBJECT is not empty), but ELEMENT is not the first element of OBJECT, it may still be one of the later elements. If it is a member of BUTFIRST :OBJECT, it is clearly a member of OBJECT.

So, if ELEMENT is not the first element of OBJECT, but there are more elements, the procedure may answer the original question — MEMBER? :ELEMENT :OBJECT — by outputting the answer to a simpler question — MEMBER? :ELEMENT BUTFIRST :OBJECT.

```
OUTPUT MEMBER? :ELEMENT BUTFIRST :OBJECT
```

> You've probably noticed that every predicate has the -? suffix. We will continue to use this convention throughout the chapter. When you see a primitive or procedure name ending in -?, you'll know that its behavior is to output TRUE or FALSE.

Projects with Predicates

16. Define the predicate, TO VOWEL? :LETTER, that outputs TRUE if LETTER is a vowel, and FALSE otherwise.

17. Define the predicate, TO YES?, that requests a typed line from the user and outputs TRUE if that line is a reasonable synonym of "yes," FALSE if the line is a reasonable synonym of "no," and otherwise prints a message requesting clarification and calls itself recursively to try again. Decide on the synonyms you will accept.

Ordered Rules

Testing out PLURAL reveals a number of bugs. Try the following inputs:

```
PLURAL "DOG
PLURAL "TURTLE
PLURAL "FLY
PLURAL "FINCH
PLURAL "FISH
PLURAL "MOUSE
PLURAL "CHILD
PLURAL "FOX
PLURAL [FOX TERRIER]
```

Two different kinds of bugs can be noted. One is that some of the plurals are not correct. The procedure's only rule is to tack on an S, and it must be taught more about English plurals.

The other bug is that it couldn't handle [FOX TERRIER] at all. In this case, Logo complains that WORD doesn't like [FOX TERRIER] as input in the context of OUTPUT WORD :NOUN "S in the procedure PLURAL.

Logo, of course, is not biased against cute dogs. It is merely trying to say that WORD glues pieces of words — not lists — together to make other words.

To solve this problem the procedure doesn't need more knowledge about English, but rather needs more knowledge about its inputs. We will show a solution to three of the problems and suggest several other problems as projects for you to work on.

First, the FOX TERRIERS. If NOUN is a list, PLURAL should probably do most of its work on the last word of the list.

It should OUTPUT a SENTENCE composed of all BUT the LAST word of NOUN, and the PLURAL of the LAST word of NOUN. The Logo instruction would look like this:

```
IF LIST? :NOUN OP SE BL :NOUN PLURAL LAST :NOUN
```

Edit PLURAL and add that line.

```
TO PLURAL :NOUN
 IF LIST? :NOUN OP SE BL :NOUN PLURAL LAST :NOUN
 OUTPUT WORD :NOUN "S
END
```

Try
PLURAL [BLUE BIRD]
or
PLURAL [RICKETY LADDER]
in addition to
PLURAL [FOX TERRIER].

Right now, PLURAL "FOX outputs FOXS. To get it to output FOXES, we might include a simple test to see if X is the last letter of NOUN. If it is, we should attach ES rather than S to NOUN.

```
IF "X = LAST :NOUN OP WORD :NOUN "ES
```

Where shall we put this new instruction? Certainly not as the last instruction, because if it came after the line OUTPUT WORD :NOUN "S, the procedure would

never get to it. In this case, it makes little difference in PLURAL's behavior whether the new instruction comes first or second.

Edit PLURAL and define it to look like this:

```
TO PLURAL :NOUN
 IF LIST? :NOUN OP SE BL :NOUN PLURAL LAST :NOUN
 IF "X = LAST :NOUN OP WORD :NOUN "ES
 OUTPUT WORD :NOUN "S
END
```

Now test it out. Does PLURAL give the right plural for FOX? What about [FOX TERRIER]? And what about [GREY FOX]?

A third problem is teaching the procedure how to handle the really strange cases, like CHILD, MOUSE, FOOT, and SHEEP. First, we must make a list of the exceptions.

```
MAKE "EXCEPTIONLIST [CHILD MOUSE FOOT SHEEP OX]
```

PLURAL must be told something like "If the noun is one of the exceptions . . ."

```
IF MEMBER? :NOUN :EXCEPTIONLIST . . .
```

". . . then output the special plural associated with that particular noun."

. . . OUTPUTspecial.plural.something.or.other

Where should that special-plural information reside? It could be another procedure:

```
TO EXPLU :NOUN
  IF :NOUN = "CHILD OP "CHILDREN
  IF :NOUN = "SHEEP OP "SHEEP
  IF :NOUN = "MOUSE OP "MICE
  IF :NOUN = "FOOT OP "FEET
  etc.
END
```

In that case the new addition to PLURAL would be:

```
IF MEMBER? :NOUN :EXCEPTIONLIST OP EXPLU :NOUN
```

Another approach, in some ways simpler, is to put each piece of special plural information into a box whose name is the noun itself. So we could put CHILDREN into a box named CHILD, and put SHEEP into a box named SHEEP, etc.

```
MAKE "CHILD "CHILDREN
MAKE "SHEEP "SHEEP
MAKE "OX "OXEN
```

Then IF the NOUN were a member of the EXCEPTIONLIST, PLURAL should OUTPUT the object (THING) inside a box associated with the NOUN. The Logo would look like this:

```
IF MEMBER? :NOUN :EXCEPTIONLIST OP THING :NOUN
```

This is strange-looking code, indeed. What can THING :NOUN mean? If :NOUN is CHILD, then THING :NOUN is the THING of CHILD, and if :NOUN is SHEEP, then THING :NOUN is the THING of SHEEP.

And what is the THING of CHILD? CHILDREN, because earlier you typed MAKE "CHILD "CHILDREN. So, too, the THING of SHEEP is SHEEP.

Projects with PLURAL

18. It matters where you place the new instruction. Below, we show PLURAL defined in three different ways, with the new instruction placed first, second, and third.

Define PLURAL each way and test it out enough to determine which way(s) work. (Why do we not bother even trying it as the fourth instruction?)

```
TO PLURAL :NOUN
IF MEMBER? :NOUN :EXCEPTIONLIST OP THING :NOUN
IF LIST? :NOUN OP SE BL :NOUN PLURAL LAST :NOUN
IF "X = LAST :NOUN OP WORD :NOUN "ES
OUTPUT WORD :NOUN "S
END

TO PLURAL :NOUN
IF LIST? :NOUN OP SE BL :NOUN PLURAL LAST :NOUN
IF MEMBER? :NOUN :EXCEPTIONLIST OP THING :NOUN
IF "X = LAST :NOUN OP WORD :NOUN "ES
OUTPUT WORD :NOUN "S
END

TO PLURAL :NOUN
IF LIST? :NOUN OP SE BL :NOUN PLURAL LAST :NOUN
IF "X = LAST :NOUN OP WORD :NOUN "ES
IF MEMBER? :NOUN :EXCEPTIONLIST OP THING :NOUN
OUTPUT WORD :NOUN "S
END
```

19. To teach PLURAL when to add ES at the end, you sometimes must look at the last letter of :NOUN and sometimes at the last two letters. Figure out the rule, and then make PLURAL smart enough to output the correct plural for WISH.

Does it handle [BEST WISH] correctly? Can it handle BOSS? FINCH? Does it still do the right thing for FOX? Are you satisfied with the way it handles FISH?

20. Teach it to do the right thing with FLY.

21. Does PLURAL handle BOY and KEY correctly? If not, fix it.

22. In project 15 above, you wrote a program to generate random sentences out of the nouns in PEOPLE and the verbs in ACTIONS. Without changing any of the details of the program, you can add HE, [MY MOTHER], and certain other nouns and pronouns to PEOPLE, but, as the program stands, it will stop making grammatical sentences if PEOPLE contains elements like YOU, or [CHARLES AND DIANA].

This can be fixed. ACTIONS now contains the verbs [LOVES [DREAMS ABOUT] KISSED HATES [CAN'T STAND] LIKES]. If it were changed slightly, a program similar to PLURAL could add the proper S or D endings when needed. This is what ACTIONS would need to contain: [LOVE [DREAM ABOUT] KISS HATE [CAN'T STAND] LIKE]

First, write a procedure, TO FIXVERB :VERB (the logic will be similar to PLURAL, but not the same) that adds S or ES or nothing to any verb that is its input. Write

another procedure, TO PAST :VERB that adds D or ED (or makes whatever other change is needed) to put the verb in past tense.

Now write a procedure that takes a subject such as YOU or [THE TURTLE] and figures out whether the verb needs to be "fixed" or not.

With these procedures you can make a better sentence generator.

23. If you know French, you could do the same thing for French verbs. Of course, the rules are more complicated, and you will need to do more designing and more programming.

But you have all the techniques now, and some good strategies. It is probably a good idea to have small procedures, each of which does a specific job, rather than one large procedure that does everything.

A set of procedures that conjugate French verbs can be used in a program that generates French sentences. It can also be used as part of a quiz on French verbs. The next section will deal with quiz programs.

Quiz Programs: More About REQUEST (RQ)

When REQUEST is encountered in a procedure, the procedure stops and waits until the user presses <RETURN>. Anything that the person has typed prior to the <RETURN> is then output by REQUEST as a list.

If the person types a dozen words, REQUEST outputs a 12 word list. If the person types nothing, REQUEST outputs an empty list. If the person types a single word, REQUEST outputs a one word list. The important thing to remember is that REQUEST's output is always a list, never a word.

Here is a model of a simple quiz program. QUIZ "gives" the quiz, using QA to handle each question/answer pair. QA is a subprocedure that prints the question, requests an answer from the quizee and if that answer is the official ANSWER, prints "YUP!" and stops. If the answer is not judged to be correct, QA prints the correct answer.

```
TO QUIZ
  PRINT [TEST YOUR BRILLIANCE!]
  QA [WHO IS BURIED IN GRANT'S TOMB?] [GRANT]
  QA [WHY DID THE CHICKEN CROSS THE ROAD?] [TO GET GAS]
  QA [HOW DO YOU SPELL RELIEF?] [CORRECTLY]
END

TO QA :QUESTION :ANSWER
  PRINT :QUESTION
  IF :ANSWER = REQUEST PR [YUP!] STOP
  PR SE [NOPE! THE ANSWER IS:] :ANSWER
END
```

On the surface, the logic of the addition quiz below is identical to QUIZ. ADDQUIZ "runs" the test, calling ADDQ with each number pair. ADDQ's inputs are two numbers to add. It doesn't need to be told the answer, as QA did, because it can figure out the answer itself.

Its first line prints the question — for example 7 + 9 = — and waits for the answer at the end of the line. The second line waits for the user to type an answer and compares it to the calculated correct answer.

If the user's answer is the same, ADDQ prints YAY! and stops. Otherwise it prints the correct answer. It seems like it ought to work. Yet it has a bug.

Define ADDQUIZ and its subprocedure ADDQ, try the quiz (by typing ADDQUIZ), and see if you can make it work properly before reading on.

```
TO ADDQUIZ
 PRINT [TEST YOUR ADDITION]
 ADDQ 7 9
 ADDQ 8 5
 ADDQ 9 8
END

TO ADDQ :NUMBER1 :NUMBER2
 PRINT1 ( SE :NUMBER1 "+ :NUMBER2 "= ' )
(buggy line) IF (:NUMBER1 + :NUMBER2) = REQUEST PR [YAY!] STOP
 PR ( SE "NOPE, :NUMBER1 "+ :NUMBER2 "= :NUMBER1
    + :NUMBER2 )
END
```

Forgetting that REQUEST always outputs a list is a frequent source of bugs. As the procedure ADDQ is currently written, it will never print YAY!. (:NUMBER1 + :NUMBER2) is a number (and therefore a word), while REQUEST outputs a list — the two can never be equal.

To make them comparable, we need to change REQUEST's list into a word. We can do this by taking the FIRST of REQUEST. Thus ADDQ will work if REQUEST is replaced by FIRST REQUEST or its abbreviation FIRST RQ.

Make that change and verify that ADDQ now works by typing

```
ADDQUIZ
```

Projects with REQUEST

24. In general, there is more than one right way to answer a question, yet QUIZ considers only one answer correct. Suppose QUIZ were rewritten this way:

```
TO QUIZ
 PRINT [TEST YOUR BRILLIANCE!]
 QA [WHO IS BURIED IN GRANT'S TOMB?]
    [[GRANT] [GENERAL GRANT]]
 QA [WHY DID THE CHICKEN CROSS THE ROAD?]
    [[TO GET GAS] [FOR FUN] [TO LAY EGGS]]
 QA [HOW DO YOU SPELL RELIEF?]
    [[CORRECTLY] [ROLAIDS]]
END
```

In each case, a different number of correct answers has been provided. Rewrite QA to account for the choices of answers.

25. The biggest difference between the subprocedure ADDQ for the addition quiz and the subprocedure QA for the general information quiz is that ADDQ does not need to be told the answer to the question. Because

number pairs can be selected at random, even the questions do not have to be specified one by one.

This means that the quiz can keep generating questions as long as desired, without having had to list all the questions beforehand. Write an addition quiz that poses problems with randomly selected numbers no larger than 12, and keeps going until the quizee gets ten of them correct.

26. Add a bit more intelligence to the addition quiz. Let it start by posing addition problems with very small numbers, say under 4. If a person gets three of them correct, the program begins giving slightly larger numbers, and so on. The program stops if a person gets two wrong in a row.

27. Change ADDQ's title line to read TO ADDQ :TRIES :NUMBER1 :NUMBER2 and change the procedure to allow a person two tries at the same problem before the problem is changed.

ADDQ should perhaps say TRY AGAIN if the person gets the wrong answer the first time, but should not give the correct answer until the person gets the problem wrong a second time. Then it should quit and go on to the next problem.

28. Using the procedures PICK and QA that were defined earlier in the solution to project 15 , write a STATESQUIZ program that picks question-answer sets off a pre-defined list. You might store the information in a form something like this:

```
MAKE "STATES [[OHIO COLUMBUS] [[NEW YORK]
    ALBANY] [GEORGIA ATLANTA]]
```

29. If you used the exact list shown in project 28, and wrote a working STATESQUIZ, it may be hard to add states that have multi-word capitals to the list. For example, if you now type MAKE "STATES LPUT [IOWA [DES MOINES]] :STATES, the chances are that when STATESQUIZ asks what the capital of Iowa is, it will not accept any answer as correct.

Fix the quiz so that it works, either by redesigning the data-base (:STATES) to be more consistent, or by making the procedures smart enough to handle the inconsistency. (Suggestion: redesigning the database makes the program simpler.)

30. If you have written a French verb conjugator, you can write a quiz similar to ADDQUIZ that selects a verb at random from a list, selects a pronoun, also at random, and asks the person to type in the correct verb form.

Composing Logo Objects: SENTENCE, WORD, LIST, FPUT, LPUT, TEST, IFTRUE, and IFFALSE

Here is a procedure, JUNKMAIL, that uses SENTENCE and its abbreviation SE. Define JUNKMAIL, complete with extra spaces as shown below.

```
TO JUNKMAIL :PERSON
  PR SENTENCE [DEAR] :PERSON
  PR [IF YOU ACT RIGHT NOW, YOU HAVE]
  PR [A CHANCE TO WIN A MILLION DOLLARS!]
  PR [WINNING TICKETS,  ALREADY MADE OUT]
  PR [IN YOUR NAME, ARE WAITING FOR YOU.]
  PR ( SE [THINK,] :PERSON [,  WHAT THAT COULD MEAN!] )
END
```

To run it, type JUNKMAIL followed by a list or a word, like this:

```
JUNKMAIL [MS. RACHEL LEVIN]
JUNKMAIL [ABBY]
JUNKMAIL "MIKE
JUNKMAIL PICK PEOPLE
```

Notice, first, its handling of spaces. All of the extra spaces you inserted are missing. Also, because SENTENCE creates a list — outputting DEAR ABBY instead of the word DEARABBY — it appears to leave a space between its inputs. The space, as noted earlier, is not a part of the list, but merely a separator that comes between elements of the list.

SENTENCE always outputs a list. If either input is a word, SENTENCE treats that input as if it were a one-element list. Thus, all four of these expressions output the sentence [DEAR ABBY].

```
SENTENCE "DEAR "ABBY
SENTENCE "DEAR [ABBY]
SENTENCE [DEAR] "ABBY
SENTENCE [DEAR] [ABBY]
```

The last line of JUNKMAIL contains parentheses. By surrounding the primitive SENTENCE and the three objects that follow it, those parentheses tell Logo that the primitive is to accept all three objects as input.

A few Logo primitives — in general, the ones that "associatively combine" their inputs, such as SENTENCE, WORD, and LIST, but

also some others such as PRINT and PRINT1 — have this ability to accept other than their usual number of inputs when surrounded by parentheses.

User-defined procedures cannot be given this feature.

The procedure has a formatting bug. We would like it to type,

```
THINK, MIKE, WHAT THAT COULD MEAN!
```

but the space that separates elements of a list has separated PERSON from the following comma, with this result:

```
THINK, MIKE , WHAT THAT COULD MEAN!
```

When, in PLURAL, you attached S to one of the words in a list, you were solving a similar problem, but JUNKMAIL adds a new twist.

If we could be certain that PERSON was a Logo word, the change would be simple:

```
PR ( SE [THINK,] WORD :PERSON ", [WHAT THAT COULD MEAN!] )
```

But this will not work if the input is a list. Since WORD cannot take lists as inputs, the list would first have to be torn apart (using FIRST or LAST to extract the elements, and BUTFIRST or BUTLAST to preserve the rest), and then recomposed (using SENTENCE) after the comma is affixed properly by WORD.

```
PR ( SE [THINK,] BL :PERSON WORD LAST :PERSON ",
    [WHAT THAT COULD MEAN!] )
```

Now try JUNKMAIL twice, once with a word and once with a list. What happens?

Since the user is free to input either word or a list, we must take still one more step. We have a choice. One possibility is to test the input with WORD? or LIST? and choose which path to follow depending on the outcome. We can perform either test and write the rest of the IF statement accordingly. So, the logic might be:

```
IF LIST? :PERSON do-the-list-version ELSE
                    do-the-word-version
                          or
IF WORD? :PERSON do-the-word-version ELSE
                    do-the-list-version
```

In either case, the result is a horribly long line that becomes nearly impossible to read. Here is how it might look inside the editor if the LIST? test were used:

```
IF LIST? :PERSON  PR  ( SE [THINK,] BL :!
PERSON WORD LAST :PERSON ", [WHAT THAT !
COULD  MEAN!] ) ELSE PR ( SE [THINK,] WO!
RD :PERSON ", [WHAT THAT COULD MEAN!] )
```

Logo provides another IF-like construction, TEST, which is useful when several actions must be performed depending on the truth of the tested conditional. TEST is also useful when the actions are very long, as they are in this case.

Here is how the same logic would be written using TEST.

```
TEST LIST? :PERSON
IFTRUE PR ( SE [THINK,] BL :PERSON WOR!
D LAST :PERSON ", [WHAT THAT COULD MEAN!
!] )
IFFALSE PR ( SE [THINK,] WORD :PERSON !
", [WHAT THAT COULD MEAN!] )
```

There is a less verbose alternative. Since (SE "ABBY) and (SE [ABBY]) both output the list [ABBY], SENTENCE can be used to convert the input, whatever form it started in, into a standard form.

Insert the statement MAKE "PERSON (SE :PERSON) as the first line of JUNKMAIL to force :PERSON to be a list. The parentheses are needed because SE is taking fewer than two inputs. Then, since you know that :PERSON is a list, you need not test and can use just the solution that applies to lists. This application of SE often comes in handy.

LIST, FPUT, and LPUT also compose lists. It is important both to compare their effects by doing some simple experiments (some will be suggested below) and to know why anybody would care about the differences.

First, compare SENTENCE and LIST this way:

```
SE [THIS IS] [A LIST]
LIST [THIS IS] [A LIST]
```

SENTENCE outputs a list whose elements are the elements of its inputs, whereas LIST outputs a list whose elements are its inputs.

When is this important? If you are trying to compose a simple list of words, as in an English sentence, SENTENCE is the right choice. Try these:

```
SE [THIS IS A] "SENTENCE
SE "THIS [IS A SENTENCE]
(SE "THIS [IS] "A [SENTENCE])
(SE [THIS IS A SENTENCE])
(SE "THIS "IS "A "SENTENCE )
```

Because SENTENCE throws away information about the structure of its inputs, each of these expressions outputs the same list, [THIS IS A SENTENCE]. Now try the same sets of inputs using the primitive LIST instead of SE.

```
LIST [THIS IS A] "SENTENCE
LIST "THIS [IS A SENTENCE]
(LIST "THIS [IS] "A [SENTENCE])
(LIST [THIS IS A SENTENCE])
(LIST "THIS "IS "A "SENTENCE )
```

The structure of the inputs is fully preserved in the output.

```
[ [THIS IS A] SENTENCE ]
[ THIS [IS A SENTENCE] ]
[ THIS [IS] A [SENTENCE] ]
[ [THIS IS A SENTENCE] ]
[THIS IS A SENTENCE]
```

LIST is the primitive to use when you need to package objects, unaltered, into a list. Like SENTENCE, LIST usually takes two inputs, but when parenthesized, it accepts any number greater than zero.

Neither SENTENCE nor LIST allows you to insert an element into an already existing list. This is the job of FPUT and LPUT.

Each takes an object (word or list) as its first argument and a list as its second argument. It then inserts the object into the list either to become the first element of the new list (in the case of FPUT) or the last element of the new list (LPUT), and outputs the new list. Try these:

```
FPUT "THIS [IS A SENTENCE]
LPUT "THIS [IS A SENTENCE]
LPUT  [FD 50]  [[RT 90] [BK 30] [LT 60]]
```

FPUT and LPUT are important when you are accumulating information gradually and want to keep track of it on a list. This is the reason why LPUT was the proper primitive for storing new names of people that GREET met in the FRIENDLY program that you defined in the section called Some Friendly Introductions.

Because LPUT created its output by packing the new object (in that case, PERSON) into a previously existing list (in that case, KNOWN), its output can later be decomposed back to the original object and list by LAST and BUTLAST respectively.

This inverse relationship of LPUT to LAST and BUTLAST, and of FPUT to FIRST and BUTFIRST is what makes these two primitives so important. This relationship is best shown by an illustration and some experimenting.

The relationship can be summarized this way (type each statement below):

If WOL represents any Logo word or list, e.g.

```
MAKE "WOL [FD 50]
```

and OLD.LIST represents any Logo list, e.g.

```
MAKE "OLD.LIST [[RT 90].[BK 30] [LT 60]]
```

then define NEW.LIST this way:

```
MAKE "NEW.LIST FPUT :WOL :OLD.LIST
```

Now type

```
PR :WOL PR :OLD.LIST PR :NEW.LIST
```

and observe that the following two statements are true:

```
:WOL = FIRST :NEW.LIST
:OLD.LIST = BF :NEW.LIST
```

Similarly, if you

```
MAKE "D LPUT :WOL :OLD.LIST
```

then these statements are true:

```
:WOL = LAST :D
:OLD.LIST = BL :D
```

An Application of LPUT in Interactive Graphics: RUN

Look back at the procedure EASY that you defined in the early section called Interactive Graphics. Each time certain characters are pressed, a turtle command is executed.

The screen "remembers" the effect of each command, but the program has no way of knowing what command it executed last. It could not, for example, run through the same sequence of commands again to make another copy of the design on the screen.

Just as FRIENDLY was given a memory, you can add memory to the QUICKDRAW program. Each time a character is pressed, EASY will run the proper command, and also store that command on a list.

Using the simplest combination of the strategies in GREET and in EASY, one might rewrite each line of EASY to look something like this:

```
IF :CHTR = "F THEN FD 10 MAKE "HISTORY FPUT [FD 10]
        :HISTORY
IF :CHTR = "R THEN RT 15 MAKE "HISTORY FPUT [RT 15]
        :HISTORY
IF :CHTR = "L THEN LT 15 MAKE "HISTORY FPUT [LT 15]
        :HISTORY
etc.
```

But there is a way of reducing the amount of repetition. If there was a procedure (let us call it RUN.AND.RECORD) that could take the command as input and be responsible for both the running and

recording of the command, EASY could be written more economically and more understandably as:

```
IF :CHTR = "F RUN.AND.RECORD [FD 10]
IF::CHTR = "R RUN.AND.RECORD [RT 15]
IF :CHTR = "L RUN.AND.RECORD [LT 15]
etc.
```

If RUN.AND.RECORD calls its input MOVE, then the line that records the history of moves might look like this:

```
MAKE "HISTORY (LPUT :MOVE :HISTORY)
```

To run a list that contains a legal Logo command or expression, Logo provides the primitive RUN.

Thus, the procedure that runs and records each move might look like this:

```
TO RUN.AND.RECORD :MOVE
  RUN :MOVE
  MAKE "HISTORY ( LPUT :MOVE :HISTORY )
END
```

To summarize, RUN.AND.RECORD takes an input list containing a Logo command. It RUNs the input, and then tucks it neatly into a list named HISTORY.

