YOUR FIRST TI 99/4A PROGRAM

Rodnay Zaks

"Yes . . . YOU can!"

YOUR FIRST TI-99/4A PROGRAM

YOUR

PRO

FIRST TI-99/4A GRAM

Rodnay Zaks

Illustrated by Daniel Le Noury

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Preface

Hundreds, perhaps thousands, of books have been written about programming.

Why another one? Simply because the audience has changed. In the past, using programming languages such as BASIC was the privilege of the few who had access to computers. Programmers were a small elite group. This is no longer the case. The majority of computer users today have little or no technical background. They use computers for fun, education, business, or their profession.

This book addresses this new group of users. Not only does it *look* different, but it *is* different. It is intended for the beginner and thus assumes that the reader has no prior technical knowledge. Personal computers have made BASIC the most widely used and most accessible computer language ever. This book is for everyone—whether aged 8 or 88—who wants to learn quickly how to get started in BASIC with their TI-99/4A computer.

The author believes that all new computer users who want to learn how to write their own programs in BASIC are enthusiastic and young, or young-at-heart. They want a simple, straightforward, educational approach to learning BASIC. That is the approach of this book: It is designed to make learning to program in BASIC on the TI-99/4A easy and fun.

Furthermore, this book aims at teaching you the essentials of BASIC in just a few hours. You should be writing your first BASIC program within one hour. And within a few hours, you should know enough to start writing useful and meaningful programs.

Time is passing . . . let's begin.

The author wishes you a pleasant journey along the magical path to knowledge.

Rodnay Zaks
Berkeley, September 1983

How To Read This Book

This is an educational book. You should read every chapter in sequence and understand each one before you continue on to the next. I have provided exercises at the end of each chapter to help you test your new skills. Do as many of them as you can. Answers to selected exercises are provided in Appendix C at the end of this book.

If you have a TI-99/4A computer, try all the programs. To truly learn and remember, you must practice and experiment. This book will bring you the skills and knowledge you need to get started—but remember, nothing can substitute for experience.

The main goal of this book is to get you started programming your TI-99/4A in BASIC quickly and effectively. To achieve this goal and make your path simple, I have had to make choices; therefore this book does not describe every feature or concept of BASIC—just the important ones.

It is my hope that with this book you will understand everything quickly, and that in no time at all you will be writing your first BASIC programs, and appreciating and enjoying the power of your new programming skills.

What You Will Learn

Chapter One explains the language of computers and introduces you to the heroes of this book: the Computer, the Interpreter, the Program, the Instructions, and other characters of the cast.

Chapter Two shows you how to communicate with your computer, using the resources of the keyboard and the display. You will learn to type your first BASIC programs and execute them.

Chapter Three shows you how to perform calculations with BASIC.

Chapter Four helps you write programs that can be used repeatedly. In addition, you will learn how to use variables correctly and effectively.

Chapter Five shows you how to make your programs clear and readable.

Chapter Six shows you how to make complex decisions based on logic and values.

Chapter Seven explains how to automate repetitive tasks, using program loops.

Chapter Eight shows the correct method for designing a program from the algorithm to the working, documented program—including designing the flowchart.

Chapter Nine helps you apply all these concepts to a practical case study.

Chapter Ten helps you examine the next step to programming expertise.

The appendices A, B, and C offer answers to selected exercises, a list of common reserved words, and a glossary.

If you are ready, let's open up the family album and I'll introduce you to the heroes of this book . . .
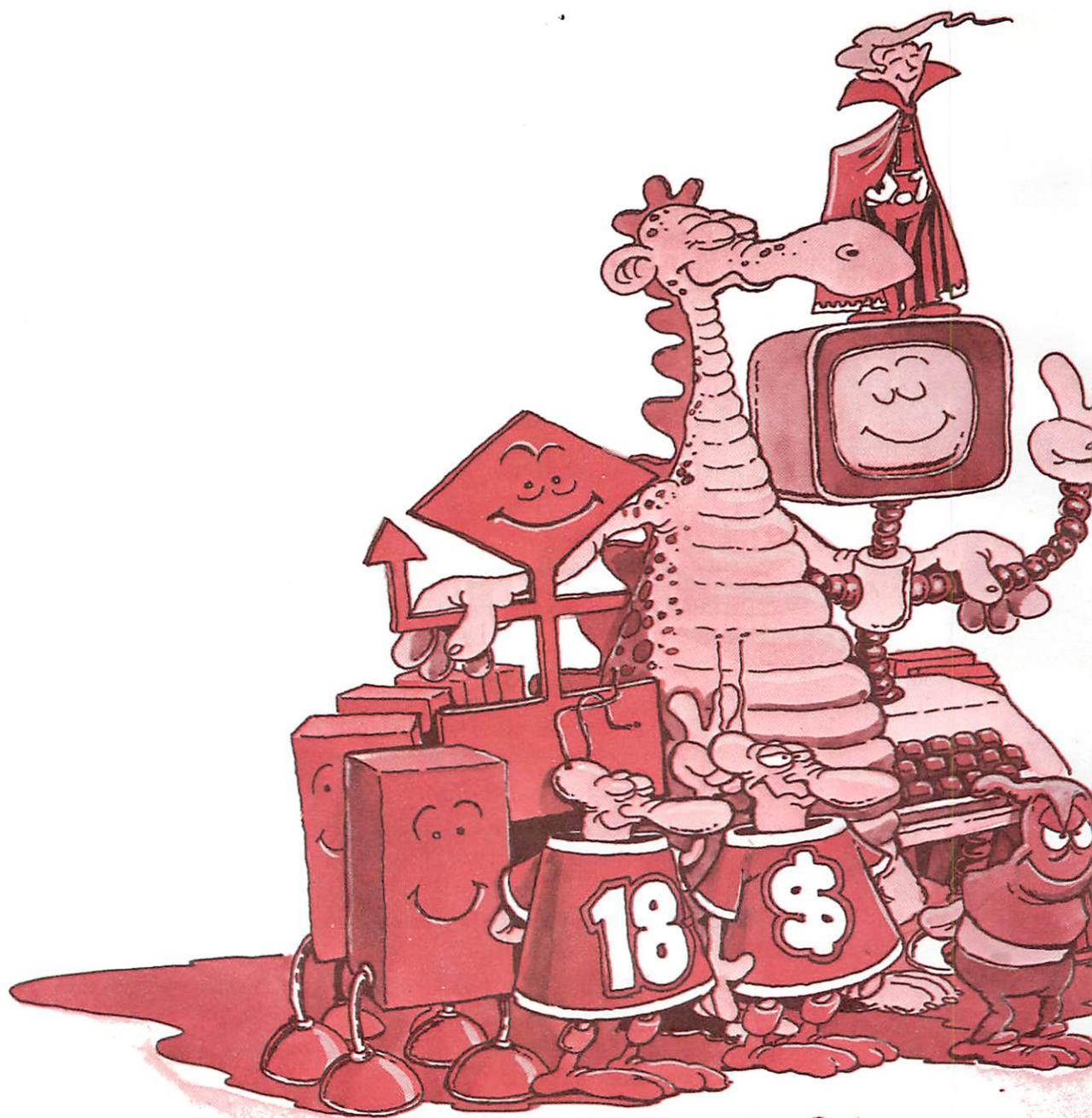
Meet Our Heroes

Featuring (going clockwise): Dino the Programmer, the BASIC Interpreter standing on his friend the Computer, the Program Snake, the mischievous Bug, two Variables, Program Instructions ready to walk to their assigned spot, and the indispensable flowchart on which Dino rests . . . Oops, our bug seems to be up to something!
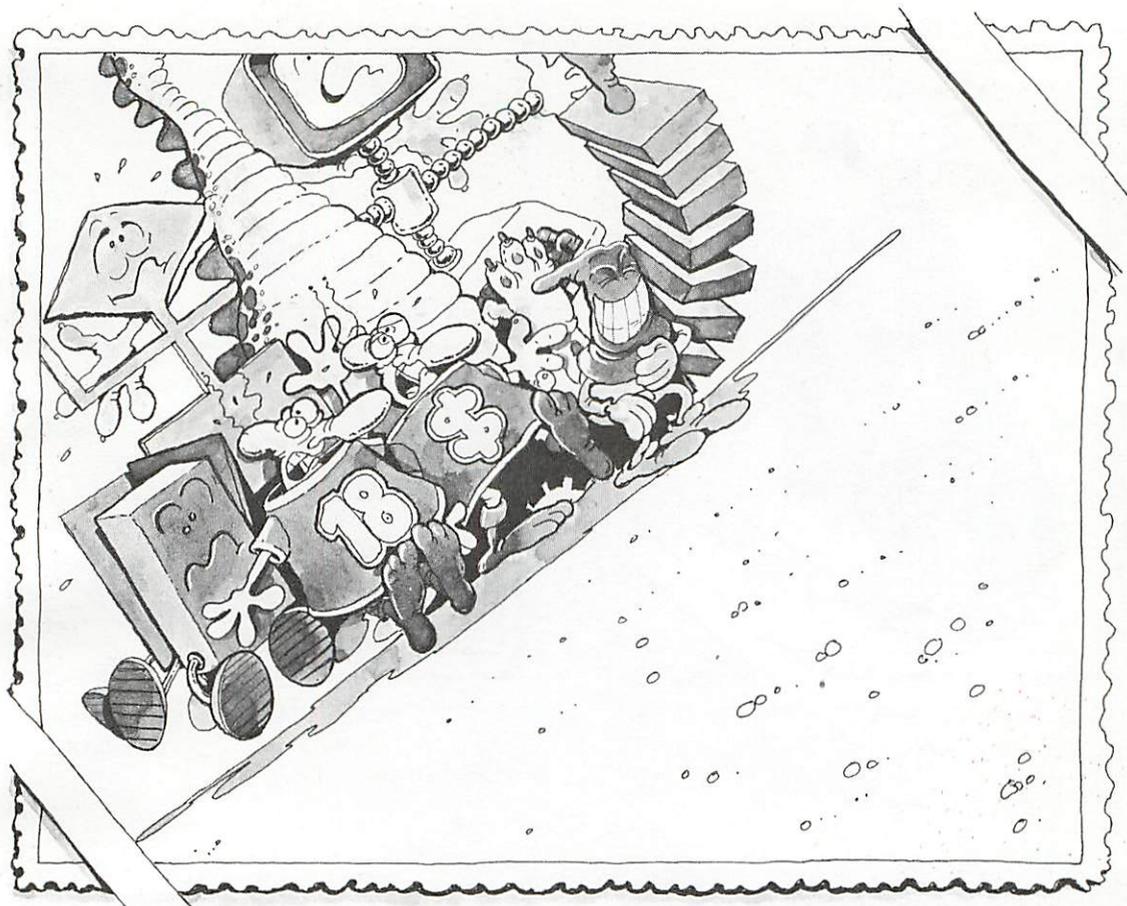
Sorry . . .
our mischievous
Bug did it again.
So much for
a group shot. . .
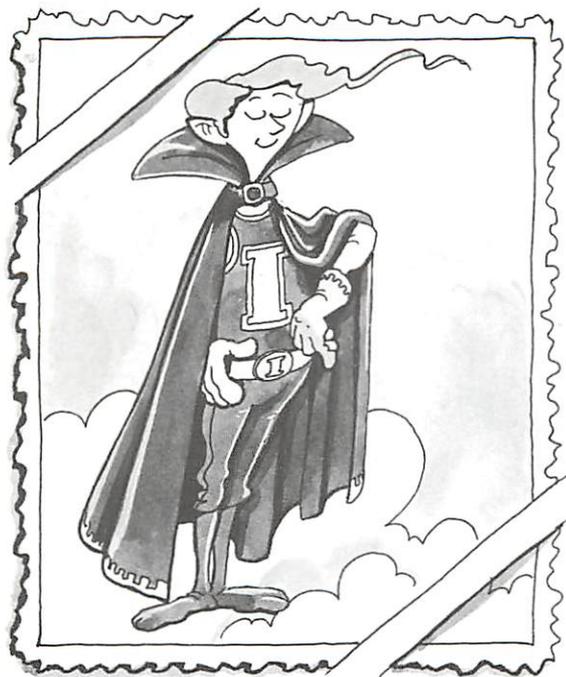
This is the BASIC Interpreter. When awake, he resides in your Computer's memory. His job is to translate your instructions to the computer. He will help you in any way he can.

Never forget this face. This is a Bug. He will make your life miserable. Do your utmost to keep him away from your programs.
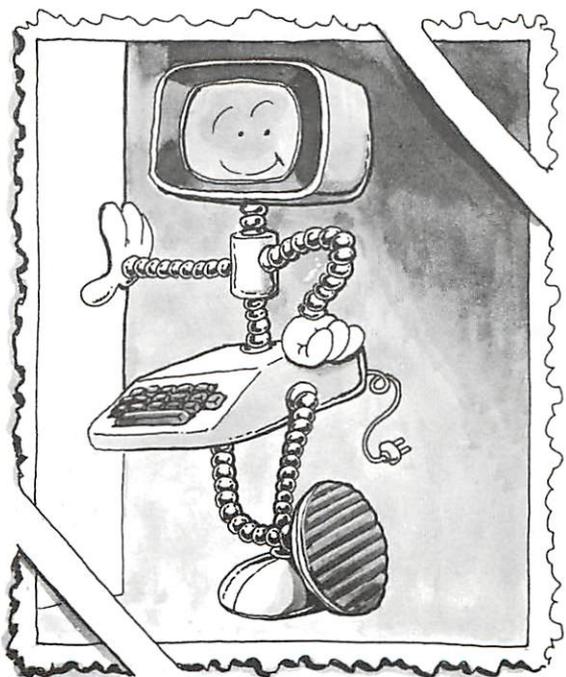
This is your friend the Computer—at your command.
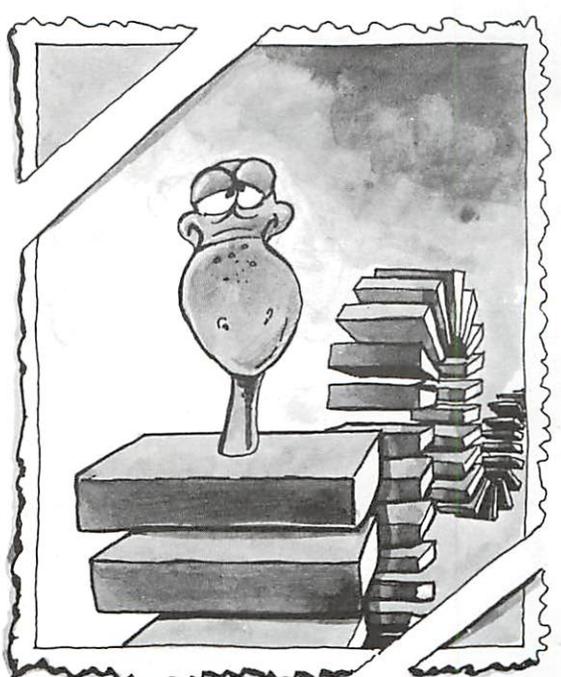
No, this is no monster—it's the Program Snake. He's made up of instructions. You'll learn to assemble him. He's very tame once you know him. Just keep Bugs away from him.

The Family Album
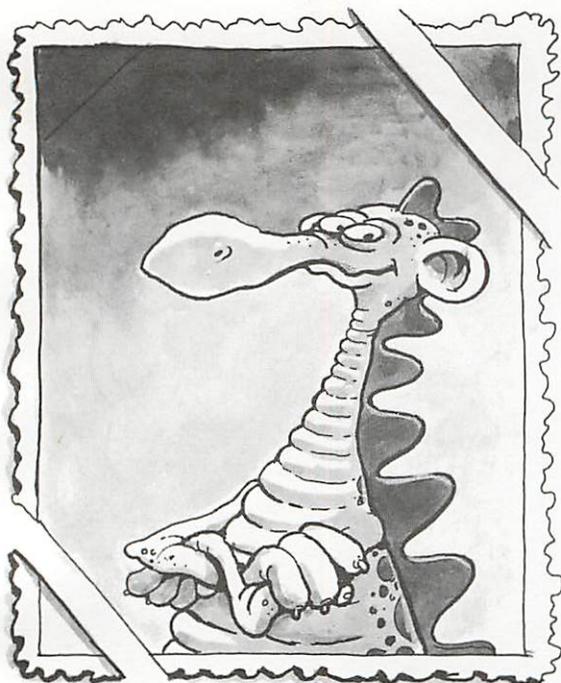
This is Dino. He's friendly and, although he has no formal education, he will show you how simple it is to write BASIC programs.
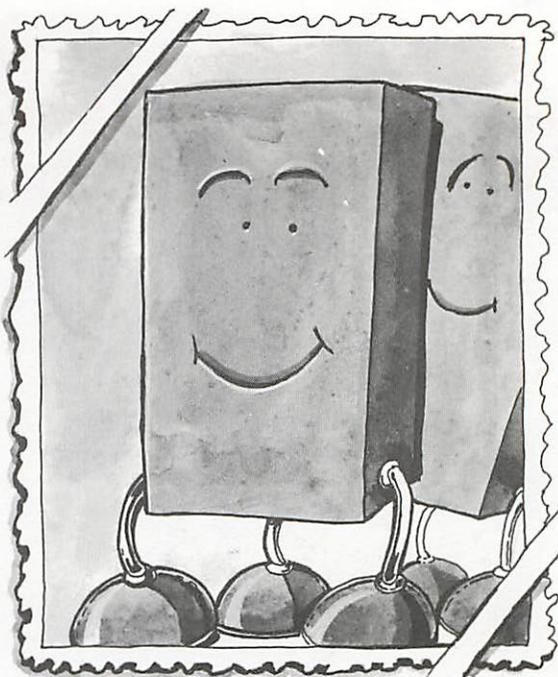
Here are the BASIC instructions, ready to join the Program Snake.

This is a numeric variable. His coat is labeled with his name, and he has a value imprinted on him. He's unhappy because he wants to go back to his reserved box in the memory.
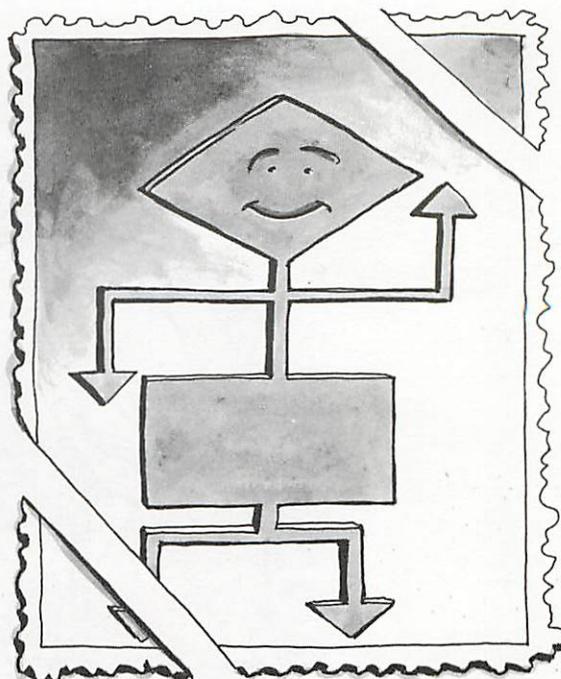
This is your best friend, the Flowchart. He'll help you design programs that work.

Speakin

g BASIC

1

I claimed in the preface that "You will be writing BASIC programs within one hour."—so, why start with a chapter on concepts and definitions? Aren't we wasting time? On the contrary: Our purpose is to *learn* and *retain* information, and true learning requires depth of understanding. The information presented in this chapter will help you better understand what programming is, how a BASIC program is executed, and the vocabulary of computers.

Before we begin writing our first program, there are a few important definitions and concepts you should learn. Once you understand these terms, I can explain *what happens* and *what to do,* in a simple yet

accurate manner, and you should be able to follow along easily. So read this chapter carefully to ensure that you truly understand what you are doing—and won't just be hitting keys.

We will begin by learning how to give instructions to a computer—this is called *programming.* Next, we will explain the need for *programming languages,* such as BASIC. Then we will discuss what a BASIC *interpreter* is, and we will explore the history of BASIC, its *dialects* and its uses. Finally, we will examine the components of a *computer system* and learn some of the technical jargon used to describe these components.

Programming

Your computer is a machine designed to process *information*—both textual and numerical. For example, you can make your computer display words and sentences on a screen—this is known as *text processing*—or you can make it convert a weight expressed in ounces into its value in grams—this is known as *numerical processing.* In order to make your computer perform this processing, it is necessary to issue instructions in a format or "language" it understands. Each computer can only "understand" (i.e., recognize and execute) a small number of different instructions (say, a few hundred).

Instructions that a computer can understand directly are called *machine language* instructions. These instructions are stored in *binary* format, i.e., in groups of 0's and 1's in the computer's memory. Each 0 or 1 is called a *bit,* and a group of eight bits is called a *byte*.

A sequence of instructions that accomplishes something useful is called a *program.* (A sequence of instructions that accomplishes nothing is an *error.*) Your computer executes a program by executing each instruction in turn. Unfortunately, writing a computer program (a sequence of instructions) in machine language, i.e., in binary form, is a slow and tedious process.

Ideally, we would like to be able to give spoken or written commands in everyday language (say, in English) to the computer and have it execute them. But, this is not possible since a computer cannot understand any of the usual languages—whether spoken or written. The reason for this is quite simple: A computer executes orders strictly and exactly; it is logical and precise; and it requires

Learn how to give instructions to your computer!
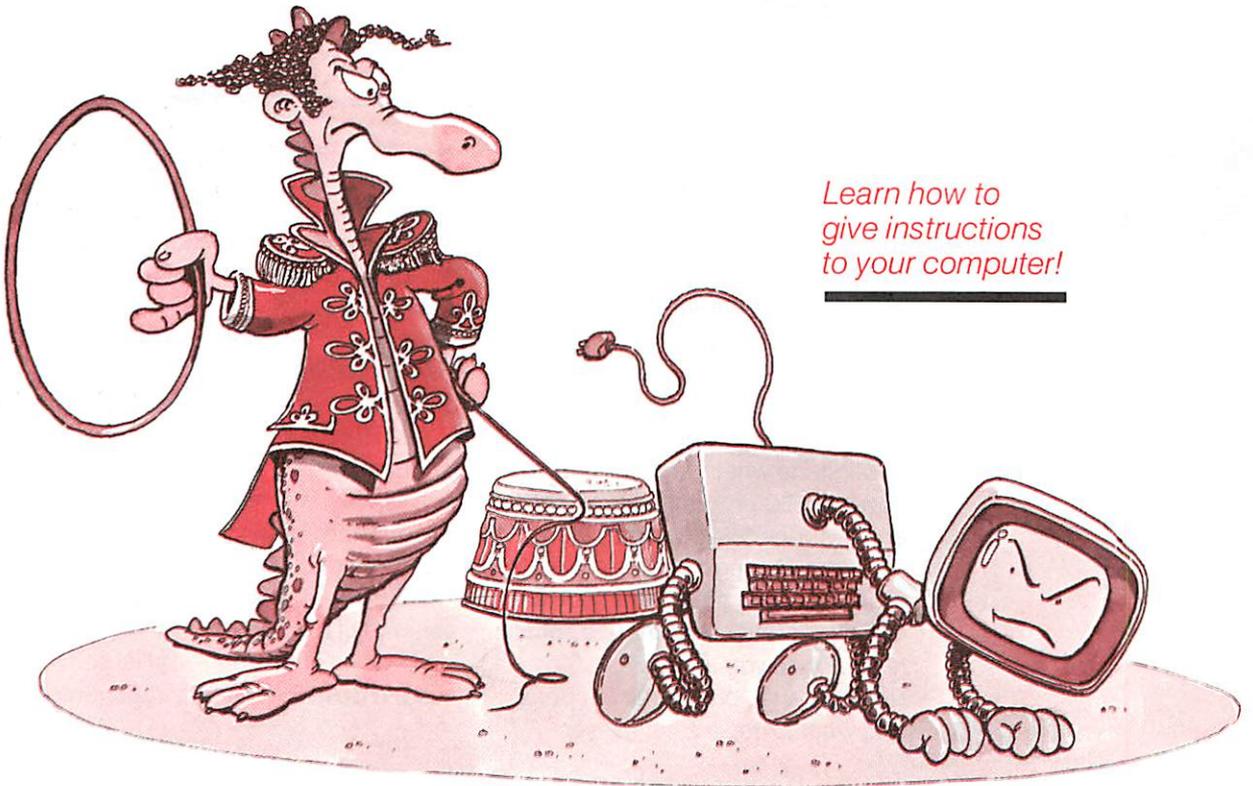
clear, unambiguous instructions in the proper sequence and form. The problem with a spoken language lies in the language itself— sentences can be ambiguous and often their meanings can depend on context, such as facial expressions or gestures. This type of communication cannot be interpreted by a computer.

Even carefully written English remains insufficiently precise for a computer. For example, you cannot tell a computerized robot to "go to the kitchen and boil an egg," and expect results, unless the robot has been programmed to know its way around your kitchen. A robot has to be trained (or programmed) before it can operate in an environment like ours. And, even if a robot is trained to know its way around *your* kitchen, it may not be successful in a friend's kitchen, because things may be located in different places. Remember, communication with a computer must be clear, precise and unambiguous.

It is for this reason that simplified "languages" were invented to communicate with computers. Recall that the binary language (also known as machine language) is the easiest language for a computer to understand. However, this language is hardly practical for people. Therefore, other languages have been invented to facilitate communications. These languages resemble common English and are called *high-level languages*.

For effective and clear communication with a computer, only a limited number of English words may be used, as predefined commands. In addition, sentences or *statements* that specify instructions to a computer must obey strict grammatical rules, called the *syntax* of the language. The combination of a restricted vocabulary and a syntax is called a programming language. BASIC is one such language.

In summary, a *programming language* is a collection of rules (the syntax) and words and symbols (the vocabulary) that allow you to issue instructions to a computer in a format that can be understood exactly. A sequence of such instructions is called a *program*.

Here is an example. Suppose we want to

```
add   2 + 2
```

and display the result. Using BASIC, we would write:

```
1   R = 2 + 2
2   PRINT  R
```

where R stands for "result."
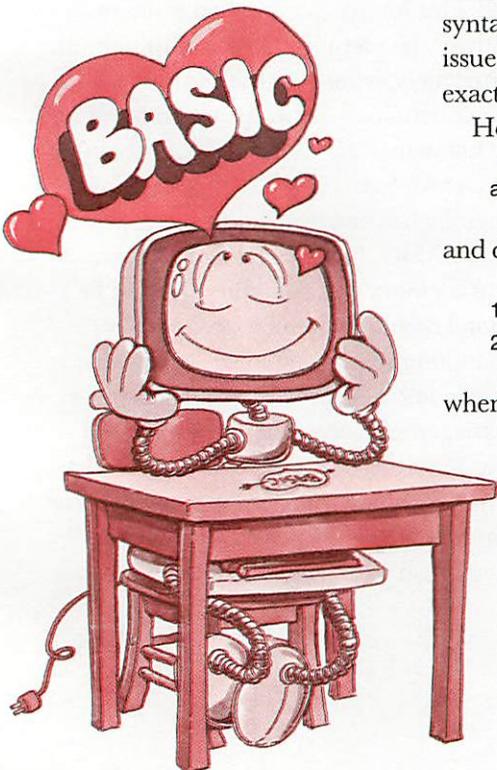
*"I love BASIC!
Please speak BASIC to me."*

3
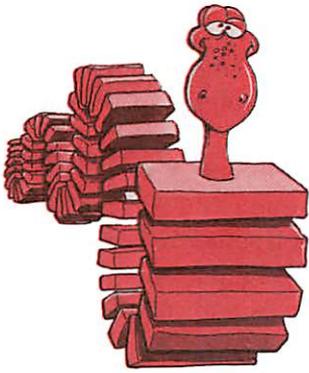
But wait . . . we said earlier that the only language that a computer can understand directly is *machine language;* and we are now issuing instructions to a computer in a language close to English. Isn't there a contradiction?

There is no contradiction. Indeed, the bare computer cannot understand BASIC directly, or for that matter, any other high-level programming language (a language that uses English-like sentences). Therefore, to be understood by a computer, a program written in a high-level language, such as BASIC, must be *interpreted* by a special program, called quite appropriately an *interpreter.* In other words, you speak BASIC to your computer via an interpreter. Therefore, in order to execute a BASIC program, your computer must have a BASIC interpreter. Let's now learn what an interpreter does.

The BASIC Interpreter

A BASIC interpreter reads each BASIC instruction you type at the keyboard, analyzes it, and uses its own special procedures to carry it out. This process is completely invisible to you (i.e., it takes place inside your computer). Once you activate the interpreter program on your computer, for all practical purposes, your computer can speak BASIC. Your computer can speak other programming languages as well (if the appropriate interpreters are provided).

There are several kinds of BASIC interpreters. Here we will explain the type you have on your TI-99: a resident interpreter.

A *resident* BASIC interpreter is provided on most small computers, including your TI-99. This interpreter is called resident because it resides permanently in the memory of the computer. On the TI-99, it is available immediately, whenever the computer is turned on. Once the BASIC confirmation symbol (or *prompt* ($>$)) appears on your screen, you know that the computer is ready to execute your BASIC instructions for you.

A resident interpreter generally has one drawback: it can provide only a minimal version of BASIC. Since a resident interpreter is "built-in" to the permanent memory of a computer, it must be kept small in size, since the total memory size of a computer is limited. The memory of a computer must contain the programs, including the BASIC interpreter, and also provide sufficient space for computations, system management, and data to be operated on. These space requirements limit the size, and therefore restrict the complexity, of the resident interpreter. On computers that come with a small amount of memory, the resident interpreter is often a "tiny BASIC" that imposes limits on what you can do with it.
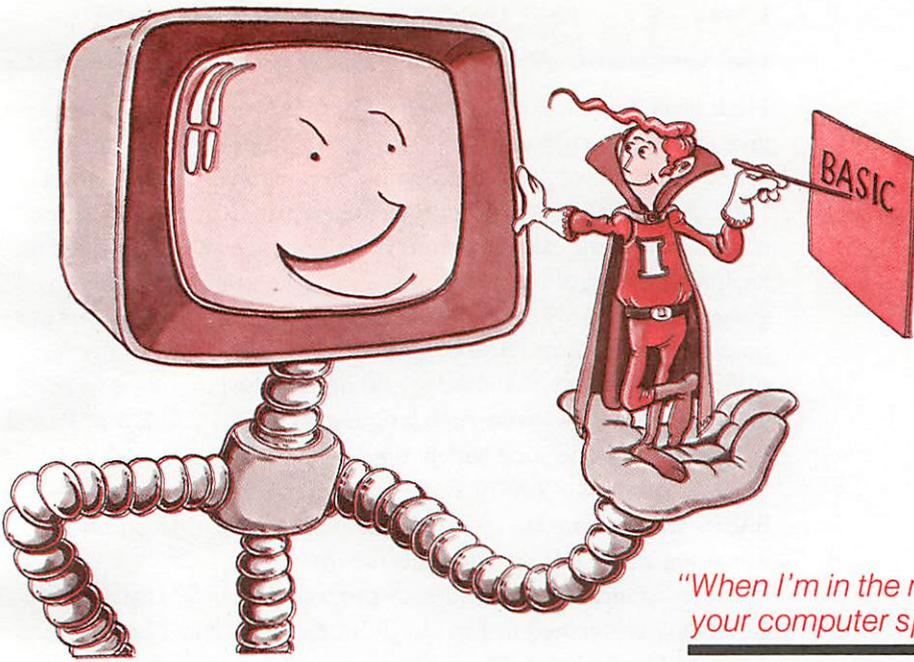
*"When I'm in the memory,
your computer speaks BASIC."*

A "mini" or "tiny BASIC," therefore, has fewer features and conveniences than a "full" or "extended BASIC." A usual limitation of a "mini-BASIC" is that it operates on integers only; that is, it does not handle fractional numbers. Such a version of BASIC is also called an "integer BASIC." By contrast, an improved version of BASIC that also handles fractional numbers is called a "floating-point BASIC." This feature is highly desirable if you plan to do computations.

The BASIC interpreter resident in your TI-99/4A has some of the features found in more powerful, *full* or *extended* BASICs, including floating-point notation. It is sufficient for learning how to program in BASIC, at least for the purposes of this book. Later on, if you learn to write more complex programs, however, you may find that you want facilities not provided by the TI-99/4A resident BASIC interpreter.

Let us now explain what BASIC is, how it was invented, and the resulting dialects.

What is BASIC?

High-level languages were invented to make it easier for a user to give instructions to a computer, that is, to program it. Over the years, hundreds of programming languages have been invented.