Define this new procedure and test it out a few times. As was necessary in the FRIENDLY program, you must first create an empty HISTORY list for RUN.AND.RECORD to add its new moves to.

```
MAKE "HISTORY [ ]
```

Now type these commands. (Use <CTRL>P to repeat the line and the <DEL> key to change the last few characters. It will save you some typing!):

```
RUN.AND.RECORD [FD 30]
RUN.AND.RECORD [RT 120]
RUN.AND.RECORD [BK 10]
RUN.AND.RECORD [RT 24]
RUN.AND.RECORD [BK 5]
```

To print the history list, type

```
PR :HISTORY
```

and notice that it contains a record of the commands that generated the picture on the screen.

```
[FD 30] [RT 120] [BK 10] [RT 24] [BK 5]
```

Using the History List: Applying a Command (RUN) to Each Element of a List

Whole new possibilities are now opened up. Re-running each of these commands will copy the design onto the screen a second time.

Alternatively, you can achieve the effect of "undoing" the last command (BK 5) by erasing the screen, removing the [BK 5] from the history list and running what remains.

The INSTANT program on your Utilities Disk uses this strategy. Several of the procedures described in this section are similar to those

used in INSTANT. You may want to study that program. See the Graphics chapter for a description of its use.

Both of these functions require that you have a procedure capable of doing the same thing — in this case, RUNning — to each of the elements of a list.

Normally RUN takes a list and executes the command(s) in the list. Here, the list to be run is composed of sub-lists, each of which must be run individually.

The procedure will take the list as input:

```
TO RUN.ALL :COMMANDS
```

If the list is empty, then the job is done, so the procedure stops.

```
IF EMPTY? :COMMANDS STOP
```

If the list is not empty, then perform the required action to the first element of the list.

```
RUN FIRST :COMMANDS
```

And then, following the same logic, deal with the remainder of the list.

```
RUN.ALL BF :COMMANDS
```

Define the procedure RUN.ALL.

```
TO RUN.ALL :COMMANDS
 IF EMPTY? :COMMANDS STOP
 RUN FIRST :COMMANDS
 RUN.ALL BF :COMMANDS
END
```

RUN.ALL can be thought of as a model for a whole class of procedures. For instance, you have already seen MEMBER?, NTH, and COUNT. The structure of this kind of procedure is shown in the "ghost" procedure below:

```
TO X.ALL :LIST                          title with input
 IF EMPTY? :LIST STOP       condition for stopping
 Y FIRST :LIST      action to take with first element
 X.ALL BF :LIST          recursive call with BF input
END                                              end
```

Here is a procedure of similar structure which erases a list of procedures.

```
TO ERLIST :PROCS
 IF EMPTY? :PROCS STOP
 RUN LIST "ERASE FIRST :PROCS
 ERLIST BF :PROCS
END
```

Type these commands:

```
RUN.ALL :HISTORY
RUN.ALL :HISTORY
REPEAT 2 [RUN.ALL :HISTORY]
PR :HISTORY
```

The picture has changed, but the history list has not. Why? Because RUN.ALL did not record any of the commands it ran; it just ran them.

To "undo" a command, we clear the screen and run all but the last element of the history list. Of course, if the history list is already empty, we cannot undo any more and so should just stop.

Here is a procedure which does that:

```
TO UNDO
 IF EMPTY? :HISTORY STOP
 MAKE "HISTORY BL :HISTORY
 DRAW
 RUN.ALL :HISTORY
END
```

Clear the screen with DRAW and type RUN.ALL :HISTORY. Now type UNDO a few times to see its effect.

Projects with History Lists

31. Edit EASY to take advantage of RUN.AND.RECORD and UNDO. Some changes need to be made in addition to inserting the two new procedures.

Try out all of the features — the old as well as the new — in a variety of combinations to be certain they work together properly. In particular, make certain that UNDO does the right thing when pressed right after you have pressed the D key to erase the screen.

To start up the program with an empty history list, it might be convenient to define this startup procedure:

```
TO STARTUP
  MAKE "HISTORY []
  QUICKDRAW
END
```

32. Add right-curving circles and left-curving circles to QUICKDRAW.

Substituting One Word for Another in a Sentence: A Procedure with Two Recursive Calls

We will design a procedure that will work like this:

```
SUBST "DOGS "CATS [WE THINK DOGS ARE GREAT]
RESULT: [WE THINK CATS ARE GREAT]
SUBST "X PICK PEOPLE [WE LOVE X MORE THAN ANYBODY]
RESULT: [WE LOVE SANDY MORE THAN ANYBODY]
SUBST "ADV PICK ADVERBS [COLORLESS GREEN IDEAS
    SLEEP ADV]
RESULT: [COLORLESS GREEN IDEAS SLEEP FURIOUSLY]
```

It will serve as a building block for a variety of language activities, and a model for a procedure that can work Mad-Libs.

What is its design? It takes three inputs: a key word it is looking for, a word to replace that one with, and a sentence as a context in which to perform the replacement.

This version of SUBST will replace all occurrences of the key word with the replacement word. Described concretely, it can look through sentences like [WE THINK DOGS ARE GREAT] and wherever it finds DOGS, it substitutes CATS.

The logic is absolutely like the recursive model shown before.

Let's review the model:

```
title with inputs
condition for stopping
action to take with first element
recursive call with BF input
end
```

The title line and stop condition are straightforward. If there is nothing in the sentence CONTEXT, there is nothing to substitute, so the procedure outputs an (identical) empty sentence.

The remaining two lines introduce a new twist. The action to take with the first element is clear: if it is the key word :KEY that we are looking for

```
IF ( FIRST :CONTEXT ) = :KEY
```

the procedure must replace it with :NEW. Replacing the first element of a list means keeping the butfirst. SUBST must output a sentence composed of the new first element with the butfirst of the original CONTEXT. This, by itself, is

```
OP SE :NEW BF :CONTEXT
```

But the object is to catch every occurrence of KEY in CONTEXT. SUBST changed one occurrence at the beginning, but the code line we just wrote takes the butfirst of the CONTEXT without checking further.

Instead of BF :CONTEXT itself, what we really want is the result of a continued substitution of NEW for KEY in that BF :CONTEXT. So the action really is

```
OP SE :NEW SUBST :KEY :NEW BF :CONTEXT
```

and the logic of that line is

```
IF ( FIRST :CONTEXT ) = :KEY OP SE :NEW SUBST :KEY :NEW
    BF :CONTEXT
```

If there is no substitution to make, of course, SUBST will keep the first element, but it still must check further in the sentence for later occurrences of the key word. The action in this case is nearly identical to the previous action except that the first element of the list is not changed to NEW but kept as is:

```
OP SE FIRST :CONTEXT SUBST :KEY :NEW BF :CONTEXT
```

Here is the entire procedure:

```
TO SUBST :KEY :NEW :CONTEXT
 IF :CONTEXT = [] OP []
 IF ( FIRST :CONTEXT ) = :KEY OP SE :NEW SUBST :KEY
    :NEW BF :CONTEXT
 OP SE FIRST :CONTEXT SUBST :KEY :NEW BF :CONTEXT
END
```

And here are some examples of its use.

```
SUBST "VERB "LOVES [PAUL VERB CINDY]
SUBST "VERB PICK ACTIONS [THE TURTLE VERB DALE]
SUBST "NAME "CHRIS [NAME KISSED NAME]
SUBST "NAME PICK PEOPLE [NAME WON'T SPEAK TO
    NAME]
SUBST "ADV PICK [STEALTHILY CREATIVELY [WITH
        EXCEPTIONAL SPEED] HUNGRILY] [CATS CAN CLIMB
        TREES ADV BECAUSE OF THEIR SHARP CLAWS]
```

Although the procedure does everything it is advertised to do, it is not quite right for Mad-Libs. The problem is that in a command like PR SUBST "NAME PICK PEOPLE [NAME WON'T SPEAK TO NAME], both NAMEs are replaced by the same PICK from PEOPLE.

Why? Because the picking is done first. SUBST is presented with one name, selected at random by PICK, to use everywhere it finds the key word.

SUBST is useful as it is (because sometimes it is necessary to specify a particular replacement to make) but for Mad-Libs, it would be better to have a procedure that looked for a key word and each time it found one, selected at random from a list of potential substitutes.

Such a procedure would need inputs giving the key word and context as before, but instead of having a designated substitute, it should be given a list of alternates from which to pick each time the need arises.

```
TO MAD :KEY :ALT :CONTEXT
```

The stop rule would be the same.

```
IF :CONTEXT = [] OUTPUT []
```

And if there's no substitution to make, the action is the same.

```
OP SE FIRST :CONTEXT MAD :KEY :ALT BF :CONTEXT
```

Only when a KEY is found must MAD behave differently from SUBST. Compare the corresponding lines.

```
IF ( FIRST :CONTEXT ) = :KEY OP SE :NEW SUBST :KEY :NEW
    BF :CONTEXT
IF ( FIRST :CONTEXT ) = :KEY OP SE PICK :ALT MAD :KEY :ALT
    BF :CONTEXT
```

SUBST is given a fixed substitute as input, whereas MAD picks the alternate itself whenever it needs to. Otherwise, they are identical.

Here is the finished procedure:

```
TO MAD :KEY :ALT :CONTEXT
  IF :CONTEXT = [] OUTPUT []
  IF ( FIRST :CONTEXT ) = :KEY OP SE PICK :ALT MAD :KEY
     :ALT BF :CONTEXT
  OP SE FIRST :CONTEXT MAD :KEY :ALT BF :CONTEXT
END
```

And here are some examples of its use.

```
MAD "NAME PEOPLE [NAME KISSED NAME]
MAKE "ADVERBS [STEALTHILY CREATIVELY [WITH EXCEP-
   TIONAL SPEED] HUNGRILY]
```

```
MAD "ADV :ADVERBS [DOGS DO NOT CLIMB TREES ADV OR
  ADV]
MAD "V ACTIONS [PAT V CHRIS, BUT DALE V DANA.]
```

More can be done with MAD. Since MAD creates and outputs an object (rather than just printing its finished product), that object can be processed further. Try this:

```
MAD "NAME PEOPLE [NAME V NAME]
```

The object it produced is something like [SANDY V THE TURTLE]. If this object were made the input to MAD, the V could be replaced with some action. This can be done in one step.

```
MAD "V ACTIONS MAD "NAME PEOPLE [NAME V NAME]
```

The output from MAD "NAME PEOPLE [NAME V NAME] becomes the third input to MAD "V ACTIONS ____.

Try

```
MAD "ADV :ADVERBS MAD "X PEOPLE MAD "V ACTIONS [X
  V AND V X ADV AND ADV]
```

Projects with Mad-Libs

33. Create a MADLIB procedure that takes one input, a text, and looks for Verbs, Nouns, Proper Names, ADVerbs, and ADJectives to substitute. You might use [THE ADJ N V MY ADJ N PN ADV] as a test text.

34. Punctuation in a sentence will interfere with MAD the way it is now written. For example, MAD "V ACTIONS [PAT V CHRIS, BUT DALE V DANA.] will work, but MAD "PN PEOPLE [PN LOVES PN, BUT PN CAN'T STAND PN.] will not. (You may want to try it to see it fail.)

The substitution must be more sophisticated to handle punctuated sentences. It must look at each word in the sentence and perform tests to determine if it is a key word. Then, after choosing an alternative, the procedure must affix the proper punctuation to that new word.

Write a version of MAD that works correctly in both of the contexts shown above.

35. As MADLIB is now written, it finds substitutes for a fixed set of key words. A slightly more versatile program would take two inputs, the context (as always) and a list of key words to look for. Then it would systematically look through the context for instances of each of the key words and make the proper substitutions. Write a procedure that will do this.

Understanding Language: Searching for Key Words and Matching Sentences to Templates. ALLOF, ANYOF

FRIENDLY, when we last left it, expected a nice, tame answer to its question, "WHAT'S YOUR NAME?" It would respond unintelligently if you typed MY NAME IS PAUL or NONE OF YOUR BUSINESS when it asked. Here is a scenario that looks more intelligent, as if FRIENDLY really understands language.

```
FRIENDLY
WHAT'S YOUR NAME?
MY NAME IS PAUL.
HI, PAUL! IT'S NICE TO MEET YOU.

FRIENDLY
WHO ARE YOU?
NONE OF YOUR BUSINESS
YOU SEEM TO BE IN A BAD MOOD. BYE.

FRIENDLY
WHAT'S YOUR NAME?
WHAT'S IT TO YOU?
I WAS JUST CURIOUS.

FRIENDLY
MY NAME IS LOGO. WHAT'S YOURS?
PLEASE CALL ME PAUL.
GOOD TO SEE YOU AGAIN, PAUL.

FRIENDLY
HI, WHAT'S YOUR NAME?
PAUL
AH, YOU'RE BACK. HI, PAUL.
```

FRIENDLY is exhibiting a number of behaviors we regard as intelligent. It is not confused by punctuation. Also, its phrasing is flexible. But, most important, it has always responded appropriately.

How can we design it so that it will reliably recognize the name in an arbitrary phrase? We might start by trying to figure out how people do that.

Do we listen to all the words in the sentence and look up each one on a list of possible names? Unlikely. If a Martian said to you, "Hi, my name is Xqpsnpfltk," you might not be able to repeat the name, but you'd know you were being told one.

You'd know because you understood the rest of the sentence and realized that whatever that sound was that came at the end, that had to be this creature's name.

All is not hopeless. Although we cannot expect to write a procedure that is capable of understanding all of English, we can analyze the likely language that this particular conversation will contain.

If the procedure encounters something we have anticipated, it can give a specific appropriate answer. Otherwise, it will have to give a neutral answer.

Here's how it might work. First we list some possible phrases it may see. One limitation we will impose is that people always respond only with their first name, and not with first and last, or title and last, etc. (That complication comes later.)

Cooperative responses might include:

<name>
My name is <name>
People call me <name>
Please call me <name>
<name> is my name
I am <name>

Uncooperative responses should include:

None of your business!
I won't tell you.
I don't want to tell
I'm not telling you.
What's it to you?
Go away

Let's work with the cooperative responses first. Suppose we create a series of templates based on likely response patterns. If we had a procedure that could match what the person types to each of the templates, and, where it found a match, record what word corresponded to the "wild card" <name>, that would be a big help.

For example, suppose we had a procedure MATCH? which would tell if a sentence matched a template. For example, the actual sentence

```
MATCH? [MY NAME IS PAUL]
```

used with the template

```
[MY NAME IS @NAME]
```

with the wild card identified by the at-sign, would give the result TRUE.

Suppose, furthermore, that if the sentence and template do match, then the matching word in the sentence (in this case, PAUL) and the name of the wild card it corresponded to (in this case, there is only one, @NAME) are saved in a special variable named @@MATCHES. Then, after this match,

@@MATCHES would have the value [[@NAME PAUL]].

Let's also suppose we have a way of looking for a wild card in this list and outputting the word associated with it; thus LOOKUP "@NAME would output PAUL. If we had such procedures, then we could write a language understander that looked like this.

```
TO OUTPUT.NAME :SENT
 IF MATCH? :SENT [MY NAME IS @NAME] OP LOOKUP "@NAME
    :@@MATCHES
 IF MATCH? :SENT [@NAME IS MY NAME] OP LOOKUP "@NAME
    :@@MATCHES
 IF MATCH? :SENT [I AM @NAME] OP LOOKUP "@NAME
 :@@MATCHES
 IF MATCH? :SENT [@JUNK CALL ME @NAME] OP LOOKUP
    "@NAME :@@MATCHES
 IF 1 = COUNT :SENT OP FIRST :SENT
 OP [I WAS JUST CURIOUS]
END
```

The first three lines explain themselves. If the sentence typed by the person to FRIENDLY is of any of those forms, a match will occur, and LOOKUP will find the name.

The fourth line has two wild cards in it. It takes care of both PLEASE CALL ME PAUL and PEOPLE CALL ME PAUL.

The fifth line assumes that if the person answers with only a single word, that word is probably the name. And the sixth line is a "punt." If no other strategy worked, this answers "neutrally" with a nothing answer.

There are some problems with this procedure as it was written. The most striking is that it can supply either the right answer (a name) which must then be tucked into some reply by GREET (depending, for example, on whether GREET has met the person before or not) or an entire reply which should not be further altered.

GREET, of course, can tell the two situations apart, as the name is a word, and the full reply is a list.

Second, we have not dealt at all with the "uncooperative responses." More on those later. Meanwhile, how do MATCH? and LOOKUP work?

MATCH? will need two inputs — the sentence in question, and the template to check it against.

```
TO MATCH? :SENTENCE :TEMPLATE
```

It will need to make sure that the variable @@MATCHES is cleaned out before checking to see if the sentence matches the template.

```
MAKE @@MATCHES []
```

Finally, it performs the check.

```
OP CHECK :SENTENCE :TEMPLATE
```

So the procedure looks like this:

```
TO MATCH? :SENTENCE :TEMPLATE
  MAKE "@@MATCHES []
  OP CHECK :SENTENCE :TEMPLATE
END
```

But, we've put off the major part of the work! How does CHECK check?! It, too, must take both the sentence and template as inputs.

```
TO CHECK :S :T
```

If these two do match, it should output TRUE. If they don't, it should output FALSE. (This is not, of course, all it does. It must also identify what element of the sentence corresponded to the "wild card" in the template, but we will worry about that later.) A trivial case of matching is when both the sentence and the template are empty.

```
IF ALLOF :S = [] :T = [] OP "TRUE
```

If they are not both empty, but one of them is empty, then they surely do not match.

```
IF ANYOF :S = [] :T = [] OP "FALSE
```

If the first element of the sentence and the first element of the template are the same, then a match is possible, but not definite. In this case, the answer is to be found in checking the remaining elements of the sentence and the template for a match.

```
IF (FIRST :S) = FIRST :T OP CHECK BF :S BF :T
```

Likewise, if the first element of the template is a wild card, then a match is possible, but not definite. Again, the answer is to be found in checking the remaining elements of the sentence and the template for a match.

In this case, however, the procedure must do one additional thing. It must record what the first element of the sentence was when it encountered the wild card as the first element of the template.

```
IF WILD? FIRST :T (RECORD FIRST :T FIRST :S) OP CHECK BF
   :S BF :T
```

Notice that both WILD? and RECORD are just tossed in there as if we already knew how they should work. We don't, and Logo has no such primitives to help us with, but we can design those procedures later.

At present, all we are trying to do is handle the top level logic of CHECK. Surely, if WILD? and RECORD existed, this line would be what we want.

Finally, if the first of T is neither wild nor matches the first of S, then there is no match, so we output FALSE.

This is how the procedure looks so far.

```
TO CHECK :S :T
 IF ALLOF :S = [] :T = [] OP "TRUE
 IF ANYOF :S = [] :T = [] OP "FALSE
 IF (FIRST :S) = FIRST :T OP CHECK BF :S BF :T
 IF WILD? FIRST :T (RECORD FIRST :T FIRST :S) OP CHECK BF
    :S BF :T
 OP "FALSE
END
```

What WILD? does depends on how we choose to indicate a wild card. Since we have decided that wild cards begin with the at-sign character, WILD? need only check for that character as the first character of its input.

```
TO WILD? :WORD
 OP "@ = FIRST :WORD
END
```

RECORD creates a list of the key and the matched word, and tucks that list into @@MATCHES to be retrieved when needed by LOOKUP.

```
TO RECORD :KEY :MATCHEDWORD
 MAKE "@@MATCHES LPUT LIST :KEY :MATCHEDWORD
 :@@MATCHES
END
```

And LOOKUP will look systematically through each element of @@MATCHES until it finds one whose first element is the key word. It will then output the second element. Notice how similar its structure is to the model recursive procedures you have seen before.

```
TO LOOKUP :KEY :LIST
 IF :LIST = [] OP "
 IF :KEY = FIRST FIRST :LIST OP LAST FIRST :LIST
 OP LOOKUP :KEY BF :LIST
END
```

Now try running OUTPUT.NAME a few times.

```
OUTPUT.NAME [MY NAME IS ASHER]
OUTPUT.NAME [PLEASE CALL ME ISHMAEL]
OUTPUT.NAME [WHAT'S IT TO YOU?]
OUTPUT.NAME [PAUL]
```

Projects with Language Understanding

36. Add OUTPUT.NAME to the FRIENDLY program. FRIENDLY must still be capable of responding differently to old people and new people, and must have the added ability to pull names out of the contexts in which they are typed. Do not yet worry about other details (e.g. punctuation) yet.

37. To add a bit more sensitivity to the uncooperative responses, you might design a procedure that looks for "negative words" in the sentence, words like WON'T, NONE, DON'T, NOT, and the like, and outputs a "neutral" response to a negative.

Such a response might be YOU SEEM TO BE IN A BAD MOOD, or SORRY I ASKED. Add that to OUTPUT.NAME in such a way that no other changes need to be made to GREET or FRIENDLY.

38. Wherever fixed phrases are now used, teach the program to vary them using PICK and a phrase list. If it is necessary to embed the name in a phrase, SUBST can do the work.

39. Finally, fix the program not to get stumped by punctuation.

40. As CHECK is currently written, [MY NAME IS @NAME] would match [MY NAME IS ASHER] but would not match [MY NAME IS ASHER LEV] because only one word can match a wild card.

Likewise, [@JUNK CALL ME @NAME] would not match [CALL ME ISHMAEL], because some word must be present to match @JUNK.

A better CHECK program would recognize two kinds of wild cards, one that matches to exactly one word in the sentence (the situation we already have), and another that matches to any number of words in the sentence, including 0.

The new wild card would have to be symbolized differently, perhaps by a number-sign prefix. So CHECK would be able to tell that both CALL ME ISHMAEL and MY CLOSE FRIENDS CALL ME SIR OLIVER match the template [#JUNK CALL ME #NAME], but that [MY NAME IS HARRIET BEECHER STOWE] fits another template.

MUSIC

MUSIC

The music chapter of this tutorial assumes that you are familiar with your Apple keyboard and some Logo primitives (commands Logo already knows). For explanations of commands and concepts not explained in detail here, see the Graphics chapter. In addition, the Technical Manual lists all Logo primitives and their uses.

Some background: a Logo procedure is a series of instructions to the computer stored for recurrent use. A procedure can be used in other procedures just as if it were a Logo primitive.

Procedures are stored in files on disks. The SAVE command stores the entire contents of the workspace to the disk as a file with the name which you give it. See the Saving Procedures section in the Graphics chapter. Care should be taken to SAVE work before turning the computer off, as this clears the workspace.

Preparation: READ

The Utilities disk contains the procedures required to make music in Logo, as well as the demonstration procedures we shall use. Start Logo as described in the Beginning in Logo chapter. Then insert your copy of the Utilities disk. Type

READ "MUSIC <RETURN> (only one quote)

(Logo does not hear what you type until you press the <RETURN> key.)

Wait for the light on the disk drive to go off and the question mark prompt to appear on the screen.

There are three music files on the Utilities disk. You have just read one file, MUSIC, into the workspace. MUSIC automatically reads in another of the music files called MUSIC.BIN, which contains the machine-language routine which does the actual work of making the Apple produce a sound. The third file is a demonstration file called TWINKLE, which will be used later.

To start, we will experiment with pitch and duration, concepts with which most people are familiar.

Duration

Duration is usually thought of as how long a note is held. (You could also think of it as the time from the beginning of one note to the beginning of the next.) To start, let's use a procedure named TONE which plays a note for a specified duration. Type

```
TONE 40
TONE 80
TONE 80 TONE 80
TONE 80 TONE 40 TONE 80
```

Typing TONE over and over gets tiresome. To save yourself work, try using the REPEAT command. For instance:

```
REPEAT 10 [TONE 40]
REPEAT 10 [TONE 20]
REPEAT 10 [TONE 20 TONE 40]
```

There is an even better way: the TONES procedure. TONES takes a list of durations to play. (A list for Logo is any list of items enclosed in square brackets.) Type

```
TONES [40 40 40 40]
TONES [80 80 80 80]
TONES [40 80 40 80 40 80]
```

You have probably noticed that the numbers for durations are related in a special way. For instance, a duration of 80 is twice as long as one of 40 and similarly, 60 is twice as long as a duration of 30. Try typing

```
TONES [80 80 80 80 40 40 40 40]
TONES [30 30 30 30 60 60]
TONES [40 40 20 20 40]
TONES [80 80 40 40 80]
```

Notice that the last two examples sound the same except that the last one goes slower. Another way of saying this is that the relative durations of the last two examples are the same.

If you know the symbols used in music notation, you will see that they relate to each other in a manner similar to that of the numbers we have been using. If 40 were used as a whole note, then 20 would be a half note, 10 a quarter note and 5 an eighth note.

Of course, we could have used another number instead of 40 as our whole note. If we made 60 a whole note, then 30 would be a half note, and 15 a quarter note. Using 40 as the whole note instead of 60 will speed up the tempo.

You don't have to change the durations to be able to change the tempo (the speed at which the piece is played). The procedure TEMPO allows you to do this. (The default value for TEMPO is 100.) Speeding up or slowing down the tempo will make the durations sound shorter or longer, but each duration will still have the same relation to the other durations as it did before. Try

```
TONES [80 80 40 40 80]
TEMPO 50
TONES [80 80 40 40 80]
TEMPO 100
TONES [80 80 40 40 80]
```

You can use TONES to create any rhythm you want. For example, try

```
TONES [80 40 40 80 40 40 80]
```

You can use <CTRL>P to bring back copies of the previous line so that it will play several times in a row. However, let's use REPEAT instead.

```
REPEAT 3 [TONES [80 40 40 80 40 40 80]]
REPEAT 3 [TONES [60 15 15 60 15 15 60]]
```

Notice how the beats seem to regroup when you REPEAT these patterns several times instead of playing them just once.

You can vary the duration within a wide range. Numbers higher than 1000 can be used but a duration of 1000 is very long. You can also use decimal numbers as well as whole numbers for durations.

Pitch

Now let's try varying the pitch while keeping the durations constant. To do this we use a different procedure named PLAY, which takes as input a list of pitches and a list of durations. The first duration is paired with the first pitch, the second duration with the second pitch and so on. Type

```
PLAY [1 2 3 4 5 6][40 40 40 40 40 40 40]
```

(Notice that there is an extra duration in the second list. Logo ignores extra durations in input lists, but it will give an error if there are more pitches than durations.)

Each pitch is a half step higher than the one before. This is called the chromatic scale. An octave is divided into twelve pitches, each a half step apart. The numbers below correspond to the more common musical notation as follows.

1	2	3	4	5	6	7	8	9	10	11	12	13
C	C#	D	D#	E	F	F#	G	G#	A	A#	B	C

You should notice that the letters that are not followed by a # sign (read sharp sign in music notation) correspond to the white keys on the piano. The numbers that are paired with these letters (1, 3, 5, 6, 8, 10, 12, and 13) make the C major scale. You can make a major scale starting with any number using the same relations among the numbers as in the C major scale.

C Major Scale	1	3	5	6	8	10	12	13
D Major Scale	3	5	7	8	10	12	14	15

An interesting project for more advanced users is to make a procedure that will generate a major scale starting on any pitch. The major scale is one of the diatonic scales. Try typing

```
PLAY [1 3 5 6 8 10 12 13][30 30 30 30 30 30 30 30]
PLAY [3 5 7 8 10 12 14 15][30 30 30 30 30 30 30 30]
```

Notes are numbered from 1 to 24. However, adding a plus sign (+) to a number will make the note one octave higher. Similarly, adding a minus sign makes the note an octave lower.

For instance, 1+ is an octave higher than 1. (Do you see that 1+ is the same as 13?)

Try your own combinations of pitches and durations with PLAY. The pitches can only be whole numbers, but you can use any number, even a decimal or fraction, for durations.

There is also a procedure named SING which takes only a list of pitches and plays each with a constant duration. If you are experimenting with just pitches, this procedure will save you a lot of typing. The two PLAY commands above could easily have been done instead as

```
SING [1 3 5 6 8 10 12 13]
SING [3 5 7 8 10 12 14 15]
```

Rests are another feature which you can use with PLAY or SING. Type in the letter R in place of one of the

pitches, and no sound will be played for the duration corresponding to that pitch. Type

```
PLAY [1+ 1+ R 1+ R 1+] [40 40 40 40 40 40]
SING [1+ 1+ R 1+ R 1+]
```

Procedures

Typing everything out each time can become tiresome, even if you do make use of <CTRL>P and the REPEAT command. Writing procedures will allow you to keep a record of the tunes you create.

For instance, to make a comparison of the chromatic and major scales easier, you might want to create the two following procedures so you can play them again easily in any order you want.

```
TO C
PLAY [1 2 3 4 5 6 7 8 9 10 11 12 13]
    [30 30 30 30 30 30 30 30 30 30 30 30 30]
END

TO M
PLAY [1 3 5 6 8 10 12 13]
    [30 30 30 30 30 30 30 30]
END
```

Here is a neat way of turning a PLAY statement into a procedure.

a. Find a tune you like using PLAY.
b. Press <CTRL>P to print it out again, but do not press <RETURN>.

c. Use <CTRL>A to move the cursor to the beginning of the line.
d. Type the name of your procedure, e.g. TO TUNE1, followed by a space. The rest of the line will move to the right as you insert new words.
e. Press <RETURN>. You will be in EDIT mode with everything you typed on the first line (the title line).
f. Move the cursor to the space between the title and the word PLAY.
g. Press <RETURN>. The part of the line to the right of the cursor will move down to the next line.
h. Press <CTRL>C to define your procedure.
i. Type the procedure name (e.g. TUNE1) to play it.

Following is an example of a procedure that will give you quick feedback, which is useful if you are trying to pick out a tune.

```
TO QUICK
PLAY (LIST RC) [15]
QUICK
END
```

Type QUICK to start the procedure and <CTRL>G when you want to stop it. Now typing any single digit number (except 0) will play a note.

It is useful to make procedures that will play phrases or pieces of a song. We will call these tune blocks. Then you can link these tune block procedures together to make the whole song, like putting together the blocks in a jigsaw puzzle. As an example, type

```
TO BELL1
PLAY [5+ 1+ 3+ 8][80 80 80 80]
END
```

Now type BELL1 if you haven't already. The tune is part of Westminster Chimes. So far we only have the first part of it and the rhythm doesn't seem quite right. Try increasing the duration of the last note to see if that sounds better. Instead of trying to add the entire tune into the procedure BELL1, you can break it up into blocks and write a superprocedure which uses them. This also allows you to use any of the blocks over again. The superprocedure could look like this:

```
TO BELL
BELL1
BELL2
BELL3
BELL2
END
```

So far we have BELL1. The following procedure makes the third block in the tune.

```
TO BELL3
PLAY [5+ 3+ 1+ 8] [80 80 80 160]
END
```

Notice that the only change is that two of the pitches are reversed, but even a small change makes an important difference. We leave BELL2 to you to create. (Hint: Try rearranging these same pitches in another way, keeping the durations in the same order.)

For a similar example, read in the file TWINKLE by typing

```
READ "TWINKLE
```

You have probably already guessed what tune this file will play. If you haven't, or even if you have, type STAR. Type PO STAR to see what the superprocedure looks like. Each of the subprocedures for STAR is a tune block.

```
TO STAR
STAR1
STAR2
STAR3
STAR3
STAR1
STAR2
END
```

The STAR superprocedure is designed in the same way as the BELL superprocedure. If you print out STAR1, STAR2, and STAR3, you can see that each uses the procedure RHYTHM1 to specify its duration list. Notice what happens if you change the rhythm

```
from [40 40 40 40 40 40 120]
to   [60 20 60 20 60 20 120]
```

You can still recognize the original tune but this makes a varied version of it. It works because each pair of 40's is changed to 60 and 20, and both 40+40 and 60+20 add up to 80. Notice that it sounds like a waltz now instead of a march. Try reversing the 60 and the 20 so it is 20 60 20 60 20 60 120. It sounds strange, right, almost like a new tune? This is because the durations make the pitches group together in a different way.

Try playing STAR1, 2 and 3 in various orders to see if you can make a new tune. Don't forget the possibility of repeating the same block twice. Here is one example of a different tune.

```
STAR3 STAR2 STAR1 STAR1 STAR3 STAR2
```

You already know what the durations are for STAR1. Now, see if you can figure out what the pitches are without looking. The only pitches you will need are 1, 3, 5, 6, 8, and 10, pitches in the C Major Scale. To experiment, use the QUICK procedure shown earlier.

Try creating tune blocks for other tunes that you know. Instead of numbering the blocks in the proper order, pick a random order and see if your friends can figure out how the blocks fit together. Most familiar tunes use only the pitches of a major scale.

Analyses of the Utilities Disk Music Procedures: STOP, FIRST, BUTFIRST (BF), THING, WORD, Top Level

PLAY: a recursive procedure to play a list of notes with a list of durations.

```
TO PLAY :PITCHES :DURS
IF EMPTY? :PITCHES STOP
PLAY.NOTE ( FIRST :PITCHES ) ( FIRST :DURS )
PLAY (BF :PITCHES ) ( BF :DURS )
END
```

Line 1: title, including the local variables :PITCHES and :DURS, which represent values input when the procedure is run.

Line 2: IF-THEN statement without the optional THEN. Line 2 says IF it is true that there are no more pitches to be played (i.e. the list :PITCHES is empty, THEN STOP running this procedure and return control to whatever called it, which might be another procedure or the user (also called "top level").

Line 3: Run the procedure PLAY.NOTE, using for inputs the first elements of the lists :PITCHES and :DURS. The local variables in the title line of PLAY.NOTE, :PERIOD and :DURATION, are given the values FIRST :PITCHES and FIRST :DURS, respectively.

Line 4: Run PLAY again, using the rest of the list :PITCHES and the rest of the list :DURS as the two inputs.

BF is short for BUTFIRST. BF :PITCHES is the list :PITCHES without its first element. USing BF recursively, as it is used here, enables one to work through a list element by element. The procedure will stop in Line 2 when the list is exhausted.

Use of the list operators FIRST and BUTFIRST is explained in the Words and Lists chapter.

TONE, TONES, SING: All these procedures are special versions of PLAY. Note that TONE and SING use the primitive SENTENCE (SE) to put information into a list before passing it to PLAY, which requires lists for its inputs.

For a full discusion of SENTENCE, see the Words and Lists chapter.

PLAY.NOTE: a procedure to play one note.

```
TO PLAY.NOTE :PERIOD :DURATION
MAKE "PERIOD THING WORD "# :PERIOD
.CALL.2  :TONE  :PERIOD  :DURATION*:BASE.PERIOD
    /:PERIOD
END
```

Line 1: The title, including the local variables :PERIOD and :DURATION.

Line 2: Line 2 pastes a # onto the front end of the :PERIOD brought into the procedure. The Logo primitive WORD makes one word out of # and whatever came in as :PERIOD; for instance, # and 5 make #5.

The THING of a variable is the value associated with that name. THING "PERIOD is the same as :PERIOD. THING is used when there is no actual variable name to put the dots on.

MAKE gives this value to the global variable :PERIOD.

Line 3: Runs the procedure .CALL.2 using the following for inputs:
For :ADDR—the value of the global variable :TONE (defined by SETUP)
For :INPUT1—the value of the local variable :PERIOD
For :INPUT2—a value obtained by the calculation shown

Harmony: The Terrapin Music System

The Terrapin Music System, available separately, gives the user the ability to create 6-part harmony over a six-octave range, as well as some rhythm sounds. The Music System uses the techniques described in this tutorial, plus primitives and procedures for putting the voices together.

APPENDIX

APPENDIX A

ERROR MESSAGES

Error messages are Logo's way of trying to help the user find errors, those things which Logo does not understand. They may be misspellings or wrong usage.

The list of error messages, as given here, is divided. In both parts, capital letters indicate the unchanging part that Logo types to you; what is in the parentheses will vary depending on the circumstances. Both parts of the list are alphabetical according to the first unchanging word.

The first part of the list includes those messages which will start with different words at different times; here you must look for that part of the message after the variable portion.

The second part includes the messages that always start out the same way.

PART I

(word) CAN BE USED ONLY INSIDE PROCEDURES

Example:

```
PR:X
LABELS CAN BE USED ONLY INSIDE PROCEDURES
```

You meant to type PR :X. Logo sees PR: which is the form of a label (used with GO). It does not infer the missing space between PR and :X.

(command) CANNOT BE USED INSIDE THE EDITOR

This occurs only when (in EDIT mode) you type text which, when you leave the editor and it is executed, will interfere with the rest of the edit buffer text. Very rare bird indeed.

(procedure) DIDN'T OUTPUT

Example:

```
FORWARD SQUARE 5
SQUARE DIDN'T OUTPUT

SQUARE FD 100
FD DIDN'T OUTPUT
```

This occurs when Logo cannot find the input for something that requires an input, either a procedure or a primitive. (It looks at the next thing on the line and complains that it didn't get anything from that thing to use as an input. To produce something that could be used as an input, that thing would have to output it.)

What it usually means is that you forgot to type the input Logo was looking for.

(primitive) DOESN'T LIKE (data) AS INPUT

Example:

```
PRINT 5 * "SIDE
*DOESN'T LIKE SIDE AS INPUT
```

This occurs when you try to do an operation on the wrong type of data. Here Logo is trying to multiply a name (specified by ") instead of a value (specified by :).

(primitive) DOESN'T LIKE (data) AS INPUT.
IT EXPECTS TRUE OR FALSE

Example:

```
IF 2 THEN PRINT 5
IF DOESN'T LIKE 2 AS INPUT. IT EXPECTS TRUE OR FALSE
```

The primitives IF, NOT, ALLOF, and ANYOF expect only expressions which will evaluate to TRUE or FALSE, such as :X = 3 (which is either true or false). You probably neglected to type the rest of the test.

(message) , IN LINE
(line)
AT LEVEL (level) OF (procedure name)

Example:

```
THERE IS NO PROCEDURE NAMED FD100, IN LINE
FD100
AT LEVEL 1 OF SQUARE
```

The (message) here is another error message, with this larger message pinpointing the location of the error, by printing the line, level, and procedure in which it occurred.

(name) IS A LOGO PRIMITIVE

Example:

```
FIRST IS A LOGO PRIMITIVE
```

Logo reserves the words which are Logo primitives and does not allow them to be used as procedure names. Choose another name for your procedure.

(procedure) NEEDS MORE INPUTS
(primitive) NEEDS MORE INPUTS

Examples:

```
SQUARE NEEDS MORE INPUTS
FD NEEDS MORE INPUTS
```

SQUARE required more inputs than were used; FD was used without an input. With a procedure, this can happen when the second input is negative and is used without parentheses. The parentheses are necessary to distinguish a second input from a first input obtained by subtraction.

(arithmetic-operator) NEEDS SOMETHING BEFORE IT

Example:

```
PRINT / 8
/ NEEDS SOMETHING BEFORE IT
```

The number to be divided by 8 is omitted.

(primitive) SHOULD BE USED ONLY INSIDE A PROCEDURE

Example:

```
OUTPUT  SHOULD BE USED ONLY INSIDE A PROCEDURE
```

OUTPUT, STOP, and GO cannot be used in immediate mode (top level). They have meaning only in a procedure.

PART II

CAN'T DIVIDE BY ZERO

Example:

```
PRINT :X / :Y
CAN'T DIVIDE BY ZERO
```

:Y is (no doubt inadvertently) zero. This message occurs with QUOTIENT, REMAINDER, and /. Get around this by testing :Y to see if it is zero before the division.

DISK ERROR

Example:

```
CATALOG
[ ]- -DISK ERROR
```

The Logo Language Disk files cannot be listed with CATALOG. You will also get this message when you try to access a disk with no disk in the disk drive, or try to SAVE to a protected disk.

END SHOULD BE USED ONLY IN THE EDITOR

Example:

```
PRINT 5 END
END SHOULD BE USED ONLY IN THE EDITOR
```

You have done one of these things:

1. tried to use END in IMMEDIATE mode
2. put END on a line with something else in a procedure
3. put it in the list used by the Logo primitive DEFINE.

ELSE IS OUT OF PLACE

Example:

```
PRINT 5 ELSE PRINT :C
ELSE IS OUT OF PLACE
```

ELSE has no meaning in this context. It must be used in an IF ... THEN ... ELSE statement.

FILE NOT FOUND

Example:

```
READ "NUSIC
FILE NOT FOUND
```

NUSIC is not a file on the disk in the disk drive. (MUSIC might be.) Check your spelling with this one before despairing. Type CATALOG to see what IS on the disk.

LINE GIVEN TO DEFINE TOO LONG
LINE GIVEN TO REPEAT TOO LONG
LINE GIVEN TO RUN TOO LONG

You have exceeded the maximum length of a line used by DEFINE, REPEAT, or RUN, which is 256 characters.

MISSING INPUTS INSIDE ()'S

Example:

```
(FORWARD)
MISSING INPUTS INSIDE ()'S
```

The procedure or primitive in the () was used with too few inputs.

NO STORAGE LEFT!

You have used up all the storage. The exclamation mark means this is very unusual. Erase some unnecessary procedures. If this doesn't help, SAVE the workspace and type GOODBYE.

NUMBER TOO LARGE OR TOO SMALL

An arithmetic operation has resulted in a number too large or too small for Logo, i.e. greater than 10 ** (38) or less than 10 ** (−38). Use different numbers.

PROCEDURE NESTING TOO DEEP

You have exceeded the limit for nesting procedures (which is over 200). This will be rare. Send a copy of your procedure to Terrapin, Inc. for its museum of the unusual.

RESULT: (data)

Example:

```
12 * 10
RESULT: 120
```

Besides giving you a quick way to calculate, Logo is also telling you that you have not specified what is to be done with the results of the computation. This is important to note if you are intending to use the line in a procedure.

THE : IS OUT OF PLACE AT (something)

Example:

```
PRINT X:
THE : IS OUT OF PLACE AT X
```

The : has no meaning in this position. Logo realizes that PRINT expects an input, and sees the : which, in the right place, denotes a variable. You probably meant :X.

THE DISK IS FULL

Example:

```
SAVE "NEWMUSIC
THE DISK IS FULL
```

When the disk is full and Logo will not save your workspace, you have several choices.

1. You can type CATALOG, locate a file you no longer need, and erase it with ERASEFILE;

2. You can use another disk which is not full;
3. You can trim the amount you are saving by erasing procedures from your workspace.

THE DISK IS WRITE PROTECTED

You tried to write on a write-protected disk. This might mean you forgot to remove the Language Disk.

THE FILE IS LOCKED

Example:

```
ERASEFILE "MUSIC
THE FILE IS LOCKED
```

Locking a file is a way to protect it from inadvertent erasing. However, do not lock a file you will be changing; you can READ from locked files, but you cannot SAVE to them.

The file cannot be erased while it is locked. To lock or unlock a file on a disk, use FID on the Utilities Disk.

Type CATALOG to list the files on the disk. Files with * before them are locked.

THEN IS OUT OF PLACE

Example:

```
PRINT 5 THEN PRINT 6
THEN IS OUT OF PLACE
```

THEN has no meaning in this context. THEN must be used in an IF ... THEN statement.

THERE IS NO LABEL (whatever you used)

Example:

```
THERE IS NO LABEL QUAD
```

You have used GO to go to a label that is not specified in the procedure. You can avoid this by not using GO. To fix it, add the missing label to your procedure.

THERE IS NO NAME (whatever you used)

Example:

```
PRINT :X
THERE IS NO NAME X
```

X has not been defined, or is used only in a procedure and is local to it. This will also occur if you forget to list the variables in the title line of a procedure.

THERE IS NO PROCEDURE NAMED (whatever you typed)

Example:

```
THERE IS NO PROCEDURE NAMED FD100
```

When Logo does not recognize a primitive, it looks for a procedure name. Mis-typing accounts for most instances of this message; forgetting to read in the file is another possibility.

THERE'S NOTHING TO SAVE

Example:

```
SAVE "MYSTUFF
THERE'S NOTHING TO SAVE
```

There are no procedures or global variables in the workspace to save. Logo would rather tell you now than have you be disappointed when you read the (empty) file back in from the disk.

TOO MANY PROCEDURE INPUTS

You have exceeded the limit on procedure inputs (which is over 200). This will be exceedingly rare. Send a copy of the procedure which generated this message to Terrapin, Inc. for its museum.

TOO MUCH INSIDE PARENTHESES

Logo uses this when it cannot figure out some parenthesized expression. Interior parentheses may be incorrectly placed.

TURTLE OUT OF BOUNDS

Example:

```
FD 200
TURTLE OUT OF BOUNDS
```

In NOWRAP mode, the turtle would go off the screen if it moved, so it doesn't move.

UNRECOGNIZED DOS COMMAND

Example:

```
DOS [TICKLE]
[TICKLE]—UNRECOGNIZED DOS COMMAND
```

Either the Apple does not like the file name specified in a READ or SAVE command, or an invalid command was used with the Logo DOS primitive.

YOU DON'T SAY WHAT TO DO WITH (data)

Example:

```
YOU DON'T SAY WHAT TO DO WITH 25, IN LINE
:SIDE * :SIDE
AT LEVEL 1 OF SQUARE
```

The line is missing a command such as OUTPUT, PRINT, FORWARD, etc. This corresponds to RESULT: in immediate mode. Add the missing instruction (in the example, perhaps PRINT) to the line.

THE TERRAPIN LOGO UTILITIES DISK

Before you begin, make a copy of your Utilities Disk because it is possible to damage it or erase it accidentally. Put the original away in a safe place. To copy disks, use the COPYA program on the DOS System Master Disk that came with your Apple.

All procedures in the files on the Utilities Disk may be considered to be models, to be analyzed and their ideas and constructions used. Note particularly the brevity of Logo procedures, the constant use of subprocedures, and the use of procedure names which describe the procedure explicitly.

In addition to serving as models, the procedures in the files on the Utilities Disk fill a variety of roles.

To Use the Utilities Disk Files

1. Start Logo using the Terrapin Language Disk, then remove the Language Disk from the disk drive and put it away.

2. Insert your backup copy of the Utilities Disk into the disk drive.

3. To list the files on the disk, type CATALOG.

4. To read a file from the disk, after the ? prompt type

```
READ    "(file name without .LOGO extension)
```

Example:

```
? READ "TEACH                    (only one quote, please)
```

Logo will read the file, confirming the presence of each procedure as it reads it in by printing its name and the word DEFINED. Example:

```
? READ "TEACH
TEACH1 DEFINED
TEACH DEFINED
?
```

5. To use the file, type the name of a procedure, as described below.

Summary of Utilities Disk Files

Music System Files:

MUSIC.LOGO	procedures used and described in the Music chapter.
MUSIC.BIN	machine language program used in running Logo music.
MUSIC.SRC	assembler language and Logo procedure MCODES.
TWINKLE	procedures to play "Twinkle, Twinkle, Little Star."
	The music system is an example of Logo/assembler language interfacing, explained in Chapter 6 of the Technical Manual.

Aids to Using Logo:

INSTANT	System of single letter Logo commands which makes Logo graphics available to non-readers, among others. INSTANT and its use are described in the Graphics chapter and Chapter 4 of the Technical Manual.
TEACH	System of writing Logo procedures without using the editor. The TEACH system and its use are described in this chapter.

Utilities:

ARCS	Collection of procedures for drawing arcs with variable radii. Another procedure for drawing an arc is developed in the Procedures section of this tutorial. The ARCS file is described in this chapter.
CURSOR	Collection of procedures for outputting the cursor's position and for placing the cursor in a specific location. Described in this chapter.
DPRINT	Collection of procedures for printing text into disk files. DPRINT is described in Chapter 4 of the Technical Manual. Its use is described in this chapter.

FID	File utility program for deleting, renaming, locking, and unlocking files. FID is described in this chapter and Chapter 4 in the Technical Manual.
SCREENDUMP	Utility for printing graphics screen using Grappler card. SCREENDUMP is described in this chapter and in chapter 2 of the Technical Manual.
SHAPE.EDIT	System for changing the shape of the graphics turtle. This is useful for games and animation. ROCKET uses a new turtle shape. How to create your own turtle shape is described in Chapter 5 of the Technical Manual.
TEXTEDIT	Procedures for using the Logo system as a text editor. Described in this chapter and Chapter 7 of the Technical Manual.

Demonstration Programs:

ANIMAL	Game which adds your information about animals to its knowledge base. Described in this chapter and Chapter 4 of the Technical Manual. The structure and procedures of this program are discussed in the section on advanced use of lists in Logo for the Apple II, by Harold Abelson, professor of mathematics at M.I.T.

ANIMAL.INSPECTOR
Procedures for examining the ANIMAL knowledge base. Described in this chapter.

DYNATRACK — Game using principles of physics to simulate a ride around a frictionless race track. Described in this chapter and Chapter 4 of the Technical Manual.

INSPI.PICT — Picture described in Chapter 4 of the Technical manual.

ROCKET.AUX
ROCKET.SHAPES
ROCKET
A demonstration of a use for a turtle with a different shape. The shape was created with the SHAPE.EDIT utilities program.

TET — Example of a simple recursive procedure which draws a complex design. Described in Chapter 4 of the Technical Manual.

Logo Files for Logo/Assembler Interfacing:

ADDRESSES — File of names describing addresses in the Logo interpreter for the assembler.

AMODES — File of names describing the 6502 addressing modes.

ASSEMBLER	Logo assembler procedures.
OPCODES	File of names describing the 6502 mnemonics for the assembler.
	Chapter 6 in the Technical Manual describes Logo/Assembler interfacing.

Color Plotter Utility Files

SWEET-P	Procedures for controlling the Sweet-P Personal Plotter
RSPLOTTER	Procedures for controlling the Radio Shack 4-Color Plotter

Explanation of Utilities Disk Files

MUSIC, TWINKLE: How to Write and Run Logo Music Procedures

See the Chapter MUSIC in this tutorial.