In the early days computers were used primarily for scientific purposes, and the early programming languages were designed to facilitate numerical computations. Thus, the granddaddy of languages, FORTRAN ("FORmula TRANslator"), was designed purposely to specify numerical computations. FORTRAN, however, suffered from many drawbacks, and many new languages were invented. BASIC was one such language; COBOL, APL and Pascal were others that became widely used.

The invention of BASIC represented a major breakthrough. BASIC was designed to be simple and easy to learn. In addition, it was *interactive*. Let's see what this means.

BASIC stands for **B**eginners **A**ll-purpose **S**ymbolic **I**nstruction **C**ode. It was invented in 1964 by John Kemeny and Thomas Kurtz at Dartmouth College, working under a National Science Foundation grant. The goal of the authors was to design a language that could be used easily by a beginner. They succeeded in reaching this goal. To this day, BASIC is one of the easiest programming languages to learn.

Because BASIC was designed to be interactive—in fact it was the first interactive language—a user could interact with the program at a terminal, rather than submit batches of perforated IBM cards, as with older languages. BASIC originally ran on the GE225 time-sharing system at Dartmouth College. Terminals were available throughout the campus, and many users could access the computer simultaneously.

The success of BASIC was rapid. General Electric (GE) immediately decided to use it commercially. Kemeny and Kurtz published the first book on BASIC in 1967. And, Hewlett Packard (HP) and Digital Equipment Corporation (DEC) decided to make BASIC available on most of their computers.

BASIC offers two major advantages over languages like FORTRAN:

1. **For a user:** BASIC is the easiest language to learn, *especially* for a beginner.

2. **For a manufacturer:** BASIC is the easiest language to provide on a computer. Since the language is simple, the interpreter is also simple and requires only a small amount of memory.

A third factor contributed to the enormous success of BASIC: the advent of low-cost microcomputers. When microcomputers became widely available in the late 1970's, BASIC became the universal programming language on these small computers. Because the BASIC interpreter for a simplified version of BASIC requires only 4K (4,096 bytes) of memory, even the smallest computers could accommodate a resident BASIC. (Remember that a resident BASIC refers to an interpreter stored in the permanent memory of the computer.) The larger more recent computers have larger memories (64K and more—where 1K refers to 1,024 bytes) and can, thus, provide more powerful versions of BASIC.

Today BASIC is used on almost all computers. Over the years manufacturers have added extensions and "features" to the language, so that today the BASIC language is probably the most non-standard computer language. No two BASICs are the same. In fact, BASIC has become a family of languages and is no longer a single language. Although many standards have been proposed, none has succeeded, and none is likely to succeed at this late date. Does this mean then that you must relearn BASIC on each computer? Not quite. Once you know the essentials of BASIC that are common to all versions, you can easily learn the enhancements that each version offers. All BASICs have essentially the same core of instructions. You will learn more about these instructions as you read on in this book.

Which BASIC?

The version of BASIC you will be using with your computer was developed by Texas Instruments (TI for short). In this book we will refer to this version as "TI BASIC."

As you type in and run the programs in this book, you will become skilled in the main capabilities of TI BASIC. More advanced features, such as color graphics and sound, will not be covered here.

Now that we understand more about programming languages in general and BASIC in particular, let's learn more about your computer and how it processes information.

Your Computer

Your computer processes information and communicates with you via a keyboard and a screen, plus maybe a printer. The *keyboard* is used to send information to the computer. Every time a key is
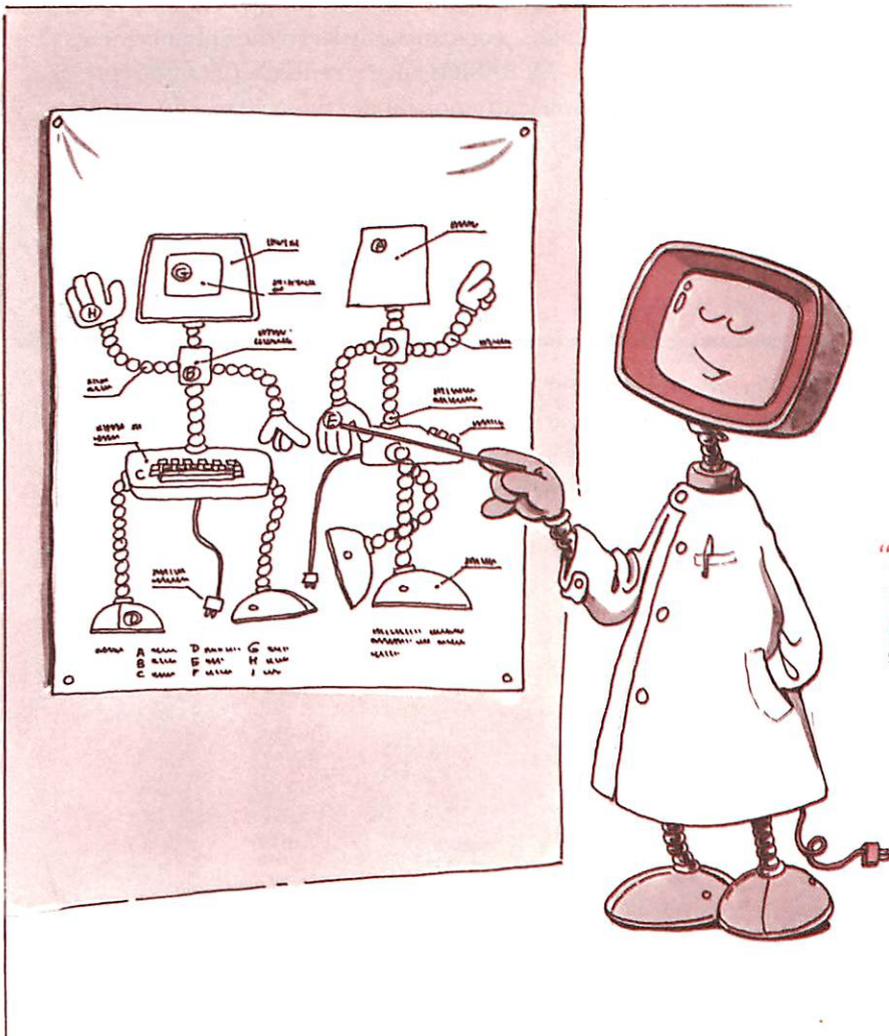
"I'm robust, helpful and friendly once you know me."

pressed, the electronic code corresponding to the character for that key is sent to the computer, where it is recognized and acted on, or ignored. The keyboard is your *input device;* it provides information to the computer.
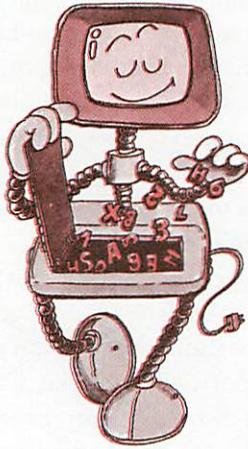
"This is my keyboard."

"I need an input from you to know what to do."

A television *screen* or *monitor* displays information generated by the program. Normally, each character you press at the keyboard will appear on the screen. It is first sent to the computer, then "echoed" to the screen. Generally, there is no direct connection between the keyboard and the screen. All communications go through the computer. This is illustrated below.
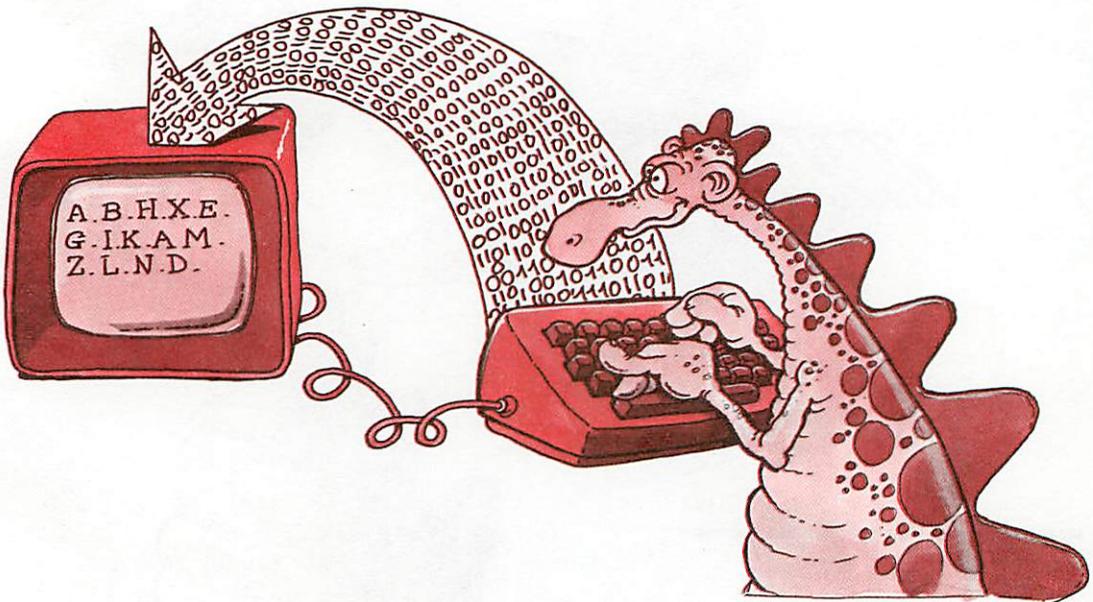
The keyboard sends information to the screen through the computer

With the TI-99/4A, the computer proper is integrated with the keyboard. The screen is separate. Depending on your investment, your computer system may also include a cassette recorder and/or disk units, and a printer.

Regardless of whether you have these extras or not, the computer proper includes a processing unit (the central processing unit), a memory, and several interfaces (the electronics for connecting printers and other devices). Let's examine these three elements.

The *central processing unit* (CPU) fetches program instructions, one instruction at a time, from the memory and executes them. The CPU requires few components. These components are called integrated circuits or "chips." All microcomputers use a *microprocessor* chip as the main element of the CPU. A typical chip is shown in the drawing below.

The *memory* stores the programs and all the information that the programs manipulate, read, or generate during their execution. To execute a program, the program must first be placed in the computer's memory. For example, if a program is originally stored on a cassette or a diskette, it must be transferred into the computer's memory. This is called *loading* the program. There must be enough memory inside the computer to accommodate the largest program size, plus the data the program will manipulate.

Two types of memories are present in your computer: ROM and RAM. The "normal" type of memory that you will use to store your program is the RAM or random access memory. RAM is a read/write memory: information may be written into RAM and read from it. A RAM looks just like the microprocessor shown below except that there is a different chip inside. Unfortunately, in
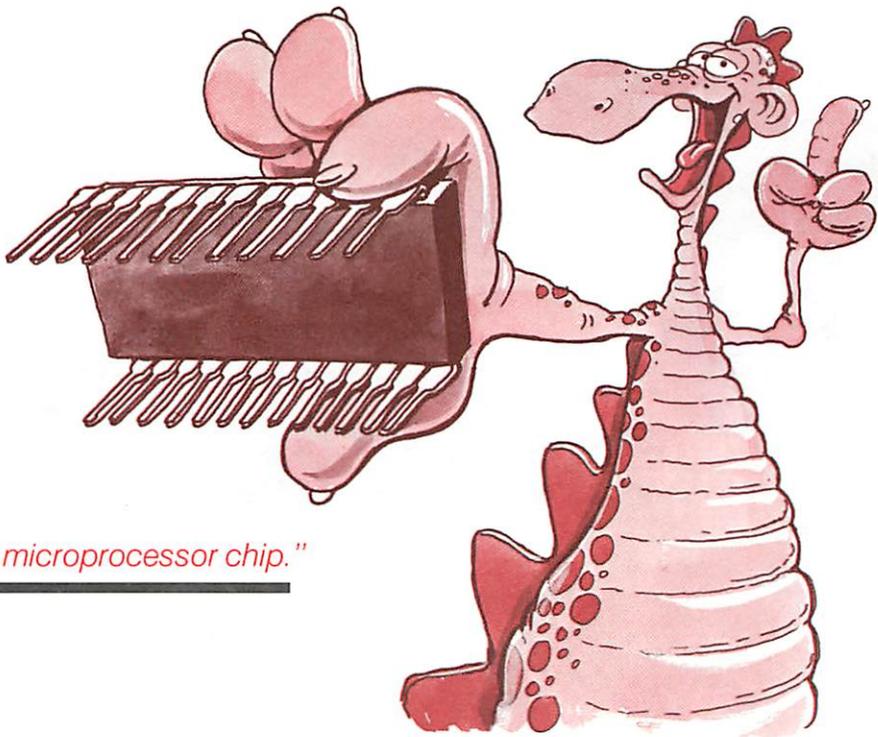
"This is a microprocessor chip."

the present state of the technology, this type of memory is volatile: the contents of RAM disappear once the power is turned off. This is why, at the end of a session, you must always store your program on a nonvolatile medium, such as a cassette or a diskette, if you want to keep it.

The TI-99/4A's BASIC interpreter is stored in the computer's ROM. *ROM* stands for read-only memory. This type of memory has been permanently loaded with programs by the manufacturer and cannot be changed. It is nonvolatile and is never erased. As well as the resident BASIC interpreter, it contains a special program, the *monitor*, which is needed to communicate with the computer once it is turned on.

If your ROM contains nothing, the computer would not know what to do when you pressed the keys on your keyboard. At a minimum, your ROM must contain a monitor. This program examines the information sent by the keyboard, and reacts to it by

Your computer will do nothing until you enter a program in its memory

11
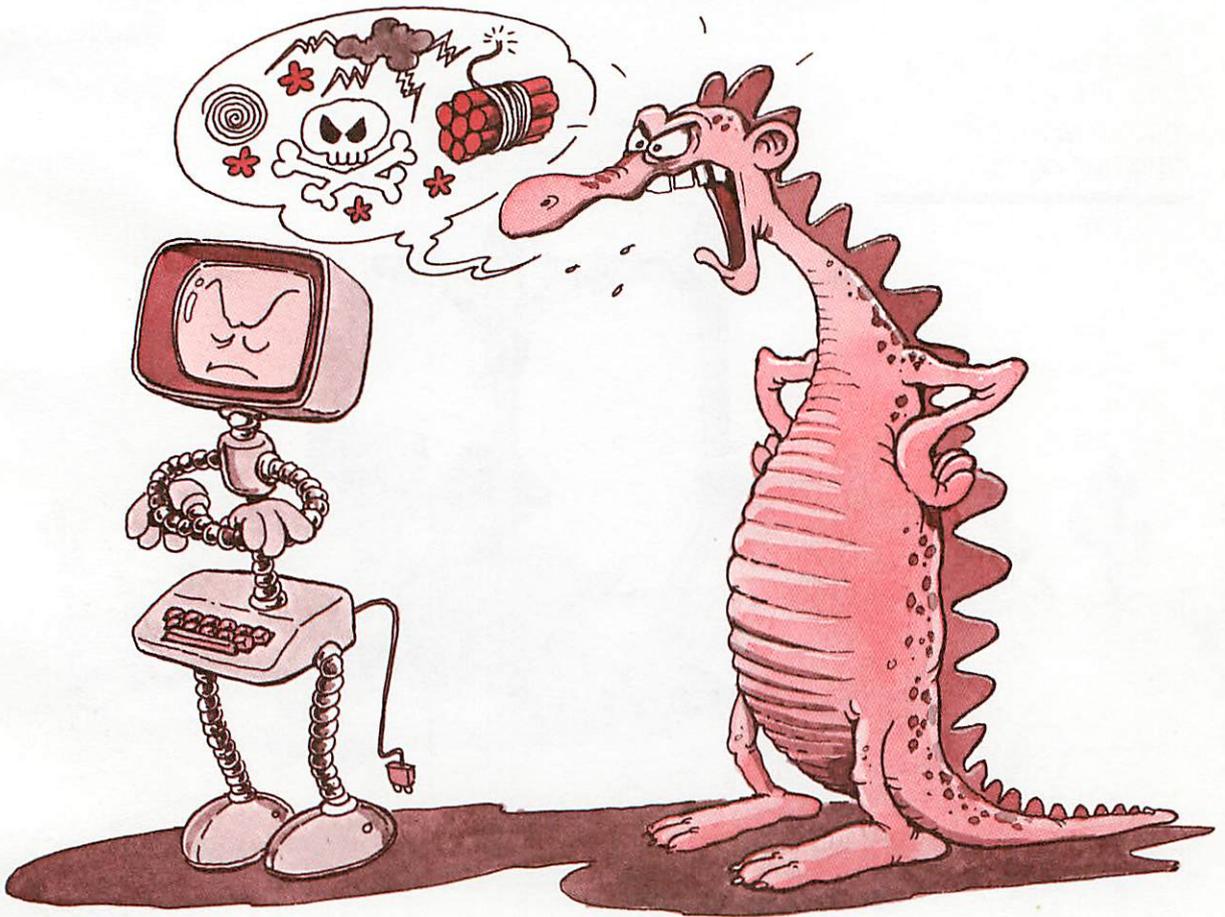
performing housekeeping actions, such as starting the resident BASIC interpreter or loading a program from a cassette.

You cannot use the ROM to store any other programs. All other programs that you enter on your computer are loaded into RAM. You can also purchase program cartridges for your computer. In these cases, the programs are stored in ROM chips inside the cartridge.

At least two additional devices are commonly connected to a computer: a mass memory and a printer. These devices connect through the *interfaces*—the electronics required to connect special devices. The mass storage device may be a *cassette recorder* and/or one or more *disk drives*. (**Note:** Both of these devices use a magnetic medium to record information and can store much more information than the internal electronic memory of the computer.) These special devices require a specific interface in the computer box that allows them to communicate with the computer. Your TI-99 computer has built-in interfaces (couplings) for a tape recorder and for the wired remote controllers ("joysticks"). However, a separate interface unit is generally required to connect one or more disk units to the computer. The TI Thermal Printer has the necessary interfaces built into it.

A printer is required to obtain a permanent printout of programs or results. A printer is an *output device,* just like a TV screen or monitor, and specific instructions are provided in BASIC to send information to either the display or the printer.

The monitor program runs all the time, ready to perform all common chores
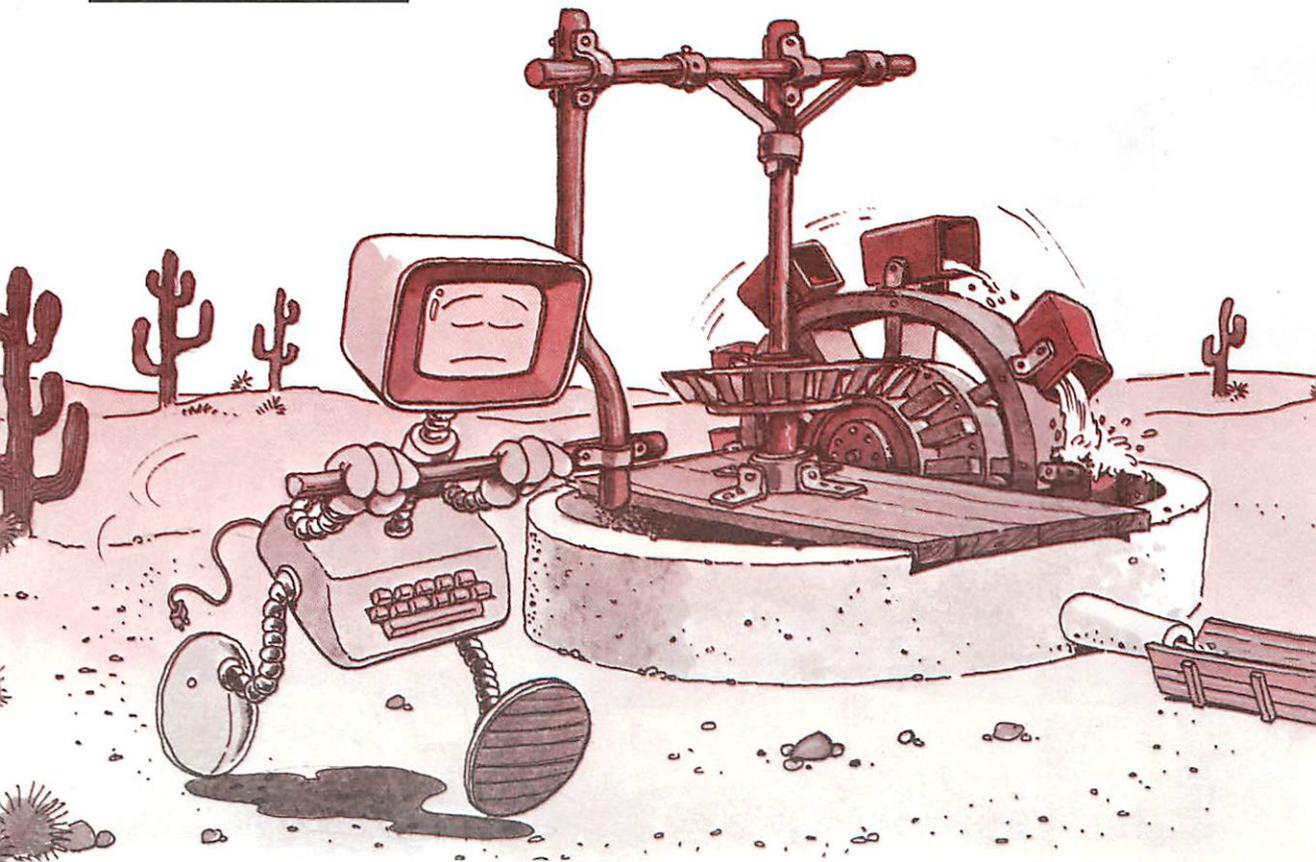
Finally, a *modem* is another device often used. A modem allows you to communicate with another computer or terminal over ordinary telephone lines. It is useful when using a commercial network or for accessing *data banks* (collections of information).

We have now learned the required vocabulary. Before we go on to Chapter 2 and start using the computer, *one word of caution is in order.*

Computers and Syntax

Computers are fast, patient, and accurate. They do only what they are told to do, and they do it exactly. In order to communicate successfully with your computer you must be exact. If you make an error or a mistake in writing a BASIC instruction, you will not damage anything in the computer, but your program will not execute successfully. It will generally stop and say: "syntax error."

Recall that the *syntax* is the set of rules that specify the correct way to write a BASIC instruction. Syntax rules are rigid. For example, you may not use an approximate spelling. If the rules specify a period, you may not use a comma or a semi-colon instead. Each character is rigidly interpreted by the computer and has a precise meaning. Any deviation will mean failure, or, at the very least, unexpected results.

Remember that if you do not obey the rules exactly, your program will probably not run. Do not attempt to be creative. The rules are simple, straightforward, and easy to follow when writing program instructions. It is best to save your creativity for the overall program design and for planning the tasks you wish to accomplish. In short, it is important that you carefully follow the instructions and recommendations given in this book.

"Remember . . .
be exact."

Communic
Your

2

In this chapter, you will learn how to communicate with your computer. You will learn to issue BASIC instructions and make the computer display words and sentences. The information exchanged between you and the computer will include programs (instructions in BASIC that you send) and data (the numbers and characters that you send or receive).

You will first learn how to use the keyboard of a computer, so that you can start sending instructions. In particular, you will learn how to move the cursor around the screen, and how to correct typing errors. You will then issue your first instructions in BASIC and make the computer display messages on the screen. You will learn the difference between *immediate* and *deferred* execution. Finally, you will learn the steps involved in writing a simple program and in executing it.

By the end of this chapter, you should be familiar with the basic skills required to communicate with your computer.
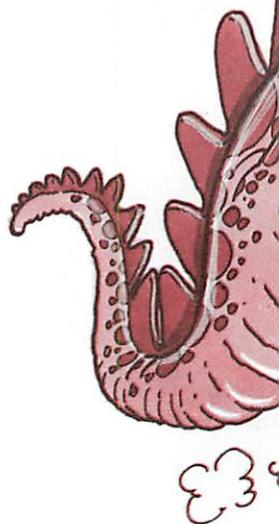
ating with
Computer
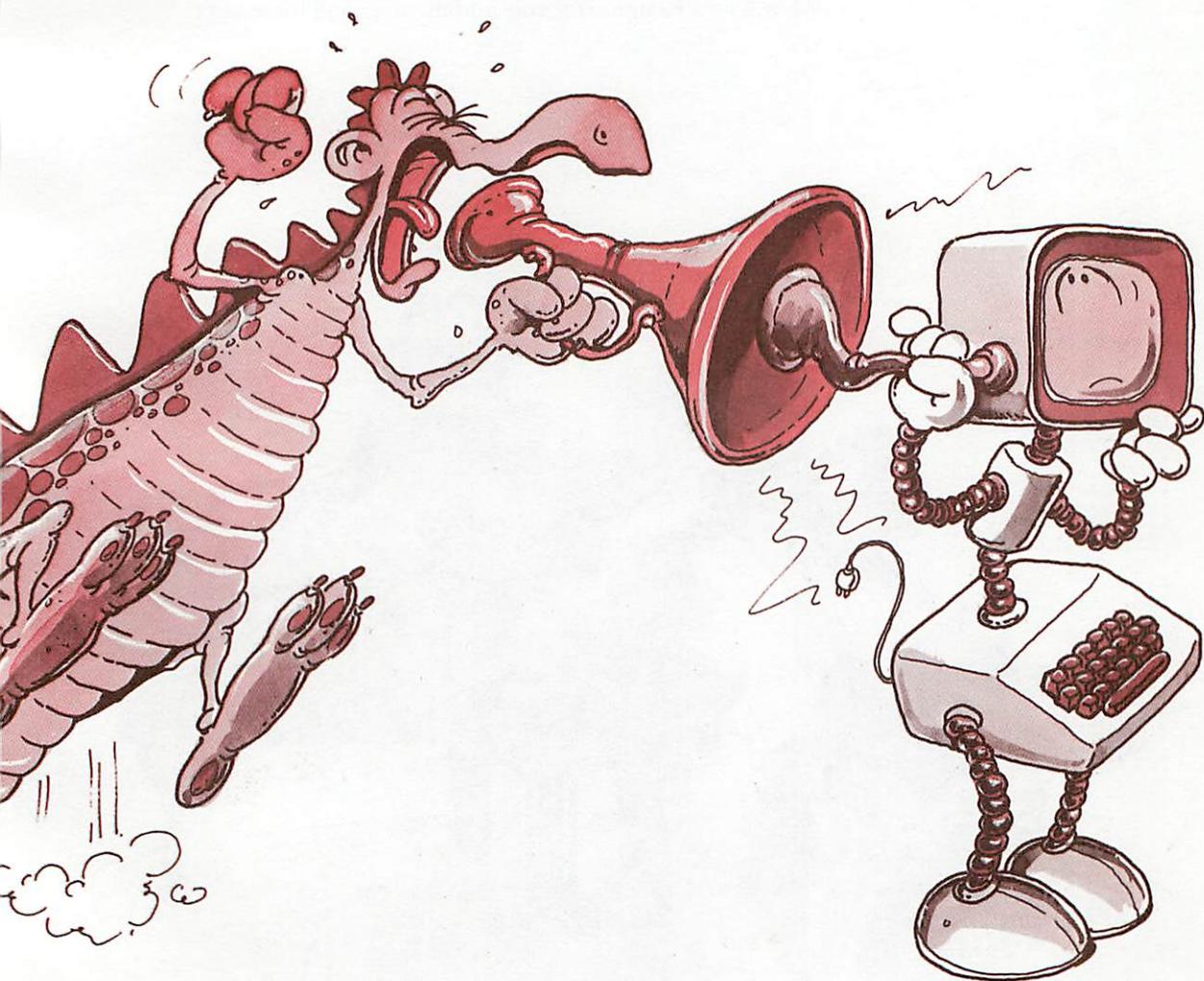
Using The Keyboard

The TI-99's keyboard looks just like a regular typewriter keyboard, except that it has extra keys. Most of its features are similar to those found on other computers, but it does have a few unique ones. The main keys are:

1. the letters of the alphabet (A through Z)

2. the digits 0 through 9

3. symbols, such as = , + , ∗ , ", and $

4. a "carriage return" key marked ENTER

5. a SHIFT key and a "control" key marked CTRL

6. a "function" key marked FCTN and an ALPHA LOCK key.

We will now examine the role and the use of all these keys.

*Learn about
the keyboard*
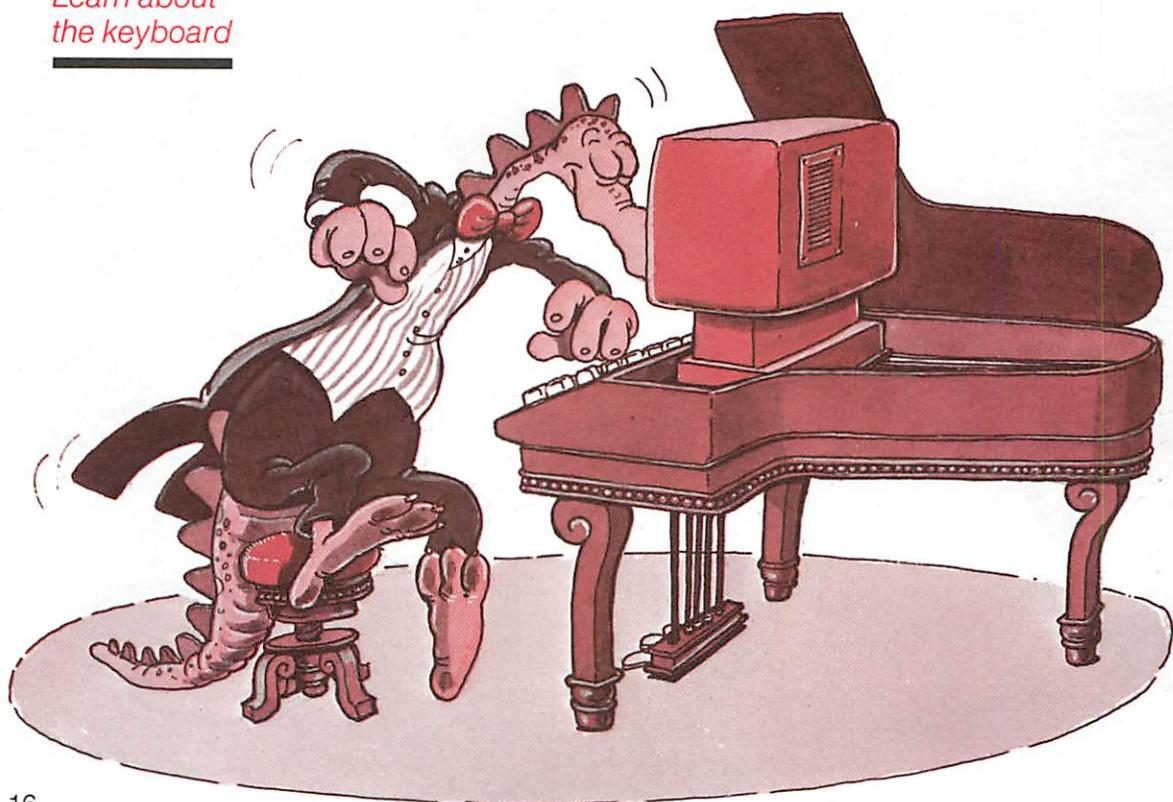
Characters, Numbers, and Symbols

The purpose of each *letter, number,* and *special symbol* key is obvious. These keys are used for the same purposes as on a regular typewriter.

Enter (Carriage Return)

On a typewriter, the carriage return lever or key performs two actions: it returns the carriage to the beginning of a line, and it advances the paper to the next line. Hence its name. On your TI-99, however, the ENTER key moves the *cursor* to the beginning of the next line on the screen. (The cursor is a blinking, black square that indicates the next position at which a character will be displayed on the screen.) It is called the ENTER key, because its main function is to ENTER a character or a line of text or data into the computer's memory.

In any case, each instruction to the computer, including BASIC instructions, must be terminated with an ENTER. The ENTER means, "enter the line into memory." In fact, anything you type on a line is ignored by the computer until you press ENTER. This way, you can correct any errors you may have made, before you enter the line into the computer's memory.

ENTERs are used only at typing time. Although necessary, an ENTER is not stored as part of a program instruction. In this introductory chapter, to help you learn, we will show all the characters you must type, and display a symbol indicating ENTER at the end of each line. This symbol will appear as ⇁.

Remember: you must press the ENTER key to transmit an instruction to the computer or else nothing will happen. Similarly when the computer later asks you for values, you enter each response by pressing ENTER as well.