MUSIC.BIN, MUSIC.SRC: An example of Logo/Assembler Interfacing

See Chapter 6 in the Technical Manual.

INSTANT: Single Letter Logo Commands

See INSTANT section of the Graphics chapter in this tutorial.

TEACH: How to Write Logo Procedures Without Using the Editor

TEACH is used to define procedures whenever you want to avoid the complexities introduced by using the editor.

To define the following procedure using TEACH

```
TO COUNTDOWN :N
 IF :N = 0 STOP
 PRINT :N
 COUNTDOWN :N-1
END
```

Type what appears in the usual computer font. What TEACH prints is in italics.
If there are no inputs, press <RETURN>.

```
? TEACH
NAME OF PROCEDURE>  COUNTDOWN
INPUTS (IF ANY)?   :N
< IF :N = 0 STOP
< PRINT :N
<COUNTDOWN :N-1
< END
COUNTDOWN DEFINED
?
```

To run COUNTDOWN, type

```
COUNTDOWN 10
```

The screen is not cleared when TEACH is used, as it is when the editor is used. The instructions developed in IMMEDIATE mode can be copied into a procedure using TEACH. In GRAPHICS mode, TEXTSCREEN (<CTRL> T) will show the previous typing, possibly hidden by the picture. SPLITSCREEN (<CTRL> S) will return the picture and four lines of text.

WARNING: Reading a file from the disk DOES clear the screen. Therefore, read TEACH in from the disk before beginning to type any instructions that you might want to copy into a procedure using TEACH.

The TEACH system uses two procedures:

TEACH asks for and receives the name of the procedure and any inputs, then passes the information on to TEACH1. If there are no inputs, just hit <RETURN>.

TEACH1, a recursive procedure, receives the lines of the procedure (after the prompt <), testing each for END. When END is received, TEACH1 completes the defining of the procedure, and passes control back to TEACH, which announces the procedure defined.

ARCS: Variable Radii Arc and Circle Procedures

In the Procedure section of this tutorial an **additional** variable radius arc procedure is developed.

To use the arc and circle procedures provided on the Utilities Disk, type the name with numbers for the inputs required. Examples:

RARC 50 90	for a 90 degree (quarter circle) arc to the right with a radius of 50.
RARC1 1 90	for a 90 degree (quarter circle) arc to the right with a radius of 360/(2 PI) or about 57.2.
RCIRCLE 30	for a circle to the right with a radius of 30.

Substitute LARC, LARC1, and LCIRCLE for arcs and circles to the left.

ARC Procedures

RARC :RADIUS :DEGREES
Procedure which draws an arc to the right with given :RADIUS and length :DEGREES. Uses RARC1.

LARC :RADIUS :DEGREES
Procedure which draws an arc to the left with given :RADIUS and length :DEGREES. Uses LARC1.

RCIRCLE :RADIUS
Procedure which draws a circle to the right with given :RADIUS. Uses RARC.

LCIRCLE :RADIUS
Procedure which draws a circle to the left with given :RADIUS. Uses LARC.

RARC1 :SIZE :DEGREES
Procedure which draws an arc to the right with a radius equal to :SIZE x 360/(2 PI). Uses CORRECTARCR.

LARC1 :SIZE :DEGREES
Procedure which draws an arc to the left with a radius equal to :SIZE x 360/(2 PI). Uses CORRECTARCL.

CORRECTARCR :SIZE :AMOUNT
Procedure which makes a small correction with each step of RARC1.

CORRECTARCL :SIZE :AMOUNT
Procedure which makes a small correction with each step of LARC1.

The CORRECTARC procedures compensate for the error introduced by trying to make a fractional number of repetitions in the ARC1 procedures, in the line

REPEAT QUOTIENT :DEGREES 5 [FD :SIZE * 5 RT 5]

CURSOR: Procedures for Character Output Control; Position, Flashing, Inverse

Character Control Procedures

CURSOR.HV Outputs a list of two elements: the cursor's horizontal position and its vertical position. Type

```
CURSOR.HV                Logo will respond
RESULT: [0 19]
```

CURSOR.H Outputs the cursor's horizontal position. Type

```
CURSOR.H                 Logo will respond
RESULT: 0
```

CURSOR.V Outputs the cursor's vertical position. Type

```
CURSOR.V                 Logo will respond
RESULT: 23
```

CURSORPOS Requires a two element list of the horizontal and vertical cursor coordinates; moves the cursor to that position. Type

```
CURSORPOS [23 23]
```

and the cursor will be placed in the lower right corner of the screen. [0 0] is in the upper left corner.

FLASHING — All characters printed after this command will flash alternately black on white, white on black. This includes what Logo prints as well as everything typed at the keyboard. Use NORMAL to restore to white on black. To enter this mode type

```
FLASHING
```

INVERSE — All characters printed after this command (by Logo or from the keyboard) will appear in inverse video, black on white. To enter this mode, type

```
INVERSE
```

NORMAL — Restores the normal mode of white on black. Type

```
NORMAL
```

Everything printed after this will be white on black.

How to Print Text Into Disk Files: Using DPRINT

Using DPRINT to store files:

The procedures in DPRINT can be used to write text into disk files. TEXTEDIT contains procedures for

saving, reading, examining, and printing the files. For most uses, the TEXTEDIT procedures are more appropriate and easier to use. See also Chapter 4 in the Technical Manual.

To create a new text file, type

```
OPEN    "(name of file)
DPRINT  [what you want to type into the file]
CLOSE   "(name of file)
```

Example:

```
OPEN "SESAME
DPRINT [THIS IS A TEST]
CLOSE "SESAME
```

The text is stored with the CLOSE procedure. To see the file listed on the disk, type CATALOG. To see the contents of the file, use the procedure SHOWTEXT in TEXTEDIT. Example:

```
SHOWTEXT

THIS IS A TEST
```

To add to a file, use OPEN.FOR.APPEND instead of OPEN. Example:

```
OPEN.FOR.APPEND "SESAME
DPRINT [TESTING APPENDING]
CLOSE "SESAME

SHOWTEXT

THIS IS A TEST
TESTING APPENDING
```

WARNING: If you use OPEN with an existing file, the newly entered text will overwrite the text already in the file. Example:

```
OPEN "SESAME                (assuming text above in it)
DPRINT [HI]
CLOSE "SESAME

SHOWTEXT

HI
  IS A TEST
TESTING APPENDING
```

TEXTEDIT: How to Save, Read, Examine, and Print Text Files

Using Logo as a text editor:

To start a text file, type

```
TO<RETURN>
```

This puts you into the editor, with the white line across the bottom of the screen.

Type the text you want, making use of the editing commands described in the Edit section of the APPENDIX.

NOTE THE DIFFERENCE HERE: When you have finished and are ready to print or save the text, leave the editor by typing

```
<CTRL> G
```

Do NOT type the <CTRL> C used to define procedures.

Use SAVETEXT (described below) immediately to save the file on the disk. You can always replace it with a corrected version, but if you accidentally erase it from your workspace before you save it, you must retype the whole thing.

Read the file back from the disk using READTEXT (also described below).

WARNING: To work on the file again after using READTEXT, type EDIT (or ED). If you type TO when there is text in the editor, it will be erased. If you have not yet saved it, it will be lost completely. However, if it is on the disk, it only means reading it in again.

Type

```
EDIT
```

to work on the file again. (See warning above.)

See also Chapter 7 in the Technical Manual.

READTEXT :FILE Reads a Logo text file into the editor. In this example, "SESAME has the two lines in it. Example:

```
READTEXT "SESAME
SHOWTEXT

THIS IS A TEST
TESTING APPENDING
```

SAVETEXT :FILE Saves the contents of the editor to the disk in the file named. To store the lines above in a different file (GEORGE), type

```
SAVETEXT "GEORGE
```

SHOWFILE :FILE Reads the file named and prints it out on the screen. SHOWFILE is a combination of READTEXT and SHOWTEXT. Example:

```
SHOWFILE "GEORGE
```

PRINTFILE :FILE Reads and prints the file in the editor on the printer. Uses SHOWFILE. If your printer is not controlled from Slot 1, change the value of :PRINTER. Example: if your printer card is in Slot 7, type

```
MAKE "PRINTER 7
```

To print the contents of the file SESAME on the printer, type

```
PRINTFILE "SESAME
```

SHOWTEXT Prints on the screen the text which is in the editor. See examples above. Uses PRINT.MEM.

PRINTTEXT Prints on the printer the text which is in the editor. Uses SHOWTEXT. Example: to print the contents of the editor, type

```
PRINTTEXT
```

PRINT.MEM :FROM :END
The procedure used by SHOWTEXT.

FID: File Management Utility: How to Delete, Rename, Lock, and Unlock Files, Set Default File Extension

Type

```
FID
```

Then use the character indicated by FID to list, delete, rename, lock, or unlock files on the disk, or to set the default file extension. See Chapter 4 of the Technical Manual.

SCREENDUMP: Printing the Logo Graphics Screen

The procedure SCREENDUMP in this file can be used with a Grappler card to print Logo screen pictures. To use it, read in the file, draw (or read in) the desired picture, and type SCREENDUMP. (Remember that reading in a file erases the screen, so SCREENDUMP should not be read in after the picture is drawn.)

SHAPE.EDIT: How to Change the Shape of the Turtle

See Chapter 5 of the Technical Manual.

ANIMAL: The Game that Teaches the Computer About Animals

ANIMAL is a game in which the computer tries to guess the animal you are thinking of by asking you questions. If it doesn't guess correctly, it will ask you for your animal's name and a question to distinguish that animal from the animal it guessed. This information it adds to its knowledge tree for the next game.

To play ANIMAL, type

READ "ANIMAL then

Type ANIMAL

The ANIMAL game is a good example of brief, single purpose procedures:

ANIMAL Prints the greeting, then uses GUESS with the stored :KNOWLEDGE. After a round of the game, prints another greeting, uses WAIT for a pause, then begins again by calling itself, ANIMAL.

ANIMAL.INSPECTOR: What's in the ANIMAL Knowledge Base?

This file is intended as a learning aid to be used in the discussion of the ANIMAL game.

The global variable :KNOWLEDGE in the file ANIMAL is the knowledge base examined. Therefore, it is necessary to read in the file ANIMAL to use the ANIMAL.INSPECTOR.

To examine the knowledge base available to ANIMAL, type

```
INSPECT.KNOWLEDGE
```

INSPECT.KNOWLEDGE uses INSPECT1 with the stored :KNOWLEDGE, beginning at level 0.

INSPECT1 :KNOWLEDGE :LEVEL
calls itself and IPRINT to inspect and print each branch of the knowledge tree.

IPRINT
Does a pretty print of the ANIMAL tree of knowledge. Type <CTRL> W (hold down the <CTRL> key and press <W>) to stop the scrolling (to read the tree). Press any key to resume scrolling.

DYNATRACK: A Game: the Dynamic Turtle On a Frictionless Surface

Steering without friction is a very different world, as people riding on rocket power have discovered. Dynatrack puts you on a rocket sled on a frictionless track and gives you the power to do two things:

1. You can turn the sled, BUT it will keep moving in the old direction, moving sideways.
2. You can give it a burst of rocket power. The force will be applied in the direction in which it is pointing, BUT, since it was already moving, the resultant direction will be somewhere between the original dirction and the direction in which you are pointing.

This is one of the trickiest games you will meet. It requires strategy more than eye-hand co-ordination.

Type `READ "DYNATRACK` and then

Type `DYNATRACK`

and follow directions to play.

The dynamic turtle keeps moving when you give it a "kick." Type R to turn it right, L to turn it left, K to kick it in the direction it is facing.

If it is moving in another direction when you "kick" it, the direction of movement will be changed, but it will take more than one one kick to change to the direction in which it is pointing.

INSPI.PICT: Sample Logo Picture

To see the picture, type

```
READPICT "INSPI
```

The procedure which drew it is listed in Chapter 4 of the Technical Manual.

ROCKET, ROCKET.AUX, ROCKET.SHAPES: Example of User-Defined Turtle Shape

After the file ROCKET is read, type

```
ROCKET
```

The moving rocket is the turtle, defined using SHAPE.EDIT as described in Chapter 5 of the Technical Manual.

After you run the procedure, type

```
SETSHAPE :ROCKET
DRAW
```

and try moving the rocket-turtle around. (See the Graphics chapter.) Type

```
SIZE 5
```

and graphics commands. The rocket will move, no matter how large it is (SIZE 1 is the normal size). However, figures other than the turtle figure will make only 90 degree turns, although the trail each leaves behind will go in the designated direction.

TET: A Graphics Procedure of Variable Complexity

TET is a good example of a recursive procedure. It draws tetrahedra on the points of tetrahedra. The largest tetrahedron is of the size specified. On its points are drawn half-size tetrahedra, on their points are drawn quarter-size tetrahedra, and so on, to the depth specified. A depth of 1 draws only the one large tetrahedron. Try

```
TET 50 3
```

Spaces in the procedure listing below are to help isolate the individual commands. They are not a necessary (or usual) inclusion. The REPEAT statement must be typed as one line (without a <RETURN> in it).

```
TO TET :SIZE :DEPTH
 IF :DEPTH = 0 STOP
 REPEAT 3 [ LEG :SIZE
       TET :SIZE * .5 :DEPTH-1
       RT 150     FD :SIZE
       RT 150     LEG :SIZE     RT 180]
END

TO LEG :SIZE
 FD :SIZE / ( 2 * COS 30)
END
```

Type as one line

ADDRESSES, AMODES, ASSEMBLER, OPCODES: Interfacing Logo and the Assembler

Chapter 6 in the Technical Manual describes the use of these files in Logo/Assembler interfacing.

SWEET-P: Plotter Procedures

The procedures in this file make it easy to create Logo graphics on the Sweet-P Personal Plotter from Enter Computer.

To start, read in the file and type

```
SETUP
```

The names of most procedures resemble their Logo screen graphics equivalents; for example, PFD moves the plotter pen forward, PPU does a plotter PENUP, and so on. For a listing of commands, type

```
HELP
```

The procedure POLYSPI is given as an example of a plotter superprocedure. Its only difference from procedures you've already seen is that it uses PFD and PRT instead of FD and RT.

The Sweet-P has the added advantage of being able to print text as well as graphics. The following procedures make it easy to vary the size and direction of text printing.

PRINTTEXT	Takes an input and prints it on the plotter. The input may be either a word or a list.
TEXTSIZE	Controls the magnification of text size. The input range is 1 to 255, although values much larger than 90 will create characters too big for a regular sheet of paper. Default value is 1.
TEXTORIENT	Sets the direction for text printing. The possible inputs are 0, 90, 180, and 270. Default is 0.

The procedure CHANGEPEN is provided so you can tell a procedure to pause for manual pencolor change.

You can also vary the magnification of graphics figures. To do so, change the global variable EXPANSION. A value of 7.6 will give the plotter page the same turtle-step dimensions as the graphics screen. (This means that the default value, 3, allows more turtle steps in all directions than is possible on the monitor.)

RSPLOTTER: Procedures for the Radio Shack Plotter

The procedures in this file allow you to control the Radio Shack four-color plotter (model CGP-115) from Logo. As with the SWEET-P procedures, most procedure names resemble their Logo screen graphics equivalents.

A few differences should be noted, however. You do not have to change pens manually on the Radio Shack plotter. Instead, the procedure PPC is provided.

In addition, the procedure NEWPAGE allows you to feed clean paper from the roll into the plotter.

Finally, the Radio Shack plotter can also print text as well as graphics, but must first be put into text or graphics mode. The procedures TXTMODE and GRMODE permit you to switch back and forth with ease.

EDIT MODE

USE OF CONTROL CHARACTERS FOR EASE IN EDITING

The EDIT mode discussion in Chapter 2 of the Technical Manual includes a listing of the keyboard editing commands.

The <CTRL> key is used like the <SHIFT> key. Hold it down while you type the character indicated. (<CTRL> N: hold down <CTRL> and type <N>.)

Moving the Cursor

These commands move the cursor without changing the text.

Arrow Keys — The Left Arrow moves the cursor to the left, and, if it is at the beginning of a line, up to the end of the previous line.

The Right Arrow moves the cursor to the right, and, if it is at the end of a line, down to the beginning of the next line.

<CTRL> N — NEXT: Moves the cursor down to the next line.

<CTRL> P — PREVIOUS: Moves the cursor up to the previous line.

Note that the up and down arrow keys on the Apple IIe can be used instead of <CTRL>P and <CTRL>N.

<CTRL> A — Moves the cursor to the beginning of the line.

<CTRL> E END: Moves the cursor to the end of the line.

<CTRL> F FORWARD: When editing more than one screenful of text, moves the cursor one screenful forward, or to the end of the buffer, whichever comes first.

<CTRL> B BACK: When editing more than one screenful of text, moves the cursor one screenful back, or to the beginning of the buffer, whichever comes first.

<RETURN> typed at the end of a line: moves the cursor to the next line.

Moving the Text

These commands move the text without changing it or changing the position of the cursor in the text.

<RETURN> typed in the middle of a line: moves the cursor and the text after it on the line to the next line.

<CTRL> O OPEN: Opens a new line at the cursor position. The cursor remains on the open line. Equivalent to typing <RETURN> <CTRL> P. Use it to add new lines in the middle of a procedure.

<CTRL> L Scrolls the text so that the line with the cursor is in the middle of the screen. Useful for seeing a particular sequence completely on the screen.

Deleting Text

These commands delete text. Deleted text is not recoverable. When text is deleted within a line, the rest of the line moves to the left.

<DEL> Each stroke of the <DEL> (<ESC>) key deletes the character to the left of the cursor. <DEL> used at the beginning of the line deletes the <RETURN> from the previous line, and joins the two lines.

<CTRL> D DELETE: Deletes the character under the cursor. When used at the end of a line <CTRL> D deletes the <RETURN>.

<CTRL>X Deletes from the cursor to the end of the line. If the cursor is at the beginning of the line, <CTRL>X kills the whole line.

Restoring Text

<CTRL> Y YANK: Recalls the most recently deleted line. This feature is especially useful when you want to move a line to a different location in the procedure. Also, if you are writing a procedure with several similar lines, try this trick: type the first line, delete it, and then restore it several times. Then you can make the minor changes necessary in each line.

Leaving EDIT Mode

<CTRL> C COMPLETE: Exits EDIT mode with changes intact. Use it when you complete a procedure or changes to a procedure.

<CTRL> G GONE: Exits EDIT mode without making any changes to your procedure. Use it when you change your mind about making changes or have just done a lot of typing without realizing you were still in EDIT mode.

When using Logo as a text editor, <CTRL> G is the only way to exit from the editor.

Procedures

GRAPHICS CHAPTER

Turtle Driving Projects

1. through 4. Screen size:

Hint: type <CTRL> F to see when the whole turtle goes off the edge and appears at the other edge of the screen. Type <CTRL> T to see the whole list of numbers (distances). Add up the numbers (or tell Logo to: 100 + 50 + ...), type DRAW and type FD (the total number) to check it out. You could also say FD 100 + 50 + ..., but you would not know what it totalled.

3. and 4. Diagonals:

To get to the first corner: use half the distance across (from 2) to get to the edge, and half the distance down to get to the bottom. Write down this list of instructions in case you do not get the true diagonal on the first try. Then aim the turtle at the opposite corner.

5. Command with a negative number and the equivalent:

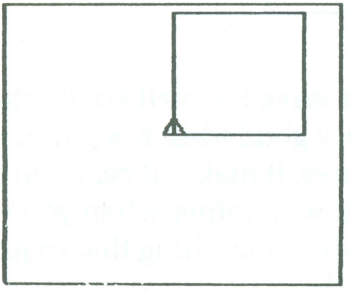
Try FD -20 and BK 20

6. Square examples (Type <RETURN> only where indicated):

```
1) FD 100    RT 90 <RETURN>
   <CTRL> P      <SPACE> <CTRL> P
                 <SPACE> <CTRL> P <RETURN>
```

Type as one line

```
2) FD 100    RT 90 <RETURN>
   FD 100    RT 90 <RETURN>
   FD 100    RT 90 <RETURN>
   FD 100    RT 90 <RETURN>

3) FD 100    RT 90 <RETURN>
   <CTRL> P       <RETURN>
   <CTRL> P       <RETURN>
   <CTRL> P       <RETURN>

4) FD 100    RT 90 FD 100 RT 90 FD 100
             RT 90 FD 100 RT 90 <RETURN>
```



Square

Rectangle examples:

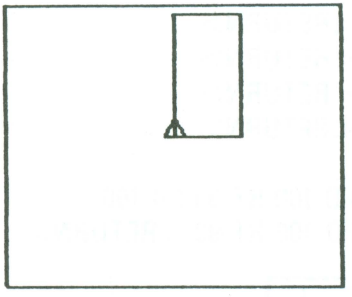
```
1) FD 100 RT 90 FD 50 RT 90 <RETURN>
   <CTRL> P <RETURN>
```

(Why does it take only one repetition for the rectangle but three for the square?)

```
2) FD 100 RT 90 <RETURN>
   FD 50  RT 90 <RETURN>
   FD 100 RT 90 <RETURN>
   FD 50  RT 90 <RETURN>
```

Type as one line, with only the one <RETURN>:

```
3) FD 100 RT 90 FD 50 RT 90 FD 100
        RT 90 FD 50 RT 90 <RETURN>
```

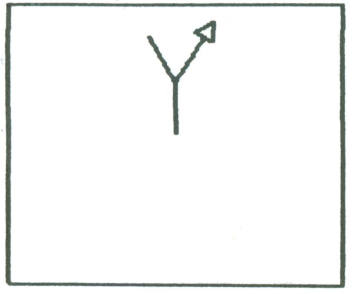


Rectangle

These instructions leave the turtle in its starting position, which is a very good idea. Keep it in mind when you write procedures. It makes it easier to plan how one procedure follows another when you want to use several, as in drawing something that requires both a square and a triangle.

7. Some straight line initials (<RETURN> is assumed after each line):

```
L:  LT 90 FD 50 RT 90 FD 100
I:  FD 100
V:  LT 15 FD 100 BK 100 RT 30 FD 100
T:  FD 100 LT 90 FD 25 BK 50
Y:  FD 50 LT 30 FD 50 BK 50 RT 60 FD 50
```



Initial Y

These instructions leave the turtle at the end of the initial. Later the tutorial will tell you how to move the turtle without leaving a track. (See section which includes PENUP and PENDOWN.)

Procedure Projects

1. Trackless SETUP:

```
TO SETUP
 DRAW
 PU
 LT 90
 FD 140
 RT 90
 BK 110
 PD
 FULLSCREEN
END
```

gives the same final result as

```
TO SETUP
 DRAW
 LT 90
 FD 140
 RT 90
 BK 110
 CS
 FULLSCREEN
END
```

Use PU / PD to avoid having to get rid of the track.

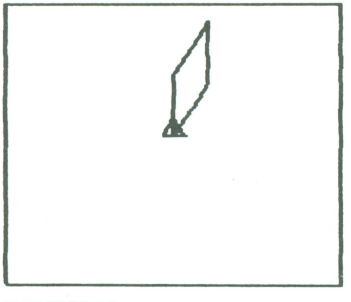
2. Design with MOVE repeated:

```
TO MOVE
 FD 100
 RT 15
 BK 80
 RT 25
END
```

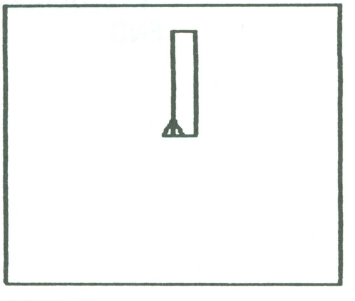
```
TO MOVEIT
 REPEAT 24 [MOVE]
END
```

3. A four-sided figure:

```
TO FOURSIDE
 REPEAT 2 [FD 60 RT 30 FD 60 RT 150]
END
```



FOURSIDE



RECT1

4. Rectangles:

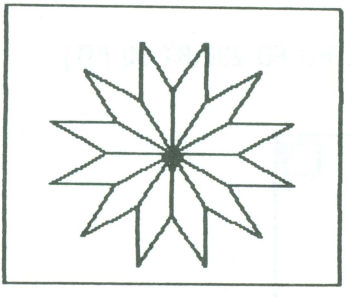
```
TO RECT
 REPEAT 2 [FD 100 RT 90 FD 50 RT 90]
END

TO RECT1
 REPEAT 2 [FD 110 RT 90 FD 10 RT 90]
END
```

5. Setup and a rectangle:

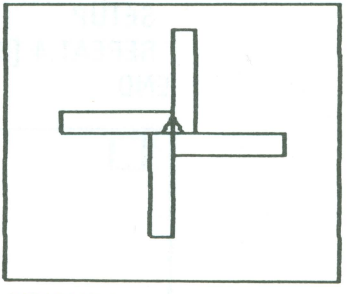
```
SETUP          SETUP
RECT           RECT1
```

6. REPEAT, a shape, and a turn:

```
TO HOTPAD
 REPEAT 12 [FOURSIDE RT 30]
END

TO WINDMILL
 REPEAT 4 [RECT1 RT 90]
END
```



HOTPAD

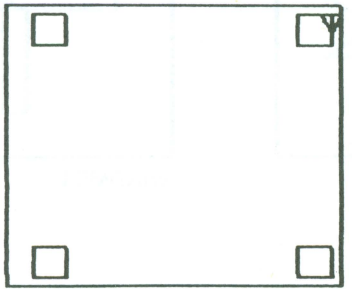


WINDMILL

Projects Using Shapes

1. A square in each corner of the screen:

```
TO CORNER.SQ
 SETUP
 SQUARE
 PU
 FD 200
 PD
 SQUARE
 PU
 RT 90
 FD 220
 LT 90
 PD
 SQUARE
 PU
 BK 200
 PD
 SQUARE
END

TO SETUP
 PU
 LT 90
 FD 140
 RT 90
 BK 110
 PD
END

TO SQUARE
 REPEAT 4 [FD 30 RT 90]
END

TO FOUR.SQ
 SETUP
 REPEAT 4 [SQUARE PU FD 230 RT 90 PD]
END
```



CORNER.SQ

Note how in the first version, the turtle walks around the screen getting to the location of the closest corner, while in the second version it starts each square from the corner. It is always more elegant and more understandable if you can figure out a pattern and repeat it.