Shift

The SHIFT key works similarly to the one on a typewriter. It allows you to shift between the upper- and lowercase symbols that appear

on the keys. Except for the letter keys, most keys have two symbols printed on them, a lower one and an upper one. As long as you don't press the shift key, the lower symbol will be generated when the key is pressed. When you press SHIFT together with a key, the upper symbol will be generated. With the letter keys, you normally generate lowercase and uppercase letters. Your TI-99 keyboard normally generates lowercase letters. In most cases, TI BASIC accepts either uppercase or lowercase letters. Because there are exceptions, throughout this book we will use only uppercase letters in our programs. You can use lowercase letters for comments and text.

To generate uppercase letters on your TI-99, you must depress the ALPHA LOCK key. Depressing this key allows you to lock the keyboard into the uppercase position. (It only affects letters, however.)

Let's now practice what we have just learned. Go to your keyboard, and hit keys at random. Press any key; you won't damage anything. Use the SHIFT key and watch the characters being displayed on the screen. Now, press ENTER, and see what happens.

Control

The control (CTRL) key is provided to issue frequently used commands to your computer in shorthand. It does not exist on type-writers. The CTRL key is used like the SHIFT key: by holding it down and pushing another key on the keyboard at the same time. This is called generating a control character. For example, "CTRL A" is generated by holding down the CTRL and A keys simultaneously. This is a convenient way to generate a command or control code—by pressing only two keys.

On the TI-99, the CTRL key is used primarily for telecommunications and with some software programs. We will not use any control codes in this book.

The Function Key

The function (FCTN) key on the TI-99 is very important. It serves two main purposes. First, it is used in conjunction with some of the letter keys to generate certain symbols. Second, it is used in conjunction with the number keys to produce special functions. Let's examine each of these in turn.

If you look at your computer's keyboard, you will notice that

some of the letter keys have symbols on the front. For example, the I key has the ?, the P key has the ", and the O key has the '. To generate these symbols, you must hold down the FCTN key and press the appropriate letter key. Thus, to produce the double quotation mark ("), you must hold down the FCTN key and, while holding it down, press the P key. You will also notice that the keys E, S, D, and X have up, left, right, and down arrows on them. Holding down the FCTN key and simultaneously pressing one of these keys will move the cursor in the direction of the arrow. You can use this function to correct typing mistakes.

To use the FCTN key to produce special functions, you should have the "keyboard overlay" in its proper place. The keyboard overlay is the strip of plastic with the words "DEL, INS, ERASE, CLEAR . . ." printed on it. It is placed in the recessed area directly above the number keys. Pressing the FCTN key in conjunction with the number key produces the function described on the overlay. Let's look at some of these.

FCTN = (QUIT)   Pressing the FCTN key and the key with the equals sign causes the computer to leave TI BASIC and return to the master computer title screen. This erases anything you may have had in the computer's memory.

FCTN 2 (INS)   Pressing the FCTN key and the 2 key allows you to insert characters immediately to the left of the cursor.

FCTN 1 (DEL)   Pressing the FCTN key and the 1 key allows you to delete whatever character the cursor is over.

FCTN 3 (ERASE)   Pressing the FCTN key and the 3 key causes the entire line you are on to be erased.

FCTN 4 (CLEAR)   This key acts like the "break" key on other computers. Pressing the FCTN key and the 4 key will stop any program from running.

The other special functions (BEGIN, PROC'D, AID, REDO, and BACK) are used with TI game cartridges and will not be discussed here.

The Cursor

Recall that the cursor is the solid, black square on the screen that shows your current position. It blinks so that you can see it easily. Here is a cursor showing you where you are on the screen after you have typed HELLO:
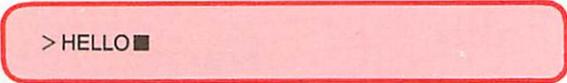
> HELLO ■

As we have said, by moving the cursor back and forth and up and down on the screen, you can type over characters and modify any text you have typed previously. This is a great convenience for making changes. You will use the cursor extensively to correct typing errors.
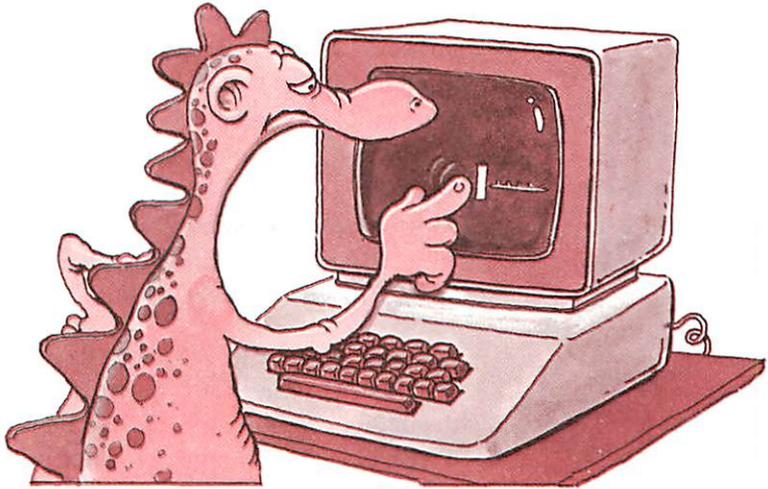
You may now want to go back to your keyboard and practice some of the things you have just learned. When you feel reasonably familiar with your keyboard, come back and learn how to issue BASIC instructions to the computer.

Speaking BASIC

To speak BASIC with your computer you need a BASIC interpreter in the memory. Since your computer has a built-in (resident) BASIC interpreter, you do not have to do anything to activate it.

When you turn on your TI-99 computer, you will see on your screen the TI logo, and the instructions "READY — PRESS ANY KEY TO BEGIN." After you press a key, your screen will display the options that are available to you. The number of selections will depend upon whether or not you have a cartridge installed and/or other peripherals connected to your TI-99. In any case, you will have the first option, "PRESS 1 FOR TI BASIC." When you press the 1 key, the TI BASIC interpreter is activated, and a confirmation, or prompt, appears on the screen:

```
TI BASIC READY

>  ■
```

"TI BASIC" is the name given to the interpreter. > is the *prompt,* a message from the BASIC interpreter, meaning, "I'm ready. Go ahead and tell me what to do." As soon as you see this symbol, you know that the BASIC interpreter is ready and waiting for your instructions.

We will now proceed, assuming that:

1. The TI BASIC interpreter has been activated.

2. The BASIC prompt used by your interpreter (the > symbol) appears on your screen. If the prompt does not appear, press ENTER and see what happens. If this does not work, turn your computer off, and restart it.

We will now issue our first BASIC instruction to the computer. Type the following (exactly as it appears here):

    PRINT "HELLO"

The screen should look like this:
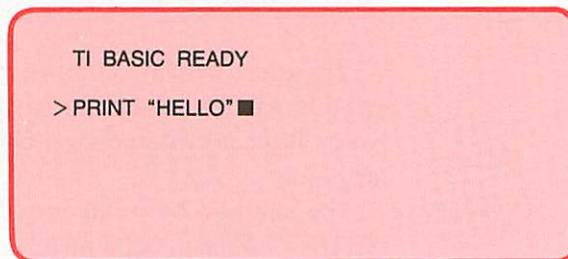
```
TI BASIC READY

> PRINT "HELLO" ■
```

The > on the left is the *prompt* telling you that the BASIC inter-preter is waiting for an instruction. The characters on the right have just been typed by you. Nothing should happen yet. Do you remember why?

This is because you must hit the ENTER key to *enter* your instruc-tion. Now press ENTER. Your screen should look like this:
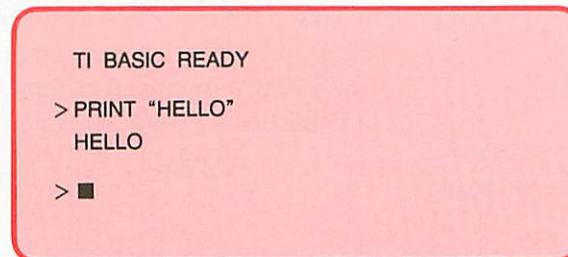
```
TI BASIC READY

> PRINT "HELLO"
  HELLO

> ■
```

The interpreter has received your instruction and has immedi-ately executed it by displaying HELLO as requested. Next, the

interpreter displays a new prompt (>), telling you it is ready for a new instruction.

Let's examine our first BASIC instruction more closely:

```
PRINT "HELLO"
```

This instruction has two parts: PRINT and "HELLO". PRINT is a *reserved word* that has a specific meaning to the BASIC interpreter. "HELLO" is the message to be PRINTed. It must be enclosed in quotes. You can use any message within the quotes. Let's try another. Type:

```
PRINT "TEST NUMBER 2"
```

The following should appear on your screen:
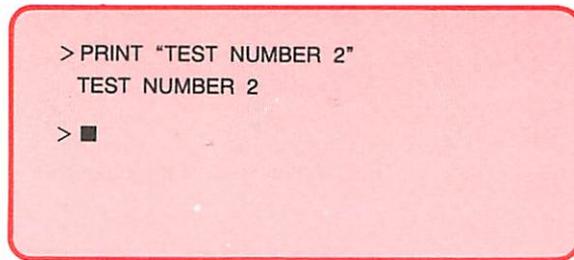
```
> PRINT "TEST NUMBER 2"
  TEST NUMBER 2

> ■
```

Try again. Display your own message, but remember: if you forget one of the quotes or if you misspell PRINT, it will not work, and you will get an error message. Go ahead; try it. You won't damage anything.

You may now be wondering why this instruction is called "PRINT" when in fact it merely displays, and does not print, the information on your screen. Even if you have a printer connected to your computer, nothing will be printed. You have probably guessed the reason. The early terminals were typewriter-like, and in fact, did print (not display) the information. And, although the technology has changed, the BASIC instruction has not. Another BASIC instruction is now used to send information to the printer, rather than to the display.

Before we proceed, make sure that the BASIC prompt appears on your screen, i.e., that the BASIC interpreter is ready to accept another command. If the prompt does not appear, you cannot execute a BASIC command. Try pressing ENTER or FCTN CLEAR, or if that doesn't work, try restarting your system.

We will now write our first BASIC program, rather than just execute a single instruction or "statement." Type the following:

```
10   PRINT "HELLO" ⤸
20   PRINT "HOW ARE YOU?" ⤸
30   END ⤸
```

Your screen should look like this:

```
10   PRINT "HELLO"
20   PRINT "HOW ARE YOU?"
30   END
> ■
```

You may be surprised that nothing has happened. The computer merely responds with a $>$. These three lines are more than just three BASIC statements. They constitute a short BASIC *program*. Note that each line begins with a number; this number is called a line number or *label*. It tells the computer that we want to write a complete program, and not execute each instruction immediately. Now, type:

```
RUN ⤸
```

"RUN!"

BANG

STARTER

You should now see on your screen:

```
HELLO
HOW ARE YOU?

* * DONE * *
> ■
```
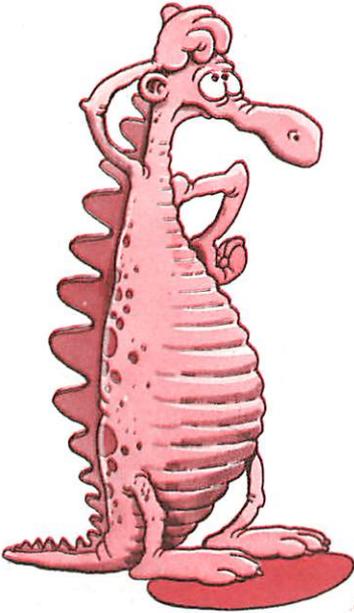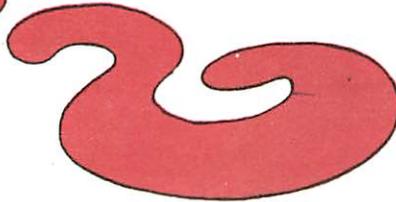
How does this work? We first created a three-line program and stored it in memory, a line at a time, by pressing ENTER. We then executed the program by typing: RUN. This is the normal way of writing and executing a program. We will follow this procedure from now on. All lines will be preceded by a numerical label, and the program will be executed automatically in the order of the labels.

"How does this work?"

If at any time you type an unlabeled BASIC statement in response to a > , the statement will be executed immediately; it will not be memorized. This is called the *immediate mode* or *command mode* in TI BASIC. If at any time you type a labeled BASIC statement in response to a > , the statement will be memorized when you hit ENTER, but not executed until you type RUN. This is called the *deferred* mode. Let's demonstrate how this works.

Our three-line program has been stored in memory. It can be executed any number of times, expanded or modified. Now, type:

RUN ⤾

again, and you should see:

```
HELLO
HOW ARE YOU?

* * DONE * *
> ■
```

Let's now examine the computer's memory and display its contents. To do this type:

LIST ⤾

and you should see the following displayed on your screen:

```
10   PRINT "HELLO"
20   PRINT "HOW ARE YOU?"
30   END
> ■
```

Your program is listed on the screen as it is stored in the computer's memory.

To demonstrate the difference between immediate and deferred instructions, type:

PRINT "GOOD BYE" ⤾

You see on the screen:

```
> PRINT "GOOD BYE"
  GOOD BYE

> ■
```

Now type:

LIST ⤶

again, and you should see on your screen:

```
10   PRINT "HELLO"
20   PRINT "HOW ARE YOU?"
30   END
> ■
```

The new direct instruction: PRINT "GOOD BYE" is nowhere to be seen. It has not been memorized.

If you haven't used a line number, the instruction is gone!

Program Summary

In summary, an immediate statement is executed as soon as you type it. It is not stored in the computer's memory, and you will need to type it every time you want to execute it. This facility is called the *immediate execution* mode. In practice, this mode is used infrequently—generally when you want to verify some values after a program has stopped. Feel free to experiment by typing BASIC instructions and see what happens.

When a line is preceded by a label, the mode is called the *deferred execution* mode. In this mode, each line of the program is stored away in the computer's memory. When a complete program has been typed in, you simply issue the RUN command, and the entire program will be executed. Remember that when you turn the computer off, the contents of the RAM memory disappear, including any program you may have typed. If you wish to keep your program for later use, you must save it on a cassette or diskette.

Each line of a BASIC program must start with a label. The label specifies the order in which the line will be executed. Thus, line 10 will be executed before line 20.

The END statement, line 30 in our example, is optional with TI BASIC, but required with older BASICs. The END statement tells the interpreter that it has reached a legitimate END, rather than an accidental one, during execution.

The computer executes each instruction in turn
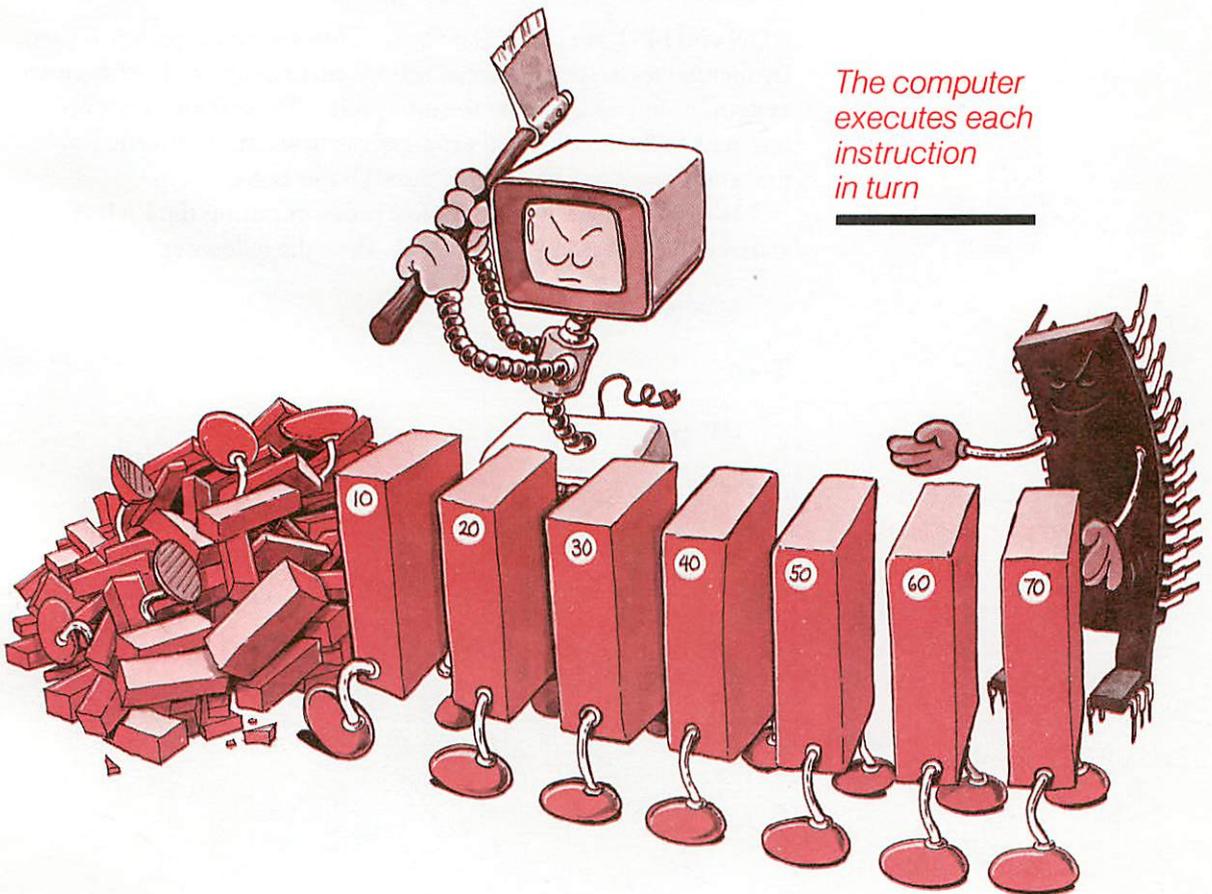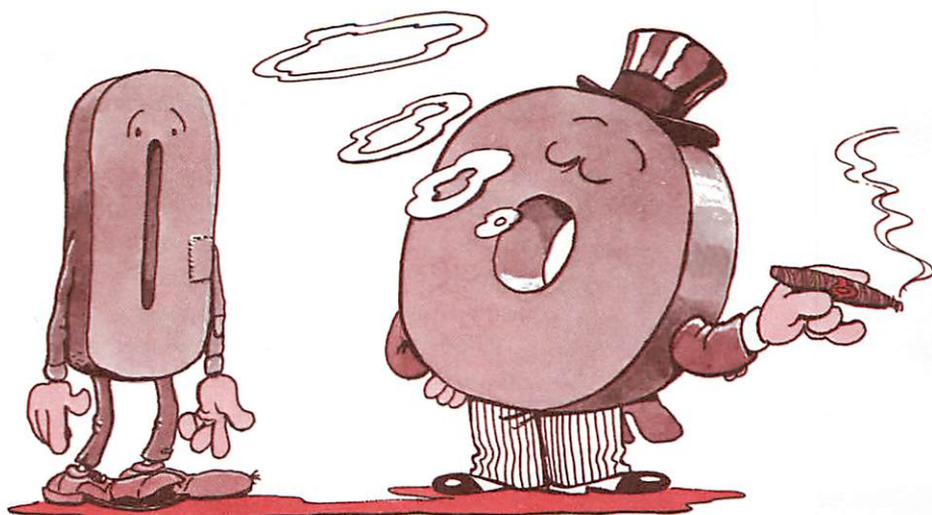
As a final detail, note that the digit 0 must look different from the letter O. The traditional way to avoid confusion is to show the digit 0 as Ø—an O overstricken with a slash. On the TI-99 keyboard, the number 0 is overstriken with a slash. However, it does not appear this way on your screen. On your screen, the number 0 has rounded edges, whereas the letter O has square corners.

A Longer Program

RUN and LIST are called *commands*. They are reserved words used by themselves to specify special actions carried out by the computer system, or more exactly by the interpreter. These commands are also part of BASIC. We will progressively learn more statements and commands as we continue through this book.

Let's now write a more complete program, using the PRINT statement and the NEW command. Type the following:

NEW ⤎

Then:

LIST ⤎

Nothing happens. There is no longer any program in the memory. The NEW command clears the computer's memory. Now type:

```
NEW ⤶
10   PRINT "THIS" ⤶
20   PRINT "IS" ⤶
30   PRINT "ANOTHER" ⤶
40   PRINT "EXAMPLE" ⤶
50   END ⤶
```

Let's find out what this program does. Type:

```
RUN ⤶
```

You should now see on your screen:

```
THIS
IS
ANOTHER
EXAMPLE

* * DONE * *

> ■
```

Our program displays the text as expected. Let's verify that the program has been stored correctly in memory by typing:

```
LIST ⤶
```

You should now see on your screen:

```
10   PRINT "THIS"
20   PRINT "IS"
30   PRINT "ANOTHER"
40   PRINT "EXAMPLE"
50   END
> ■
```

The NEW command has been used to clear the memory of the computer, i.e., to erase it, to make room for the new program. If the

NEW command is not used, the new statements would erase and replace any older statement with identical labels previously typed into memory. This could lead to errors since old statements might be "leftover" in a new program. If you do not use NEW, then every time you type a statement with the label 10, the new version will automatically erase any older version of that statement. But, *beware,* if you had previously written a statement with the label 15, then typed in the above program without a NEW, the statement "15" would remain in the computer's memory and would automatically be incorporated into your new program in sequence (since the label 15 is not used in the new program). Let us demonstrate this. Type:

15   PRINT "✶ ✶ ✶ ✶ ✶" ⤺

Then:

RUN ⤺

Your screen should look like this:

```
THIS
✶ ✶ ✶ ✶ ✶
IS
ANOTHER
EXAMPLE

✶ ✶ DONE ✶ ✶
> ■
```

As you can see, the new PRINT statement, labeled 15, has been automatically inserted in the older program after statement 10. Let's list the program. Type:

LIST ⤺

Your screen should look like this:

```
10  PRINT "THIS"
15  PRINT "✶ ✶ ✶ ✶ ✶"
20  PRINT "IS"
30  PRINT "ANOTHER"
40  PRINT "EXAMPLE"
50  END
> ■
```

You just verified that statement 15 is now part of your program. Remember that every time you type a program statement with a label, it is automatically inserted in the memory of the computer in the proper sequence.

We will now demonstrate that when you use a label number that *already exists,* your new statement will automatically erase the previous one. Let's now use this feature to erase statement 15. Type:

15   PRINT "........" ⫤

Then:

RUN ⫤

Your screen should look like this:

```
THIS
........
IS
ANOTHER
EXAMPLE

* * DONE * *
> ■
```

As you can see, your new PRINT statement with the label 15 has superseded the previous one. Verify it by typing:

LIST ⫤

Your screen should look like this:

```
10   PRINT "THIS"
15   PRINT "........"
20   PRINT "IS"
30   PRINT "ANOTHER"
40   PRINT "EXAMPLE"
50   END
> ■
```

To avoid accidents, whenever you write a new program, you should use the NEW statement to clear your computer's memory and avoid interference by "leftover" statements from previous use.

Let's now erase statement 15. There are many ways to do this. Here we will type:

15 ⟳

This statement merely consists of a label. This is called an *empty statement*. Statement 15 does nothing, except erase any previous version. Now type RUN. You should see the following on your screen:

```
THIS
IS
ANOTHER
EXAMPLE

* * DONE * *

> ■
```

Be careful. This feature can be dangerous. If you type:

20 ⟳

by accident, you will erase the previous version of statement 20, and replace it with an "empty" statement that does nothing. To avoid surprises, always verify your program listing prior to execution.

Summary

We have now learned how to write elementary BASIC programs that display information on the screen. We have written a BASIC program using labeled statements. We have discussed why programs should be preceded with the NEW command and terminated with the END statement. We have seen that a program is stored automatically in the computer's memory as it is entered, and that it can be executed by typing the RUN command. We have also seen how a program listing can be displayed with the LIST command.

We have learned that the execution of program statements is in the order of the labels. If you duplicate a label number either intentionally or by mistake, the new statement will automatically erase any previous statement with the same label number. Also, if at any time you add a line with a new label, the interpreter will automatically insert it in its proper sequence within the program.

In this chapter, we have introduced many new concepts. If you truly want to learn how to program, it is essential that you start practicing what you have learned. Several self-test exercises follow. You are strongly encouraged to try them out. Answers to selected exercises are given at the end of this book.

Exercises

2-1: Write a program that prints the following: "HAVE A GOOD DAY."

2-2: Write a program that prints:

    AAAAA
    BBBB
    CCC
    DD
    E

2-3: Write a program that prints:

    * * * * * * *
    * T I T L E *
    * * * * * * *

2-4: Define the following terms:

      a.   label

      b.   deferred execution

      c.   immediate execution

      d.   empty statement

      e.   cursor

      f.   control key

      g.   reserved word

      h.   prompt

2-5: Why is "PRINT" used as a command to display on the screen?

2-6: Can you execute a whole program by typing statements one at a time in the immediate mode?

2-7: Why use NEW before typing a new program?

2-8: Can you type labeled program statements out of sequence?

2-9: Give examples of some TI BASIC commands.

2-10: Is the following statement a valid way to display the word EXAMPLE?

      PRINT EXAMPLE

2-11: What is the use of the ENTER key?

2-12: Explain how to erase statement 20 in a program.

2-13: If you have already typed statement 30 and wish to substitute a new statement 30, do you have to erase the old one first?

2-14: Write a program that displays the following:

```
TTTTT   H  H   EEEEE
  TT    H  H   EE
  TT    H  H   EE
  TT    HHHH   EEEE
  TT    H  H   EE
  TT    H  H   EE
  TT    H  H   EEEEEE
```

Calculat

3

In this chapter, we will start using
numbers. We will display them
and add, subtract, multiply, and
divide them. We will learn to perform
computations using the simple
arithmetic operators, and we will
describe the other important built-in
operators in BASIC.

ing with
BASIC

Printing Numbers

So far we have only printed text. Let's now print a number. Type:

PRINT 3 ⏎

The result should be:

```
3
```

Recall from our discussion in Chapter 2 that this statement is in the immediate mode, where an instruction does not need to be preceded by a label and is executed immediately. In this chapter, we will write all of the examples in the immediate mode, so that you can execute them by pressing only a few keys.

Notice that in BASIC, numbers do not need to be enclosed in quotes, only text. The use of quotes allows the interpreter to easily differentiate between user-provided text and the BASIC reserved words, such as PRINT. The text inside the quotes is called a *string,* and a string may include numbers.

Let's now try to print several large numbers, say 100, 1000, 10000, etc. When you try to print a number with more than ten digits, you will notice that something odd happens—a decimal point appears to the right of the first digit, an "E" appears after the last digit, followed by a plus sign and a number. Your TI BASIC interpreter has converted your number into scientific notation. We'll discuss scientific notation shortly.

"I'll show you more ways to print numbers."

Your BASIC interpreter allows you to use decimal numbers. Type:

```
PRINT 1.5 ⏎
```

You now see 1.5 displayed on your screen. In computer jargon, decimal numbers are called *floating-point numbers*. A BASIC interpreter that allows the use of floating-point numbers is called a *floating-point BASIC*.

Scientific Notation

Let's discuss decimal numbers further. As with integers, in the case of decimal numbers, the interpreter will only retain a set number of digits. For example, the correct value of one third is:

```
0.33333333333 ...    (etc.)
```

Inside the computer, this value may be stored as:

```
0.33333333   (eight significant digits are retained besides the zero)
```

The correct value is said to have been *truncated* (cut) to eight digits. (**Note:** This is an approximation, but it is generally sufficient.)

Your BASIC interpreter allows decimal numbers; it also uses a *scientific representation* for these numbers. When a number becomes very large or very small, it will be displayed in scientific notation to save space.

Here is an example:

```
3.2 E +06
```

means

$$3.2 \times 10^6 = 3200000$$

10^6 means 10 to the power 6, i.e., 10 multiplied 5 times by itself:

$$10 \times 10 \times 10 \times 10 \times 10 \times 10 = 1000000$$

Similarly

```
1.12E – 07
```

means

$$1.12 \times 10^{-7} = 0.000000112$$

10^{-7} means 1/10 to the power 7, i.e., 1/10 multiplied 6 times by itself (1/10 is 10^{-1}).

Using scientific notation, your TI BASIC interpreter can handle numbers as small as -9.99×10^{-127} and as large as 9.99×10^{127}!

Doing Arithmetic

Let's now perform simple arithmetic calculations. Type:

PRINT 2 + 2 ⤸

The result appearing on your screen should be:

4

We have just performed our first arithmetic computation. The addition symbol, + , is called an *operator.* An operator is a symbol that represents an operation to be performed on one or more operands. BASIC provides five built-in arithmetic operators:

–	*(minus)*
+	*(plus)*
*	*(multiplication)*
/	*(division)*
^ *or* **	*(exponentiation or power)*

"You need more practice."

Now try this example. Type:

PRINT 2 * 3 �

The result should be 6. The * symbol is the symbol for multiplication. The usual multiplication symbol, ×, could be confused with the letter X, so programming languages use the * symbol instead.

Here are other examples of valid arithmetic statements:

PRINT 1 + 2 * 3 �

The result is

> 7

PRINT 3 – 2 �

The result is

> 1

PRINT 8/2 �

The result is

> 4

PRINT 1 + 2 + 3 + 4 �

The result is

> 10

Since TI BASIC allows decimal numbers, the following statement is also legal:

PRINT (6/3 + 12/4)/2 �

The result is

> 2.5

Note that parentheses have been used in this example to clarify the

grouping of operations. Let's try another example. Type:

PRINT 2 + 3 + 4 / 2 ⤶

The result is:

> 7

The division (/) was performed first on the 4. This is due to the fact that in BASIC, if given a choice (i.e., if parentheses are not used), the division (/) or the multiplication (*) will take place before the addition (+) or the subtraction (−). If you had intended to divide the group 2 + 3 + 4 by 2, then it would have been necessary to type:

PRINT (2 + 3 + 4) / 2 ⤶

The result would then be:

> 4.5

The division would then have been performed on the group (2 + 3 + 4). It is good practice to use parentheses freely, to avoid any confusion. For example, the following expression (or group of values and operators)

$$\frac{1 + 2 + 3}{4 + 5} \times 3$$

could be translated into the following BASIC expression:

((1 + 2 + 3) / (4 + 5)) * 3

or

(1 + 2 + 3) / (4 + 5) * 3

because execution proceeds from left to right when operators have the same precedence (standing), i.e., the division occurs here before the multiplication.

If you were to write the following in BASIC:

(1 + 2 + 3) / ((4 + 5) * 3)

it would be equivalent to:

$$\frac{1 + 2 + 3}{(4 + 5) \times 3}$$

Use parentheses to denote groups. Be sure to make sure there is always a matching right parenthesis for each left one.

Let's now use our new computing skill to display useful values.

Printing Formats

If you type:

PRINT "TWO TIMES THREE IS", 2 * 3 ⏎

The result will be:

> TWO TIMES THREE IS
> 6

In the above PRINT statement, we have mixed text and numbers, separated by a comma. More precisely, we have used an *expression,* 2 * 3, rather than a number. Now, type:

PRINT "TWO TIMES THREE IS, 2 * 3" ⏎

and you will get:

> TWO TIMES THREE IS, 2 * 3

This is a valid BASIC statement, but not the one you had intended. Remember, everything within quotes is displayed literally. The comma or semicolon must be *outside the quotes* to work correctly.

A PRINT statement may be used to print several items on the same line. The items must, however, be separated by a semicolon or a comma. A semicolon will result in a small space between the items being printed, while a comma will result in a larger space. Like a tab stop on a typewriter, the comma symbol is used to create *tabs,* i.e., fields on the screen. This technique is convenient for displaying tables.

Let's try this new feature. Type:

PRINT 1;2;3 ⏎

Your display should show:

> 1 2 3

Now type:

PRINT 1,2,3 ⏎

Your display should show:

> 1   2
> 3

Let's now compute the sales tax for a sale of $1234. The tax rate is 6.5%. The statement is:

PRINT   "SALES TAX IS"; 1234 * 6.5 / 100 ⮐

The result is:

> SALES TAX IS 80.21

We could also type:

PRINT "SALES TAX IS"; 1234 * 0.065 ⮐

and we would obtain the same result. There are many equivalent ways to write a program.

You can print many items on a line. Look:

PRINT 1;2;3;4;5;6;7;8;9;"MANY ITEMS" ⮐

The screen will show:

> 1 2 3 4 5 6 7 8 9
> MANY ITEMS

We have now learned how to perform simple arithmetic computations, and how to display the results. Let's use this new skill to solve some simple problems.