2. Keeping that in mind, let's see what would draw a square and place the turtle in position to draw another in a row.

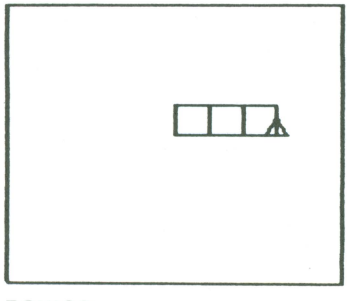
SQUARE RT 90 FD 30 LT 90 would do it,

```
TO ROW.SQUARE
 REPEAT 3 [SQUARE RT 90 FD 30 LT 90]
END
```

and, if the turtle turned LT 90 first, so would

```
SQUARE FD 30

TO ROW.SQUARE.LEFT
 LT 90
 REPEAT 3 [SQUARE  FD 30]
END
```

Lengthening the distance forward would produce a row of separated squares.

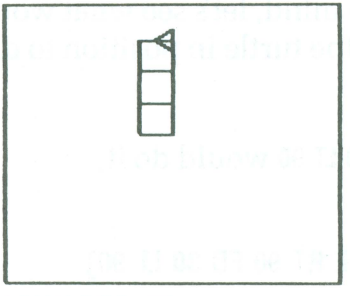


ROW.SQ

3. Tower of squares:

```
TO SQUARE.TOWER
 LT 90
 ROW.SQUARE
END
```

```
TO SQUARE.TOWER.LEFT
 RT 90
 ROW.SQUARE.LEFT
END
```



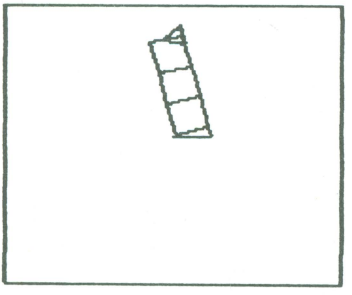
SQUARE.TOWER

4. A leaning tower:

```
TO LEANING.TOWER
 BASE
 SQUARE.TOWER
END
```

```
TO BASE
 RT 90
 FD 30
 LT 105
 FD 10
END
```

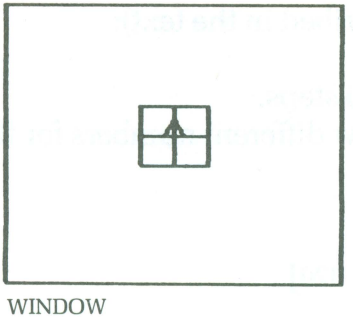
Discover the distances in a procedure like BASE by trying different ones.



LEANING.TOWER

5. A window with four panes:

```
TO WINDOW
 REPEAT 4 [SQUARE  LT 90]
END
```



WINDOW

6. Square

```
1) TO SQ2
    FD 30
    RT 90
    FD 30
    RT 90
    FD 30
    RT 90
    FD 30
    RT 90
   END

2) TO SQ3
    REPEAT 4 [FD 30 LT 90]
   END
```

7. Analyzing the problem of drawing a triangle:

Decisions (as described in the text):

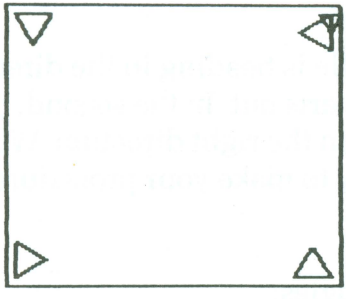
1. Sides will be 30 steps.
2. Have to try a few different numbers for the turn
3. Want 3 sides

```
TO TRI
 REPEAT 3 [FD 30RT 120]
END
```

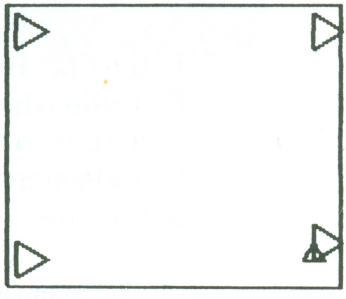
8. 1—4 using triangles:

(1) A triangle in each corner of the screen: Substitute the triangle procedure for the square procedure (and change the name):

```
TO FOUR.TRI
 SETUP
 REPEAT 4 [TRI PU FD 230 RT 90 PD]
END

TO CORNER.TRI
 SETUP
 TRI
 PU
 FD 200
 PD
 TRI
 PU
 RT 90
 FD 220
 LT 90
 PD
 TRI
 PU
 BK 200
 PD
 TRI
END
```



FOUR.TRI

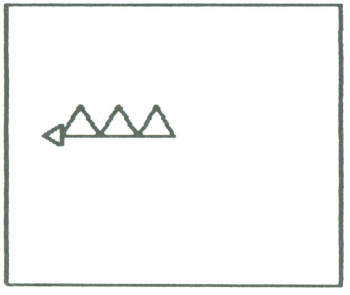


CORNER.TRI

Notice that the two procedures produce different results with triangles. The orientation of a triangle makes a difference.

(2) A row of triangles:
Turn LT 90 (or RT 30) first to lay the triangle down to make it easier to connect the triangles.

```
TO ROW.TRI
 LT 90
 REPEAT 3 [TRI FD 30]
END

TO ROW.TRI.RIGHT
 RT 30
 REPEAT 4 [TRI RT 60 FD 30 LT 60]
END
```



ROW.TRI

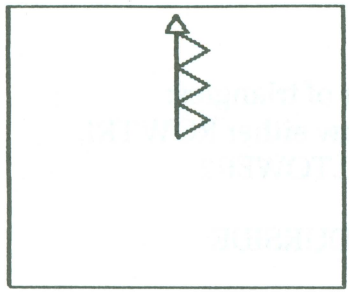
In the first, the turtle is heading in the direction of the first side when it starts out. In the second, it has to turn each time to head in the right direction. Which is easier to understand? Try to make your procedures as simple as possible.

(3) A tower of triangles:
There are several choices:
1) Turning the row of triangles will produce a tower of triangles balancing on their points.
2) Drawing another row, fitted into the first, will produce a tower with triangles pointing in opposite directions, either balanced on a point,

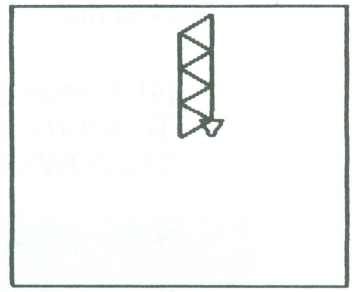
3) or with a base.
4) Drawing triangles with each base balanced on the point of the one below requires a new procedure.

```
TO TRI.TOWER1
 RT 90
 ROW.TRI
END
```

```
TO TRI.TOWER2
 RT 90
 ROW.TRI
 RT 60
 FD 30
 RT 120
 RT 90
 ROW.TRI
END
```



TRI.TOWER1

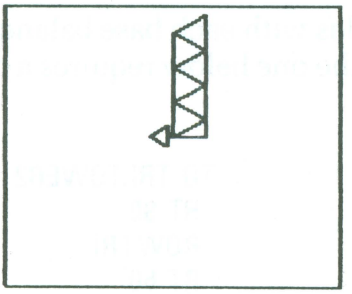


TRI.TOWER2

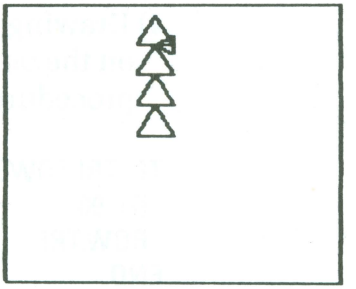
```
TO TRI.TOWER3: Add to 2) (before END)
                FD 15
                RT 90
                FD 30
```

FD 30 is slightly too long. Adjust it by trial.

```
TO TRI.TOWER4
 LT 90
 REPEAT 3 [TRI RT 60 FD 30 LT 60 BK 15]
 TRI
END
```



TRI.TOWER3



TRI.TOWER4

(The REPEAT statement must be typed as one line, with only one <RETURN>, at the end.) Note that the turtle draws the triangle, turns and moves to the top, then turns again and backs into position to draw the next one.

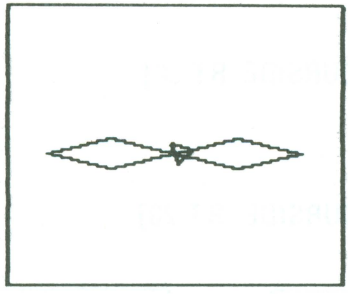
(4) A leaning tower of triangles:
Turn turtle and draw either ROW.TRI, TRI.TOWER or TRI.TOWER2.

9. Designs using FOURSIDE:

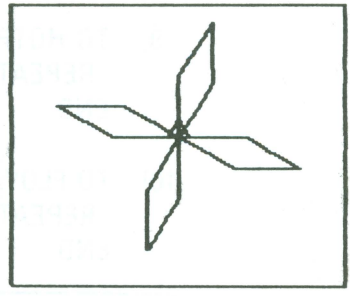
NOTE: These designs were named after they were drawn.

```
1)  TO PROPELLER
      REPEAT 2 [FOURSIDE RT 180]
    END

2)  TO BOW.TIE
      LT 105
      REPEAT 2 [FOURSIDE RT 180]
    END

3)  TO TRI.PROP
      REPEAT 3 [FOURSIDE RT 120]
    END
```

4) TO PINWHEEL
  REPEAT 4 [FOURSIDE RT 90]
 END



BOW.TIE

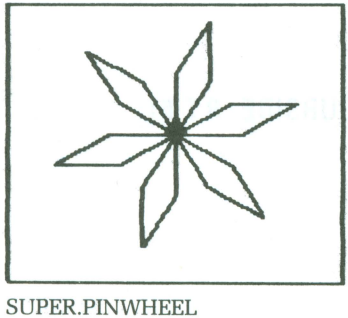


PINWHEEL

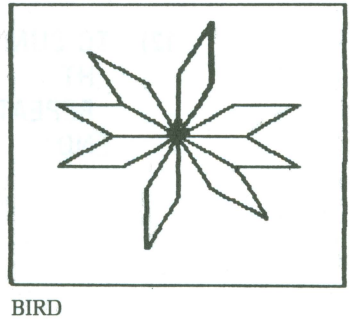
5) TO FIVE
  REPEAT 5 [FOURSIDE RT 72]
 END

6) TO SUPER.PINWHEEL
  REPEAT 6 [FOURSIDE RT 60]
 END

7) TO BIRD
  PINWHEEL
  SUPER.PINWHEEL
 END

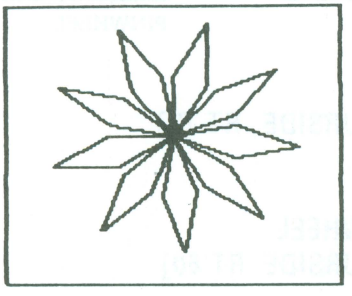


SUPER.PINWHEEL

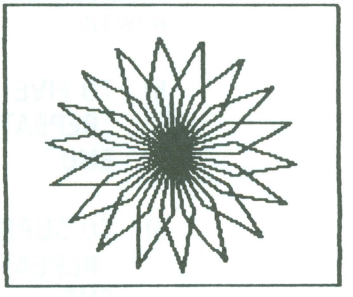


BIRD

```
8)  TO FLEUR
     REPEAT 9 [FOURSIDE RT 40]
    END

9)  TO HOTPAD
     REPEAT 12 [FOURSIDE RT 30]
    END

10) TO FLOWER
     REPEAT 18 [FOURSIDE RT 20]
    END
```

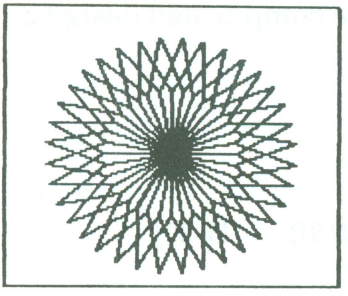


FLEUR

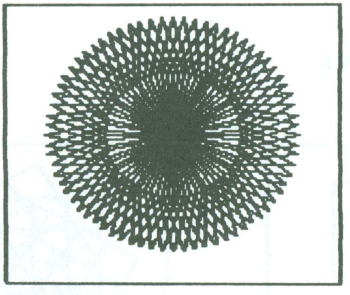


FLOWER

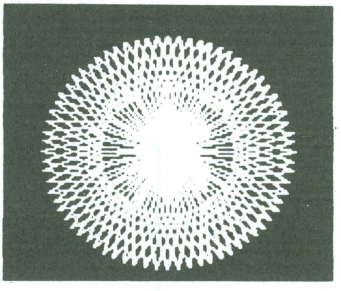
```
11) TO MUM
     HT
     REPEAT 36 [FOURSIDE RT 10]
    END

12) TO SUN
     HT
     REPEAT 72 [FOURSIDE RT 5]
    END
```



MUM



SUN



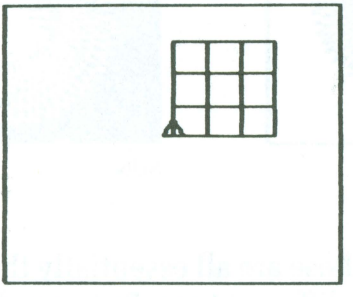
SUN

Except for BIRD, these are all essentially the same procedure, with a different turn. But see what different designs they are! HT (HIDETURTLE) makes the drawing go faster.

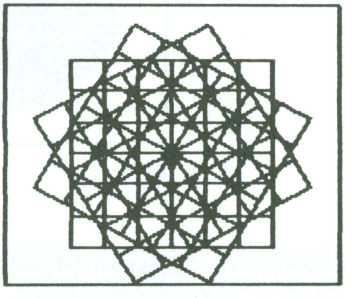
Progressively more complicated designs:

Using ROW.SQ:

```
1)  TO NINE
     HT
     REPEAT 4 [ROW.SQ      LT 90]
    END

2)  TO LACE
     HT
     REPEAT 12 [NINE      RT 30]
    END
```



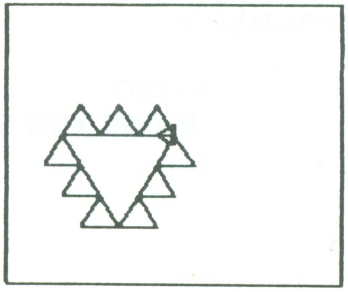
NINE



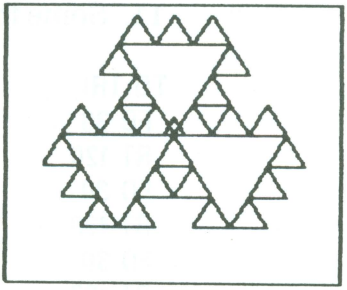
LACE

Using TRI.TOWER:

```
1)  TO JAG.TRI
     LT 90
     REPEAT 3 [TRI.TOWER1      LT 120]
    END

2)  TO JAG3
     REPEAT 3 [JAG.TRI LT 30]
    END
```



JAG.TRI

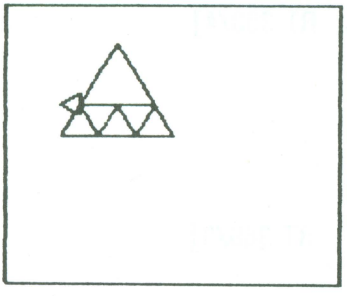


JAG3

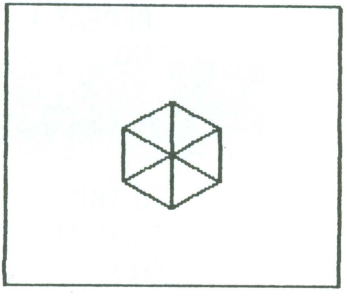
10. A window with 6 triangular panes:

```
TO TRI.WINDOW
 ROW.TRI
 RT 120
 FD 90
 REPEAT 2 [RT 120 FD 60]
END
```

```
TO TRI.WINDOW2
 REPEAT 6 [TRI RT 60]
END
```



TRI.WINDOW



TRI.WINDOW2

11. Some triangle procedures:

```
TO TRI
 FD 30
 RT 120
 FD 30
 RT 120
 FD 30
 RT 120
END
```

```
TO TRI2
 REPEAT 3 [FD 30 LT 240]
END
```

Projects: More Shapes

1.—3. Using REPEAT and division:

1) A square

```
TO SQ1
 REPEAT 4 [FD 30     RT 360/4]
END
```

2) A triangle

```
TO TRI3
 REPEAT 3 [FD 30     RT 360/3]
END
```

3) A pentagon (5 sides)

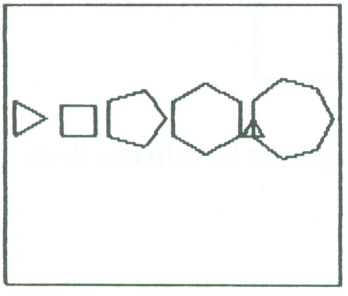
```
TO PENTA
 REPEAT 5 [FD 30     RT 360/5]
END
```

4) A hexagon (6 sides)

```
TO HEXA
 REPEAT 6 [FD 30     RT 360/6]
END
```

5) A septagon (7 sides)

```
TO SEPTA
 REPEAT 7 [FD 30      RT 360/7]
END
```



Polygons

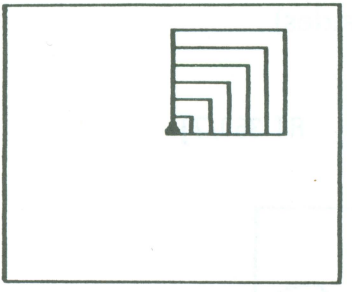
6) A pentadecagon (15 sides)

```
TO FIFTEEN
 REPEAT 15 [FD 30      RT 360/15]
END
```

Projects: Sizable Shapes

1. SQUARE4 to draw squares of various sizes:

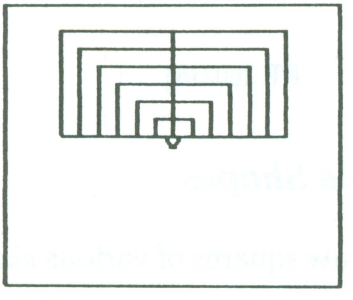
```
TO SQUARE4
 SQV 10
 SQV 20
 SQV 30
 SQV 40
END

TO SQV :LENGTH
 REPEAT 4 [FD :LENGTH RT 90]
END
```



SQUARE4

2. Another set of squares beside the first:

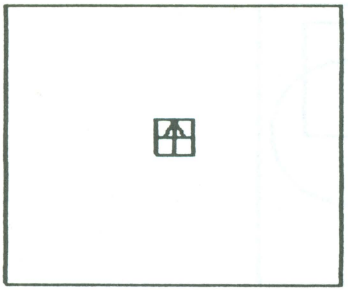
```
TO TWO.SQUARES
 SQUARE4
 LT 90
 SQUARE4
END
```



TWO SQUARES

3. A procedure using a specific size square:

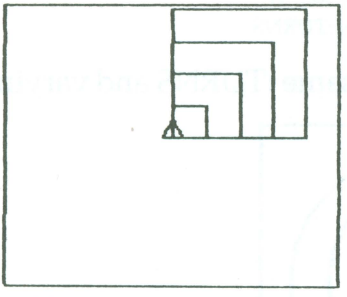
```
TO WINDOW1
 REPEAT 4 [SQV 30 RT 90]
END
```



WINDOW1

4. 4 squares, each 25 bigger than the last, with size of the first square input:

```
TO BIGGER.SQ :LENGTH
 SQV :LENGTH
 SQV :LENGTH + 25
 SQV :LENGTH + 50
 SQV :LENGTH + 75
END
```

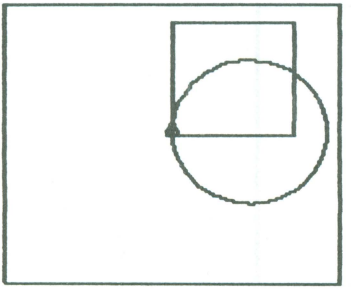


BIGGER.SQ

Projects with Regular Polygons

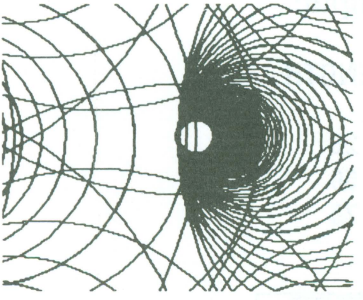
1. POLY 4 100 and POLY 100 4:

```
TO POLY :LEN :TURNS
 REPEAT :TURNS [FD :LEN RT 360/:TURNS]
END
```



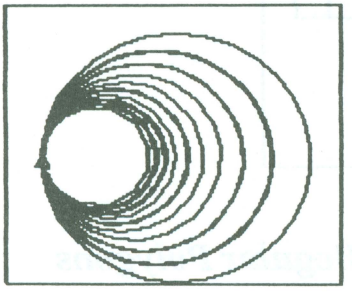
POLY 4 100 and POLY 100 4

2. POLY with the same :LEN and varying :TURNS:



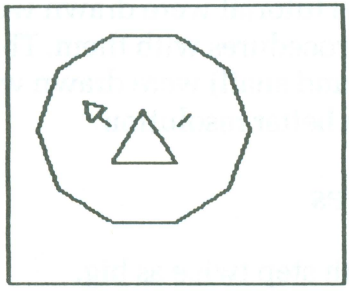
POLY: Same :LEN, varying :TURNS

3. POLY with the same :TURNS and varying :LEN:



POLY: Same :TURNS, varying :LEN

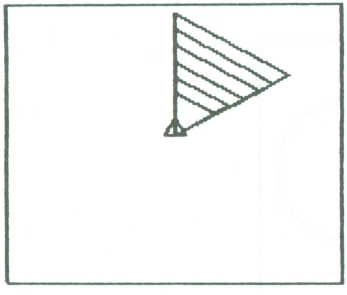
4. POLY twice, with different :TURNS:



Using POLY Twice with Different :TURNS

5. Using POLY to make a triangle:

```
POLY 100 3
```



POLY Triangles

6. The largest number you can use for :TURNS:

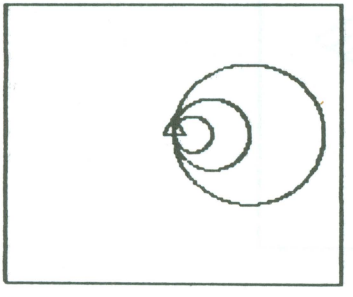
There is no largest number ... The figure becomes a rough circle at 15, and after that, larger numbers increase the exactness of the curve, but after a while there is no more visible improvement and the only effect is to make the turtle go more slowly and the circle to get larger (with the same length of side). Monitors do not have a high enough resolution to distinguish between a many-sided figure and a circle. The only reason you might want to be that exact (and slow)

would be for printing the designs on paper. The designs shown in the tutorial were drawn with the turn indicated in the procedures with them. The mascots (rabbit, elephant, and snail) were drawn with slower arc procedures for better resolution.

Projects: Curves

1. Circles: 2nd with step twice as big,
3rd with turn twice as big.

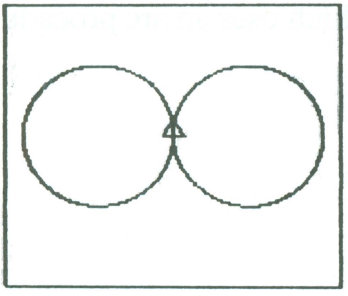
```
DRAW
REPEAT 360 [FD 1     RT 1]
REPEAT 360 [FD 2     RT 1]
REPEAT 180 [FD 1     RT 2]
```



Circles

2. Circles to right and left:

```
DRAW
REPEAT 360 [FD 1     RT 1]
REPEAT 360 [FD 1     LT 1]
```



Circles Left and Right

3. To figure out the diameter (distance across) of a circle, turn the turtle 90 and walk it across. You can see the line better if you type HT (HIDETURTLE).