Only feed reasonable numbers to your program

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Application Examples

Let's compute a car's mileage in miles per gallon. The mathematical formula is:

MILEAGE = DISTANCE (in miles) ÷ GAS (in gallons)

Let's assume that the distance was 510 miles and the amount of gasoline used was 20.2 gallons. Here is the statement written in BASIC:

PRINT "MILEAGE IS"; 510 / 20.2 ; "MPG" ⤵

For metric readers we will now convert this into liters per kilometer. One gallon is 3.8 liters. One mile is 1.6 kilometers. The consumption in liters per kilometer is:

PRINT "GAS CONSUMPTION IS"; (20.2 * 3.8) / (510 * 1.6) ; "L PER KM" ⤵

Here is another simple problem. Given a temperature in Fahrenheit, the Celsius equivalent is computed by the formula:
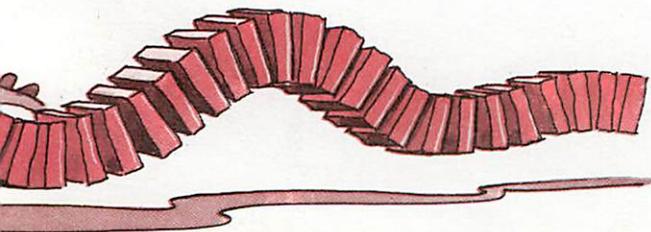
CELSIUS value = (FAHRENHEIT value − 32) × 5/9

To compute the Celsius equivalent of 79° F, type:

PRINT "79 DEGREES F = "; (79 − 32) * 5/9; "DEGREES C" ⤵

The result is:

```
79 DEGREES F = 26.11111111
DEGREES C
```

To be complete, note that 5/9 has not been enclosed in parentheses, as it does not matter whether * or / is executed first.

Summary

In this chapter, we have learned how to perform arithmetic computations and how to display text and results on the same line. We have used this new skill to automate the computation of simple formulas by writing one-line BASIC statements.

So far we have specified all the values within the BASIC statement itself. What we now want to do is first write a program, then supply values repeatedly from the keyboard so different values can be used with the program without having to rewrite it. We will accomplish this with *variables*. This is the topic of the next chapter.

Exercises

3-1: Write a BASIC statement that computes:

$$\frac{5 + 6}{1 + 2 \div 3}$$

3-2: Write a BASIC statement that computes:

$$1 + \frac{1}{2} \quad \frac{1}{1 + \frac{1}{2}}$$

3-3: Write a BASIC statement that computes the Fahrenheit equivalent of 20° C.

3-4: Given a speed of 100 km per hour, compute the equivalent speed in m.p.h. (1 mile = 1.6 km)

3-5: Compute the number of seconds in a day, a week, a month, and a year.

3-6: Assuming an average speed of 55 m.p.h., compute the time needed to travel 350 miles.

3-7: Assuming 365 days in a year, compute the number of days you have lived so far.

3-8: Compute the equivalent annual salary for a person, given the:

       a.   weekly pay (there are 52 weeks in a year)

       b.   biweekly pay (multiply by 26)

       c.   monthly pay

       d.   hourly pay (multiply by 2080)

Memorizing
Usi

Values and Using Variables

4

In this chapter, we will learn to write programs that can be used repeatedly, without change, and that will display different results, depending on the data supplied at the keyboard. So far, to obtain the result of an arithmetic computation, such as $2 + 3$, we have had to include in the program statement the numbers to be operated on. We will now learn to write programs that can be executed with different data each time. The programs will specify the operations to be performed. The data will be supplied at the keyboard by the user at the time the program is executed. This makes the program reusable.

In addition, we will introduce the concept of a variable and learn how to use two new statements: INPUT and LET.

Let's now begin by learning how to supply information to a program while it is running.

The INPUT Statement

Type the following program. (**Note:** we will no longer display ⤶ to indicate ENTER at the end of each line):

```
10   INPUT A
20   PRINT A;  2 * A;  3 * A
30   END
```

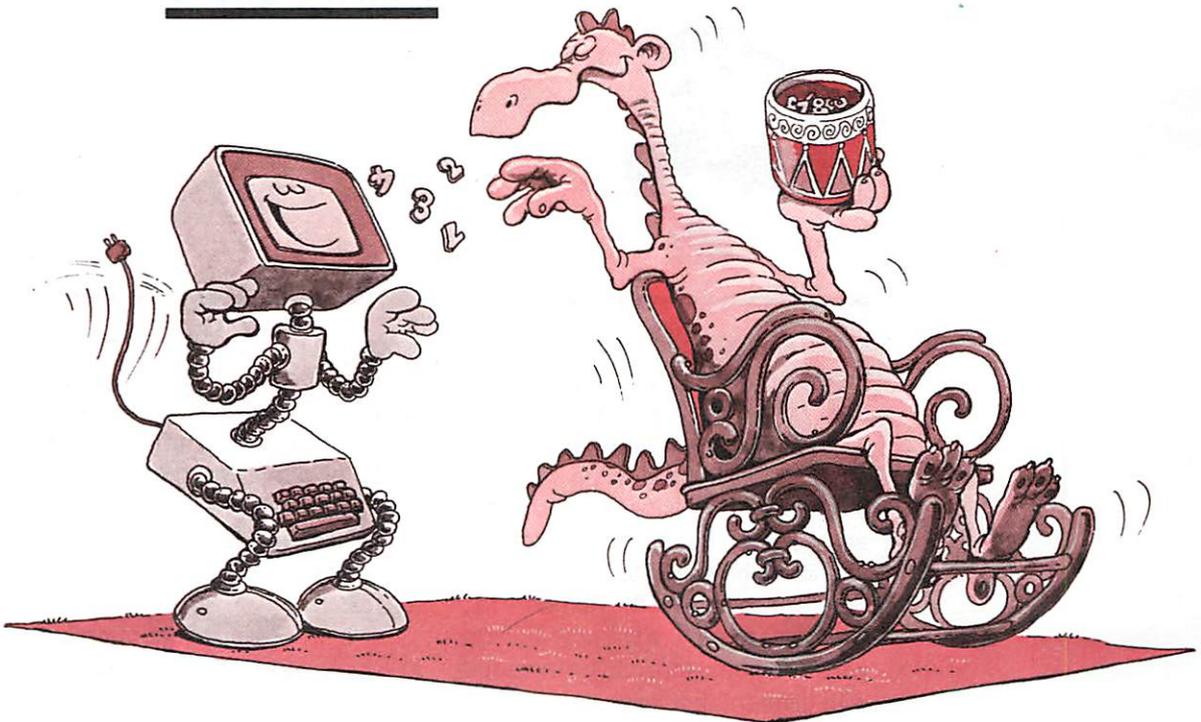Now execute this program by typing RUN, as usual. Your screen should look like this:

```
?  ■
```

A "?" appears on your screen with a blinking cursor next to it to remind you to type in the input.

Now, type in a number, say 3. Terminate your input by pressing the ENTER key as usual. Your screen should now show:

```
    3   6   9
  * * DONE * *
> ■
```

On INPUT, your computer accepts numbers and letters

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Your program has been executed. Let's see what happened. The first line was:

```
10  INPUT A
```

This statement asked you to provide a number at the keyboard. The program displayed a ?, and stopped—waiting for your input. The value 3 you supplied was then read and stored in A. "A" is called a *variable*. It is a name used to store a value. Formally, a *variable* is a name given to a memory location. Examples of some variable names are: A, B, C, F, Z1, G2. TI BASIC allows variable names with up to 15 letters as well, for example: INTEGER1, SUM, TAX, RESULT.

The second statement was:

```
20  PRINT A;  2 * A;  3 * A
```

This statement resulted in the printing of 3, 2 * 3, 3 * 3, or:

```
3  6  9
```

Using the INPUT statement, it is also possible to enter several values at the same time. Here is an example. Type:

```
10  INPUT A,B
20  PRINT A;  A * 2;  B;  B * 2
30  END
```

Now run the program. You should see the usual "?" appearing on your screen. Type two numbers, say 2 and 3, separated by a comma, then press return. The result is:

```
2  4  3  6
```

Let us examine what happened. The first line of the program was:

```
10  INPUT A,B
```

This statement resulted in a request for two values from you, which were then stored in the variables A and B. Remember that variables are names of memory locations. The contents of A and B were initially empty, but they became 2 and 3, respectively. The second statement of the program was:

```
20  PRINT A;  A * 2;  B;  B * 2
```

This statement resulted in printing the values: 2, 2 ∗ 2, 3, 3 ∗ 2, or:

```
2 4 3 6
```

Let's try running this program again. This time try typing:

    5,8

and the results should be:

```
5 10 8 16
```

We can use this program repeatedly and obtain new results by typing in new values at the keyboard. We have made our program reusable by using variable names (A and B), instead of explicit values.
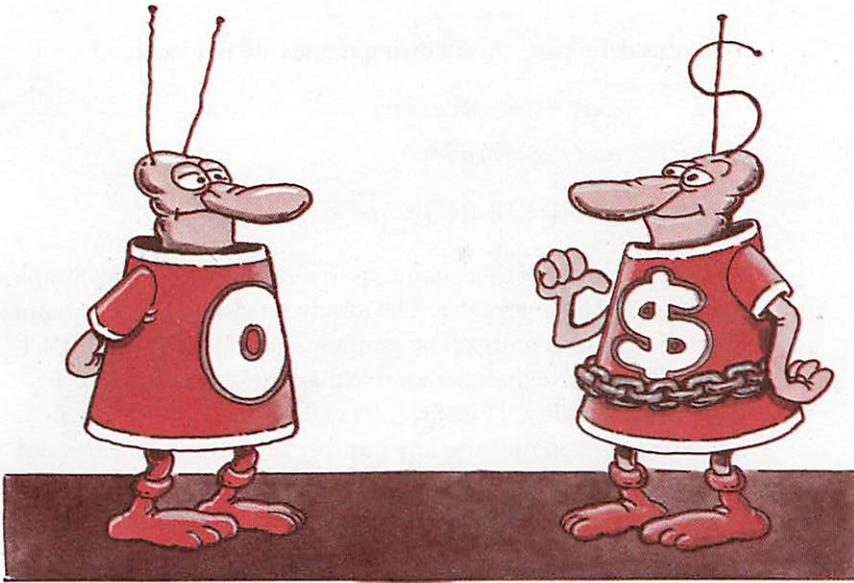
In order to make this program truly reusable, let's now improve its style and readability. Suppose that we want to save the program, and run it again in several days. We might forget what it does or we might not remember how many values we must supply. We can rewrite the program to display this information on the screen. Here is an improved version:

```
10  PRINT "A PROGRAM TO MULTIPLY"
20  PRINT "ANY TWO NUMBERS BY 2"
30  PRINT "TYPE TWO NUMBERS"
40  INPUT A,B
50  PRINT "FIRST NUMBER  :"; A,  "DOUBLE  :";  2 ∗ A
60  PRINT "SECOND NUMBER  :"; B,  "DOUBLE  :";  2 ∗ B
70  END
```

and here is the resulting display: (**Note:** throughout this text, we will display data provided by the user in **boldface** type.)

```
A PROGRAM TO MULTIPLY
ANY TWO NUMBERS BY 2
TYPE TWO NUMBERS
? 5,7
FIRST NUMBER  :  5
DOUBLE  :  10
SECOND NUMBER  :  7
DOUBLE  :  14
```

We have now learned how to supply numeric data to the program by using the INPUT statement. We have also introduced the concept of variable. Let's now learn how to use these techniques effectively and how to develop more complex programs.

The Two Types of Variables

There are two *types* of variables in BASIC: *numeric* and *string*. Numeric variables represent numbers; string variables represent text. These two types of variables look different; a string variable has a "$" at the end of the name. They are also used differently. For example, you can add numbers, but not text. Let's first learn about numeric variables, then about string variables.

Numeric Variables

Let's learn the rules for naming a numeric variable; then we will learn how to use these variables effectively. We have already used two numeric variables, called A and B, at the beginning of this chapter. We gave them a value by inputting numbers from the keyboard. Let's now learn how to name a variable.

When naming a variable, all BASICs, including the original Dartmouth BASIC, allow the use of one letter, optionally followed by a single number. TI BASIC allows any combination of letters and numbers up to 15 characters. However, a numeric variable name must start with a letter. Here are examples of valid TI BASIC variable names:

A	*(one letter)*
Z	*(one letter)*
A1	*(one letter and one digit)*
B2	*(one letter and one digit)*
ALPHA	*(five letters)*
R2D2	*(two letters and two numbers)*

With this definition, the following names are not legal:

12   *(does not start with a letter)*

1B   *(must start with a letter)*

ABCDEFGHIJKLMNOP   *(too many characters)*

The advantage of short names is to reduce the size and complexity of the BASIC interpreter. The disadvantage is that short names are difficult to remember. For example, the long name RESULT is more descriptive and memorable than the short name R. To improve readability, TI BASIC allows long names, i.e., a sequence of characters. You may use any number of consecutive letters followed by optional digits, up to a maximum length of 15 characters. For example, the following are legal longer variable names:

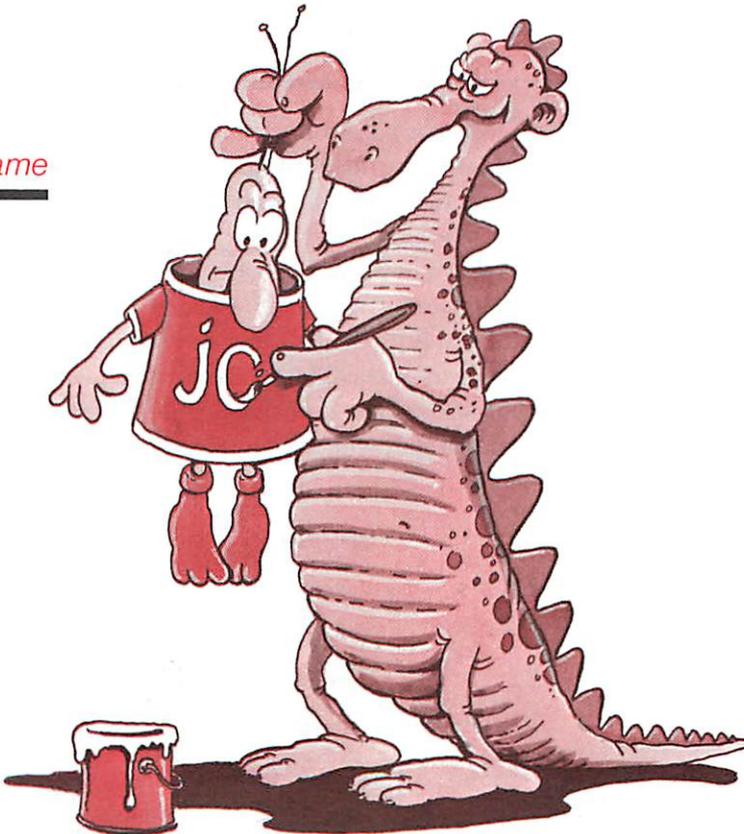|	
WINNER	STUDENT1
LOSER	STUDENT2
RESULT	STUDENT14
SUM	CASE24

The following are not legal:

3TIMES	(starts with a digit)
A-ONE	(illegal symbol)

*Every variable
must have a name*

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Clearly a program with long, explicit variable names is more readable. In this chapter, we will use both short and long names, so that you can get used to both conventions. Remember that long names are simply a matter of convenience and will not affect the program in any way.

There is one more restriction on names: you cannot use a name that is a *reserved word*, i.e., a name that has a meaning to your BASIC interpreter. For example, you may not use LIST, END or RUN as variable names. (**Note:** a list of reserved words appears at the end of this book, as well as at the end of the reference manual for your BASIC interpreter.) TI BASIC also prohibits you from using a reserved word as the first part of a variable name. To be safe, it is best never to use a reserved word as any part of a variable name.

Now that we know how to create legal names for numeric variables, let's learn how to give a name to a piece of text known as a *string*.

String Variables

First, let us introduce strings. Here are examples of strings:

"RESULT"

"THIS IS AN EXAMPLE"

"MY NAME IS JOHN"

"25 TIMES 4 = "

Note that a string is normally enclosed in quotes; otherwise, it could be confused with a variable name. A string may contain any sequence of characters, except the quotation symbol. The length of a string is limited to 256 characters.

Let us now introduce string variables. When the value stored in a variable is text (that is, a string), rather than a number, the variable is called a *string variable*.

A string variable's name is just like a numeric variable's name, except that it must have a "$" at the end. Here are some valid short string variable names:

A$

R$

A1$

B5$

Since TI BASIC allows long names, here are several more valid names:

NAME$

FIRST$

CITY$

UNIT25$

"I'm a string variable. I contain text. My name ends with a $."

55

Let's now illustrate the use of string variables, with a program that greets the user by name.

```
10  PRINT "I AM HAL, THE COMPUTER"
20  PRINT "FIRST NAME";
30  INPUT FIRST$
40  PRINT "LAST NAME";
50  INPUT LAST$
60  PRINT "HELLO, "; FIRST$; " "; LAST$; "!"
70  PRINT "NOW I KNOW YOUR NAME"
80  PRINT "I LIKE "; FIRST$; " AS A FIRST NAME."
90  END
```

Here is a sample run. Note that the characters you type appear here in boldface type.

```
I AM HAL, THE COMPUTER
FIRST NAME? JOHN
LAST NAME? SULLIVAN
HELLO, JOHN SULLIVAN!
NOW I KNOW YOUR NAME!
I LIKE JOHN AS A FIRST NAME.
```

You can now communicate with your computer! Let's point out some of the basic features of this program. Let's start with line 20:

```
20  PRINT "FIRST NAME";
```

Note that this line is terminated with a semicolon. The semicolon means "display the next character immediately after this text." The result of statement 20 and your response to statement 30 is:

```
FIRST NAME? JOHN
```

If you had written:

```
20  PRINT "FIRST NAME"
```

with no semicolon at the end, the result would have been:

```
FIRST NAME
?JOHN
```

Naturally, you may choose either way. The format is a matter of preference. But remember, if you want the characters you type to appear on the same line as the preceding message, use a semicolon at the end of the PRINT statement. Otherwise, the next position on the screen will be the beginning of the following line.

Now that we know more about numeric and string variables, let's use them as we continue our dialogue with Hal, the computer.

Let's add the following to our program:

```
90    PRINT "THIS YEAR (2 DIGITS)";
100   INPUT CURRENTYEAR
110   PRINT "WHICH YEAR WERE YOU"
120   PRINT "BORN (2 DIGITS)";
130   INPUT YEARBIRTH
140   PRINT "DEAR  "; FIRST$; ",  THIS YEAR "
150   PRINT "YOU ARE OR WILL BE";
         CURRENTYEAR – YEARBIRTH
160   END
```

Here is a sample dialogue. Again, the characters you type are shown in boldface type.

```
THIS YEAR (2 DIGITS)? 83
WHICH YEAR WERE YOU
BORN (2 DIGITS)? 50
DEAR JOHN, THIS YEAR
YOU ARE OR WILL BE 33
```

Let us examine the program in detail. The statement

```
90    PRINT "THIS YEAR (2 DIGITS)";
```

prints the obvious message. Again a semicolon is used so that the two digits will be displayed on the same line. In the next statement,

```
100   INPUT CURRENTYEAR
```

CURRENTYEAR is a numeric variable. The value 83 that you typed will be read into it. From now on, whenever the name CUR-RENTYEAR is used, the value 83 will be substituted automatically by the BASIC interpreter. This will happen in statement 130.
   The two statements

```
110   PRINT "WHICH YEAR WERE YOU"
120   PRINT "BORN (2 DIGITS)";
```

are just like statement 90. Note the semicolon at the end. The statement

```
130   INPUT YEARBIRTH
```

is just like statement 100. YEARBIRTH is a new numeric variable. It will soon contain the value 50. In statement 150 we use this variable name. Note that the value 50 is substituted automatically by the interpreter. Let's examine this:

```
140   PRINT "DEAR  "; FIRST$; ",  THIS YEAR "
150   PRINT "YOU ARE OR WILL BE";
         CURRENTYEAR – YEARBIRTH
```

When these statements are executed, the following is displayed:

```
DEAR JOHN, THIS YEAR
YOU ARE OR WILL BE 33
```

Let's break this display down and examine it.

DEAR

(This is called a literal string. A literal string is a string that is part of a program statement.)

JOHN

(This is the string value that is read at the keyboard and stored in the string variable named FIRST$. It remains there as long as you don't use the NEW command or enter a new value into FIRST$.)

THIS YEAR YOU ARE OR WILL BE

(This is another literal string.)

33

(This is the result of: CURRENTYEAR − YEARBIRTH, i.e., 83 − 50 = 33.)

In typing and examining this program, you may already have developed some frustrations. For example, you may have wanted to enter actual dates, including the day and month, so that you can compute your age, as of today. However, this requires comparing today's month and day with that of the birthdate's. To do this, we must learn about a new BASIC statement, the

IF (condition) THEN (do)

statement. We'll discuss this statement in detail in Chapter 7. Another thing that you might want to do is to design the program so that it executes repeatedly (so that you don't need to type RUN everytime). We'll learn how to do this in Chapter 6, when we discuss the GOTO statement.

Now that we are familiar with both numeric and string variables, let's learn how we can use them in a longer program—first, by assigning a value to a variable, then by using the counter technique.

Assigning a Value to a Variable
(The LET Statement)

So far, the only way we have given a value to a variable has been with the INPUT statement. For example, when the following statement is executed:

```
20  INPUT A
```

you type in a value, such as 5.2 (followed by a ⤆), and the value of A is then 5.2.

There is, however, another way to assign a value to A. This is called the *assignment* statement. Here is an example:

```
10   A = 5.2
```

This statement assigns the value 5.2 to A as part of the program, so that you do not have to supply it from the keyboard. You might also write:

```
10   B = 1
20   C = 2
30   A = B + C
```

As you can see, the value of A will be set at 2 + 1 = 3 when statement 30 is executed.

In earlier BASICs, the assignment statement must start with the reserved word LET. In such BASICs, this example would be written as:

```
10   LET B = 1
20   LET C = 2
30   LET A = B + C
```

The purpose of the LET statement was to simplify the design of the interpreter by telling it explicitly that the statement is an assignment statement. The LET statement is optional in TI BASIC. Eliminating it eliminates one step for the programmer when writing such statements.

"Z, I want you to hold this value!"

Let's now show the value of the assignment statement. We will examine two examples. In both examples, we will compute the sum and the average of two numbers. Here is our first program, without the assignment statement:

```
10    PRINT "GIVE ME TWO NUMBERS"
20    PRINT "I WILL COMPUTE THEIR"
30    PRINT "SUM AND AVERAGE"
40    PRINT "1ST NUMBER:";
50    INPUT A
60    PRINT "2ND NUMBER:";
70    INPUT B
80    PRINT "THE SUM OF"; A; "AND"; B;
90    PRINT "IS: ";
95    PRINT A + B
100   PRINT "THEIR AVERAGE IS:";
105   PRINT (A + B) / 2
110   END
```

And here is a typical run:

```
GIVE ME TWO NUMBERS
I WILL COMPUTE THEIR
SUM AND AVERAGE
1ST NUMBER:? 24
2ND NUMBER:? 41
THE SUM OF 24 AND 41
IS: 65
THEIR AVERAGE IS: 32.5
```

Notice that the expression A + B is repeated twice in the PRINT statements. This is just a minor inconvenience. However, in a longer program, this would increase the probability of typing errors. In addition, if we were to change the program to use a different formula, much rewriting would be needed.

Here is an equivalent program that uses an *intermediate variable,* called SUM, to store the result. It is easier to read, and less error prone.

```
10    PRINT "GIVE ME TWO NUMBERS"
20    PRINT "I WILL COMPUTE THEIR"
30    PRINT "SUM AND AVERAGE"
40    PRINT "1ST NUMBER:";
50    INPUT A
60    PRINT "2ND NUMBER:";
70    INPUT B
80    SUM = A + B
90    AVERAGE = SUM / 2
100   PRINT "THEIR SUM IS:";
105   PRINT SUM
```

You just verified that statement 15 is now part of your program. Remember that every time you type a program statement with a label, it is automatically inserted in the memory of the computer in the proper sequence.

We will now demonstrate that when you use a label number that *already exists,* your new statement will automatically erase the previous one. Let's now use this feature to erase statement 15. Type:

    15   PRINT "........" ⤶

Then:

    RUN ⤶

Your screen should look like this:

```
THIS
........
IS
ANOTHER
EXAMPLE

* * DONE * *
> ■
```

As you can see, your new PRINT statement with the label 15 has superseded the previous one. Verify it by typing:

    LIST ⤶

Your screen should look like this:

```
10   PRINT "THIS"
15   PRINT "........"
20   PRINT "IS"
30   PRINT "ANOTHER"
40   PRINT "EXAMPLE"
50   END
> ■
```

To avoid accidents, whenever you write a new program, you should use the NEW statement to clear your computer's memory and avoid interference by "leftover" statements from previous use.

Let's now erase statement 15. There are many ways to do this. Here we will type:

15 ⅃

This statement merely consists of a label. This is called an *empty statement*. Statement 15 does nothing, except erase any previous version. Now type RUN. You should see the following on your screen:

```
THIS
IS
ANOTHER
EXAMPLE

* * DONE * *

> ■
```

Be careful. This feature can be dangerous. If you type:

20 ⅃

by accident, you will erase the previous version of statement 20, and replace it with an "empty" statement that does nothing. To avoid surprises, always verify your program listing prior to execution.

Summary

We have now learned how to write elementary BASIC programs
that display information on the screen. We have written a BASIC
program using labeled statements. We have discussed why pro-
grams should be preceded with the NEW command and termi-
nated with the END statement. We have seen that a program is
stored automatically in the computer's memory as it is entered,
and that it can be executed by typing the RUN command. We have
also seen how a program listing can be displayed with the LIST
command.

We have learned that the execution of program statements is in
the order of the labels. If you duplicate a label number either inten-
tionally or by mistake, the new statement will automatically erase
any previous statement with the same label number. Also, if at any
time you add a line with a new label, the interpreter will automati-
cally insert it in its proper sequence within the program.

In this chapter, we have introduced many new concepts. If you
truly want to learn how to program, it is essential that you start
practicing what you have learned. Several self-test exercises follow.
You are strongly encouraged to try them out. Answers to selected
exercises are given at the end of this book.

Exercises

2-1: Write a program that prints the following: "HAVE A GOOD DAY."

2-2: Write a program that prints:

        AAAAA
        BBBB
        CCC
        DD
        E

2-3: Write a program that prints:

        * * * * * *
        * T I T L E *
        * * * * * *

2-4: Define the following terms:

       a.   label

       b.   deferred execution

       c.   immediate execution

       d.   empty statement

       e.   cursor

       f.   control key

       g.   reserved word

       h.   prompt

2-5: Why is "PRINT" used as a command to display on the screen?

2-6: Can you execute a whole program by typing statements one at a time in the immediate mode?

2-7: Why use NEW before typing a new program?

2-8: Can you type labeled program statements out of sequence?

2-9: Give examples of some TI BASIC commands.

2-10: Is the following statement a valid way to display the word EXAMPLE?

       PRINT EXAMPLE

2-11: What is the use of the ENTER key?

2-12: Explain how to erase statement 20 in a program.

2-13: If you have already typed statement 30 and wish to substitute a new statement 30, do you have to erase the old one first?

2-14: Write a program that displays the following:

```
TTTTTT   H  H   EEEEEE
  TT     H  H   EE
  TT     H  H   EE
  TT     HHHH   EEEE
  TT     H  H   EE
  TT     H  H   EE
  TT     H  H   EEEEEE
```
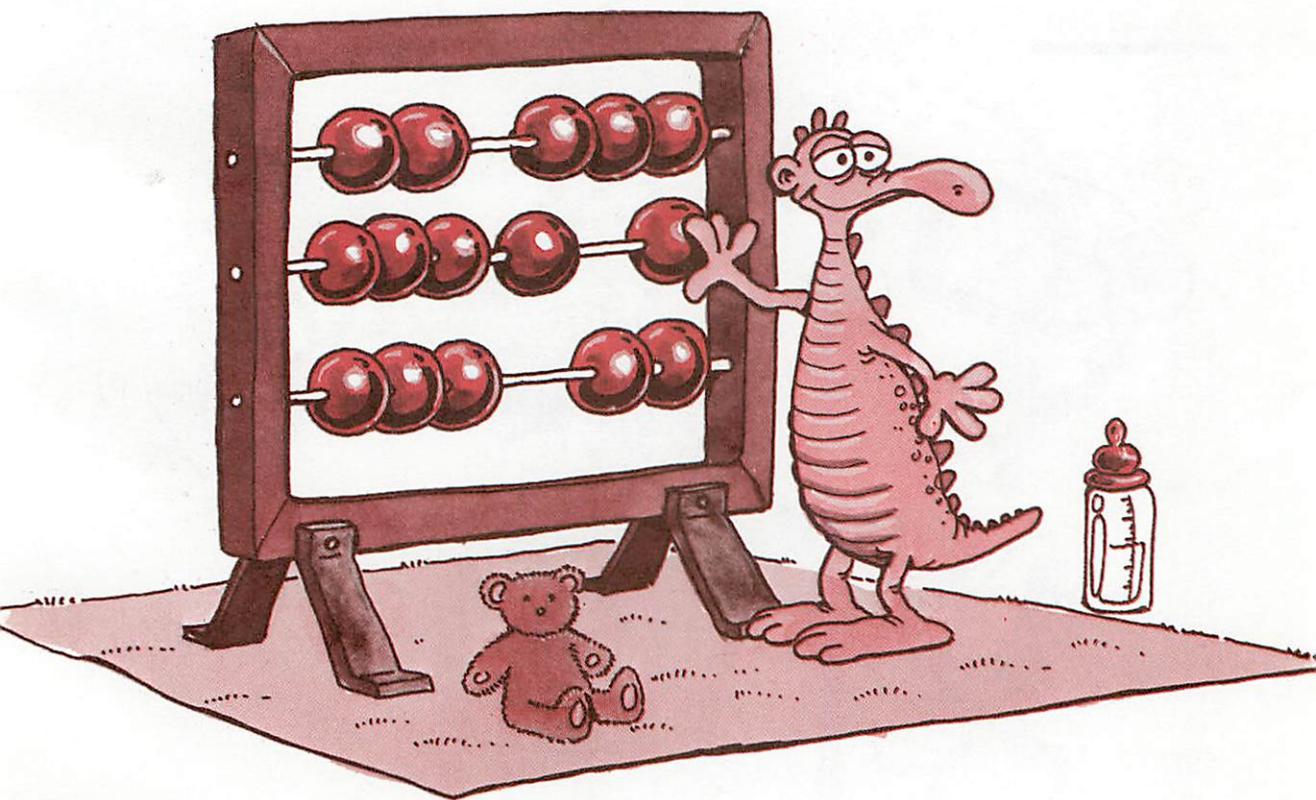
Calculat

3

In this chapter, we will start using numbers. We will display them and add, subtract, multiply, and divide them. We will learn to perform computations using the simple arithmetic operators, and we will describe the other important built-in operators in BASIC.

ing with BASIC

Printing Numbers

So far we have only printed text. Let's now print a number. Type:
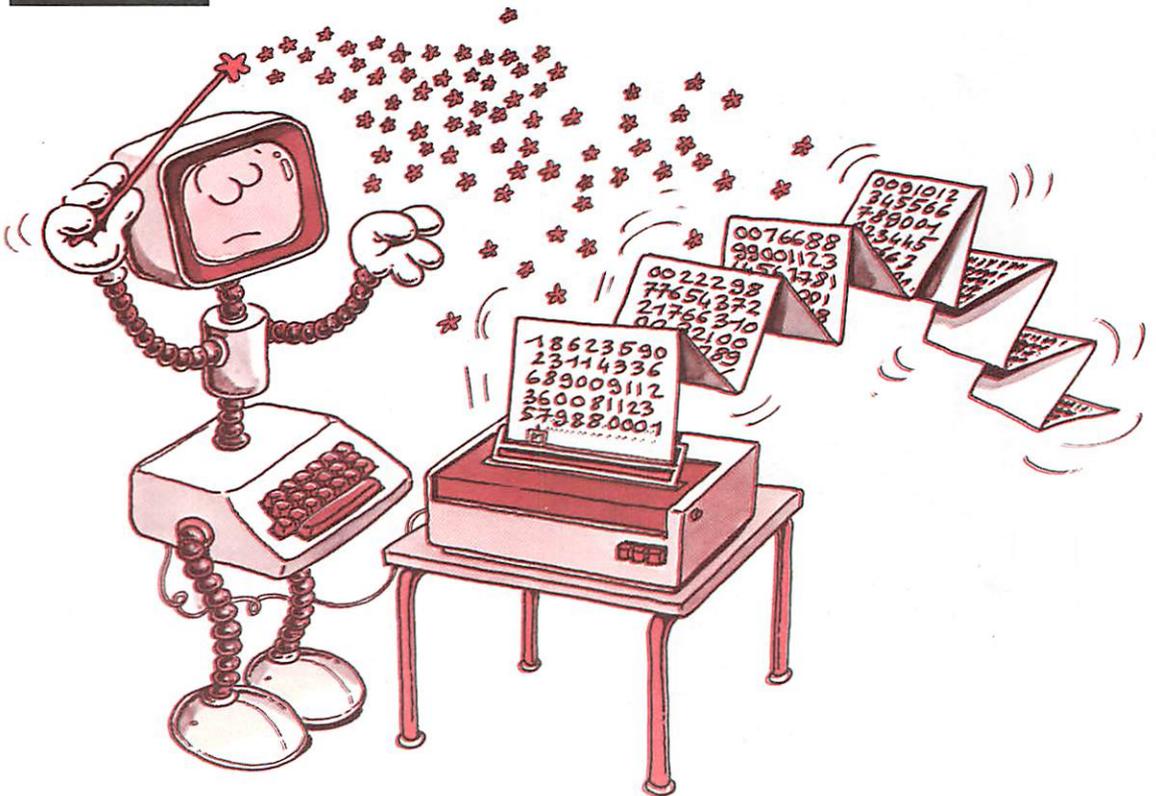
PRINT 3 ⮐

The result should be:

> 3

Recall from our discussion in Chapter 2 that this statement is in the immediate mode, where an instruction does not need to be preceded by a label and is executed immediately. In this chapter, we will write all of the examples in the immediate mode, so that you can execute them by pressing only a few keys.

Notice that in BASIC, numbers do not need to be enclosed in quotes, only text. The use of quotes allows the interpreter to easily differentiate between user-provided text and the BASIC reserved words, such as PRINT. The text inside the quotes is called a *string,* and a string may include numbers.

Let's now try to print several large numbers, say 100, 1000, 10000, etc. When you try to print a number with more than ten digits, you will notice that something odd happens—a decimal point appears to the right of the first digit, an "E" appears after the last digit, followed by a plus sign and a number. Your TI BASIC interpreter has converted your number into scientific notation. We'll discuss scientific notation shortly.

"I'll show you more ways to print numbers."

Your BASIC interpreter allows you to use decimal numbers.
Type:

```
PRINT 1.5 ⮐
```

You now see 1.5 displayed on your screen. In computer jargon,
decimal numbers are called *floating-point numbers*. A BASIC inter-
preter that allows the use of floating-point numbers is called a
floating-point BASIC.

Scientific Notation

Let's discuss decimal numbers further. As with integers, in the case
of decimal numbers, the interpreter will only retain a set number of
digits. For example, the correct value of one third is:

0.33333333333 . . .   *(etc.)*

Inside the computer, this value may be stored as:

0.33333333   *(eight significant digits are retained besides the zero)*

The correct value is said to have been *truncated* (cut) to eight digits.
(**Note:** This is an approximation, but it is generally sufficient.)
Your BASIC interpreter allows decimal numbers; it also uses a
scientific representation for these numbers. When a number becomes
very large or very small, it will be displayed in scientific notation to
save space.
Here is an example:

3.2 E +06

means

$3.2 \times 10^6 = 3200000$

10^6 means 10 to the power 6, i.e., 10 multiplied 5 times by itself:

$10 \times 10 \times 10 \times 10 \times 10 \times 10 = 1000000$

Similarly

1.12E – 07

means

$1.12 \times 10^{-7} = 0.000000112$

10^{-7} means 1/10 to the power 7, i.e., 1/10 multiplied 6 times by
itself ($1/10$ is 10^{-1}).
Using scientific notation, your TI BASIC interpreter can handle
numbers as small as -9.99×10^{-127} and as large as 9.99×10^{127}!

Doing Arithmetic

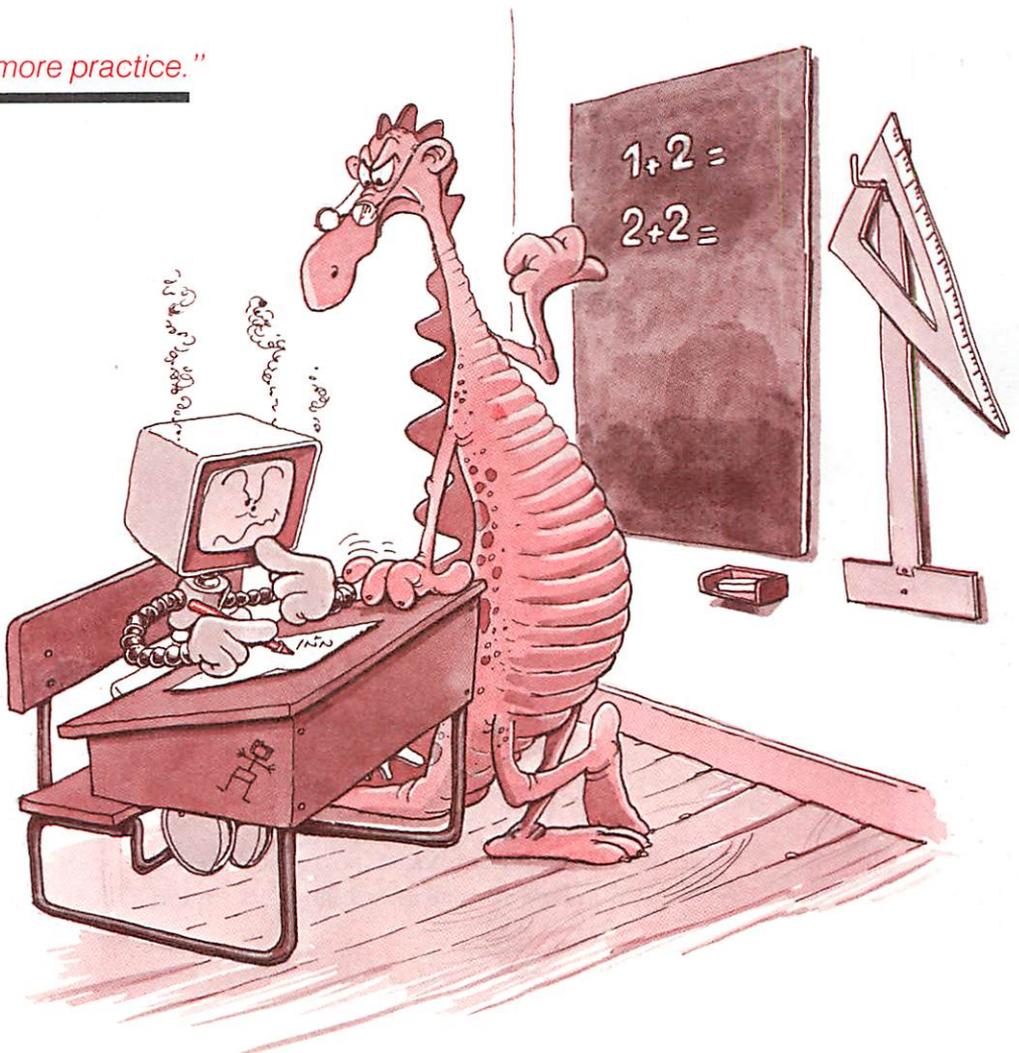Let's now perform simple arithmetic calculations. Type:

PRINT 2 + 2 ↲

The result appearing on your screen should be:

> 4

We have just performed our first arithmetic computation. The addition symbol, +, is called an *operator*. An operator is a symbol that represents an operation to be performed on one or more operands. BASIC provides five built-in arithmetic operators:

–	*(minus)*
+	*(plus)*
*	*(multiplication)*
/	*(division)*
^ *or* **	*(exponentiation or power)*

"You need more practice."

Now try this example. Type:

PRINT 2 * 3 ⊋

The result should be 6. The * symbol is the symbol for multiplication. The usual multiplication symbol, ×, could be confused with the letter X, so programming languages use the * symbol instead.
  Here are other examples of valid arithmetic statements:

PRINT 1 + 2 * 3 ⊋

The result is

> 7

PRINT 3 – 2 ⊋

The result is

> 1

PRINT 8/2 ⊋

The result is

> 4

PRINT 1 + 2 + 3 + 4 ⊋

The result is

> 10

Since TI BASIC allows decimal numbers, the following statement is also legal:

PRINT (6 / 3 + 12 / 4) / 2 ⊋

The result is

> 2.5

Note that parentheses have been used in this example to clarify the

grouping of operations. Let's try another example. Type:

```
PRINT 2 + 3 + 4 / 2
```

The result is:

7

The division (/) was performed first on the 4. This is due to the fact that in BASIC, if given a choice (i.e., if parentheses are not used), the division (/) or the multiplication (*) will take place before the addition (+) or the subtraction (−). If you had intended to divide the group $2 + 3 + 4$ by 2, then it would have been necessary to type:

```
PRINT (2 + 3 + 4) / 2
```

The result would then be:

4.5

The division would then have been performed on the group $(2 + 3 + 4)$. It is good practice to use parentheses freely, to avoid any confusion. For example, the following expression (or group of values and operators)

$$\frac{1 + 2 + 3}{4 + 5} \times 3$$

could be translated into the following BASIC expression:

```
((1 + 2 + 3) / (4 + 5)) * 3
```

or

```
(1 + 2 + 3) / (4 + 5) * 3
```

because execution proceeds from left to right when operators have the same precedence (standing), i.e., the division occurs here before the multiplication.

If you were to write the following in BASIC:

```
(1 + 2 + 3) / ((4 + 5) * 3)
```

it would be equivalent to:

$$\frac{1 + 2 + 3}{(4 + 5) \times 3}$$

Use parentheses to denote groups. Be sure to make sure there is always a matching right parenthesis for each left one.

Let's now use our new computing skill to display useful values.

Printing Formats

If you type:

    PRINT "TWO TIMES THREE IS", 2 * 3 ⏎

The result will be:

> TWO TIMES THREE IS
> 6

In the above PRINT statement, we have mixed text and numbers, separated by a comma. More precisely, we have used an *expression,* 2 * 3, rather than a number. Now, type:

    PRINT "TWO TIMES THREE IS, 2 * 3" ⏎

and you will get:

> TWO TIMES THREE IS, 2 * 3

This is a valid BASIC statement, but not the one you had intended. Remember, everything within quotes is displayed literally. The comma or semicolon must be *outside the quotes* to work correctly.

A PRINT statement may be used to print several items on the same line. The items must, however, be separated by a semicolon or a comma. A semicolon will result in a small space between the items being printed, while a comma will result in a larger space. Like a tab stop on a typewriter, the comma symbol is used to create *tabs,* i.e., fields on the screen. This technique is convenient for displaying tables.

Let's try this new feature. Type:

    PRINT 1;2;3 ⏎

Your display should show:

> 1 2 3

Now type:

    PRINT 1,2,3 ⏎

Your display should show:

> 1   2
> 3

Let's now compute the sales tax for a sale of $1234. The tax rate is 6.5%. The statement is:

PRINT   "SALES TAX IS"; 1234 * 6.5 / 100 ↵

The result is:

> SALES TAX IS 80.21

We could also type:

PRINT "SALES TAX IS"; 1234 * 0.065 ↵

and we would obtain the same result. There are many equivalent ways to write a program.

You can print many items on a line. Look:
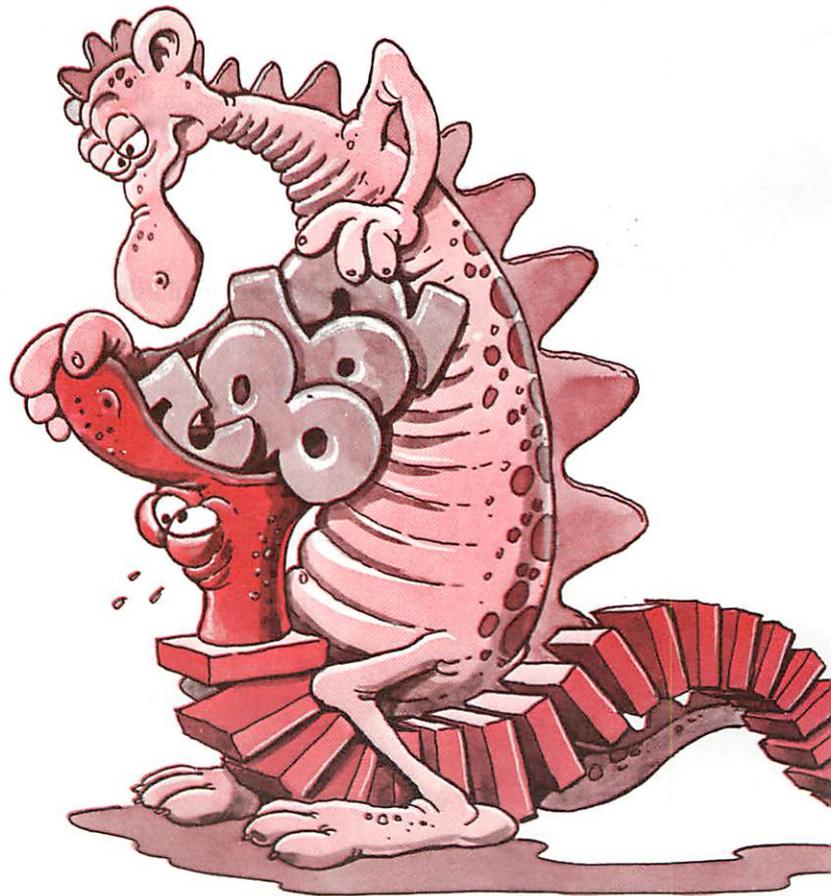
PRINT 1;2;3;4;5;6;7;8;9;"MANY ITEMS" ↵

The screen will show:

> 1 2 3 4 5 6 7 8 9
> MANY ITEMS

We have now learned how to perform simple arithmetic computations, and how to display the results. Let's use this new skill to solve some simple problems.

Only feed reasonable numbers to your program

Application Examples

Let's compute a car's mileage in miles per gallon. The mathematical formula is:

MILEAGE = DISTANCE (in miles) ÷ GAS (in gallons)

Let's assume that the distance was 510 miles and the amount of gasoline used was 20.2 gallons. Here is the statement written in BASIC:

PRINT "MILEAGE IS"; 510 / 20.2 ; "MPG" ⮐

For metric readers we will now convert this into liters per kilometer. One gallon is 3.8 liters. One mile is 1.6 kilometers. The consumption in liters per kilometer is:

PRINT "GAS CONSUMPTION IS"; (20.2 * 3.8) / (510 * 1.6) ; "L PER KM" ⮐

Here is another simple problem. Given a temperature in Fahrenheit, the Celsius equivalent is computed by the formula:

CELSIUS value = (FAHRENHEIT value − 32) × 5/9

To compute the Celsius equivalent of 79° F, type:

PRINT "79 DEGREES F = "; (79 − 32) * 5/9; "DEGREES C" ⮐

The result is:

```
79  DEGREES  F  =  26.11111111
DEGREES C
```

To be complete, note that 5/9 has not been enclosed in parentheses, as it does not matter whether * or / is executed first.

Summary

In this chapter, we have learned how to perform arithmetic computations and how to display text and results on the same line. We have used this new skill to automate the computation of simple formulas by writing one-line BASIC statements.

So far we have specified all the values within the BASIC statement itself. What we now want to do is first write a program, then supply values repeatedly from the keyboard so different values can be used with the program without having to rewrite it. We will accomplish this with *variables*. This is the topic of the next chapter.

Exercises

3-1: Write a BASIC statement that computes:

$$\frac{5 + 6}{1 + 2 \div 3}$$

3-2: Write a BASIC statement that computes:

$$1 + \frac{1}{2} \quad \frac{1}{1 + \frac{1}{2}}$$

3-3: Write a BASIC statement that computes the Fahrenheit equivalent of 20° C.

3-4: Given a speed of 100 km per hour, compute the equivalent speed in m.p.h. (1 mile = 1.6 km)

3-5: Compute the number of seconds in a day, a week, a month, and a year.
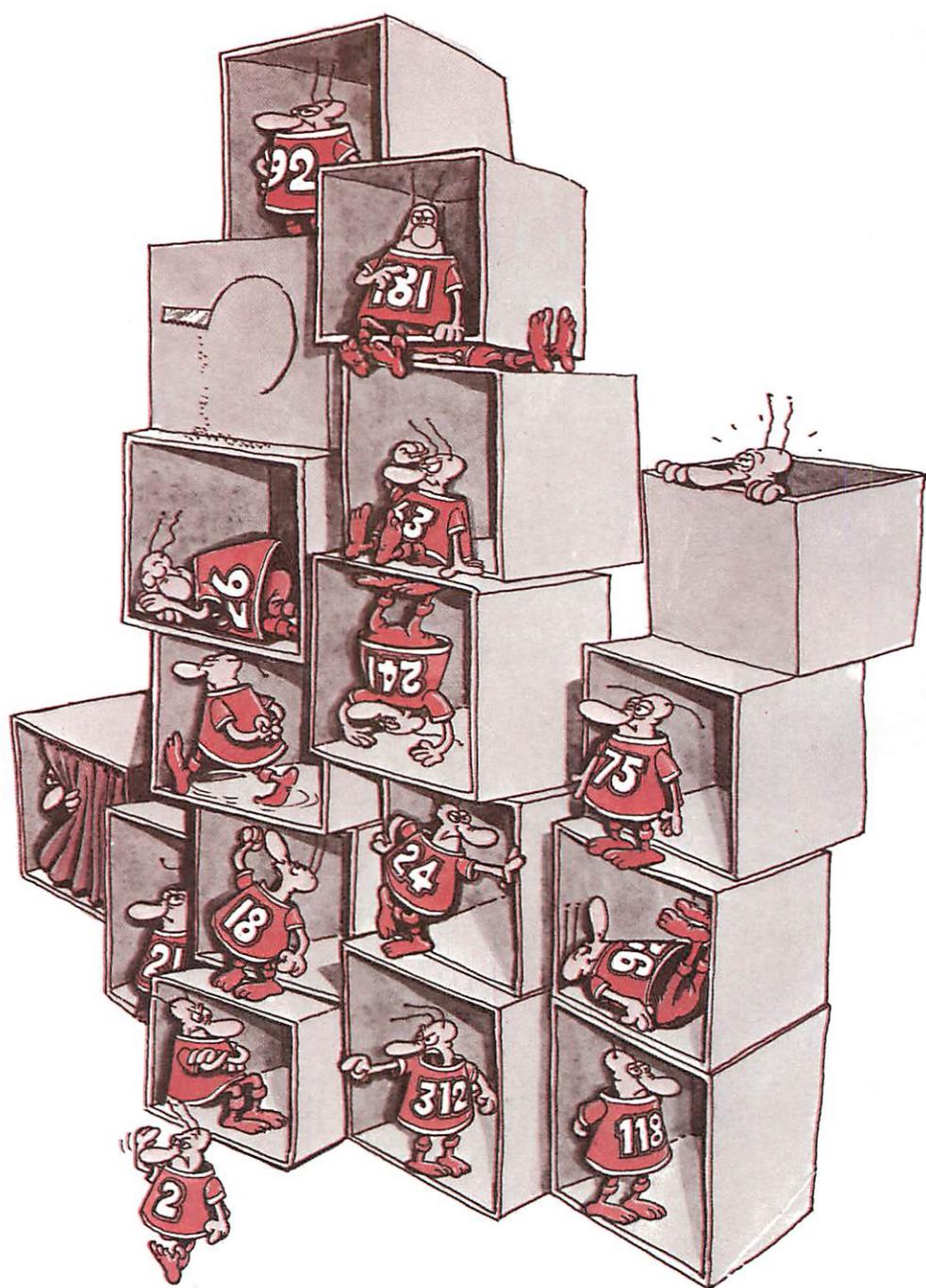
3-6: Assuming an average speed of 55 m.p.h., compute the time needed to travel 350 miles.

3-7: Assuming 365 days in a year, compute the number of days you have lived so far.

3-8: Compute the equivalent annual salary for a person, given the:

      a.   weekly pay (there are 52 weeks in a year)

      b.   biweekly pay (multiply by 26)

      c.   monthly pay

      d.   hourly pay (multiply by 2080)

Memorizing
Usi

Values and
g Variables

4

In this chapter, we will learn to write programs that can be used repeatedly, without change, and that will display different results, depending on the data supplied at the keyboard. So far, to obtain the result of an arithmetic computation, such as $2 + 3$, we have had to include in the program statement the numbers to be operated on. We will now learn to write programs that can be executed with different data each time. The programs will specify the operations to be performed. The data will be supplied at the keyboard by the user at the time the program is executed. This makes the program reusable.

In addition, we will introduce the concept of a variable and learn how to use two new statements: INPUT and LET.

Let's now begin by learning how to supply information to a program while it is running.

The INPUT Statement

Type the following program. (**Note:** we will no longer display ⏎ to indicate ENTER at the end of each line):

```
10  INPUT A
20  PRINT A;  2 * A;  3 * A
30  END
```

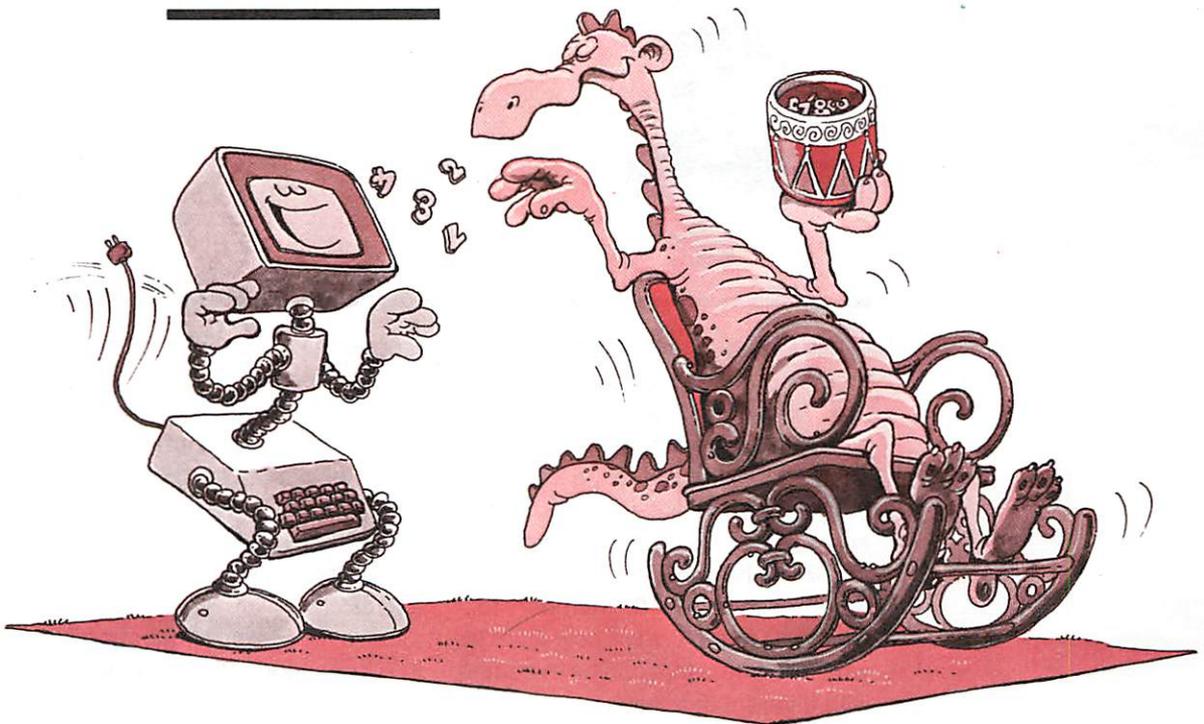Now execute this program by typing RUN, as usual. Your screen should look like this:

? ■

A "?" appears on your screen with a blinking cursor next to it to remind you to type in the input.

Now, type in a number, say 3. Terminate your input by pressing the ENTER key as usual. Your screen should now show:

```
    3   6   9
  * * DONE * *
> ■
```

On INPUT, your computer accepts numbers and letters

Your program has been executed. Let's see what happened. The first line was:

```
10  INPUT A
```

This statement asked you to provide a number at the keyboard. The program displayed a ?, and stopped—waiting for your input. The value 3 you supplied was then read and stored in A. "A" is called a *variable*. It is a name used to store a value. Formally, a *variable* is a name given to a memory location. Examples of some variable names are: A, B, C, F, Z1, G2. TI BASIC allows variable names with up to 15 letters as well, for example: INTEGER1, SUM, TAX, RESULT.

The second statement was:

```
20  PRINT A;  2 * A;  3 * A
```

This statement resulted in the printing of 3, 2 * 3, 3 * 3, or:

```
3  6  9
```

Using the INPUT statement, it is also possible to enter several values at the same time. Here is an example. Type:

```
10  INPUT A,B
20  PRINT A;  A * 2;  B;  B * 2
30  END
```

Now run the program. You should see the usual "?" appearing on your screen. Type two numbers, say 2 and 3, separated by a comma, then press return. The result is:

```
2  4  3  6
```

Let us examine what happened. The first line of the program was:

```
10  INPUT A,B
```

This statement resulted in a request for two values from you, which were then stored in the variables A and B. Remember that variables are names of memory locations. The contents of A and B were initially empty, but they became 2 and 3, respectively. The second statement of the program was:

```
20  PRINT A;  A * 2;  B;  B * 2
```

This statement resulted in printing the values: 2, 2 * 2, 3, 3 * 2, or:

```
2 4 3 6
```

Let's try running this program again. This time try typing:

5,8

and the results should be:

```
5 10 8 16
```

We can use this program repeatedly and obtain new results by typing in new values at the keyboard. We have made our program reusable by using variable names (A and B), instead of explicit values.
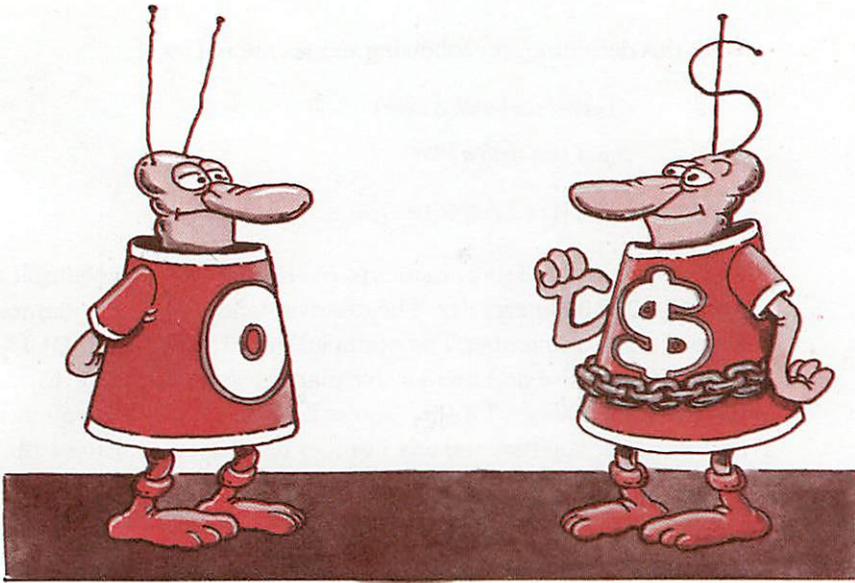
In order to make this program truly reusable, let's now improve its style and readability. Suppose that we want to save the program, and run it again in several days. We might forget what it does or we might not remember how many values we must supply. We can rewrite the program to display this information on the screen. Here is an improved version:

```
10  PRINT "A PROGRAM TO MULTIPLY"
20  PRINT "ANY TWO NUMBERS BY 2"
30  PRINT "TYPE TWO NUMBERS"
40  INPUT A,B
50  PRINT "FIRST NUMBER  :"; A,  "DOUBLE  :";  2 * A
60  PRINT "SECOND NUMBER  :"; B,  "DOUBLE  :";  2 * B
70  END
```

and here is the resulting display: (**Note:** throughout this text, we will display data provided by the user in **boldface** type.)

```
A PROGRAM TO MULTIPLY
ANY TWO NUMBERS BY 2
TYPE TWO NUMBERS
? 5,7
FIRST NUMBER  :  5
DOUBLE  :  10
SECOND NUMBER  :  7
DOUBLE  :  14
```

We have now learned how to supply numeric data to the program by using the INPUT statement. We have also introduced the concept of variable. Let's now learn how to use these techniques effectively and how to develop more complex programs.

The Two Types of Variables

There are two *types* of variables in BASIC: *numeric* and *string*. Numeric variables represent numbers; string variables represent text. These two types of variables look different; a string variable has a "$" at the end of the name. They are also used differently. For example, you can add numbers, but not text. Let's first learn about numeric variables, then about string variables.

Numeric Variables

Let's learn the rules for naming a numeric variable; then we will learn how to use these variables effectively. We have already used two numeric variables, called A and B, at the beginning of this chapter. We gave them a value by inputting numbers from the keyboard. Let's now learn how to name a variable.

When naming a variable, all BASICs, including the original Dartmouth BASIC, allow the use of one letter, optionally followed by a single number. TI BASIC allows any combination of letters and numbers up to 15 characters. However, a numeric variable name must start with a letter. Here are examples of valid TI BASIC variable names:

A	*(one letter)*
Z	*(one letter)*
A1	*(one letter and one digit)*
B2	*(one letter and one digit)*
ALPHA	*(five letters)*
R2D2	*(two letters and two numbers)*

53

With this definition, the following names are not legal:

12   *(does not start with a letter)*

1B   *(must start with a letter)*

ABCDEFGHIJKLMNOP *(too many characters)*

The advantage of short names is to reduce the size and complexity of the BASIC interpreter. The disadvantage is that short names are difficult to remember. For example, the long name RESULT is more descriptive and memorable than the short name R. To improve readability, TI BASIC allows long names, i.e., a sequence of characters. You may use any number of consecutive letters followed by optional digits, up to a maximum length of 15 characters. For example, the following are legal longer variable names:

WINNER	STUDENT1
LOSER	STUDENT2
RESULT	STUDENT14
SUM	CASE24

The following are not legal:

3TIMES	(starts with a digit)
A-ONE	(illegal symbol)

Every variable
must have a name

Clearly a program with long, explicit variable names is more readable. In this chapter, we will use both short and long names, so that you can get used to both conventions. Remember that long names are simply a matter of convenience and will not affect the program in any way.

There is one more restriction on names: you cannot use a name that is a *reserved word*, i.e., a name that has a meaning to your BASIC interpreter. For example, you may not use LIST, END or RUN as variable names. (**Note:** a list of reserved words appears at the end of this book, as well as at the end of the reference manual for your BASIC interpreter.) TI BASIC also prohibits you from using a reserved word as the first part of a variable name. To be safe, it is best never to use a reserved word as any part of a variable name.

Now that we know how to create legal names for numeric variables, let's learn how to give a name to a piece of text known as a *string*.

String Variables

First, let us introduce strings. Here are examples of strings:

"RESULT"

"THIS IS AN EXAMPLE"

"MY NAME IS JOHN"

"25 TIMES 4 = "

Note that a string is normally enclosed in quotes; otherwise, it could be confused with a variable name. A string may contain any sequence of characters, except the quotation symbol. The length of a string is limited to 256 characters.

Let us now introduce string variables. When the value stored in a variable is text (that is, a string), rather than a number, the variable is called a *string variable*.

A string variable's name is just like a numeric variable's name, except that it must have a "$" at the end. Here are some valid short string variable names:

A$

R$

A1$

B5$

Since TI BASIC allows long names, here are several more valid names:

NAME$

FIRST$

CITY$

UNIT25$

*"I'm a string variable.
I contain text.
My name ends with a $."*

55

Let's now illustrate the use of string variables, with a program that greets the user by name.

```
10   PRINT "I AM HAL, THE COMPUTER"
20   PRINT "FIRST NAME";
30   INPUT FIRST$
40   PRINT "LAST NAME";
50   INPUT LAST$
60   PRINT "HELLO, "; FIRST$; " "; LAST$; "!"
70   PRINT "NOW I KNOW YOUR NAME"
80   PRINT "I LIKE "; FIRST$; " AS A FIRST NAME."
90   END
```

Here is a sample run. Note that the characters you type appear here in boldface type.

```
I AM HAL, THE COMPUTER
FIRST NAME? JOHN
LAST NAME? SULLIVAN
HELLO, JOHN SULLIVAN!
NOW I KNOW YOUR NAME!
I LIKE JOHN AS A FIRST NAME.
```

You can now communicate with your computer! Let's point out some of the basic features of this program. Let's start with line 20:

```
20   PRINT "FIRST NAME";
```

Note that this line is terminated with a semicolon. The semicolon means "display the next character immediately after this text." The result of statement 20 and your response to statement 30 is:

```
FIRST NAME? JOHN
```

If you had written:

```
20   PRINT "FIRST NAME"
```

with no semicolon at the end, the result would have been:

```
FIRST NAME
?JOHN
```

Naturally, you may choose either way. The format is a matter of preference. But remember, if you want the characters you type to appear on the same line as the preceding message, use a semicolon at the end of the PRINT statement. Otherwise, the next position on the screen will be the beginning of the following line.