4. Quarter-circle arc to the right (make it into a procedure and call it ARCR90):

```
REPEAT 360/4 [FD 1      RT 1]
```

5. Quarter-circle arc with steps twice as big:

```
REPEAT 360/4 [FD 2      RT 1]
```

6. Sixth-of-a-circle arc to the left and right (make them into procedures and call them ARCR60 and ARCL60):

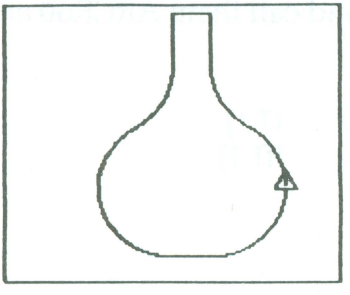
```
REPEAT 360/6 [FD 1      LT 1]
REPEAT 360/6 [FD 1      RT 1]
```

7. A procedure which uses an arc procedure and straight lines:

ARCR90

ARCL60

```
TO VASE
 PU
 RT 90
 FD 60
 LT 90
 BK 30
 PD
 HT
 ARCL60
 ARCR60
 FD 30
 LT 90
 FD 20
 LT 90
 FD 30
 ARCR60
 ARCL60
 ARCL90
 FD 20
 ARCL90
END
```

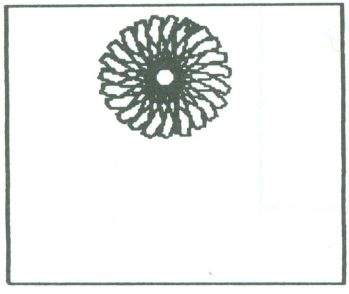


VASE

Projects: Simple Recursion

1. A recursive procedure that draws a little figure, then calls itself:

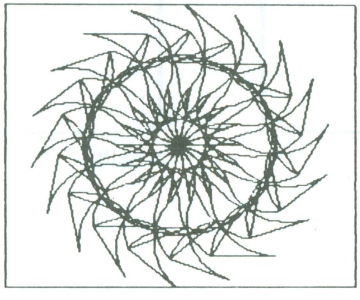
```
TO FIGURE
 FD 60 RT 49 FD 10 RT 80 FD 5 RT 90
 FIGURE
END
```



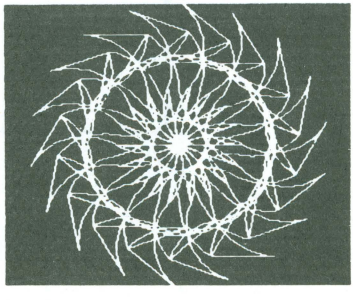
FIGURE

2. A recursive procedure that uses arcs and lines:

```
TO FAN
 PU
 RT 20
 PD
 REPEAT 3 [ARCR 50 60 ARCL 50 90 BK 50 LT 90]
 FAN
END
```



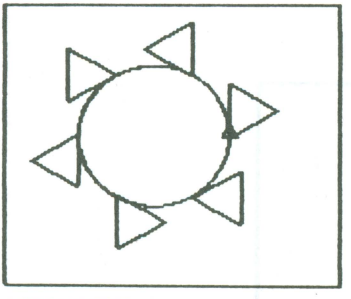
FAN



FAN

3. A recursive procedure using a triangle:

```
TO MILLWHEEL
  TRI
  ARCL60
  MILLWHEEL
END
```

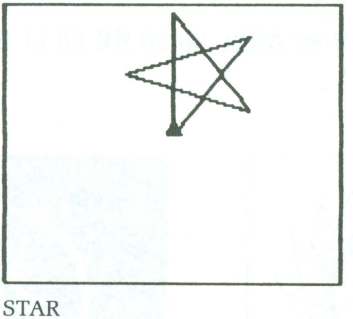


MILLWHEEL

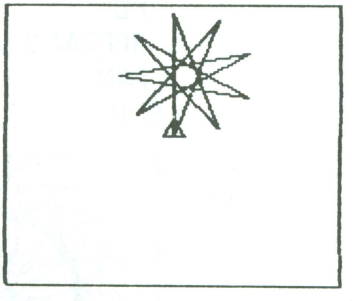
4. Stars:

```
TO STAR
 FD 75 RT 144
 STAR
END
```

```
TO STAR9
 FD 75 RT 160
 STAR9
END
```



STAR

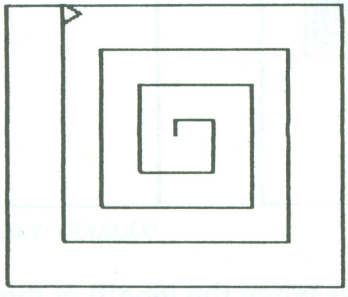


STAR9

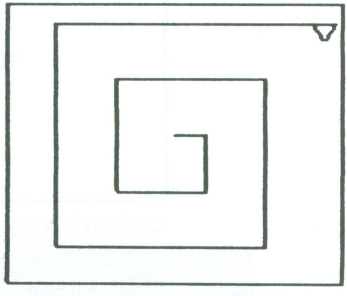
Projects: Changing Inputs

1. SQUARE with a larger increment:

```
TO SQUARE1 :LENGTH
 FD :LENGTH RT 90
 SQUARE1 :LENGTH + 15
END

TO SQUARE2 :LENGTH
 FD :LENGTH RT 90
 SQUARE2 :LENGTH + 25
END
```



SQUARE1 With + 15



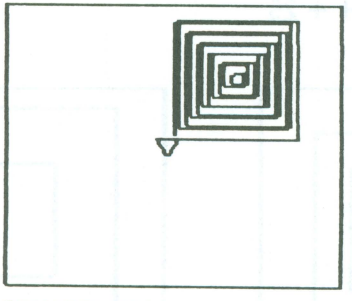
SQUARE2 With + 25

SQUARE with a smaller increment:

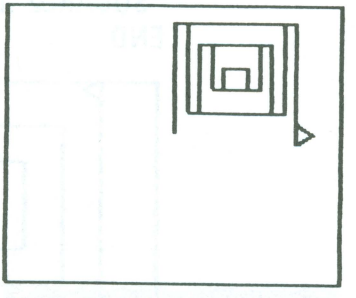
```
TO SQUARE3 :LENGTH
 FD :LENGTH RT 90
 SQUARE3 :LENGTH + 1
END

TO SQUARE4 :LENGTH
 FD :LENGTH RT 90
 SQUARE4 :LENGTH + 3
END
```

SQUARE with an increment subtracted:

```
TO SQUARE5 :LENGTH
 FD :LENGTH RT 90
 SQUARE5 :LENGTH -5
END

TO SQUARE6 :LENGTH
 FD :LENGTH RT 90
 SQUARE6 :LENGTH -10
END
```



SQUARE5 With−5

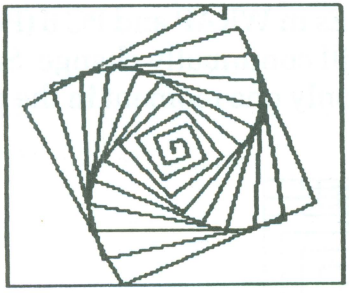


SQUARE6 With−10

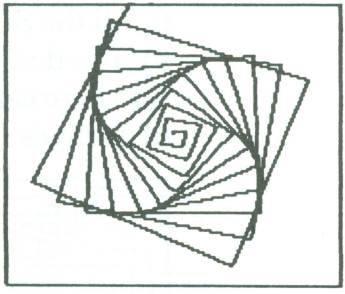
Note what happens when the length of the side becomes very small and then negative...

3. SQUARE with a slightly different turn:

```
TO SQUARE7 :LENGTH
 FD :LENGTH RT 93
 SQUARE7 :LENGTH + 5
END

TO SQUARE8 :LENGTH
 FD :LENGTH RT 87
 SQUARE8 :LENGTH + 5
END
```



SQUARE7 With RT 93

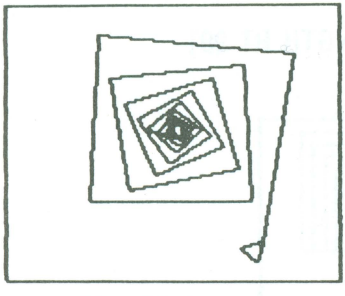


SQUARE8 With RT 87

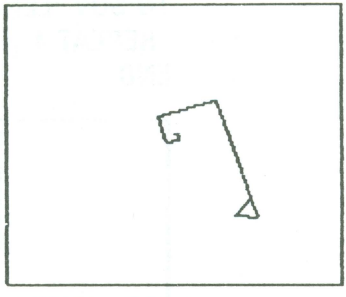
Now you begin to see some of the power of changing the input in a recursive procedure.

4. SQUARE with the input changed by multiplication:

```
TO SQUARE9 :LENGTH
 FD :LENGTH RT 93
 SQUARE9 :LENGTH * 1.1
END

TO SQUARE10 :LENGTH
 FD :LENGTH RT 87
 SQUARE10 :LENGTH * 2
END
```



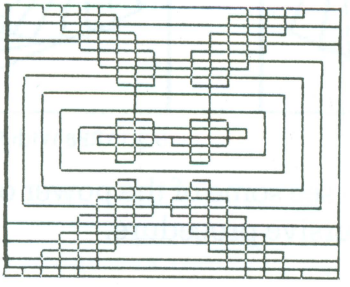
SQUARE9 With * 1.1



SQUARE10 With * 2

5. SQUARE, SQUARE1, ... SQUARE10 in both WRAP and NOWRAP mode.

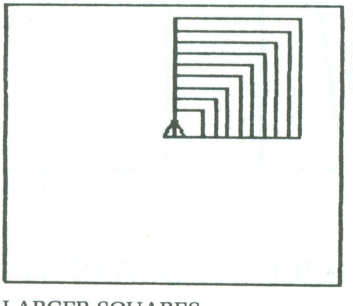
6. All the SQUAREs in WRAP and PC 6 (PENCOLOR 6): The designs will continually change. Sample picture here catches only one moment in the succession of changes.



A Squaral in Wrap Mode

7. Using a SQUARE procedure with variable input (such as SQV) in a procedure that draws successively larger squares.

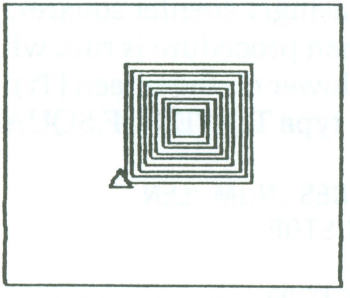
```
TO LARGER.SQUARES :LENGTH
 SQV :LENGTH
 LARGER.SQUARES :LENGTH + 10
END

TO SQV :LENGTH
 REPEAT 4 [FD :LENGTH RT 90]
END
```



LARGER.SQUARES

If you wanted to center your squares, instead of drawing them with two common sides, you would move the turtle between squares:

```
TO LARGER.SQUARES :LENGTH
 SQV :LENGTH
 PU LT 90 FD 5 RT 90 BK 5 PD
 LARGER.SQUARES :LENGTH + 10
END
```



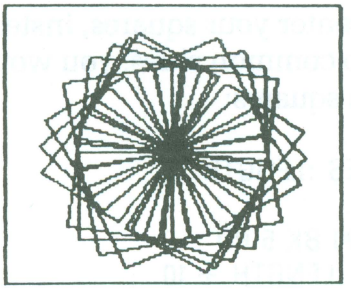
LARGER.SQUARES (Centered)

Note that the turtle turns left, moves the distance of half the increment, turns right and backs into position, moving the distance of half the increment again. The backing up saves an extra turn.

Projects: Testing and Stopping

1. Replacing the 45 in RT 45:

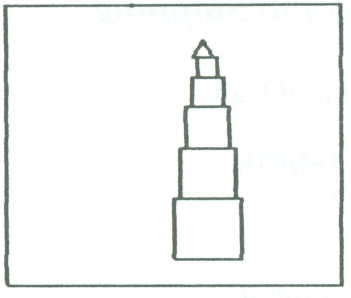
```
TO DESIGN :TIMES :LENGTH
 IF :TIMES < 1 STOP
 SQV :LENGTH
 RT :TIMES * 4
 DESIGN :TIMES-1:LENGTH
END
```



DESIGN

2. A tower of increasingly smaller squares, number of squares chosen when procedure is run, with a setup procedure to start lower on the screen (Type SET.TOWER, then type TOWER.OF.SQUARES 5 55):

```
TO TOWER.OF.SQUARES :NUM :LEN
 IF :NUM = 0 THEN STOP
 SQV :LEN
 FD :LEN RT 90 FD 5 LT 90
 TOWER.OF.SQUARES :NUM-1          :LEN-10
END

TO SET.TOWER
 PU BK 100 PD
END
```

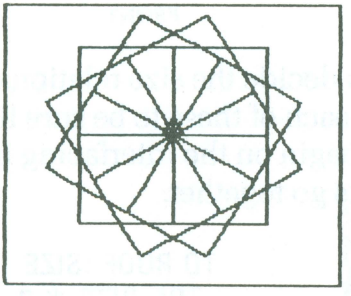


TOWER.OF.SQUARES

After drawing each square, the turtle moves up the side of the square just drawn, turns, moves half the size of the increment (so the next square is centered), and turns again, ready to begin the next square.

3. DESIGN with a variable turn:

```
TO DESIGN1 :LENGTH :TIMES :TURN
 IF :LENGTH < 0 THEN STOP
 IF :TIMES < 1 THEN STOP
 SQUARE :LENGTH RT :TURN
 DESIGN1 :LENGTH :TIMES -1 :TURN
END
```



DESIGN1

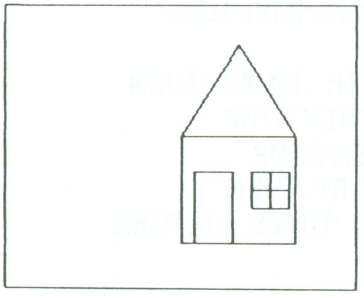
Recursion Projects

1. Successively smaller houses:

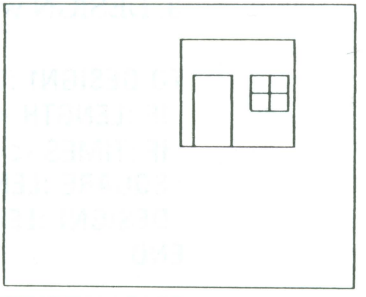
Begin by designing one house with a variable for a unit of size, to be determined later. The parts will require some instructions between them for positioning, but that too can wait. For a start, just describe what will be in the picture.

```
TO HOUSE :SIZE
 FRONT :SIZE
 ROOF :SIZE
END
```

```
TO FRONT :SIZE
 WALLS :SIZE
 DOOR :SIZE
 WINDOW :SIZE
END
```



HOUSE



FRONT

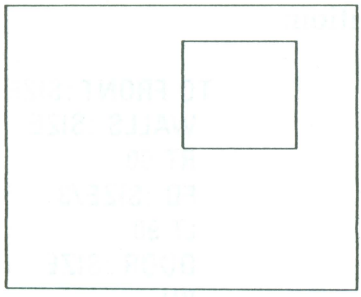
Now is the time to decide the size relationship of the components. Test each of these to be sure it works correctly before you begin on the interfacing instructions that make the parts go together.

```
TO WALLS :SIZE
 SQUARE :SIZE * 3
END
```

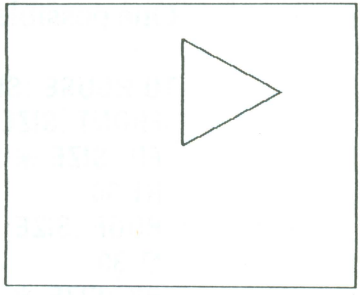
```
TO ROOF :SIZE
 TRI :SIZE * 3
END
```

```
TO WINDOW :SIZE
 REPEAT 4 [SQUARE :SIZE/2 RT 90]
END
```

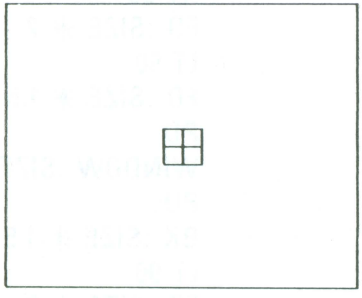
```
TO DOOR :SIZE
 RECT :SIZE * 2 :SIZE
END
```



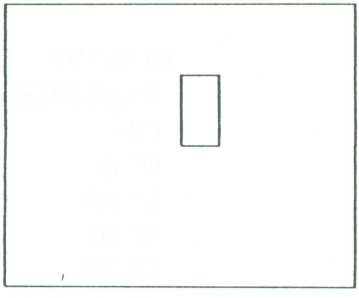
WALLS



ROOF



WINDOW



DOOR

```
TO TRI :LENGTH
 REPEAT 3 [FD :LENGTH RT 120]
END

TO SQUARE :LENGTH
 REPEAT 4 [FD :LENGTH RT 90]
END

TO RECT :LEN :WIDTH
 REPEAT 2 [FD :LEN RT 90 FD :WIDTH RT 90]
END
```

Now comes the fitting together of the parts.

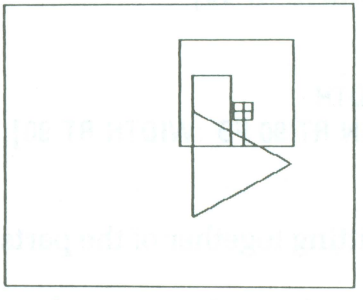
In each case, the turtle finishes in its starting position. This makes it much easier to figure out how to get to where the next part is drawn.

One possible solution:

```
TO HOUSE :SIZE
 FRONT :SIZE
 FD :SIZE * 3
 RT 30
 ROOF :SIZE
 LT 30
 BK :SIZE * 3
END

TO SETUP
 FULLSCREEN
 PU
 LT 90
 FD 135
 RT 90
 BK 115
 PD
END
```

```
TO FRONT :SIZE
 WALLS :SIZE
 RT 90
 FD :SIZE/3
 LT 90
 DOOR :SIZE
 PU
 RT 90
 FD :SIZE * 2
 LT 90
 FD :SIZE * 1.5
 PD
 WINDOW :SIZE
 PU
 BK :SIZE * 1.5
 LT 90
 FD :SIZE * 2 + :SIZE/3
 RT 90
 PD
END
```

SETUP moves the turtle to the lower left corner of the screen to draw the first house.



Interface Bug in House

The next problem is the procedure which will use HOUSE to draw a succession of smaller houses and stop.

```
TO H :SIZE
 IF :SIZE < 2 STOP
 HOUSE :SIZE
 PU
 RT 90
 FD :SIZE * 3.4
 LT 90
 FD :SIZE * 2
 PD
 H :SIZE * .75
END
```

The 3.4, 2, and .75 were determined by trial and error, to see what came out the best on the screen.

Now all that remains is to create the procedure HOUSES which will run the other procedures when you type HOUSES.

```
TO HOUSES
 HT
 SETUP
 H 30
END
```

To extend this so that you can determine the size reduction when you run the procedure, use a variable instead of the .75:

```
TO H :SIZE :FACTOR
 IF :SIZE < 2 STOP
 HOUSE :SIZE
 PU
 RT 90
 FD :SIZE * 3.4
 LT 90
 FD :SIZE * 2
 PD
 H :SIZE * :FACTOR :FACTOR
END

TO HOUSES :FACTOR
 HT
 SETUP
 H 30 :FACTOR
END
```

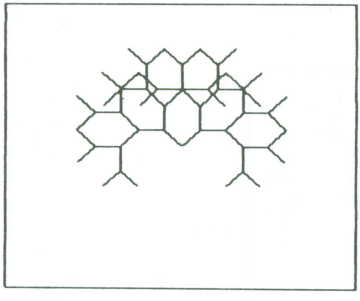
HOUSES .75

Now you have the option of making larger and larger houses, defying perspective, but you will need a test for maximum size to make the procedure stop.

2. A binary tree:

The basic pattern:

```
TO TREE :LENGTH
 RT 45
 FD :LENGTH
 BK :LENGTH
 LT 90
 FD :LENGTH
 BK :LENGTH
 RT 45
END
```



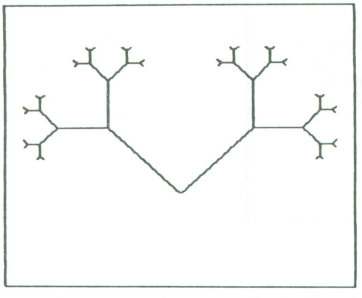
TREE 20 5

Note that the turtle finishes in its starting position.

If you want to draw another one of these at each tip, then you must determine when the turtle is at the tip and call the procedure again. Each FD :LENGTH takes the turtle to a tip, so it is after each FD that the procedure should be called again.

One way to stop this procedure so it can recurse and draw the whole tree, is to specify the number of forks:

```
TO TREE :LENGTH :FORKS
 IF :FORKS = 0 STOP
 RT 45
 FD :LENGTH
 TREE :LENGTH :FORKS -1
 BK :LENGTH
 LT 90
 FD :LENGTH
 TREE :LENGTH :FORKS -1
 BK :LENGTH
 RT 45
END
```

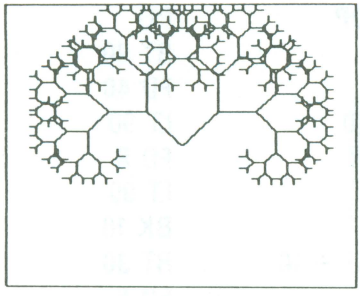


TREE1 80

A tree with successively smaller branches could be told to stop when :LENGTH reached a certain size:

```
TO TREE1 :LENGTH
 IF :LENGTH < 5 STOP
 RT 45
 FD :LENGTH
 TREE1 :LENGTH / 2
 BK :LENGTH
 LT 90
 FD :LENGTH
```

```
  TREE1 :LENGTH /2
  BK :LENGTH
  RT 45
END

TO TREE2 :LENGTH
  IF :LENGTH < 5 STOP
  RT 45
  FD :LENGTH
  TREE2 :LENGTH * .75
  BK :LENGTH
  LT 90
  FD :LENGTH
  TREE2 :LENGTH * .75
  BK :LENGTH
  RT 45
END
```



TREE2 40

Each of these makes a different design. To alter it even more, consider making it with one side different from the other, perhaps doubling the length of the branches or changing the turn.

There is a good discussion of binary trees in LOGO FOR THE APPLE II, by Professor Harold Abelson, M.I.T.

3. A fish in a fish in a fish.

First draw one fish, then try it in different sizes to be sure they will fit together. Then, as in the houses problem, write the procedure which fits them together.

```
TO FISH :SIZE
 RT 30
 PU
 RARC :SIZE * 3 10
 PD
 RARC :SIZE * 3 110
 TAIL :SIZE
 RARC :SIZE * 3 110
END
```

```
TO FISH.IN.FISH :SIZE
 IF :SIZE > 40 STOP
 FISH :SIZE
 PU
 RARC :SIZE * 3 10
 LT 60
 FD :SIZE/3
 RT 90
 FISH.IN.FISH :SIZE + 10
END
```

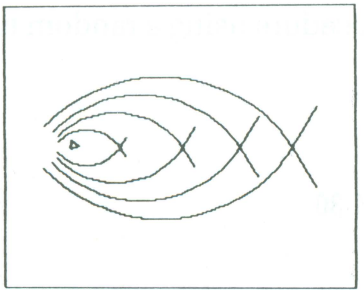
```
TO FISHES
 SETUP.FISH
 FISH.IN.FISH 10
 EYE
END
```

```
TO SETUP.FISH
 PU
 LT 90
 FD 100
 RT 90
 PD
END
```

```
TO EYE
 PU
 RT 90
 FD 40
 LT 90
 FD 8
 LT 90
 BK 10
 RT 30
 FD 5
END
```

```
TO TAIL :SIZE
 FD :SIZE
 BK :SIZE
 RT 60
 BK :SIZE
 FD :SIZE
END
```

EYE wanders about to put the turtle in an appropriate place for the eye of the smallest fish.