Now that we know more about numeric and string variables, let's use them as we continue our dialogue with Hal, the computer.

Let's add the following to our program:

```
90    PRINT "THIS YEAR (2 DIGITS)";
100   INPUT CURRENTYEAR
110   PRINT "WHICH YEAR WERE YOU"
120   PRINT "BORN (2 DIGITS)";
130   INPUT YEARBIRTH
140   PRINT "DEAR "; FIRST$; ",  THIS YEAR "
150   PRINT "YOU ARE OR WILL BE";
          CURRENTYEAR – YEARBIRTH
160   END
```

Here is a sample dialogue. Again, the characters you type are shown in boldface type.

```
THIS YEAR (2 DIGITS)? 83
WHICH YEAR WERE YOU
BORN (2 DIGITS)? 50
DEAR JOHN, THIS YEAR
YOU ARE OR WILL BE 33
```

Let us examine the program in detail. The statement

```
90    PRINT "THIS YEAR (2 DIGITS)";
```

prints the obvious message. Again a semicolon is used so that the two digits will be displayed on the same line. In the next statement,

```
100   INPUT CURRENTYEAR
```

CURRENTYEAR is a numeric variable. The value 83 that you typed will be read into it. From now on, whenever the name CUR-RENTYEAR is used, the value 83 will be substituted automatically by the BASIC interpreter. This will happen in statement 130.

The two statements

```
110   PRINT "WHICH YEAR WERE YOU"
120   PRINT "BORN (2 DIGITS)";
```

are just like statement 90. Note the semicolon at the end. The statement

```
130   INPUT YEARBIRTH
```

is just like statement 100. YEARBIRTH is a new numeric variable. It will soon contain the value 50. In statement 150 we use this variable name. Note that the value 50 is substituted automatically by the interpreter. Let's examine this:

```
140   PRINT "DEAR "; FIRST$; ",  THIS YEAR "
150   PRINT "YOU ARE OR WILL BE";
          CURRENTYEAR – YEARBIRTH
```

When these statements are executed, the following is displayed:

```
DEAR JOHN, THIS YEAR
YOU ARE OR WILL BE 33
```

Let's break this display down and examine it.

DEAR

(This is called a literal string. A literal string is a string that is part of a program statement.)

JOHN

(This is the string value that is read at the keyboard and stored in the string variable named FIRST$. It remains there as long as you don't use the NEW command or enter a new value into FIRST$.)

THIS YEAR YOU ARE OR WILL BE

(This is another literal string.)

33

(This is the result of: CURRENTYEAR − YEARBIRTH, i.e., 83 − 50 = 33.)

In typing and examining this program, you may already have developed some frustrations. For example, you may have wanted to enter actual dates, including the day and month, so that you can compute your age, as of today. However, this requires comparing today's month and day with that of the birthdate's. To do this, we must learn about a new BASIC statement, the

IF (condition) THEN (do)

statement. We'll discuss this statement in detail in Chapter 7. Another thing that you might want to do is to design the program so that it executes repeatedly (so that you don't need to type RUN everytime). We'll learn how to do this in Chapter 6, when we discuss the GOTO statement.

Now that we are familiar with both numeric and string variables, let's learn how we can use them in a longer program—first, by assigning a value to a variable, then by using the counter technique.

Assigning a Value to a Variable
(The LET Statement)

So far, the only way we have given a value to a variable has been with the INPUT statement. For example, when the following statement is executed:

```
20  INPUT A
```

you type in a value, such as 5.2 (followed by a ↵), and the value of A is then 5.2.

There is, however, another way to assign a value to A. This is called the *assignment* statement. Here is an example:

```
10   A = 5.2
```

This statement assigns the value 5.2 to A as part of the program, so that you do not have to supply it from the keyboard. You might also write:

```
10   B = 1
20   C = 2
30   A = B + C
```

As you can see, the value of A will be set at 2 + 1 = 3 when statement 30 is executed.

In earlier BASICs, the assignment statement must start with the reserved word LET. In such BASICs, this example would be written as:

```
10   LET  B = 1
20   LET  C = 2
30   LET  A = B + C
```

The purpose of the LET statement was to simplify the design of the interpreter by telling it explicitly that the statement is an assignment statement. The LET statement is optional in TI BASIC. Eliminating it eliminates one step for the programmer when writing such statements.

"Z, I want you to hold this value!"

Let's now show the value of the assignment statement. We will examine two examples. In both examples, we will compute the sum and the average of two numbers. Here is our first program, without the assignment statement:

```
10    PRINT "GIVE ME TWO NUMBERS"
20    PRINT "I WILL COMPUTE THEIR"
30    PRINT "SUM AND AVERAGE"
40    PRINT "1ST NUMBER:";
50    INPUT A
60    PRINT "2ND NUMBER:";
70    INPUT B
80    PRINT "THE SUM OF"; A; "AND"; B;
90    PRINT "IS: ";
95    PRINT A + B
100   PRINT "THEIR AVERAGE IS:";
105   PRINT (A + B) / 2
110   END
```

And here is a typical run:

```
GIVE ME TWO NUMBERS
I WILL COMPUTE THEIR
SUM AND AVERAGE
1ST NUMBER:? 24
2ND NUMBER:? 41
THE SUM OF 24 AND 41
IS: 65
THEIR AVERAGE IS: 32.5
```

Notice that the expression A + B is repeated twice in the PRINT statements. This is just a minor inconvenience. However, in a longer program, this would increase the probability of typing errors. In addition, if we were to change the program to use a different formula, much rewriting would be needed.

Here is an equivalent program that uses an *intermediate variable*, called SUM, to store the result. It is easier to read, and less error prone.

```
10    PRINT "GIVE ME TWO NUMBERS"
20    PRINT "I WILL COMPUTE THEIR"
30    PRINT "SUM AND AVERAGE"
40    PRINT "1ST NUMBER:";
50    INPUT A
60    PRINT "2ND NUMBER:";
70    INPUT B
80    SUM = A + B
90    AVERAGE = SUM / 2
100   PRINT "THEIR SUM IS:";
105   PRINT SUM
```

```
110   PRINT "THEIR AVERAGE IS:";
115   PRINT AVERAGE
120   END
```

Two new variables are used:

```
80   SUM = A + B
90   AVERAGE = SUM / 2
```

Using additional variable names has two advantages: the program is clearer, and it is easier to modify. For example, let's assume that we now want to modify this program to obtain the average of three numbers. To do this, we would type:

```
72   PRINT "3RD NUMBER:";
74   INPUT C
80   SUM = A + B + C
90   AVERAGE = SUM / 3
```

We would leave the rest of the program unchanged. We have simply read in a third number, and modified the formulas at a single location. Here is the complete program:

```
10    PRINT "GIVE ME TWO NUMBERS"
20    PRINT "I WILL COMPUTE THEIR"
30    PRINT "SUM AND AVERAGE"
40    PRINT "1ST NUMBER:";
50    INPUT A
60    PRINT "2ND NUMBER:";
70    INPUT B
72    PRINT "3RD NUMBER:";
74    INPUT C
80    SUM = A + B + C
90    AVERAGE = SUM / 3
100   PRINT "THEIR SUM IS:";
105   PRINT SUM
110   PRINT "THEIR AVERAGE IS:";
115   PRINT AVERAGE
120   END
```

And a typical run:

```
GIVE ME TWO NUMBERS
I WILL COMPUTE THEIR
SUM AND AVERAGE
1ST NUMBER:? 5
2ND NUMBER:? 3
3RD NUMBER:? 10
THEIR SUM IS: 18
THEIR AVERAGE IS: 6
```

We have now learned two methods for associating a value with a variable:

- ► We can use the INPUT statement—where a value is supplied at RUN time, i.e., when the program is executed.

- ► We can use the assignment statement—where a value or a method to compute the value (a formula) is stored within the program itself.

The first method (using the INPUT statement) should be used when you expect that the value explicitly supplied to the variable (that is, not a *computed* value) will be different every time the program is executed.

The second method (using the assignment statements) should be used whenever you are using a formula to compute the value of the variable, or whenever you expect the explicit value (i.e., not a *computed* value) to remain the same every time the program is executed.

Let's now learn the complete rules for writing an assignment statement.

The Syntax of an Assignment

The rules (or syntax) for writing an assignment statement are simple. The general form of an assignment statement is:

$$<\text{variable}> = <\text{expression}>$$

There must always be a variable on the left and an expression on the right. More precisely, an expression is:

- ► a number or a variable, or

- ► a number or a variable followed by an operator (such as $+, -, *, /$), and another expression.

Here are a few sample expressions:

3	*(a number)*
A	*(a variable)*
2 + 2	*(number, operator, number)*
A + 2	*(variable, operator, number)*
A + B * 3	*(variable, operator, expression)*

Expressions may be enclosed in parentheses, for example:

$$3 + (A + 2) / 2$$
$$B + ((C * 2) + (D / 2)) / 4$$

You may want to think of an expression as a value, or as something that will be computed and will result in a value (in other words, as a formula for computing a value).

The equal (=) sign used in an assignment statement is not interpreted the same as in standard mathematics. In an expression it means "receives the value of." For example, you may write:

```
10  A = 1
20  A = A + 1
```

(The expression A = A + 1 would be meaningless or absurd in ordinary mathematics.) In BASIC, after statement 20 is executed, the value of A will be 1 (the previous value of A) + 1 = 2. Remember that in an assignment statement in TI BASIC, the = sign means that the variable on the left receives the value of the expression on the right.

Here are examples of valid assignment statements:

A = −3 + 2   (−3 is a negative integer)

B = A + 1

C = (2 ∗ 3) + (A / B)

AVERAGE = SUM / INTEGER

SQUARE = A ∗∗ 2

X = B ∗∗ 2 = (4 ∗ A ∗ C)

Let's examine this last assignment and verify that it satisfies our definition:

```
B ∗ ∗ 2
```

is

<variable> <operator> <number>

followed by

− (4 ∗ A ∗ C)

i.e.,

<operator> <parenthesized expression counting as a value>

Inside the parentheses:

```
4 ∗ A ∗ C
```

is

<number> <operator> <variable> <operator> <variable>

Yes, it is a valid expression.

The following assignments, however, are not valid:

B + C = SUM	*(only one variable (not an expression) on the left of the = sign)*
2 = A	*(there must be a variable, not a value on the left)*
SUM = B + C (D / 3)	*(missing operator after C)*
(AVERAGE) = (B + C) / 2	*(no parenthesis allowed on the left)*
A =	*(missing value on the right)*

Finally, note that at the time an assignment is executed, all variables on the right of the = sign must have received a value. If you write

```
10  B = 2
20  SUM = B + C
30  INPUT  C
```

the program will fail at line 20, since C does not have a value. You probably meant to write:

```
10  B = 2
20  INPUT  C
30  SUM = B + C
```

We've now learned the syntax of assignments. Let's use this new skill and introduce an important technique that uses assignments: the *counting technique.* We will use it in many of our programs.

The Variable Counter Technique

Remember that a variable is simply a name given to a memory location. A value can be stored in a memory location by using an INPUT statement or an assignment statement (=). In this example,

"Let's play counter!"

64
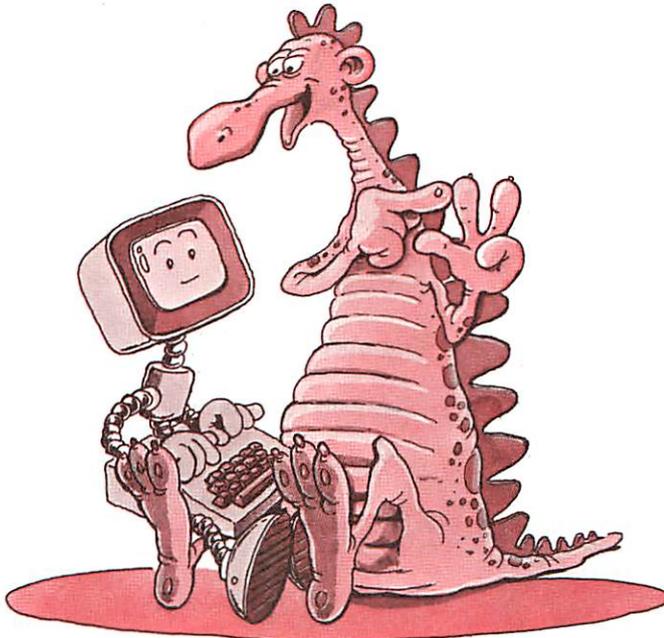
we want to change the value of a variable repeatedly, in order to count events. The technique we will use to do this is called the *variable counter* technique.

Let's now demonstrate how successive assignments can change the value of the variable N. Type the following in the immediate mode:

    N = 1

The value is automatically stored in N. Let's verify that it is. Type:

    PRINT N

The value 1 appears. Now type:

    N = 2

N now contains 2. Type:

    PRINT N

The response is:

    2

The value 2 has been substituted for the value 1 in N. Type:

    N = 3

Now type:

    PRINT N

and verify that the value 3 has been stored in N. The mechanism works. We will soon use this technique to count events. In other words, a variable can be used as an event counter. Here is a preview of an advanced program that counts how many times you supply a number at the keyboard. It stops when you hit zero.

```
10   SUM = 0
20   SUM = SUM + 1
30   PRINT "ENTER ANY NUMBER"
40   PRINT "TYPE 0 TO STOP";
50   INPUT VALUE
60   PRINT "YOU HAVE ENTERED"
70   PRINT SUM; "NUMBERS"
80   IF NUMBER < > 0 THEN 20
90   END
```

Later on in Chapter 6, we will examine statements like statement 80 in greater detail. The statement means: IF VALUE is not

equal to (< >) zero, THEN execute statement 20. Here is a typical run:

```
ENTER  ANY  NUMBER
TYPE  0  TO  STOP?  5
YOU  HAVE  ENTERED
   1  NUMBERS
ENTER  ANY  NUMBER
TYPE  0  TO  STOP?  1
YOU  HAVE  ENTERED
   2  NUMBERS
ENTER  ANY  NUMBER
TYPE  0  TO  STOP?  0
YOU  HAVE  ENTERED
   3  NUMBERS
```

In this program, the value of SUM is *initialized* to 0 in the first statement. It increases by one every time a new number is entered. This is a counter variable. We will see many examples of this technique as we write more programs. Later, we will learn how to tune up such a program, if we don't want to have 0 count as a number when we stop the program.

Summary

In this chapter we have learned to write programs that can be used repeatedly. These programs will supply new results depending on values provided at the keyboard. We have achieved this by using variables and assigning values to them in various ways.

A variable should be thought of as a name given to a memory location in which a value or text may be stored or accumulated.

We have learned to change the contents of a variable by using an INPUT or assignment statement. We can now write a simple program that automates a dialogue or a simple computation.

However, our programs now consistently exceed ten lines. They have become long. Let's keep them clear. In the next chapter, before proceeding any further and learning new tools and techniques, we will learn how to write a clear program.

Exercises

4-1: Read four numbers at the keyboard and display the total, the average, and the product of the four numbers.

4-2: Are the following variable names valid?

a. 24B	e. ALPHA2D	i. PI
b. B24	f. EXAMPLE	j. 3$
c. A + B	g. INPUT	k. THREE
d. APLUSB	h. INPUT1	l. NAME$

4-3: Write a program that asks the name of the user and says: "I THINK I KNOW A (name here)!"

4-4: Write a program that requests:

— the name of an object

— the name of a piece of furniture

— the name of a friend

then says: "DOES YOUR FRIEND (name) HAVE A (object) ON A (piece of furniture)?"

4-5: Write a program that requests the color of your eyes, then says: "I LIKE (color) EYES."

4-6: Are the following assignments valid:

a. A + 1 = A	d. B + C = A
b. A = A + A + A	e. 3 = 2 + 1
c. A = B + C	f. INTEGER = FIRST + LAST $\star$ 2

Writing a Cl

5

So far, we have written short programs using three different types of statements: PRINT, INPUT, and assignment (=). We have also learned how to write simple arithmetic expressions. In the chapters that follow, we will learn new techniques and statement types, and we will write longer programs. Before we proceed, however, let's learn to make our programs clear and readable.

Making a program readable is important. If you write a program today and wish to use it or change it in a few days, it will probably take you some time to remember and understand what the program does, and how. As a rule, plan in advance and make each program as readable as possible as soon as you write it. The purpose of this chapter is to help you improve your program readability.

We will examine seven techniques:

1. The use of the REM statement (to introduce *remarks* in a program)

2. The use of multiple statements on one line

3. The use of blanks within a statement

4. The use of the "empty PRINT" and the CALL CLEAR statements (to improve the display on the screen)

5. The use of the "shortcut INPUT" statement (to reduce the number of lines in a program)

6. The selection of meaningful names for variables

7. The proper line numbering.

We will now describe each technique in turn.
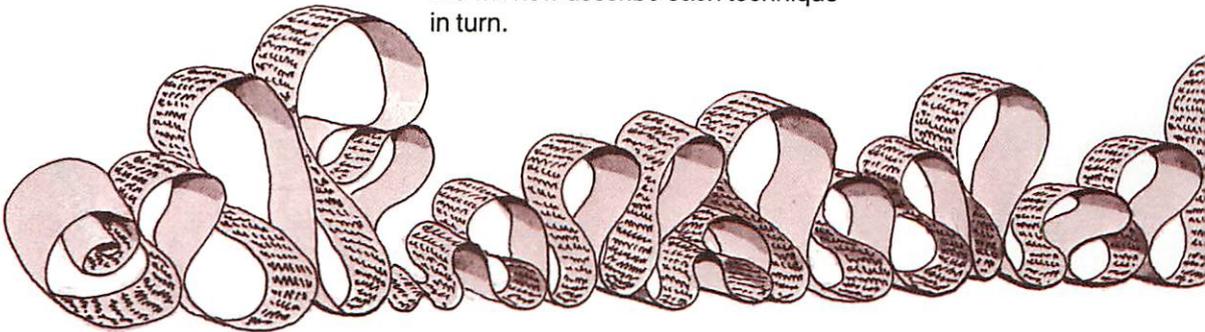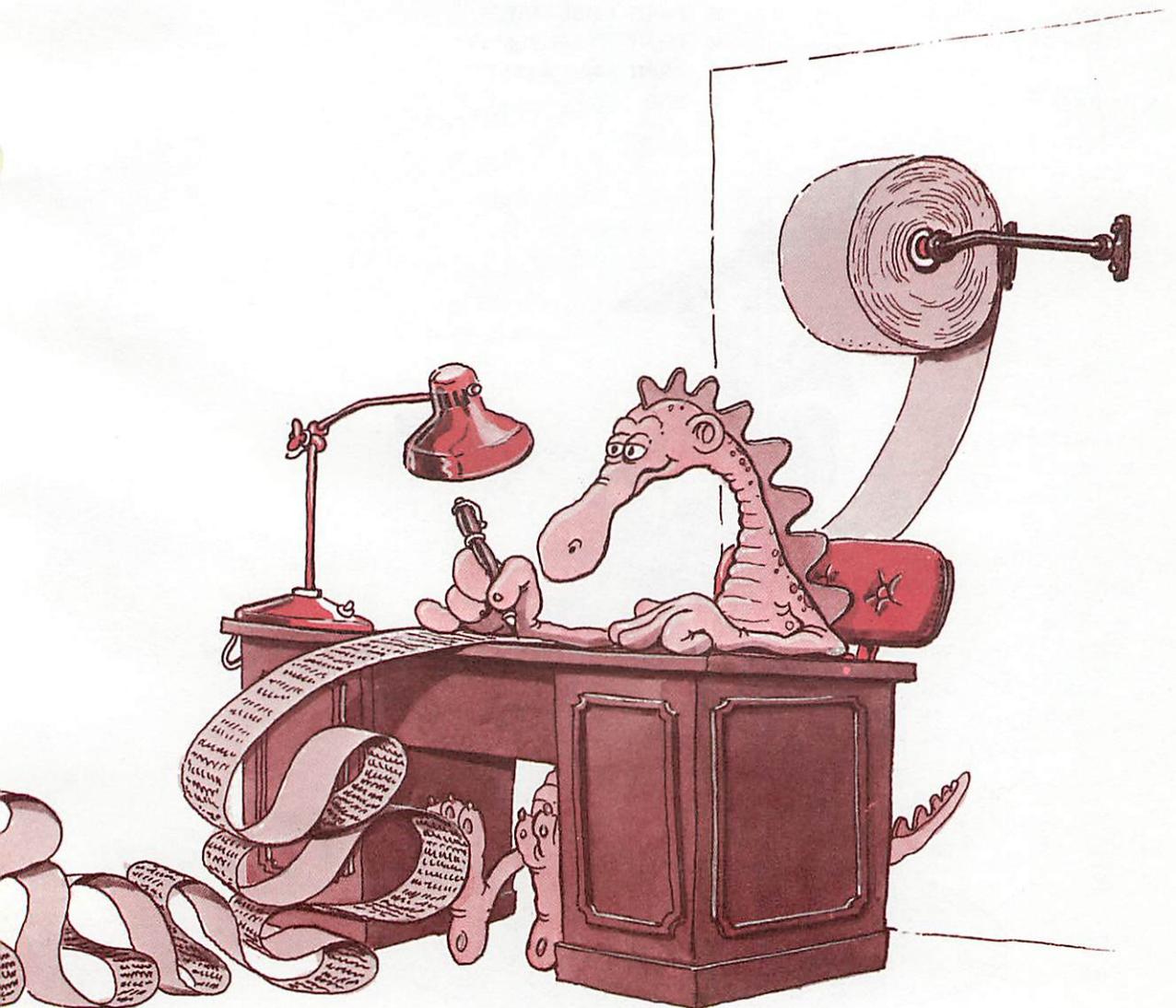
The REM Statement

Here is an example using the REM statement:

```
10   REM * * * ADDITION  PROGRAM  * * *
20   PRINT "GIVE ME TWO NUMBERS:";
30   INPUT FIRST,  LAST
40   PRINT "THEIR SUM IS:   ";
45   PRINT FIRST + LAST
50   END
```

The REM statement is used to make the program more readable by introducing comments in the text. This statement is ignored by the interpreter when the program is executed and has no effect on the program. Here is an additional example of a remark you could use:

```
25   REM NOW READ THE TWO NUMBERS
```

and here is the resulting program

```
10   REM * * * ADDITION  PROGRAM  * * *
20   PRINT "GIVE ME TWO NUMBERS:";
25   REM  NOW READ  THE  TWO  NUMBERS
30   INPUT FIRST,  LAST
40   PRINT "THEIR  SUM  IS:";
45   PRINT  FIRST + LAST
50   END
```


*REMarks are
invisible to
the interpreter*
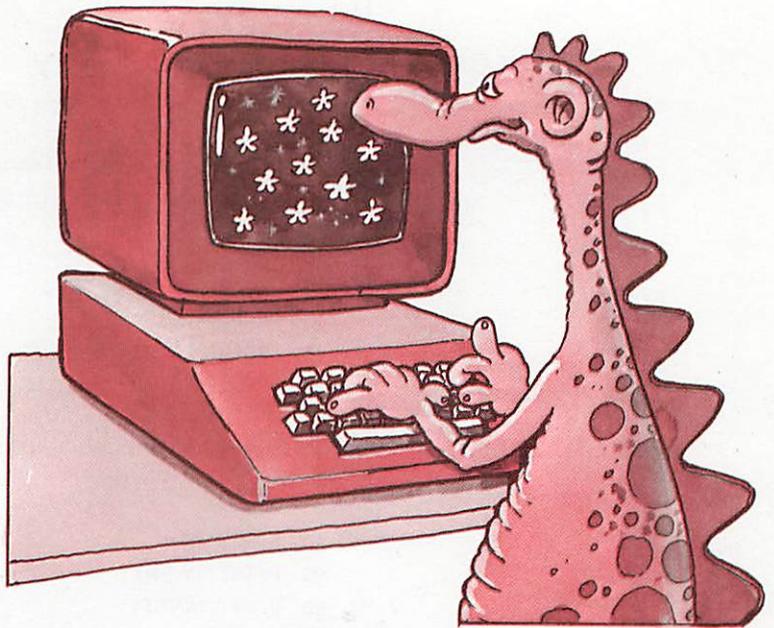
For improved readability, you may want to use stars, dashes, or other symbols:

```
10    REM * * * ADDITION  PROGRAM * * *
60    REM - - - - -SECOND  PART- - - - -
100   REM = = = = =GRAND  FINALE = = = = =
200   REM $$$$$CHANGE  THIS  SECTION  LATER$$$$$
```

Multiple Statements on a Line

Some BASICs allow you to write two or more statements on the same line, separated by a colon. However, TI BASIC does not offer this facility. Each instruction must appear on its own line.

Using Blanks

With the exception of names, strings, or input data, blanks are generally ignored by BASIC. For example, you may write:

```
20  PRINT 4 + 2 * 3
```

However, a statement like this is hard to read. To facilitate reading back your program, use blanks liberally. Use blanks:

► *after each reserved word, such as PRINT and INPUT.*

Here are examples:

```
50   PRINT  4
60   INPUT  VALUE
```

► *before and after each operator.*

Here are examples:

```
30  PRINT  4  +  2  *  3
40  RESULT  = A1 / ((B  -  C)  *  D)
```

You may also want to use blanks before a reserved word, to align or indent statements in your program. Here is an example:

```
10    PRINT "TEN"
20    PRINT "TWENTY"
90    PRINT "NINETY"
100   PRINT "ONE HUNDRED"
200   PRINT "TWO HUNDRED"
```

Without the two leading blanks in lines 10, 20, and 90, the program would look like this:

```
10   PRINT "TEN"
20   PRINT "TWENTY"
90   PRINT "NINETY"
100  PRINT "ONE HUNDRED"
200  PRINT "TWO HUNDRED"
```

Finally, here is an example of using blanks within a REM statement to even further facilitate reading:

```
1  REM   THIS PROGRAM MAINTAINS MY INVENTORY
2  REM   COPYRIGHT MYSELF 1982
3  REM   THESE ARE THE VARIABLES:
4  REM   C    IS THE COLOR (1 TO 10)
5  REM   U    IS THE NUMBER OF UNITS (UP TO 1000)
6  REM   S    IS THE SIZE (1 TO 50)
7  REM   CST IS THE UNIT COST
8  REM   R    IS THE RETAIL PRICE
9  REM   Q    IS THE REORDER QUANTITIES
```

Note how the blanks are used to enhance readability. You may not, however, add blanks in the middle of a reserved word, a variable name, or during a response to INPUT, unless the blanks are part of a string.

Improving the Display

Two new techniques can be used to improve the way your results look on the screen: the CALL CLEAR statement and the empty PRINT statement.

The CALL CLEAR statement clears the screen at the time it is used. You may want to start each new program with:

```
10  CALL CLEAR
```
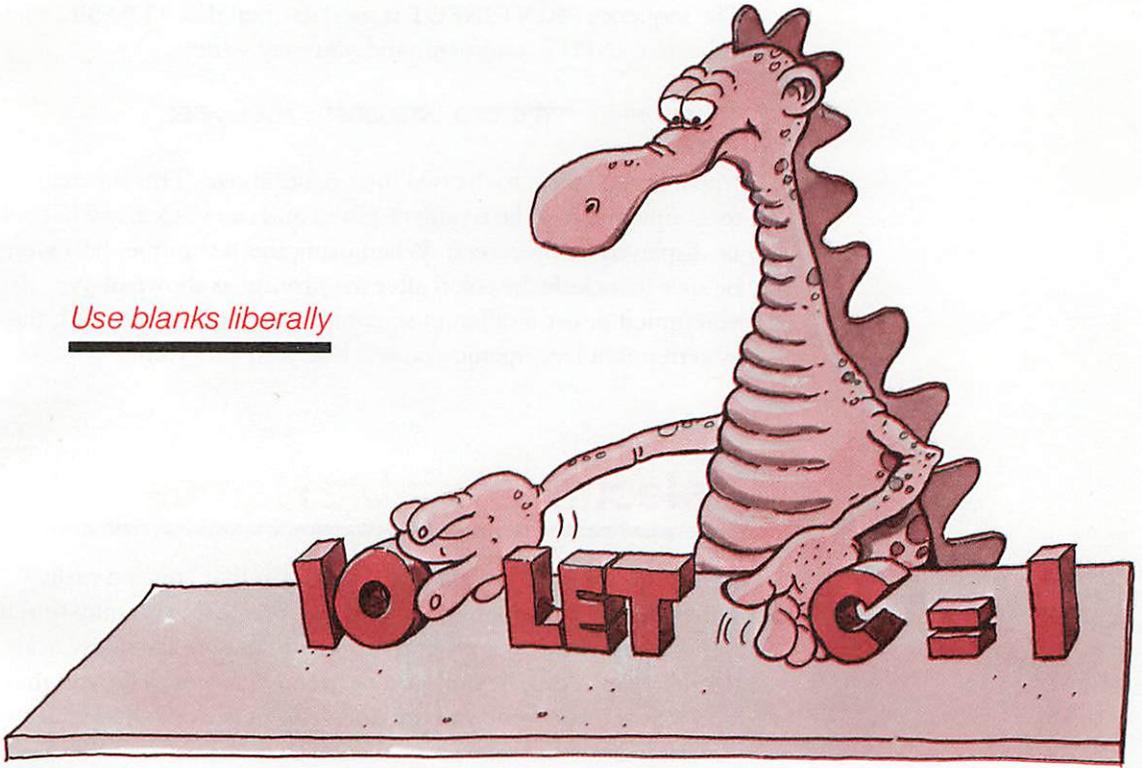
Here is a trick you may want to use. At the end of your program, you can write:

```
110  CALL CLEAR
120  LIST
```

This will clear the screen and list the entire program—after it is executed.

The empty PRINT statement can be used to display a blank line. You simply type:

```
50  PRINT
```

and a blank line will be displayed. If you want to skip three lines on the screen, type:

```
50  PRINT
60  PRINT
70  PRINT
```

Shortcut INPUT

Everytime you use an INPUT statement, you should prompt the user of the program by explaining what to enter. Here is an example:

```
50  PRINT "TYPE TWO INTEGERS";
60  INPUT AGE1, AGE2
```

The sequence PRINT-INPUT is used so often that TI BASIC allows a shortcut INPUT statement, and you may write:

```
50   INPUT "TYPE TWO INTEGERS" : AGE1, AGE2
```

which is equivalent to the two statements above. This shortcut technique reduces the typing required and shows clearly what will be displayed on the screen. When using this technique, however, be sure to include the colon after the prompt as shown above. If you omit it or use a different separator (such as a semicolon), the system might lock up and you will lose your program.

Selecting Variable Names

You should always select variable names so that you can easily remember what the name represents. Otherwise, you may find it difficult to write a long program, and you may make many accidental errors. Also, if your variable names are not clear, you may find that at a later date you are unable to figure out what your program does.

TI BASIC allows multiple letter names, so use them. Here is an example showing the use of variable names that are easy to remember.

```
10   REM  HERE  ARE  THE  VARIABLES  FOR  THE  SECOND  NUMBER
20   REM       RESULT     FOR  THE  RESULT
30   REM       FIRST      FOR  THE  FIRST  NUMBER
40   REM       LAST       FOR  THE  LAST  NUMBER
```

Two main restrictions apply:

- ► TI BASIC restricts you to a maximum of 15 characters.

- ► You may not use a reserved word, such as PRINT, REM or INPUT, as a variable name.

It is a good idea to identify all your variable names at the beginning of each program, as well as any formulas or equations you will be using.