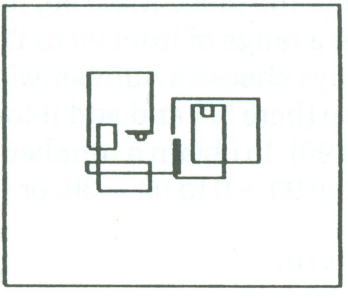
FISHES

Projects Using Random

1. SQUARE3 using FD RANDOM 100 in SQUARESIDE:

```
TO SQUARESIDE
 FD RANDOM 100
 RT 90
END
```

```
TO SQUARE3
 SQUARESIDE
 SQUARE3
END
```



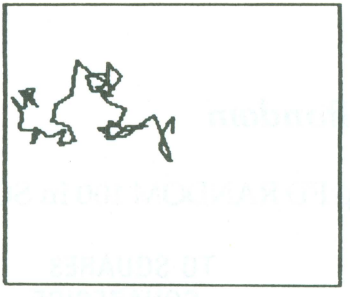
SQUARE3 with RANDOM 100

2. REPEAT using a random turn between 0 and 360:

```
REPEAT 50 [FD 20 RT RANDOM 360]
```

3. A recursive procedure using a random turn between 90 and 120:

```
TO WORM
 FD 20
 RT 90 + RANDOM 30
 WORM
END
```



WORM

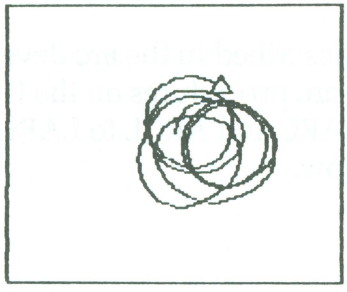
To specify a range BETWEEN two numbers, add the beginning number of the range (here 90) to the amount of the range (30, for a range of from 90 to 120). The computer will always choose a number within the amount of the range (here 30) and add it to the beginning number (here 90), to obtain a number within the specified range (here 90 + 0 to 90 + 30, or 90 − 120).

4. Other ranges of turn:

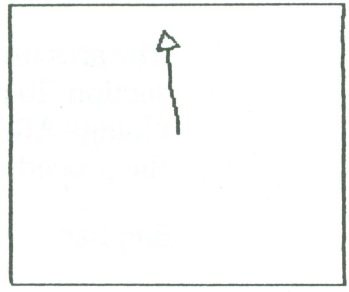
```
TO WANDER
 FD 2
 RT RANDOM 10
 WANDER
END
```

```
TO WIGGLE
 FD 5
 RT -10 + RANDOM 20
 WIGGLE
END
```

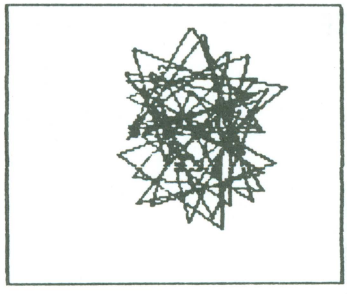
```
TO VARY
 FD 10
 RT 120 + RANDOM 30
 VARY
END
```



WANDER



WIGGLE



VARY

Mascots: Elephant, Rabbit, Snail

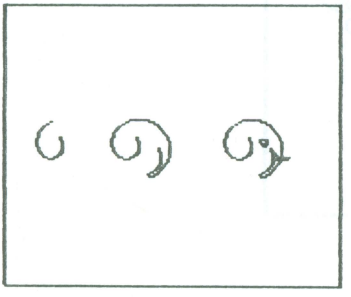
No lions and tigers and bears, but an elephant (that's for remembrance), a rabbit (denoting speed and ingenuity), and a snail (go slow... slow... slow).

The arcs used are described in the arc development section. To use the arc procedures on the Utilities Disk, change ARCR to RARC and ARCL to LARC in each of the procedures below.

Elephant

```
TO ELEPHANT :SIZE
 HT
 ELEPHANT.EAR :SIZE
 TRUNK :SIZE
 TUSK :SIZE
 EYE :SIZE
END

TO TUSK :SIZE
 ARCL 10 ✳:SIZE 70
 RT 160
 ARCR 10 ✳ :SIZE 50
END

TO ELEPHANT.EAR :SIZE
 RT 160
 FD 3 ✳:SIZE
 ARCR 7 ✳ :SIZE 180
 ARCR 13 ✳:SIZE 90
END

TO TRUNK :SIZE
 ARCR 17 ✳ :SIZE 180
 ARCR :SIZE 180
 ARCL 10 ✳ :SIZE 100
 RT 180
END
```

```
TO EYE :SIZE
 PU
 RT 60
 ARCL 10 * :SIZE 60
 PD
 RCIRCLE 2 * :SIZE
END
```



Evolving the Elephant

For the mascot elephant, :SIZE = 1.

Rabbit

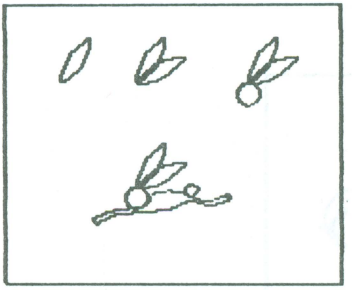
```
TO RABBIT
 HT
 HEAD
 ARCL 7.5 90
 RT 60
 BODY
END
```

```
TO BODY
 ARCR 20 60
 LCIRCLE 3.5
 ARCL 20 60
 ARCR 1.5 180
 ARCR 20 60
 LT 60
 ARCR 50 30
 ARCL 50 30
 ARCR 1.5 180
 ARCR 50 30
END
```

```
TO EARS
 EAR
 RT 150
 EAR
END
```

```
TO EAR
 ARCR 30 60
 RT 120
 ARCR 30 60
END
```

```
TO HEAD
 EARS
 ARCL 6 540
END
```



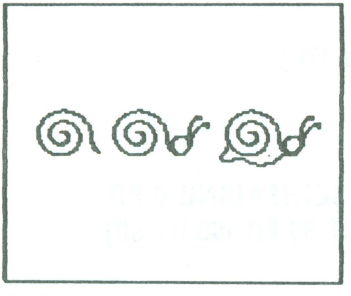
Evolving the Rabbit

Snail

```
TO SNAIL
 HT
 SNAIL.BODY
 SNAIL.HEAD
 RT 180
 ARCR 5 (270-HEADING)
 SNAIL.FOOT
END

TO POLYARC :SIZE :TIMES
 IF :TIMES = 0 THEN STOP
 ARCR :SIZE 60
 POLYARC :SIZE + 1 :TIMES—1
END
```

```
TO SNAIL.BODY
 POLYARC 1 15
 ARCL 10 60
END

TO ANTENNA
 ARCR 15 60
 ARCR 1 360
 PU
 RT 180
 ARCL 15 60
 RT 180
 PD
END
```

```
TO SNAIL.HEAD
 ARCL 5 475
 ANTENNA
 ARCL 5 20
 ANTENNA
END

TO SNAIL.FOOT
 ARCR 5 40
 LT 100
 ARCL 15 90
 ARCL 10 60
 ARCR 3 120
 RT 60
 ARCL 8 90
END
```



Evolving the Snail

Procedures for Saving Pictures

The illustrations in the Graphics Procedures section were drawn (2/3 scale) and stored on the disk with the following procedures:

```
TO STORE :PROCEDURE
 DRAW
 FRAME
 H
 RUN SENTENCE :PROCEDURE [ ]
 TURTLE
 SAVEPICT :PROCEDURE
END

TO TURTLE
 LT 90 BK 6
 REPEAT 3 [FD 12 RT 120]
END

TO FRAME
 PU SETXY -90 (-85) SETHEADING 0 PD
 REPEAT 2 [FD 160 RT 90 FD 180 RT 90]
END

TO H
 PU
 HOME
 PD
END
```

Example: type

```
STORE "TOWN
```

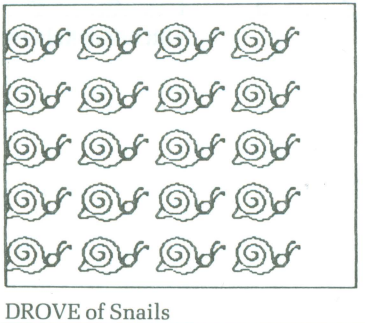
STORE clears the screen, draws the frame, moves the turtle to the HOME position, then runs the procedure TOWN. The SENTENCE :PROCEDURE [ ] makes a list out of the procedure name, so it can be RUN by another procedure. It turns the command into RUN [TOWN]. (See the chapter on Words and Lists.) The procedure TURTLE draws a little turtle, since SAVEPICT does not draw the turtle. SAVEPICT stores the picture on the disk under the procedure name.

Here is a set of procedures used to generate droves of wild animals. This also illustrates a use for SETXY.

```
TO DROVE :ANIMAL
 FULLSCREEN
 QUAD :ANIMAL (-90)
END

TO QUAD :PROC :Y
 IF :Y > 90 STOP
 LINE (-125) :Y :PROC
 QUAD :PROC :Y + 45
END

TO LINE :X :Y :PROC
 IF :X > 55 STOP
 PU
 SETXY :X :Y
 PD
 SETHEADING 0
 RUN SE :PROC [ ]
 LINE :X + 60 :Y :PROC
END
```

To draw a lot of little pictures, type DROVE and the name of the procedure that draws the picture. For example, type

```
DROVE "SNAIL
```

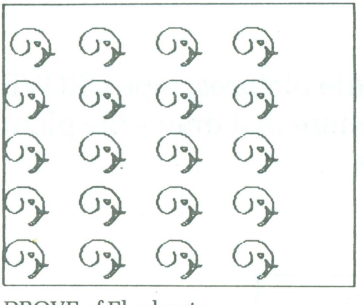


DROVE of Snails

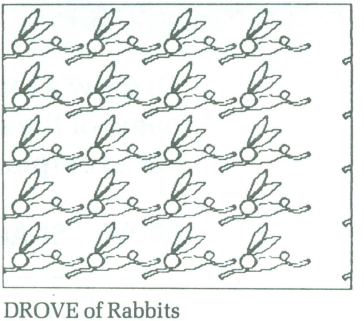
DROVE shows you the whole screen, since the drawing begins in the lower left corner, and calls QUAD with a Y value of -90, close to the bottom of the screen. DROVE is in charge of the whole project.

QUAD tests to be sure you are not going to be drawing off the top of the screen (Y > 90), then calls LINE with a value for X (-125) which will start the drawing near the left edge of the screen. When LINE has finished, QUAD moves into position for the next line of pictures and calls LINE again. QUAD uses LINE several times to draw rows of pictures.

LINE tests to be sure you are not drawing off the right side of the screen, then takes the beginning value of X and the value of Y, and moves to that position. LINE then uses RUN to call the procedure that draws the picture, and calls itself with a new position to the right (incremented value of :X, same value of :Y). LINE draws one row of pictures.



DROVE of Elephants



DROVE of Rabbits

Developing an Arc Procedure

It is easiest to develop a circle procedure, then generalize it to do arcs. Then you can use the arc procedure to do everything, including circles.

We want a circle procedure which will depend on the radius, so that we can specify the size by giving the radius when the procedure is run. We work from the fact that the circumference of a circle equals the radius times 2 PI: C = 2 PI (times) R, or, translating for the computer, C = 2*3.14159*R.

In Logo, every drawing is some combination of steps and turns, so the circle must also consist of steps and turns. A circle of a certain fixed size is drawn by

```
REPEAT 360 [FD 1 RT 1]
```

The 360 comes from the turn of 1; to turn 360 degrees with a turn of 1 degree requires 360 turns, or 360/1 = 360.

The 360 might also be said to represent the circumference, the distance around. We can substitute for it the equivalent 2*3.14159*R. This makes the circumference depend on the radius, as we wanted.

The turn must also be changed to be a function of the radius; if we use the same step and turn as before, we will not have changed the size of the circle. How can we figure out what the turn should be?

With a turn of 1 degree, we figured out the number of turns by dividing 360 degrees by that amount, to get

360 turns. If we use the same relationship, we see that the amount of turn is 360 divided by the number of turns.

The number of turns in our new model is 2 ✳ 3.14159 ✳ R, so the amount of the turn will be 360 / 2 ✳ 3.14159 ✳ R.

Our circle statement (type as one line) becomes

Type as one line

```
REPEAT 2 ✳ 3.14159 ✳ :RADIUS
  [FD 1 RT 360/(2 ✳ 3.14159 ✳ :RADIUS)]
```

Our circle procedure becomes

Type as one line

```
TO RCIRCLE :RADIUS
 REPEAT 2 ✳ 3.14159 ✳ :RADIUS
  [FD 1 RT 360/(2 ✳ 3.14159 ✳ :RADIUS)]
END
```

Type the REPEAT statement as one line, with only one <RETURN>, at the end. Substitute LT for an LCIRCLE procedure.

To change the circle procedure to an arc procedure, we must change the number of turns to draw the fraction of the circle the arc represents. How do we figure that fraction?

A 60 degree arc is 60/360, or 1/6th of a circle. The fraction of the circle which is any arc then, would be represented by (its size) / 360. If we call its size :DEGREES, then :DEGREES / 360 would be the fraction of the circle which is the arc of the size :DEGREES. (360/360 = the circle)

The number of turns would be the fraction of the circle represented by the arc, times the number required by the full circle, or

```
(DEGREES/360)*(2*3.14159 *:RADIUS)
```

The arc procedure would be

Type as one line

```
TO ARCR :RAD :DEG
 REPEAT (:DEG/360)*(2*3.14159*:RAD)
   [FD 1 RT 360/(2*3.14159*:RAD)]
END
```

Simplifying by doing the arithmetic gives

```
TO ARCR :RAD :DEG
 REPEAT .0174532 *:DEG *:RAD [FD 1 RT 57.295827 / :RAD]
END
```

The circle procedure becomes

```
TO RCIRCLE :RADIUS
 ARCR :RADIUS 360
END
```

LCIRCLE would use ARCL, the same as ARCR with LT substituted for RT. If you wanted to be silly, you could write

```
TO ARCL :RADIUS :DEGREES
 ARCR  -:RADIUS (-:DEGREES)
END
```

Now all the arc and circle procedures are based on one, and only one, procedure. Making the radius negative has the effect of making the turn negative, or LT.

To increase the resolution of the picture, really only desirable when you are going to print a design on paper, decrease the size of the step. Replace the original 1 with :STEP and add the variable to the title.

To keep our procedure drawing arcs with the specified radius, we must multiply the turn by the :STEP and consequently, divide the number of turns by :STEP, giving us (name changed to avoid confusion with the non-variable step version):

Type as one line

```
TO RARC :RADIUS :DEG :STEP
 REPEAT (.0174532 * :DEG * :RADIUS)/:STEP
  [FD :STEP RT (57.295827 * :STEP) /:RADIUS]
END
```

Debugging with TRACE, NOTRACE

TRACE allows you to watch the execution of your procedure line by line. Logo prints a statement, waits for you to type a character, then executes the statement. TRACE also tells you when it is starting a subprocedure, and tells you what the inputs are.

In TRACE mode, type <CTRL> G, as usual, to stop a procedure. <CTRL> Z will make it PAUSE; type CO (or CONTINUE) to resume. Type NOTRACE to stop tracing.

TRACE and NOTRACE may be used in a procedure to trace just a portion of it.

Adding Remarks in Your Procedures

When you use descriptive procedure names and variable names, and write short procedures and subprocedures, your need for remarks throughout your procedures is lessened, and in many cases, eliminated.

However, for those remarks that simply must go in, precede them with a semi-colon (;) as in the (not to be taken seriously as an) example:

```
TO SQUARE
FD 100;GOES FORWARD 100
RT 90;GOES RIGHT 90
SQUARE;CALLS ITSELF
END
```

Switching Disk Drives: SETDISK

Occasionally you may want to use more than one disk drive in your Logo system. Use the SETDISK command to switch back and forth between drives. SETDISK takes two inputs, a drive number and a slot number, and causes all subsequent file operations to be done in that drive. For example, SETDISK 2 6 transfers control to the second drive in a two-drive system. Default is SETDISK 1 6.

Creating Self-Starting Files Using the STARTUP Variable

It is possible to write Logo files which begin executing immediately after being read into the workspace. There is an interesting way of doing this using the address SAVMOD found in the ADDRESSES file (see section 7.2 of the Technical Manual); however, this way is also rather difficult.

A much easier way to create self-starting files is to use a STARTUP variable. Simply include in the file a global variable consisting of a list of the procedure to be started automatically. For example, if Logo encounters the message

```
MAKE "STARTUP [DEMO]
```

while reading in a file, the procedure DEMO will begin automatically.

Reading Apple Logo Files

Using Terrapin Logo, you can read files created with Apple Logo from Apple Computer. It's as easy as typing

```
READ "FILENAME
```

Of course, you will need to alter the syntax of some procedures to make them run correctly.

You may encounter a message similar to THERE IS NO PROCEDURE NAMED PPROP. If so, read in the file using the READTEXT procedure which is found in the TEXTEDIT file on the Utility disk.

Now type ED <return> and delete the offending command. Now type <CTRL>C to define the procedures.

A separate product available through Terrapin, **Utilities II**, contains an Apple Logo Translator program which does this work for you. Contact Terrapin for more information.

STRATEGIES FOR THE WORDS AND LISTS PROJECTS

1. Here is one version.

```
TO EASY :CHTR
  IF :CHTR = "F FD 10
  IF :CHTR = "R RT 15
  IF :CHTR = "L LT 15
  IF :CHTR = "D DRAW
  IF :CHTR = "U PU
  IF :CHTR = "P PD
END
```

2. Use the same strategy, adding lines like

```
IF :CHTR = "S ST
IF :CHTR = "H HT
```

3. For a two-keystroke method, EASY would need to contain a line such as

```
IF :CHTR = "C SETPENCOLOR RC
```

As in QUICKDRAW, RC grabs a character from the user, and SETPENCOLOR examines that character and, if it is a number from 0 to 6, sets the color accordingly.

SETPENCOLOR could be written several ways. One way that uses no new techniques is this:

```
TO SETPENCOLOR :CHTR
 IF :CHTR = 0 PC 0
 IF :CHTR = 1 PC 1
 IF :CHTR = 2 PC 2
 IF :CHTR = 3 PC 3
 IF :CHTR = 4 PC 4
 IF :CHTR = 5 PC 5
 IF :CHTR = 6 PC 6
END
```

Logo, however, makes life much simpler. If the character is not a number, it certainly is not a 0, 1, 2, 3, etc., and so we need not make all of those tests separately. This is worded concisely in Logo:

```
IF NOT NUMBER? :CHTR STOP
```

Then, if it is a number less than 7, it must be a 0 through 6, and we can just set the PENCOLOR to whatever CHTR happens to be.

```
IF :CHTR < 7 PC :CHTR
```

And that is all the procedure needs to do. Here are two ways to write that procedure.

```
TO SETPENCOLOR :CHTR
 IF NOT NUMBER? :CHTR STOP
 IF :CHTR < 7 PC :CHTR
END
```

```
TO SETPENCOLOR :CHTR
 IF NUMBER? :CHTR THEN IF :CHTR < 7 PC :CHTR
END
```

As a frill, the line in EASY could be:

```
IF :CHTR = "C PRINT1 [WHAT COLOR?] SETPENCOLOR RC
```

Look up PRINT1 in the Logo glossary.

4. You can use exactly the same strategy as above. Because the test for the second character is the same for setting the background color as for setting the pen color, it might make sense to use one procedure for both.

The problem is that after the procedure has verified that the character is a 0 through 6, it must know not only what character was typed, but also which to set, pen or background color.

Here is a procedure that can do both, but it involves more advanced techniques than we have yet explained in the tutorial. Don't worry! You can choose either to use the ones fully explained, or jump the gun and try the new technique.

```
TO SETCOLOR :WHICHCOLOR :CHTR
 IF NOT NUMBER? :CHTR STOP
 IF :CHTR > 6 STOP
 IF :WHICHCOLOR = [PEN] PC :CHTR ELSE BG :CHTR
END
```

The lines in EASY would need to be slightly different, stating which color, PEN or BACKGROUND, was to be changed. Here is one set of possibilities.

```
IF :CHTR = "C PRINT1 [WHAT COLOR?] SETCOLOR [PEN]
   RC
IF :CHTR = "B PRINT1 [WHAT COLOR?] SETCOLOR
   [BACKGROUND] RC
```

5. Recognizing and using digits can be done several ways. The simplest (if not most elegant) way to write EASY would be to add a bunch of lines like this:

```
IF :CHTR = 2 MAKE "MULTIPLE 2
IF :CHTR = 3 MAKE "MULTIPLE 3
IF :CHTR = 4 MAKE "MULTIPLE 4
IF :CHTR = 5 MAKE "MULTIPLE 5
IF :CHTR = 6 MAKE "MULTIPLE 6
IF :CHTR = 7 MAKE "MULTIPLE 7
IF :CHTR = 8 MAKE "MULTIPLE 8
IF :CHTR = 9 MAKE "MULTIPLE 9
```

Of course, all these lines say essentially the same thing, namely: "If the character is a number, make MULTIPLE that number." That can be translated straightforwardly into Logo with the much more compact statement.

```
IF NUMBER? :CHTR MAKE "MULTIPLE :CHTR
```

Inserting this new logic into EASY requires that we use the new value, and so the lines that move the turtle must now incorporate MULTIPLE thus:

```
IF :CHTR = "F FD 10 * :MULTIPLE
IF :CHTR = "R RT 15 * :MULTIPLE
IF :CHTR = "L LT 15 * :MULTIPLE
```

Alternatively, the lines could be

```
IF :CHTR = "F REPEAT :MULTIPLE [FD 10] etc.
```

Finally, we always want to reset the multiple to 1 so that it doesn't spill over from one command to the next.

Here is how the procedure might look.

```
TO QUICKDRAW
 EASY RC
 QUICKDRAW
END

TO EASY :CHTR
 IF :CHTR = "F FD 10 * :MULTIPLE
 IF :CHTR = "R RT 15 * :MULTIPLE
 IF :CHTR = "L LT 15 * :MULTIPLE
 IF :CHTR = "D DRAW
 IF :CHTR = "U PU
 IF :CHTR = "P PD
 IF :CHTR = "H HT
 IF :CHTR = "S ST
 IF :CHTR = "C PRINT1 [WHAT COLOR?] SETCOLOR [PEN]
    RC
 IF :CHTR = "B PRINT1 [WHAT COLOR?] SETCOLOR [BG]
    RC
 MAKE "MULTIPLE 1
 IF NUMBER? :CHTR MAKE "MULTIPLE :CHTR
END
```

EASY sets MULTIPLE to 1 every time it is executed. As already mentioned, this is so that L or F or R will mean the same as 1L or 1F or 1R each time unless some other number is typed.

The placement of the MAKE "MULTIPLE 1 line is important. It must be placed after the lines that use the value of MULTIPLE and before the line that sets MULTIPLE to values other than 1. Otherwise the special values of MULTIPLE would persist too long or be erased too soon.

A second thing to notice is that EASY cannot use MULTIPLE before setting it the first time. So before QUICKDRAW can be started, MULTIPLE must be given a value (presumably the value 1). This startup procedure seems convenient:

```
TO QD
 MAKE "MULTIPLE 1
 QUICKDRAW
END
```

6. The procedure PEN picks the pen up if it is already down, and puts it down if it is already up. We say it "toggles the pen state." To include it in EASY, only one line is needed:

```
IF :CHTR = "P PEN
```

The line IF :CHTR = "U PU can be eliminated, because P now takes care of both PD and PU.

Since PEN uses the variable PENPOS, QD (the setup procedure written earlier) should initially set the pen position to [DOWN].

```
TO QD
 MAKE "MULTIPLE 1
 MAKE "PENPOS [DOWN]
 QUICKDRAW
END
```

It is also possible to set up a toggle that works without setting a global variable with MAKE. Look up TURTLESTATE in the Logo glossary, and learn about FIRST (from the glossary or later in this chapter) to understand this alternate version of PEN which we are calling TOGGLEPEN.

```
TO EASY :CHTR
 IF :CHTR = "F FD 10
 IF :CHTR = "R RT 15
 IF :CHTR = "L LT 15
 IF :CHTR = "D DRAW
 IF :CHTR = "P TOGGLEPEN
END

TO TOGGLEPEN
 IF FIRST TS PU ELSE PD
END
```

TS is the abbreviation for TURTLESTATE. The first element of the list that TS outputs tells whether the turtle's pen is up or down. If it is down (if FIRST TS is TRUE) TOGGLEPEN puts it up, otherwise it puts it down.

In this case, since no global variable is involved, no additions to QD would need to have been made.

```
7. TO TOGGLE.SHOWN
    TEST :SHOWN = [SHOWN]
    IFTRUE HT MAKE "SHOWN [HIDDEN]
    IFFALSE ST MAKE "SHOWN [SHOWN]
   END
```

It is not necessary to tell the user whether the turtle is shown or not, so the PRINT statement was not added. Since the values [SHOWN] and [HIDDEN] now serve only as information to the procedure (they will not be printed as information to the user), it would be more "natural" to use TRUE and FALSE to state whether the turtle was shown.

The logic would then be this: If the turtle is shown (that is, if SHOWN is TRUE) then hide the turtle, else show it. In either case, make SHOWN whatever it was not; use the primitive NOT to make it FALSE if it is TRUE, or TRUE if it is FALSE.

```
TO TOGGLE.SHOWN
 IF :SHOWN HT ELSE ST
 MAKE "SHOWN NOT :SHOWN
END
```

Finally, a strategy using TURTLESTATE and avoiding the use of global variables works for showing and hiding the turtle as well as for the pen position.

Again, this strategy makes use of techniques we have not yet described, but which you can look up if you want to begin learning about them now.

TOGGLE.SHOWN using TURTLESTATE would look like this:

```
TO TOGGLE.SHOWN
 IF FIRST BUTFIRST TS HT ELSE ST
END
```

See TURTLESTATE, and learn about BUTFIRST (in the glossary or later in this chapter).

8. ACTION no longer needs to control the turns directly, but can handle turning the way it handles speed. So, it might look like this:

```
TO ACTION :CHTR
 IF :CHTR = "R MAKE "ANG :ANG + 2 ;TURN RIGHT
    MORE
 IF :CHTR = "L MAKE "ANG :ANG - 2 ;TURN LEFT MORE
 IF :CHTR = "F MAKE "DIST :DIST + 2 ; FASTER
 IF :CHTR = "S MAKE "DIST :DIST - 2 ; SLOWER
 IF :CHTR = "D DRAW
END
```

START now has to initialize one more global variable ANG, to something sensible, and might look like this:

```
TO START
 MAKE "DIST 0
 MAKE "ANG 0
 LOOP
END
```

It might also be nice if the D key really reset everything. As the program currently stands, D will clear the screen, but still leave the turtle flying around in whatever way it last flew. It might be reasonable to change

```
IF :CHTR = "D DRAW
```

to

```
IF :CHTR = "D CLEAR
```

and then to write a procedure CLEAR which reinitializes the global variables and clears the screen.

```
TO CLEAR
 MAKE "ANG 0
 MAKE "DIST 0
 DRAW
END
```

9. The feature to stop the turtle must reinitialize ANG and DIST without clearing the screen. Here is one.

```
TO RESET
 MAKE "ANG 0
 MAKE "DIST 0
END
```

Then the lines in ACTION would be

```
IF :CHTR = "D CLEAR
```

to accomplish the previous task of clearing the screen, and

```
IF :CHTR = ". RESET
```

to stop the turtle without clearing the screen. (The command character to stop the turtle is the period.)

Here are lines for reversing the rotation of the turtle, reversing the direction of the turtle and reversing both. Insert them and play with them. The effects are very interesting.

```
IF :CHTR = "T MAKE "ANG (- :ANG) ; REVERSES TURN
IF :CHTR = "M MAKE "DIST (- :DIST) ; REVERSES
   MOVEMENT
IF :CHTR = "B MAKE "DIST (- :DIST)
   MAKE "ANG (- :ANG) ; REVERSES BOTH
```

```
10. TO DECODE :N
      OP NTH :N "ABCDEFGHIJKLMNOPQRSTUVWXYZ
    END
```

There is another way that doesn't involve "counting" with NTH (and therefore is faster). CHAR is a Logo primitive that takes an integer as input and outputs the character whose ASCII code is that integer. The ASCII code for A is 65. For B, it is 66; for C, 67, and so on. So another way to write DECODE is:

```
TO DECODE :N
  OP CHAR (:N + 64)
END
```

```
11. TO ONENUM :LIST
      OP DECODE FIRST :LIST
    END
```

12. TO TWONUM :LIST
    OP WORD DECODE FIRST :LIST ONENUM
      BF :LIST
    END

13. TO THREENUM :LIST
    OP WORD DECODE FIRST :LIST TWONUM
      BF :LIST
    END

14. Here is the logic. If I have only one number in my list, I know exactly what to do. As in ONENUM, I simply OP DECODE FIRST :LIST.

If my list is longer than that, I cannot handle it all at once, so I get ready to glue together the decoding of the first number (which I can do immediately) and the decoding of a slightly shorter list.

Since the exact same reasoning applies to the slightly shorter list, the same procedure can be used. Either it can now handle the list directly (because there is only one number left in it), or it, too, gets ready to glue on its little piece and defers the rest of the job to another step. Here is the procedure it generates.

```
TO ANYNUM :LIST
 IF ( BF :LIST ) = []
    OP DECODE FIRST :LIST
 OP WORD DECODE FIRST :LIST
    ANYNUM BF :LIST
END
```

15. This could all be done in a single procedure with one long and ugly line that looks something like this:

```
TO RANDSENT
 PR (SE NTH 1 + RANDOM 7 PEOPLE
        NTH 1 + RANDOM 6 ACTIONS
        NTH 1 + RANDOM 7 PEOPLE)
END
```

The repetitive elements and the difficulty of seeing which words go with which make it useful to write a helpful subprocedure. Good style makes it easy to change and extend the program if you want to. Here is a first attempt:

```
TO RANDSENT
 PR SENTENCE WHO DIDWHAT
END

TO WHO
 OP PICK 7 PEOPLE
END

TO DIDWHAT
 OP SE DIDIT WHO
END

TO DIDIT
 OP PICK 6 ACTIONS
END

TO PICK :LISTSIZE :LIST
 OP NTH 1 + RANDOM :LISTSIZE :LIST
END
```

A problem with this way of doing things is that if ACTIONS or PEOPLE are edited, and the number of items in their lists is changed, WHO and DIDIT must also be edited, because they make explicit assumptions about the length of the lists they get.

This is not good programming practice, but fortunately LISTSIZE can always be determined from LIST just by counting, if we had a procedure that could count the elements in a list.

The procedure COUNT, which takes a list (or a word) as its input, does exactly this. (In Terrapin Logo version 2.0, COUNT is defined as a primitive.)

```
TO COUNT :OBJ
 IF :OBJ = [] OP 0
 OP 1 + COUNT BF :OBJ
END
```

To see what COUNT does, type

```
COUNT [L O G O]
COUNT [LOGO]
COUNT "LOGO
```

Because PICK can use COUNT to determine the list's size, it no longer needs to be told the size, and so LISTSIZE can be dropped from the title line. Where that information was needed in the body of the old version, COUNT :LIST can be substituted. The result is a procedure that looks like this.

```
TO PICK :LIST
 OP NTH 1 + RANDOM (COUNT :LIST) :LIST
END
```

Because PICK now takes only one input — the actual list — WHO and DIDIT need to be edited to use PICK properly.

```
TO WHO                TO DIDIT
 OP PICK PEOPLE        OP PICK ACTIONS
END                   END
```

The resulting program not only solves the problem raised earlier — namely, that PEOPLE and ACTIONS can be edited freely without requiring changes to be made in WHO and DIDIT — but it also looks "cleaner."

It is a general rule of good programming that by designing the "low level procedures" (such as PICK) properly, the higher level procedures (such as WHO) become cleaner, better organized, and easier to understand and debug.

16. As with all procedures, there are lots of possible designs. Here is one for VOWEL?.

```
TO VOWEL? :LETTER
 IF :LETTER = "A OP "TRUE
 IF :LETTER = "E OP "TRUE
 IF :LETTER = "I OP "TRUE
 IF :LETTER = "O OP "TRUE
 IF :LETTER = "U OP "TRUE
 OP "FALSE
END
```

But the logic is that IF the :LETTER is any one of A, E, I, O, or U, then OP "TRUE, otherwise OP "FALSE. This might be more concisely expressed as

```
TO VOWEL? :LETTER
 IF MEMBER? :LETTER [A E I O U] OP "TRUE
 OP "FALSE
END
```

But remember, MEMBER? is a predicate itself. It already outputs TRUE or FALSE, exactly what we want VOWEL? to output. So, VOWEL? can also be written:

```
TO VOWEL? :LETTER
 OP MEMBER? :LETTER [A E I O U]
END
```

or even

```
TO VOWEL? :LETTER
 OP MEMBER? :LETTER "AEIOU
END
```

18. It is tempting to write a YES? procedure modeled on VOWEL? like this:

```
TO YES?
 OP MEMBER? REQUEST [ [YES] [YUP] [Y] [SURE]
    [YEAH] ]
END
```

but all life is not that simple. What if the person types [I SUPPOSE SO]? The procedure would translate that as if it were a clear NO, when it is probably YES, or at least ambiguous. Alas, we must work harder.

Here is a suggestion.

```
TO YES?
 OP YESSUB? REQUEST
END

TO YESSUB? :RESPONSE
 IF MEMBER? :RESPONSE [ [YES] [YUP] [Y] [SURE]
    [YEAH] ] OP "TRUE
 IF MEMBER? :RESPONSE [ [NO] [NOPE] [N] ] OP
    "FALSE
 PRINT1 [PLEASE ANSWER "YES" OR "NO":]
 OP YES?
END
```

This is recursive in a new way. YES? is not defined in terms of itself, nor is YESSUB? — but each is defined in terms of the other! Make sure you understand how these two procedures work together.

18. Either of the first two work properly. To see what is wrong with the third version, try PLURAL "OX.

19. It would be convenient to have a procedure that returned the last two letters of a word. Of course, if there is only one letter in the word, LASTTWO must output the whole thing.

```
TO LASTTWO :WORD
 IF " = BL :WORD OP :WORD
 OP WORD LAST BL :WORD LAST :WORD
END
```

Now we can write a rule for handling words that need ES endings. Let's replace

```
IF "X = LAST :NOUN OP WORD :NOUN "ES
```

with

```
IF NEEDS.ES? :NOUN OP WORD :NOUN "ES
```

Cheating! NEEDS.ES? hasn't been written yet.

```
TO NEEDS.ES? :NOUN
 IF ( ANYOF "S = LAST :NOUN
            "X = LAST :NOUN
            "Z = LAST :NOUN ) OP "TRUE
 OP ANYOF "CH = LASTTWO :NOUN
            "SH = LASTTWO :NOUN
END
```

Alas, the formatting which makes the design so clear on paper is all lost in Logo's editor!

20. IF "Y = LAST :NOUN OP WORD BUTLAST :NOUN "IES

21. Ah, but not if the letter before the Y is a vowel!

```
IF "Y = LAST :NOUN OP YPLU :NOUN

TO YPLU :NOUN
 IF VOWEL? LAST BL :NOUN OP WORD :NOUN "S
 OP WORD BUTLAST :NOUN "IES
END
```

22. The big difference between FIXVERB and PLURAL is in their handling of lists. In the case of nouns, it was always the LAST element of the list that needed to be pluralized, but in the case of the verbs in ACTIONS, it is always the FIRST element that needs the modification. So the important line to change is the one that begins

```
IF LIST?
```

For FIXVERB, it might look like this:

```
IF LIST? :VERB OP SE FIXVERB FIRST :VERB BF :VERB
```

PAST and FIXVERB appear to have absolutely identical logic, but their exceptions are different. This brings up an interesting problem. The solution used in PLURAL was to create global variables which contained the proper form of exceptional words. What happens with verbs like HAVE or GO which have different exceptions for present and past forms? Although there is always a way to solve the problem if you notice it, the use of global variables is prone to surprising bugs until you notice the conflict.

```
TO PRESENT :SUBJ :VERB
 IF "BE = :VERB OP EXCEPTION.BE :SUBJ
 IF ( ANYOF "I = :SUBJ
            "YOU = :SUBJ
            "WE = :SUBJ
            "THEY = :SUBJ ) OP :VERB
 OP FIXVERB :VERB
END
```

Try to write EXCEPTION.BE yourself!

23. An extra level of analysis is needed in order to determine which class of verbs (which conjugation) is involved.

Here is a simplifying structure for the top level. It uses global variables in a risky way, but the structure will be fairly clear.

```
TO PRESENT :SUJET :VERBE
 MAKE "ROOT BL BL :VERBE ; SEPARATE ROOT
 MAKE "END LASTTWO :VERBE ; SEPARATE CONJ.
    MARKER
 ; AND NOW, HANDLE EACH CASE SEPARATELY
 IF "ER = :END OP ER.PRES :SUJET :ROOT
 IF "IR = :END OP IR.PRES :SUJET :ROOT
 IF "RE = :END OP RE.PRES :SUJET :ROOT
END
```

In the following case, make a further distinction.

```
TO IR.PRES :SUJET :ROOT
 IF "O = LAST :ROOT OP OIR.PRESENT :ROOT
 OP XIR.PRESENT :ROOT
END
```

The rest is yours.

24. The relevant change to make is this

```
IF MEMBER? REQUEST :ANSWER PR [YUP!]
```

25. This version of ADDQUIZ takes a number as input and keeps giving problems until that many problems have been answered correctly.

```
TO ADDQUIZ :TIMES
 IF :TIMES = 0 STOP
 IF ADDQ RANDOM 13 RANDOM 13 ADDQUIZ :TIMES - 1
    ELSE ADDQUIZ :TIMES
END

TO ADDQ :N1 :N2
 PRINT1 ( SE :N1 "+ :N2 "= ' )
 IF (:N1 + :N2) = FIRST RQ PR [YAY!] OP "TRUE
 PR ( SE "NOPE, :N1 "+ :N2 "= :N1 + :N2 )
 OP "FALSE
END
```

Notice that the only differences in ADDQ are that it outputs TRUE if the answer is correct and FALSE otherwise.

26. Here is one form. Are there bugs? Is there a cleaner way?

```
TO ADDQUIZ :MAX :TIMESRIGHT :TIMESWRONG
 IF :TIMESWRONG = 2 STOP
 IF :TIMESRIGHT = 3 ADDQUIZ :MAX + 1 0 0 STOP
 IF ADDQ RANDOM :MAX RANDOM :MAX
            THEN ADDQUIZ :MAX :TIMESRIGHT + 1
            :TIMESWRONG STOP
            ELSE ADDQUIZ :MAX :TIMESRIGHT
            :TIMESWRONG STOP
 ADDQUIZ :MAX :TIMESRIGHT :TIMESWRONG + 1
END
```

Start it by typing

```
ADDQUIZ 4 3 0
```

27. The logic we are trying to add is this: ADDQ is told what the problem is and how many tries the person has already made.

```
TO ADDQ :TRIES :N1 :N2
```

If that number (TRIES) is 2, ADDQ should give the correct answer and output FALSE.

```
IF :TRIES = 2 PR ( SE :N1 "+ :N2 "= :N1 + :N2 ) OP
   "FALSE
```

Otherwise, ADDQ should state the problem as before and allow the person another try. If the person gets the right answer, ADDQ says YAY and outputs TRUE, as it did before.

```
PRINT1 ( SE :N1 "+ :N2 "= ' )
IF (:N1 + :N2) = FIRST RQ PR [YAY!] OP "TRUE
```

But if the person gets the wrong answer, ADDQ should say "try again," give the same problem as before, and know that the person has taken one more try at answering it.

```
PRINT [TRY AGAIN]
OP ADDQ :TRIES + 1 :N1 :N2
```

Of course, ADDQUIZ must start ADDQ by telling it that no tries have yet been made.

```
IF ADDQ 0 RANDOM :MAX RANDOM :MAX etc.
```

The completed program might look like this.

```
TO ADDQUIZ :MAX :TIMESRIGHT :TIMESWRONG
 IF :TIMESWRONG = 2 STOP
 IF :TIMESRIGHT = 3 ADDQUIZ :MAX + 1 0 0 STOP
 IF ADDQ 0 RANDOM :MAX RANDOM :MAX
          ADDQUIZ :MAX :TIMESRIGHT + 1
          :TIMESWRONG STOP
    ELSE ADDQUIZ :MAX :TIMESRIGHT
    :TIMESWRONG + 1 STOP
END

TO ADDQ :TRIES :N1 :N2
   IF :TRIES = 2 PR ( SE :N1 "+ :N2 "= :N1 + :N2 )
     OP "FALSE
   PRINT1 ( SE :N1 "+ :N2 "= ' )
   IF (:N1 + :N2) = FIRST RQ PR [YAY!] OP "TRUE
   PRINT [TRY AGAIN]
   OP ADDQ :TRIES + 1 :N1 :N2
END
```

28. PICK can select some element from the STATES list. Each element of the STATES list contains both a question as its FIRST and an answer as its LAST (or BUTFIRST). This is just what QA needs. The hitch is that if we simply type

```
QA FIRST PICK :STATES LAST PICK :STATES
```

Logo will run PICK twice, and each time PICK is run it may pick a different element from the list! QA needs to take the FIRST and LAST (or BUTFIRST) of the same element.

The first thing to resolve is whether we use the LAST or BUTFIRST of the element. It makes a big difference, since the LAST is a word and the BUTFIRST is a list.

Since QA compares its :ANSWER with a REQUEST (which is always a list), we might as well use BF. One way STATESQUIZ might work is this:

```
TO STATESQUIZ
 REPEAT 5 [MAKE "QLIST PICK :STATES QA FIRST :QLIST
    BF :QLIST]
END
```

An alternative that is neater in a few ways is this:

```
TO STATESQUIZ
 REPEAT 5 [STATEQA PICK :STATES]
END

TO STATEQA :QLIST
 QA FIRST :QLIST BF :QLIST
END
```

29. The BF of [IOWA [DES MOINES]] is [[DES MOINES]] but we want [DES MOINES] to compare to the sentence typed to REQUEST. In this case, we would have been better off taking the LAST rather than the BUTFIRST. How do we resolve the problem?

The real problem is that the database :STATES has both words and lists as possible answers. This makes it difficult to check for equality.

If the answer-part of each element of the :STATES list was always a list, we could consistently choose the FIRST for the question, and the LAST for the answer.

So, we make states differently:

```
MAKE "STATES [[OHIO [COLUMBUS]] [[NEW YORK]
      [ALBANY]] [GEORGIA [ATLANTA]] [IOWA
      [DES MOINES]]]
```

And we redefine STATEQA

```
TO STATEQA :QLIST
 QA FIRST :QLIST LAST :QLIST
END
```

30. 'Tis all yours!

31. The changes would be in the form:

```
IF :CHAR = "F RUN.AND.RECORD SE "FD 10 * :MULTIPLE
IF :CHAR = "R RUN.AND.RECORD SE "RT 15 * :MULTIPLE
IF :CHAR = "L RUN.AND.RECORD SE "LT 15 * :MULTIPLE
```

There are two subtleties. One is that the command lines read:

```
IF :CHAR = "F RUN.AND.RECORD SE "FD 10 * :MULTIPLE
```

and not (more simply)

```
IF :CHAR = "F RUN.AND.RECORD [FD 10 * :MULTIPLE]
```

The reason is that although the second version will RUN correctly, the command that will be LPUT on the history list will be, literally, [FD 10 * :MULTIPLE] rather than the desired [FD 30] or whatever it is.

RUN and REPEAT are the only primitives that are capable of evaluating what is inside a list. Everything else just treats it as text without meaning.

Also, remember that TOGGLEPEN must be edited to record its ups and downs.

32. Lines like IF :CHAR = "< RCIRCLE :SIZE would be needed, but you must provide the mechanism for setting :SIZE just as you had for the forward and turning commands.

If you allow ARC (first introduced in the section on OUTPUT) to take an angle input as well as the two it now takes, SEGMENTS and CHORD, the new procedures RCIRCLE and LCIRCLE can then be defined by using ARC with angles of 18 and -18 respectively.

33. The procedure itself is very straightforward. It depends on lists of the verbs, nouns, proper names, and so forth.

So far, procedures to output verbs and proper names have been created, as has a global variable containing adverbs. The following definition of MADLIB further assumes procedures NOUNS and ADJECTIVES that must be created on the model of ACTIONS and PEOPLE.

```
TO MADLIB :TEXT
 OP MAD "V ACTIONS MAD "N NOUNS MAD "PN
        PEOPLE MAD "ADV :ADVERBS
        MAD "ADJ ADJECTIVES :TEXT
END
```

34. With the example that was given, all that is needed is to check both the words themselves (i.e., PN LOVES PN<comma> BUT PN CAN'T STAND PN<period>) and the butlast of the words (i.e., P LOVE PN BU P CAN' STAN PN). All of the PNs will be caught this way. The test

```
IF BL FIRST :CONTEXT = :KEY
```

will do that job. If the butlast of the word is KEY, then the last will be the punctuation mark. By picking an alternate and wording the punctuation mark to the end of it,

```
WORD PICK :ALT LAST FIRST :CONTEXT
```

the original punctuation has been restored. Finally, this word must be integrated into the developing sentence just as if the punctuation problem had not occurred.

```
OP SE WORD PICK :ALT LAST FIRST :CONTEXT
   MAD :KEY :ALT BF :CONTEXT
```

Altogether the new line of the procedure is:

```
IF BL FIRST :CONTEXT = :KEY
      OP SE WORD PICK :ALT LAST FIRST :CONTEXT
         MAD :KEY :ALT BF :CONTEXT
```

There is a problem. What if one of the keywords were N, as in problem 33, and one of the words of the sentence were "NO"? Butlast of the word NO would falsely match the keyword, and NO would be replaced with a noun!

A more complex and sophisticated procedure could be written, but the best solution is to make keywords clearly distinct from text. If keywords all began with some non-text character, so that they could never be generated from a text word (as happened when N was generated from NO), the problem would be solved.

Recommendation: Begin keywords with <period>.

Thus, madlib sentences would look like this:

```
[.PN LOVES .PN, BUT .PN CAN'T STAND .PN.]
```

Note that MAD never tests for the special keyword marker. The marker just serves to prevent mishaps.

Does the order in which the tests are performed matter?

```
TO MAD :KEY :ALT :CONTEXT
 IF :CONTEXT = [] OP []
 IF ( FIRST :CONTEXT ) = :KEY OP SE PICK :ALT
                          MAD :KEY :ALT BF :CONTEXT
 IF BL FIRST :CONTEXT = :KEY OP SE WORD PICK :ALT
    LAST FIRST :CONTEXT MAD :KEY :ALT BF :CONTEXT
 OP SE FIRST :CONTEXT MAD :KEY :ALT BF :CONTEXT
END
```

35. Let's title the procedure this way.

```
TO MADLIB :TEXT :KEYS
```

The logic is that if there are no keywords at all to find and replace, then the text must be returned as it is.

```
IF EMPTY? :KEYS OP :TEXT
```

If there are keys to replace, then

1) using the first of them, replace each instance of it in the text with a suitable alternative (this is accomplished by MAD) and

2) use that as the text in which to search for the remaining keys. This is the purpose of MADLIB, itself, and is thus the recursive step.

Worded more like the program, we are to output the MADLIB of and a list of the remaining keys.

Skipping over a detail, the Logo might look something like this:

```
OP MADLIB ( MAD FIRST :KEYS somethingorother :TEXT )
   BF :KEYS
```

The "somethingorother" needs some thinking.

In previous situations, the key words bore no relation to the procedures or variables that contained the corresponding lists. This is inconvenient, since there is no way to know from looking at the key word, just where to find its substitutes.

But that can be corrected. Abandon the old design of having V refer to a procedure ACTIONS, and ADV to a variable ADVERBS.

From now on, we must be consistent about using either procedures or variables. Further, the keyword will be the name of the variable or the title of the procedure.

Choosing to go with global variables, we can then say that if MAD's KEY is the first of MADLIB's KEYS, MAD's ALT will be the THING of the first of MADLIB's KEYS. MADLIB would then look like this:

```
TO MADLIB :TEXT :KEYS
 IF EMPTY? :KEYS OP :TEXT
 OP MADLIB (MAD FIRST :KEYS THING FIRST :KEYS
    :TEXT) BF :KEYS
END
```

If we chose to use procedures titled by KEY, then MAD's ALT would be the result of RUNning the first of MADLIB's KEYS.

```
TO MADLIB :TEXT :KEYS
 IF EMPTY? :KEYS OP :TEXT
 OP MADLIB (MAD FIRST :KEYS RUN (SE FIRST :KEYS)
    :TEXT) BF :KEYS
END
```

The most important element here became the willingness to abandon some old designs and rethink the relationship between parts of the problem.

36. GREET needs to look at what OUTPUT.NAME gives it and determine, first, if the result is a name or a response. Here is a possible method:

```
TO RESPOND :NAME.OR.PHRASE
 IF WORD? :NAME.OR.PHRASE GREET
 :NAME.OR.PHRASE STOP
 PRINT :NAME.OR.PHRASE
END

TO FRIENDLY
 PR [WHAT'S YOUR NAME?]
 RESPOND OUTPUT.NAME REQUEST
END
```

37. Just before the neutral answer (OP [I WAS JUST CURIOUS]) the procedure must look for negatives, and should respond appropriately if it finds any.

```
IF FIND? [WON'T NONE DON'T NOT NO] :SENT OP
  [SORRY I ASKED]
```

FIND? is simply a fancy MEMBER?

```
TO FIND? :ITEMS :LIST
 IF EMPTY? :ITEMS OP "FALSE
 IF MEMBER? FIRST :ITEMS :LIST OP "TRUE
 OP FIND? BF :ITEMS :LIST
END
```

38. Any of a number of strategies will work. Be of good cheer! The task of deciding which approach to take should be simple for anyone who has gotten this far.

39. If punctuation only comes at the ends of words, removing it is quite simple.

```
TO NOPUNC :WORD
 IF MEMBER? LAST :WORD [" , . ! ?] OP BL :WORD
 OP :WORD
END
```

A more general solution, more powerful but slower, is:

```
TO NOPUNC :WORD
 IF EMPTY? :WORD OP "
 IF MEMBER? FIRST :WORD [" , . ! ?] OP NOPUNC BF
    :WORD
 OP WORD FIRST :WORD NOPUNC BF :WORD
END
```

In either case, change FIRST :S to NOPUNC FIRST :S throughout the CHECK procedure.

41. Sorry. From here on in, you are on your own!

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