Proper Line Numbering

So far in this chapter we have numbered lines by multiples of 10:

```
10   (statement)
20   (statement)
30   (statement)
```

You may, however, use any sequence you want, as long as you use positive integers, and you do not go over the 32,767 limit for line numbers. For example, you may write:

```
1   (statement)
2   (statement)
3   (statement)
```

or:

```
100   (statement)
200   (statement)
300   (statement)
```

We have taken the precaution to leave a regular gap between consecutive statement numbers so that we can easily add corrections or improvements later on. For example, here is version 1 of a program:

```
10   REM * MULTIPLICATION PROGRAM *
20   PRINT "GIVE ME 2 NUMBERS";
25   INPUT N1, N2
30   PRINT "THE PRODUCT IS:   ";
35   PRINT N1 * N2
40   END
```

We now want to clarify the program and improve the display. To do this, we will type the following additional statements:

```
5    CALL CLEAR
15   PRINT "THIS IS AN AUTOMATIC"
16   PRINT "MULTIPLICATION PROGRAM"
17   PRINT
36   PRINT
```

The new statements will be inserted automatically. Let's now list the result:

```
5    CALL CLEAR
10   REM * MULTIPLICATION PROGRAM *
15   PRINT "THIS IS AN AUTOMATIC"
16   PRINT "MULTIPLICATION PROGRAM"
17   PRINT
20   PRINT "GIVE ME 2 NUMBERS";
25   INPUT N1, N2
30   PRINT "THE PRODUCT IS";
35   PRINT N1 * N2
36   PRINT
40   END
```
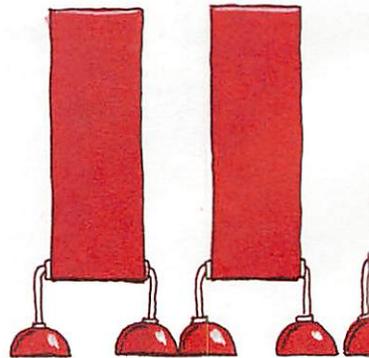
Here is a sample run of our improved program:

```
THIS  IS  AN  AUTOMATIC
MULTIPLICATION  PROGRAM

GIVE  ME  2  NUMBERS?  12, 15
THE  PRODUCT  IS  180
```

If you plan to make many corrections, or add many statements, you may want to leave large gaps in your line numbering, and use for instance:

10	(statement)
50	(statement)
60	(statement)
100	(statement)

TI BASIC has a special command called RESEQUENCE that will automatically renumber all the lines in your program with an increment of 10. This is very useful in a long program where you may run out of sequential numbers when inserting a "patch," or correction.

Number your lines properly
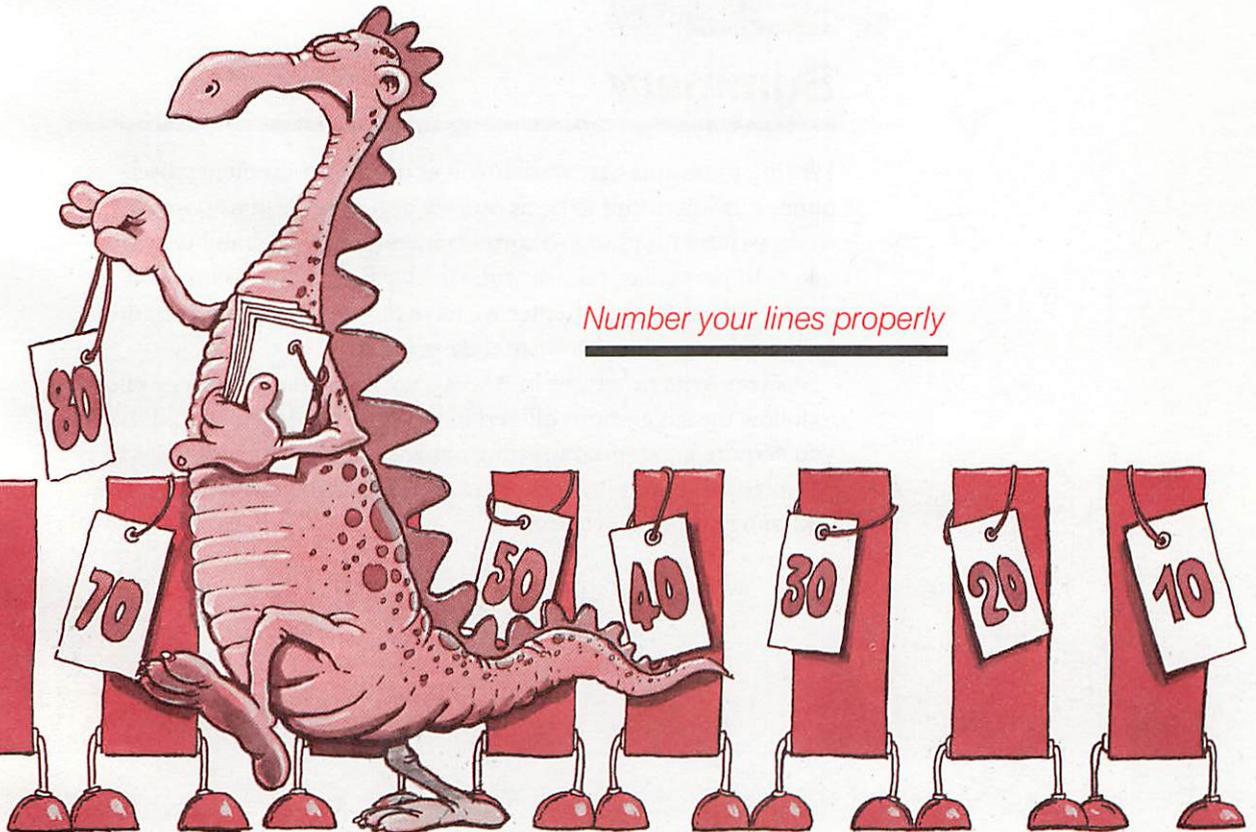
TI BASIC has another special command called NUMBER that can help you with line numbering when you are writing a program. When you type in the command NUMBER followed by two numbers, separated by a comma, your computer enters the number mode and automatically generates line numbers for you. The first number tells the computer what line number to start with. The second number determines the increment between numbers. For example, entering the command NUMBER 10,10 will cause the computer to start with line number 10; each successive line number will be ten more than the one before it (that is, 10, 20, 30, etc.).

If you do not specify the starting line number and the increment between numbers, NUMBER will start with line number 100 and 10 will be used as the increment.

To end the automatic generation of line numbers and leave the number mode, press ENTER immediately after the generated line number is displayed. The "empty" line will not be added to your program.

Summary

Writing programs that work involves one key ingredient: discipline. It is important to be as orderly and organized as possible when writing programs. Shortcuts increase the probability of mistakes. In particular, take the time to clarify your programs and your displays. In this chapter we have described and stressed the techniques necessary to write clear programs.

As you write programs in BASIC, you should make every effort to follow the suggestions offered in this chapter. It is essential that you acquire good programming habits, or else your programs may be unreadable, or may not even work, as you begin writing more and more complex programs.

Exercises

5-1: Describe techniques that improve the readability of the display.

5-2: Are the following legal?

a. A = A + 1   d. SUM = 2 + (3 + (4/5))/2

b. A   =   A   +   1   e. IN   PUT VALUE

c. PRINT   ALPHA + 2   f. SUM = 2 2 + 3 3

5-3: Explain why most INPUTs should have a prior message.

5-4: Write three examples of shortcut INPUTs.

5-5: Why use REMs?

5-6: What is the value of A after these two statements:

```
30  A = 3
40  REM A = 4
```

Making D
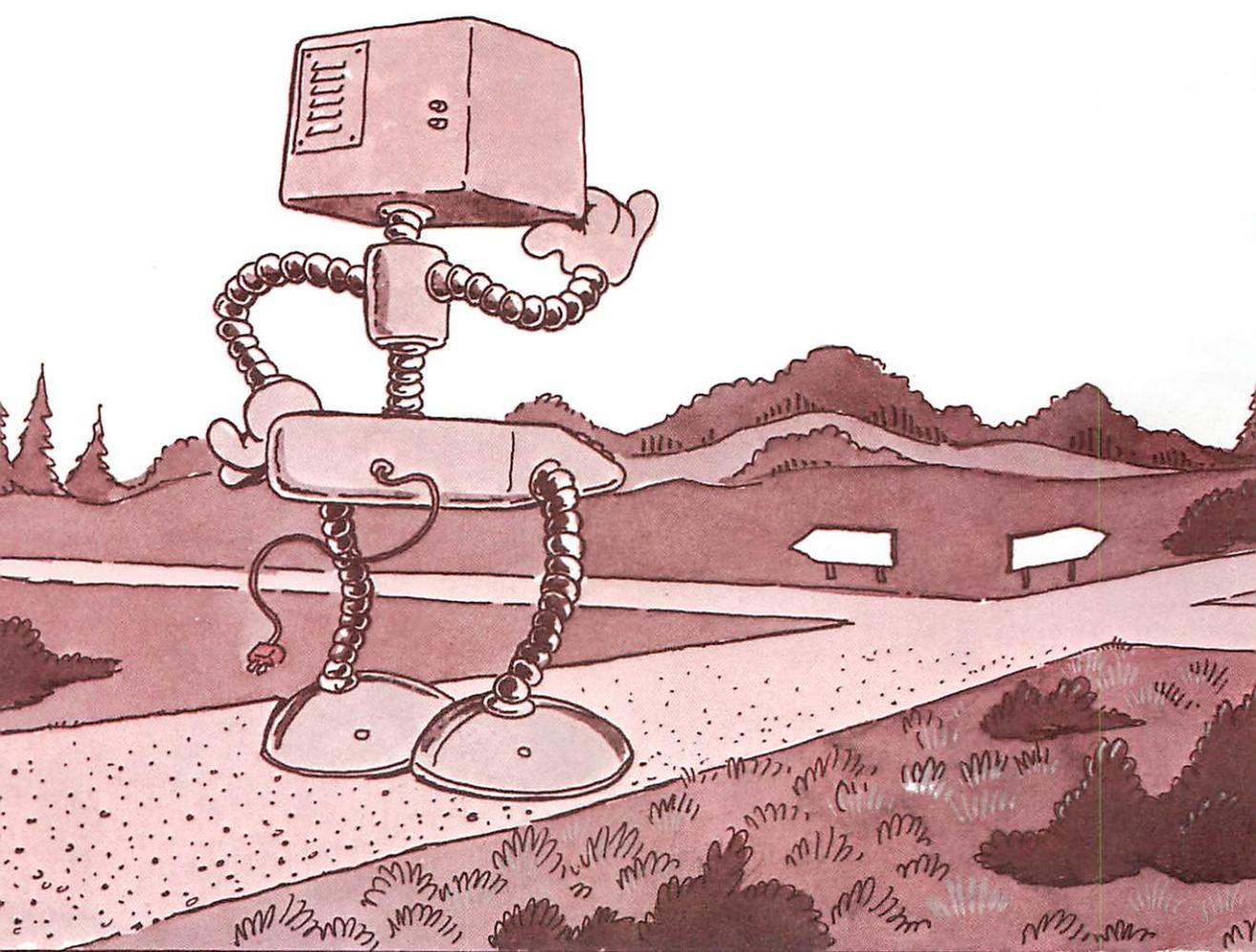
Decisions

6
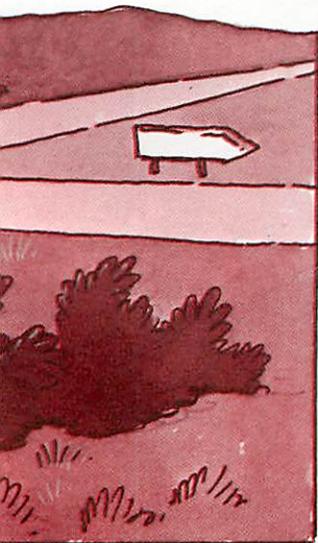
So far, we have learned how to communicate with the computer and how to perform simple arithmetic. However, our programs have been somewhat dull, and we could easily have performed the same tasks by hand. This is because we have used only the elementary resources of the computer. We have not taken advantage of the more advanced resources. For example, computers are particularly good at performing two tasks: making complex decisions (based on logic and values) and executing repetitive tasks many times in a short period of time. This is what we will learn to do in this and the following chapter. In particular, we will learn how to make decisions. Our programs will become "intelligent," as they decide what to do.

In BASIC, program decisions are made by testing a value, using the IF statement. If the test succeeds, one part of the program is executed. If it fails, another part is executed. We will now learn how to use the IF statement to perform tests. We will also learn to use the GOTO statement to force the program to execute a group of instructions out of numerical sequence.

The IF Statement

The IF statement is written:

IF (condition) THEN (line number)

Here is an example:

    IF I = 1 THEN 110

The effect of this statement should be clear: IF the value of the variable I is equal to 1 at the time this statement is executed, THEN line 110 is executed. If I is not equal to 1, nothing happens and the next statement in the program is executed.

I = 1 is called a logical *expression*. The expression I = 1 is *true* when I is equal to 1; otherwise, it is *false*.

The IF . . . THEN statement allows you to test the value of an expression and execute one statement or another—that is, to make a decision—depending on the results of the test. Here is another example:

    10   INPUT I
    20   IF I = 1 THEN 25
    23   IF I < > 1 THEN 30
    25   PRINT "ONE"
    30   END

Look at Dino's puzzled expression. He will go one of two ways.
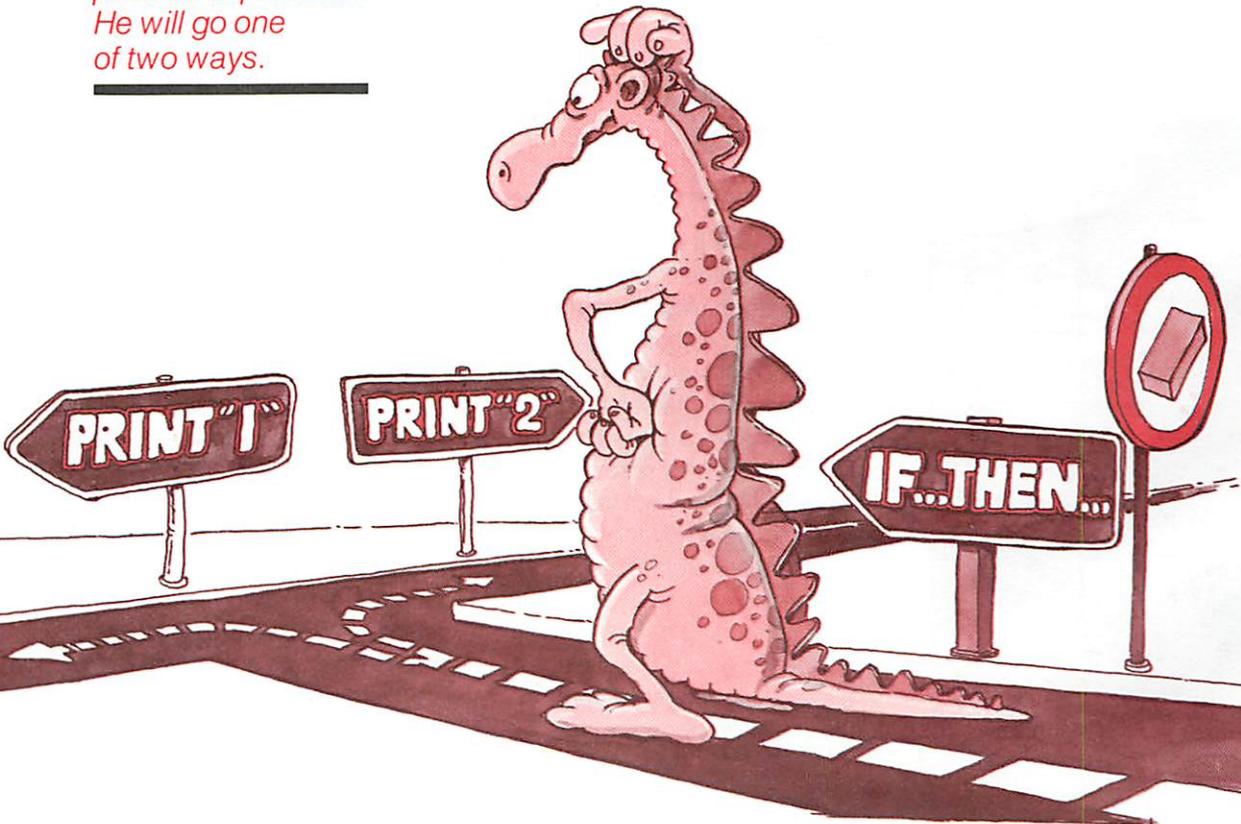
Now run this program. Type "1" at the keyboard. Your screen should look like this:

```
RUN
? 1
ONE

* *DONE * *
```

Run this program again. Type "2" at the keyboard. Your screen should look like this:

```
> RUN
 ? 2

  * *DONE * *
```

This time no message was printed in response to the 2.

Let's now teach our program to recognize the numbers 1 through 3:

```
10   REM THIS PROGRAM RECOGNIZES THE NUMBERS 1 TO 3
20   PRINT "TYPE AN INTEGER:";
25   INPUT INTEGER
30   IF INTEGER = 1 THEN 35
32   IF INTEGER < > 1 THEN 40
35   PRINT "ONE"
40   IF INTEGER = 2 THEN 45
42   IF INTEGER < > 2 THEN 50
45   PRINT "TWO"
50   IF INTEGER = 3 THEN 55
52   IF INTEGER < > 3 THEN 60
55   PRINT "THREE"
60   END
```

Let's run the program. Here are two typical runs as they appear on the screen (with emphasis added):

```
> RUN
  TYPE AN INTEGER:? 3
  THREE

   * *DONE * *
> RUN
  TYPE AN INTEGER:? 5

   * *DONE * *
```

This is good, but not yet perfect. Ideally, when we type 5, we would like the program to respond with something like:

I DON'T KNOW THIS NUMBER.

or else request a new integer. We do this as follows:

```
10  INPUT I
20  IF I = 1 THEN 50
30  PRINT "YOU DID NOT TYPE A 1"
40  END
50  PRINT "YOU TYPED A 1"
60  END
```

Run this program and type "1" at the keyboard. Your screen should look like this:

```
> RUN
 ? 1
 YOU TYPED A 1

   * * DONE * *
```

*We can make
the program
jump out
of sequence*
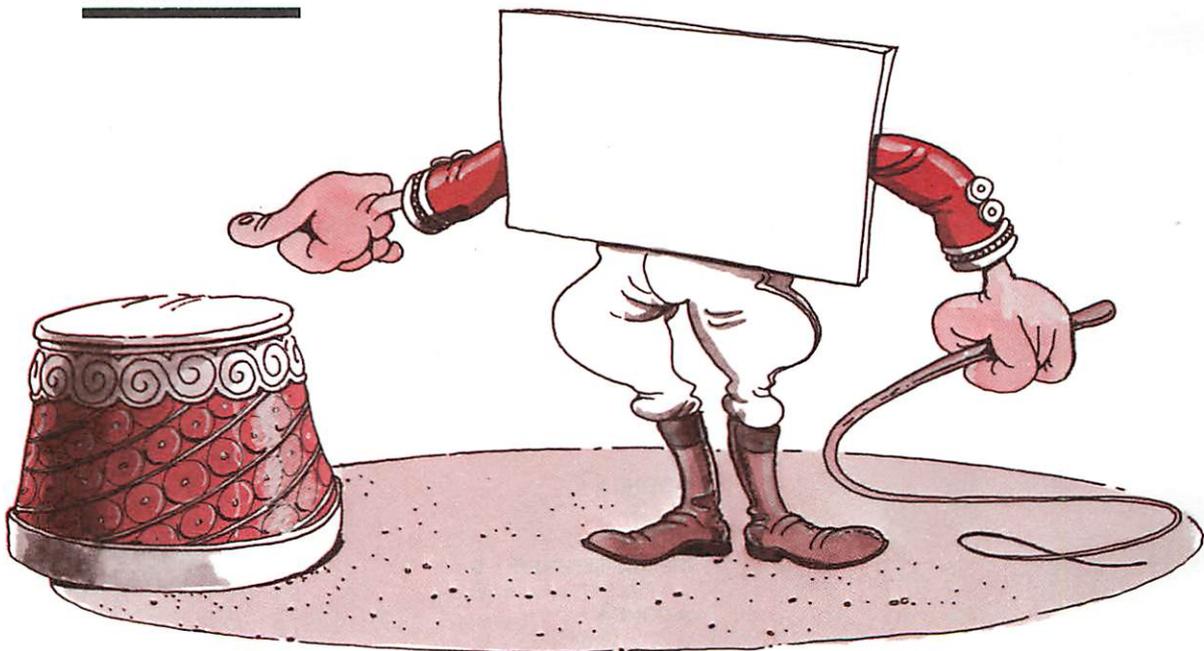
Run the program again, and type a "2" at the keyboard. Your screen should look like this:

```
> RUN
? 2
YOU  DID  NOT  TYPE  A  1

* *DONE* *
```

Our program has become "intelligent," i.e., it gives an appropriate message whether or not the input is 1. You may be wondering if we could have achieved the same result using the original form of the IF statement. Let's try it:

```
10   INPUT I
20   IF  I = 1  THEN  25
25   PRINT "THIS IS A ONE"
30   PRINT "THIS IS NOT A ONE"
40   END
```

Now, run this program and type a 1 at the keyboard. The display is the following:

```
> RUN
? 1
THIS  IS  A  ONE
THIS  IS  NOT  A  ONE

* *DONE* *
```

I'm the bug.
I got you.

It does not work. Regardless of the success or failure of the IF, the next statement following it in the program (statement 30 here) is executed.

In this example, we first get the correct message as the IF is executed:

```
THIS  IS  A  ONE
```

Then the second message is printed anyway:

```
THIS  IS  NOT  A  ONE
```

The new form of the IF statement:

```
IF  I = 1  THEN  50
```

eliminates this problem. We will use this statement frequently in our programs.
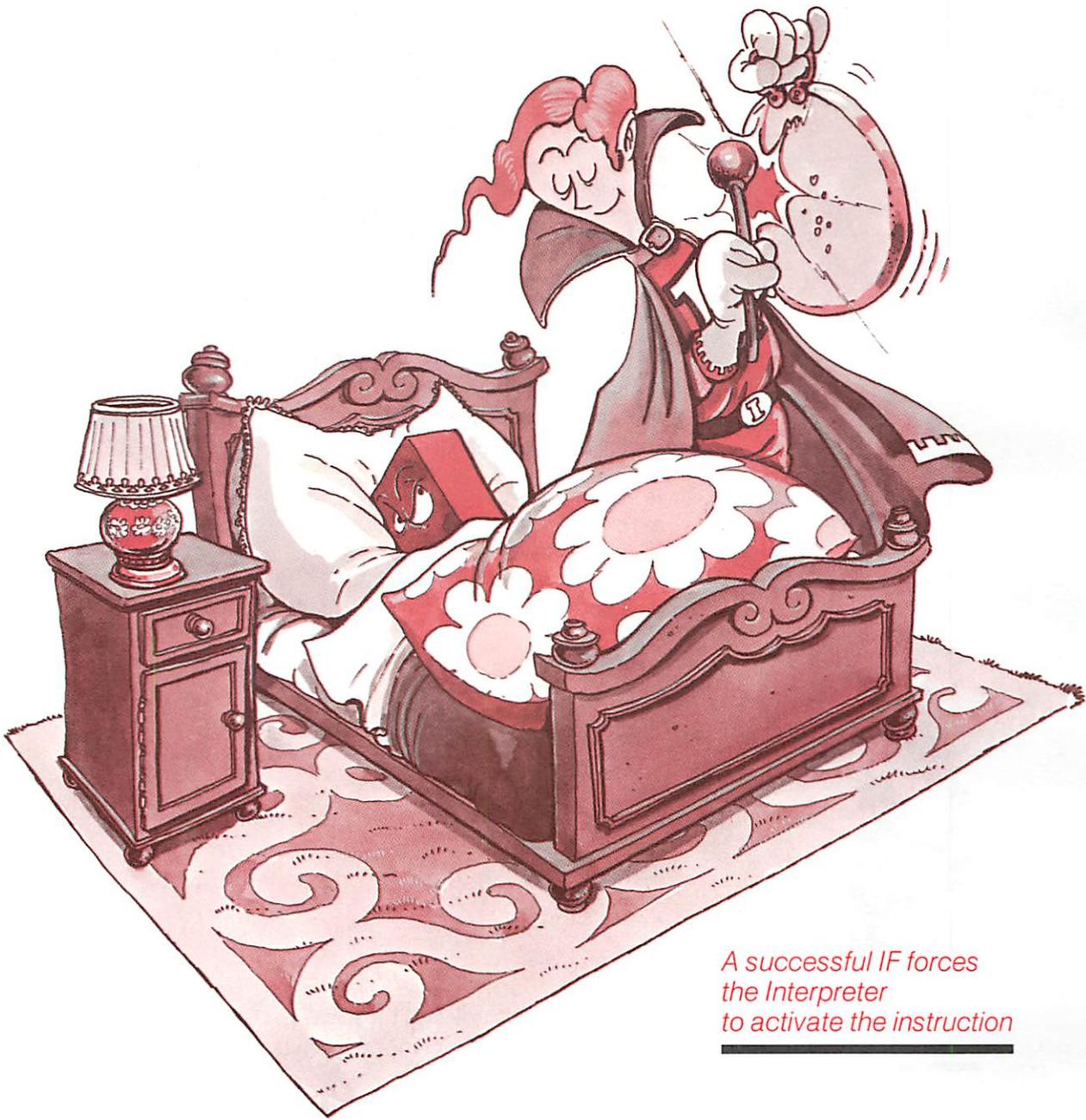
A successful IF forces
the Interpreter
to activate the instruction

Let's now take a closer look at the IF statement so that we can fully utilize it. The general form of the IF . . . THEN statement is the following:

IF (logical expression) THEN (line number)

Let's now examine logical expressions and executable statements in turn.

Logical Expressions

In our example, I = 1 is a *logical expression*, i.e., it can be either *true* or *false*. True and false are called *logical values*. Here are some examples of logical expressions:

I = 1	*(I equals 1)*
I > 4	*(I is greater than 4)*
INTEGER < 100	*(INTEGER is less than 100)*
YEAR <> 5	*(YEAR is not equal to 5)*
AGE < 13	*(AGE is less than 13)*

A logical expression combines values or variables with logical operators. For completeness, the operators you can use with logical expressions are:

=	equal	
<>	not equal	*(in mathematics, this is written as ≠ or #)*
<	less than	
>	greater than	
<=	less than or equal	*(in mathematics, this is written as ≤)*
>=	greater than or equal	*(in mathematics, this is written as ≥)*

Here are some even more complex logical expressions:

$(INTEGER + 2) > 4$

$(AGE - 5) >= 10$

$((2 * I - 5) / 2) < 10$

$2 > I$

You may also write:

$4 > 2$ *(this is always true)*

$4 = 2$ *(this is always false)*

The following are *not* valid logical expressions:

$2 < I < 0$ *(only one relational operator may be used)*

$(2 AGE - 2) < 5$ *(invalid expression—missing an *. This should read: (2 * AGE - 2) < 5)*
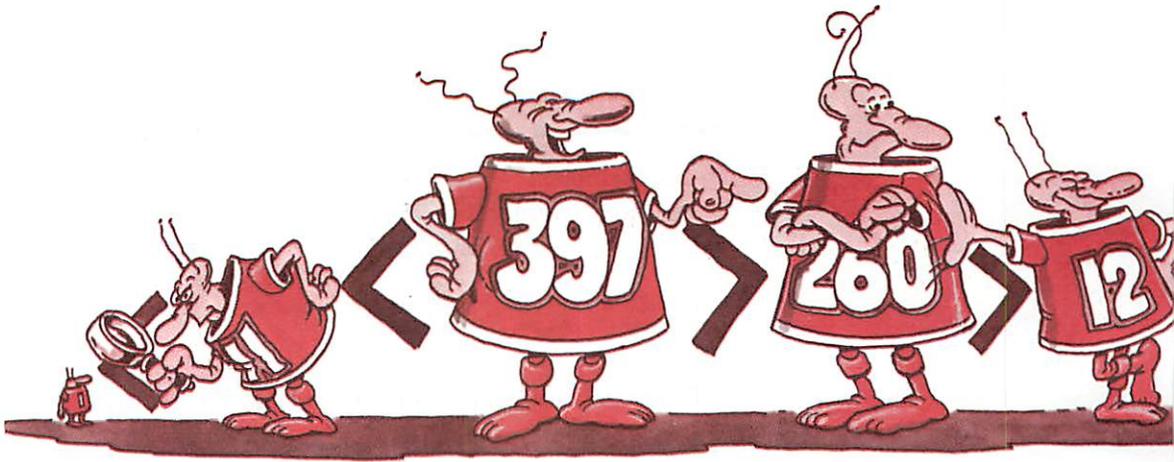
With some BASICs, you can combine logical expressions using the logical operators AND, OR, and NOT. TI BASIC does not have these logical operators. However, you can achieve similar results using the two statements IF . . . THEN and IF . . . THEN . . . ELSE. Let's examine these statements further. Suppose that you want your program to print the message "THIS IS A TEENAGER" if the variable AGE is greater than 12 and less than 20. This can be accomplished using the IF . . . THEN statement in the following way:

```
50  IF AGE < 13 THEN 80
60  IF AGE > 20 THEN 80
70  PRINT "THIS IS A TEENAGER"
80  END
```

These statements will cause "THIS IS A TEENAGER" to print whenever AGE is greater than 12 and less than 20. If the value of AGE is less than 13 or greater than 20, the program immediately jumps to line 80 and ends.

Here is another example of using the IF . . . THEN statement to perform logical comparisons:

```
20  INPUT ANSWER$
30  IF ANSWER$ = "YES" THEN 60
35  IF ANSWER$ = "NO" THEN 60
40  PRINT "INVALID ANSWER"
      . . .
60  PRINT "VALID ANSWER—LET'S PROCEED"
```

This program segment collects an answer in the variable ANSWER$. (Recall that the $ at the end of the name is used to denote a string variable, i.e., a collection of characters.) YES or NO are the only valid answers; this program checks for the validity of what you have typed.
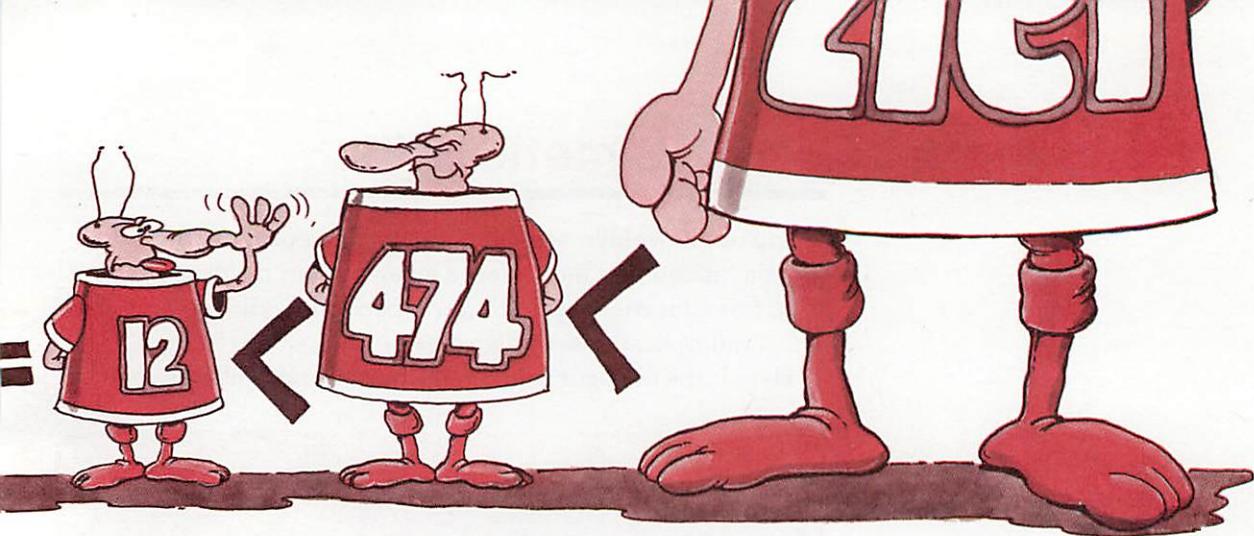
If you type YES, then ANSWER$ = "YES" is true. State-
ment 60 is executed next, and the program prints:

VALID ANSWER—LET'S PROCEED

If you type NO, the same thing happens. If you type anything
else, you are told:

INVALID ANSWER

Another statement that is very useful in performing logi-
cal comparisons is the IF . . . THEN . . . ELSE statement. The
general form of the IF . . . THEN . . . ELSE statement is the
following:

IF (logical expression) THEN (line number 1) ELSE (line
number 2).

Let's take a look at an example of the IF . . . THEN . . . ELSE
statement:

```
40  INPUT "ENTER DOLLAR AMOUNT : " : VALUE
50  IF VALUE < = 0 THEN 60 ELSE 80
60  PRINT "INVALID AMOUNT"
    . . .
80  PRINT "VALID AMOUNT—LET'S PROCEED"
```

This program segment asks for a dollar amount and stores it in the
variable VALUE. We wish to proceed only if the dollar amount is
positive. Line 50 looks at the number contained in the variable
VALUE. If VALUE is less than or equal to zero, then line 60 is exe-
cuted, and the program prints:

INVALID AMOUNT

If the number stored in the variable VALUE is not less than or
equal to zero, then the ELSE part of the statement is executed, and
the program jumps to line 80, printing:

VALID AMOUNT—LET'S PROCEED

An Arithmetic Drill

Using our new skills, we will now develop a program that displays a "menu" on the screen. Depending on the user's selection, this educational program will perform additions, subtractions, multiplications, or divisions.

Here is the dialogue we plan to generate on the screen:

```
WELCOME  TO  COMPUTER
TEACHER.  I  WILL  CHECK
YOUR  ARITHMETIC  SKILLS
WHAT  DO  YOU
WANT  TO  PRACTICE?
      – ADDITION            (1)
      – SUBTRACTION         (2)
      – MULTIPLICATION      (3)
      – DIVISION            (4)
YOUR  CHOICE :?  3

LET'S  MULTIPLY
WHAT'S  2  TIMES  3 :?  6
THAT'S  RIGHT!
CONGRATULATIONS
```


"Should I present an arithmetic menu?"
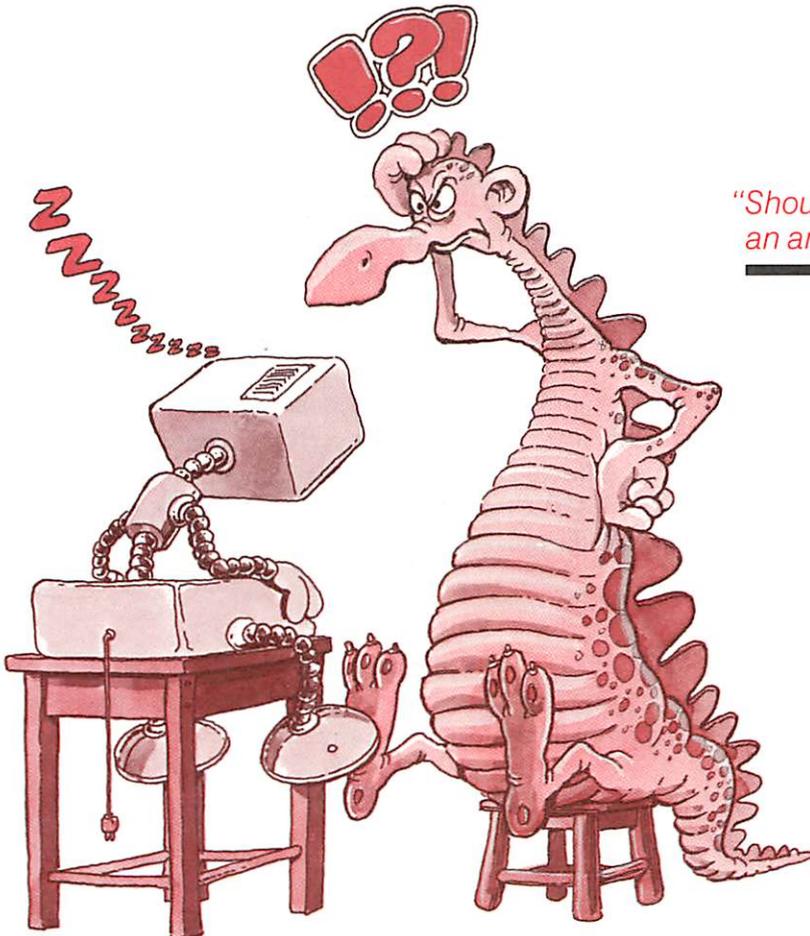
Now here is the program that accomplishes this:

```
10    REM *MATH DRILL*
20    PRINT "WELCOME TO COMPUTER"
30    PRINT "TEACHER. I WILL CHECK"
40    PRINT "YOUR ARITHMETIC SKILLS"
50    PRINT "WHAT DO YOU"
60    PRINT "WANT TO PRACTICE?"
70    PRINT " - ADDITION          (1)"
80    PRINT " - SUBTRACTION       (2)"
90    PRINT " - MULTIPLICATION    (3)"
100   PRINT " - DIVISION          (4)"
110   PRINT "YOUR CHOICE:";
115   INPUT CHOICE
120   IF (CHOICE = 1) THEN 200
130   IF (CHOICE = 2) THEN 300
140   IF (CHOICE = 3) THEN 400
150   IF (CHOICE = 4) THEN 500
160   PRINT "PLEASE CHOOSE A NUMBER";
170   PRINT "BETWEEN 1 AND 4"
180   PRINT "GOOD BYE"
185   END
190   REM - - - - ADDITION - - - -
200   PRINT "LET'S ADD"
210   PRINT "WHAT'S 4 + 7 :";
215   INPUT INTEGER
220   IF (INTEGER < > 11) THEN 600
225   PRINT "THAT'S RIGHT!"
230   PRINT "CONGRATULATIONS"
235   END
290   REM - - - SUBTRACTION - - -
300   PRINT "LET'S SUBTRACT"
310   PRINT "WHAT'S 9 - 5  :";
315   INPUT INTEGER
320   IF (INTEGER < > 4) THEN 600
325   PRINT "THAT'S RIGHT!"
330   PRINT "CONGRATULATIONS"
335   END
390   REM - - MULTIPLICATION - -
400   PRINT "LET'S MULTIPLY"
410   PRINT "WHAT'S 2 TIMES 3  :";
415   INPUT INTEGER
420   IF (INTEGER < > 6) THEN 600
425   PRINT "THAT'S RIGHT!"
430   PRINT "CONGRATULATIONS"
435   END
490   REM - - DIVISION - -
500   PRINT "LET'S DIVIDE"
505   INPUT "WHAT IS 9"
510   PRINT "DIVIDED BY 3"
```

```
515  INPUT INTEGER
520  IF (INTEGER < > 3) THEN 600
525  PRINT "THAT'S RIGHT!"
530  PRINT "CONGRATULATIONS"
535  END
590  REM – – FAILURE EXIT – –
600  PRINT "THAT'S WRONG."
605  PRINT "SORRY AND GOOD BYE."
610  END
```

This program looks imposing in size, but it is actually quite simple.
Let's examine it.

Statements 20 to 100 produce the display or "menu" on the screen.
The program checks the user's selection in statements 120 to 150
(the parentheses after each IF are not required; they are included for
readability). If the user typed "1", then (CHOICE = 1) is true,

"Congratulations!"
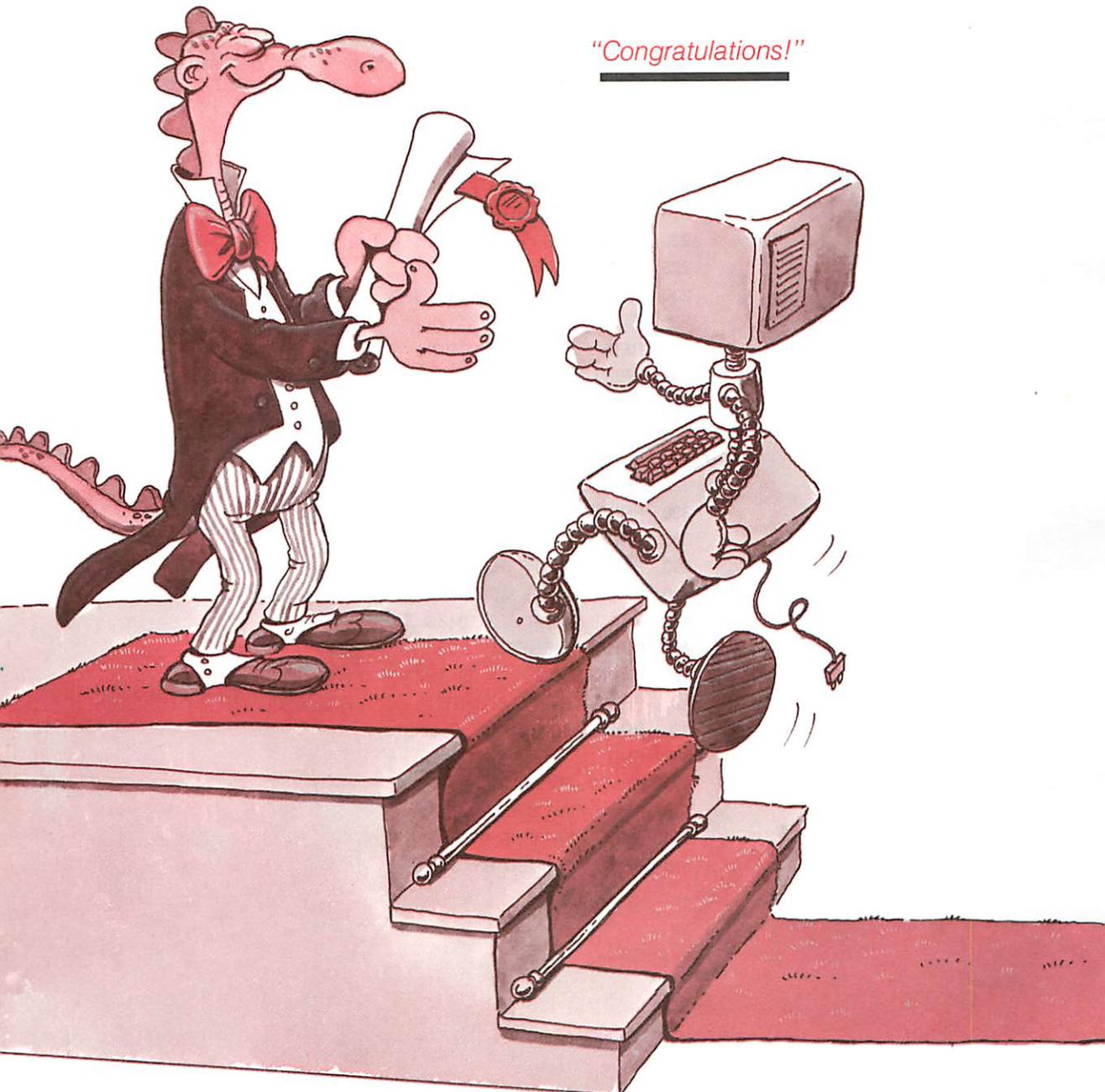
and statement 200 is executed next. If the user typed something other than 1, 2, 3, or 4, then statement 160 is executed and the program says:

PLEASE CHOOSE A NUMBER
BETWEEN 1 AND 4
GOODBYE

and quits (this is the END statement on line 185).

In our example, we type 3. Statement 120 fails, so statement 130 is executed next. Statement 130 fails, so statement 140 is executed next. Statement 140 succeeds, since (CHOICE = 3) is true, and statement 400 is executed next. Here is the corresponding program segment:

```
400   PRINT "LET'S MULTIPLY"
410   PRINT "WHAT'S 2 TIMES 3   :";
415   INPUT INTEGER
420   IF (INTEGER <  > 6) THEN 600
425   PRINT "THAT'S RIGHT!"
430   PRINT "CONGRATULATIONS" :
435   END
```

In our example, we type 6 in response to statement 415. When statement 420 is executed, (INTEGER < > 6) is false since INTEGER $= 6$. (Recall that $< >$ means not equal to.) Therefore, the next statement to be executed is statement 425, and the program responds with:

THAT'S RIGHT!
CONGRATULATIONS

and quits since line 435 contained the command END.

Looking at this program, you may quickly spot a new frustration: If you type a number other than 1, 2, 3, or 4 after the menu is shown, or if you give an incorrect arithmetic answer, the program will stop abruptly. Ideally, we would like the program to continue. For example, it would be good if, after the program tells the user that a number other than 1 to 4 is not valid, it would then ask for a new choice. We would like to be able to go back to the beginning of the program and restart it, or more generally, to be able to go to *any* part of the program next. This is possible with the GOTO statement. Let us examine this statement.

The GOTO Statement

The GOTO statement is written as:

GOTO (line number)

It forces execution of the specified statement. Here is an example:

```
10   PRINT "THIS PROGRAM"
15   PRINT "RECOGNIZES 1'S."
20   PRINT "TYPE 0 TO STOP."
25   PRINT "TYPE A NUMBER:";
30   INPUT INTEGER
40   IF INTEGER = 1 THEN 60
45   IF INTEGER = 0 THEN 70
50   GOTO 25
60   PRINT "ONE"
65   GOTO 25
70   END
```

*GOTO forces execution
of the specified statement*
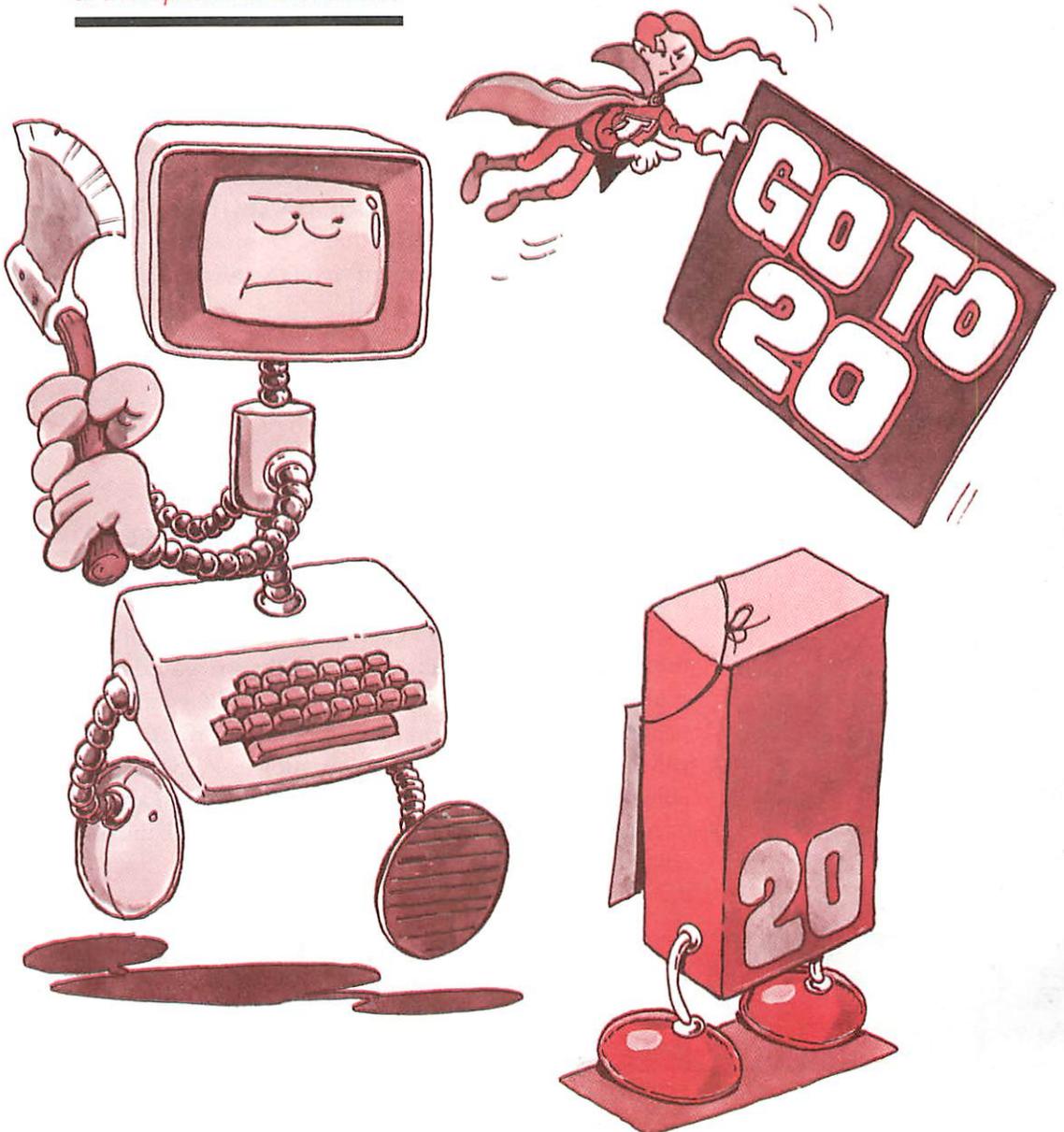
Here is a sample run:

```
THIS PROGRAM
RECOGNIZES 1'S.
TYPE 0 TO STOP.
TYPE A NUMBER:? 1
ONE
TYPE A NUMBER:? 5
TYPE A NUMBER:? 25
TYPE A NUMBER:? 0
```

Every time you type 1 the program recognizes it and spells out ONE. Every time you type anything else, the number is ignored and the program requests a new value. The program continually goes back to the beginning. This is called a *loop*. The program is said to loop upon itself. If you type a 0, it is detected by statement 45, and the program jumps to statement 70 and ends.

Let's now remove statement 45. The program looks like this:

```
10   PRINT "THIS PROGRAM"
15   PRINT "RECOGNIZES 1'S."
20   PRINT "TYPE 0 TO STOP."
25   PRINT "TYPE A NUMBER:";
30   INPUT INTEGER
40   IF INTEGER = 1 THEN 60
50   GOTO 25
60   PRINT "ONE"
65   GOTO 25
70   END
```

Here is a sample run:

```
THIS PROGRAM
RECOGNIZES 1'S.
TYPE 0 TO STOP.
TYPE A NUMBER:? 2
TYPE A NUMBER:? 1
ONE
TYPE A NUMBER:? 0
TYPE A NUMBER:? ■
```
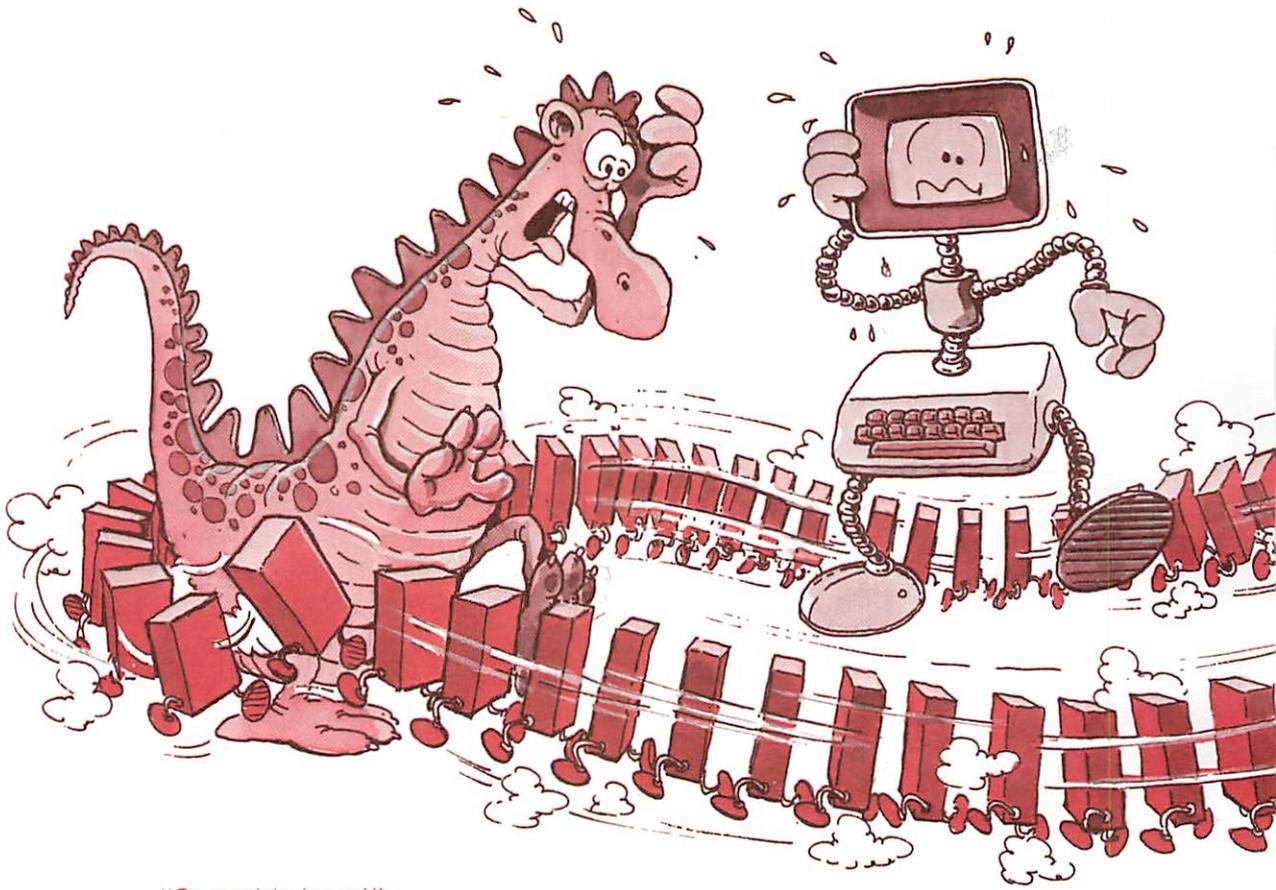
"Stop this loop!"

Like the apprentice sorcerer, we have created a terrible problem: this program will never stop! This is a common programming error called an *endless loop*. The program may continue executing forever. Don't worry. This will not damage anything. To stop it, you must press the FCTN CLEAR key. If worse comes to worst, and you can't remember what to do, turn your computer off and then turn it back on again. But remember: if you turn the computer off, you will lose everything you have typed in so far and have not previously saved on cassette or diskette. We will strive to avoid this unpleasant situation by providing a normal (programmed) exit for each program from now on.

Having introduced the GOTO statement, let's now go back to our definition of the IF statement, and simplify it.

IF Statement Revisited

Recall that the form of the IF statement is

IF (logical expression) THEN (line number)

Here is an example:

```
IF INTEGER = 0 THEN 60
```

This is equivalent to:

```
IF INTEGER = 0 GOTO 60
```

GOTO 60 is an executable statement, and you will recognize that the form

```
THEN 60
```

is simply equivalent to

```
GOTO 60
```

We will now demonstrate the use of IFs and GOTOs on program examples.
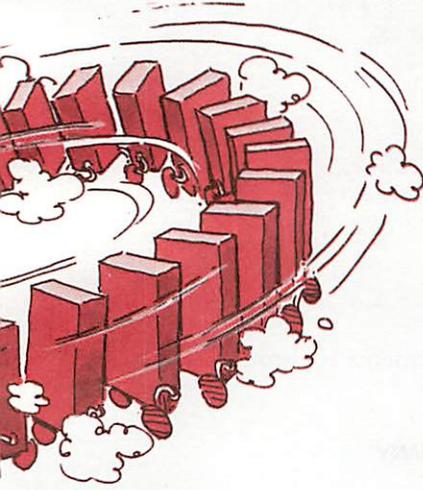
Counting Ones

In Chapter 5, we introduced the counter technique. Let's now use it to count the number of 1's typed in the last program of the previous section. Here is the improved program:

```
1     REM ONE'S COUNTER
10    PRINT "I WILL COUNT HOW MANY"
15    PRINT "SINGLE 1'S YOU TYPE."
20    PRINT "TYPE 0 TO STOP"
30    SUM = 0
35    PRINT "TYPE A NUMBER:  ";
40    INPUT INTEGER
50    IF INTEGER = 0 THEN 100
60    IF INTEGER < > 1 THEN 35
70    SUM = SUM + 1
80    PRINT "ONE. TOTAL SO FAR:  ";
85    PRINT SUM
90    GOTO 35
100   END
```

Here is a sample run:

```
I WILL COUNT HOW MANY
SINGLE 1'S YOU TYPE.
TYPE 0 TO STOP
TYPE A NUMBER: ? 10
TYPE A NUMBER: ? 1
ONE. TOTAL SO FAR: 1
TYPE A NUMBER: ? 9
TYPE A NUMBER: ? 5
TYPE A NUMBER: ? 1
ONE. TOTAL SO FAR: 2
TYPE A NUMBER: ? 2
TYPE A NUMBER: ? 1
ONE. TOTAL SO FAR: 3
TYPE A NUMBER: ?
```

Let us examine the program. Statements 10 through 20 display messages:

```
10   PRINT "I WILL COUNT HOW MANY"
15   PRINT "SINGLE 1'S YOU TYPE."
20   PRINT "TYPE 0 TO STOP"
```

Statement 30 initializes the counter variable SUM to zero:

```
30   SUM = 0
```

Then the number is collected from the keyboard:

```
35   PRINT "TYPE A NUMBER:   ";
40   INPUT INTEGER
```

If the number is 0, we are done:

```
50   IF INTEGER = 0 THEN 100
```

where 100 is the END statement. Let's assume that the number was 10, and see what happens:

```
60   IF INTEGER < > 1 THEN 35
```

If the number is not 1, then we jump back to 35 and request a new number. If the number is 1, we proceed:

```
70   SUM = SUM + 1
```

The counter variable SUM is incremented by one. Recall the meaning of an assignment statement. You can read line 70 as:

SUM receives the new value of (old value of SUM) + 1

At this point, SUM receives the value $0 + 1 = 1$. The next two statements are:

```
80  PRINT "ONE. TOTAL SO FAR:  ";
85  PRINT SUM
```

Then the program loops back to line 35, requesting a new number:

```
90  GOTO 35
```

Arithmetic Drill Revisited

Recall that we developed an arithmetic drill program at the beginning of this chapter. We regretted the fact that it was too simple and could not recycle. However, we can now make it recycle.

Since the program is rather large, let's look at the relevant segment only. First, here is the section that asks the user to select a number between 1 and 4:

```
110  PRINT "YOUR CHOICE:";
115  INPUT CHOICE
120  IF (CHOICE = 1) THEN 200
130  IF (CHOICE = 2) THEN 300
140  IF (CHOICE = 3) THEN 400
150  IF (CHOICE = 4) THEN 500
160  PRINT "PLEASE CHOOSE A NUMBER";
170  PRINT "BETWEEN 1 AND 4"
180  PRINT "GOOD BYE"
185  END
```

And here is our improvement:

```
185  GOTO 110
```

That is all. Check it.

Now, we would also like the program to present more than one arithmetic question. Say, we want it to ask ten different questions. We could do this by adding GOTOs and a counter.

Validating the Input

The examples we have just examined demonstrate an important rule when designing a program: Whenever you request data at the keyboard, do not assume that it will always be supplied correctly. A user might hit the wrong key, either deliberately or accidentally. To avoid strange or erroneous program behavior, always *validate the input*. If the information typed at the keyboard is not valid, generate a polite message and request the input again. We will perform input validation in most of our examples.

Let's now develop two complete programs that make decisions.
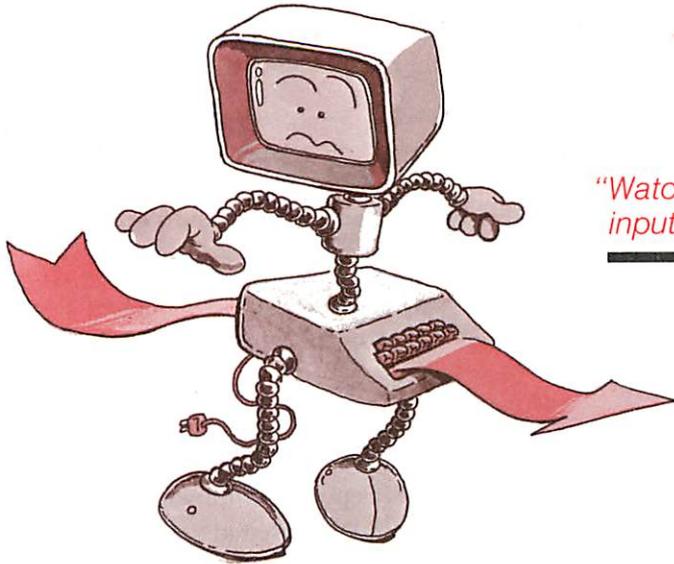
"Watch my input please."

Mileage Conversion

In Chapter 3, we learned how to perform a simple conversion of miles into kilometers. Here is a way to automate it:

```
10   REM * MILEAGE CONVERSION *
20   REM
30   PRINT "I CONVERT MILES"
35   PRINT "INTO KILOMETERS"
40   PRINT "TYPE 0 TO STOP"
45   PRINT "HOW MANY MILES   ";
50   INPUT MILES
60   IF MILES = 0 THEN 100
70   KM = MILES * 1.6
80   PRINT MILES; " MILES EQUALS"
85   PRINT KM; " KILOMETERS"
90   GOTO 45
100  END
```

Here is a sample run:

```
I CONVERT MILES
INTO KILOMETERS
TYPE 0 TO STOP
HOW MANY MILES ? 7
 7 MILES EQUALS
 11.2 KILOMETERS
HOW MANY MILES ? 10
 10 MILES EQUALS
 16 KILOMETERS
HOW MANY MILES ? 0
```

Birthday

Here is one more example. Let's now improve our earlier program that computed a person's age. You will supply today's date and the year, month, and day you were born, and the program will tell you your exact age. Here is the program:

```
10    REM * * AGE COMPUTATION * *
15    PRINT "FIRST NAME";
20    INPUT FIRST$
25    PRINT "HELLO  ";
30    PRINT FIRST$
35    PRINT "I'LL COMPUTE YOUR AGE"
40    PRINT "WHAT IS TODAY'S DATE?"
45    PRINT "(YY/MM/DD)"
50    PRINT "ENTER THE YEAR FIRST"
55    INPUT YY
60    IF YY < 0 THEN 50
65    IF YY > 99 THEN 50
70    PRINT "THE MONTH (1 TO 12)"
75    INPUT MM
80    IF MM < 1 THEN 70
85    IF MM > 12 THEN 70
90    PRINT "THE DAY:";
95    INPUT DD
100   IF DD < 1 THEN 90
105   IF DD > 31 THEN 90
110                                              REM
120   PRINT "NOW GIVE ME"
125   PRINT "YOUR BIRTHDATE"
130   PRINT "YEAR (2 DIGITS):";
135   INPUT YBIRTH
140   IF YBIRTH < 0 THEN 120
145   IF YBIRTH > 99 THEN 120
150   PRINT "MONTH (1 TO 12):";
155   INPUT MBIRTH
160   IF MBIRTH < 1 THEN 150
165   IF MBIRTH > 12 THEN 150
170   PRINT "DAY:";
175   INPUT DBIRTH
180   IF DBIRTH < 1 THEN 170
185   IF DBIRTH > 31 THEN 170
190                                              REM
200   REM - AGE COMPUTATION -
210   IF MBIRTH < MM THEN 270
220   IF MBIRTH > MM THEN 320
230   REM - BIRTHDAY THIS MONTH -
240   IF DBIRTH < DD THEN 270
250   IF DBIRTH > DD THEN 320
260   PRINT "TODAY'S YOUR BIRTHDAY!"
265   PRINT "CONGRATULATIONS!"
270   AGE = YY - YBIRTH
```

```
280   PRINT "YOU ARE";
285   PRINT AGE; "YEARS OLD"
290   END
300                                              REM
310   REM NO BIRTHDAY YET
320   AGE = YY – YBIRTH – 1
330   GOTO 280
340   END
```

Despite its length, this program is quite simple. Note how we validate each input. However, to keep the program short our validation is rough. We do not verify that each number is an integer. Nor do we verify the number of days in each month. This is left as an exercise for the thorough (and patient) reader.

Summary

Using the IF and the GOTO statements, we have learned how to write programs to perform tests on values and to make decisions. We have also learned how to perform program loops so that a portion of a program can be repeated indefinitely. In addition, we have learned how to systematically check and validate inputs typed at the keyboard. We have now learned all the basic skills required to write common programs, and we have examined several meaningful examples as well. We will now make our programs more convenient to write.

Because of the frequency and importance of loops and automation in programs, TI BASIC offers additional facilities in the form of additional statements. We will discuss these facilities in the next chapter.

Exercises

6-1: What is the use of the IF statement?

6-2: Are the following logical expressions valid?

      a. A = 4

      b. A > 5

      c. 5 > A

      d. 1 > 2

      e. SUM > INTEGER

      f. LETTER$ = "A"

6-3: Is the following valid?

      10 IF A = 5 THEN IF B = 2 THEN 18

6-4: What is a program loop?

Automating

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Using the IF and the GOTO statements, we can execute a program segment repeatedly. The corresponding program segment is called a loop; and most programs use loops. In this chapter we will learn improved techniques for creating loops. We will also develop sophisticated programs that automate tasks.

We will begin this chapter with a review of the IF/GOTO technique of generating a loop. We will then introduce a new statement, the FOR . . . NEXT statement, designed to facilitate the creation of loops. We will use this important statement extensively in our programs.

Repetitions

The IF/GOTO Technique

We will begin by examining a program that automates a loop, using the IF/GOTO technique. As we examine this program we will point out certain features common to all loops. For example, we will examine the use of a counter variable, incrementation, initialization, and test before exit. Here is the program. It computes the sum of the first ten integers.

```
1    REM * SUM OF 1ST 10 INTEGERS *
10   SUM = 0
20   I = 1
30   SUM = SUM + I
40   I = I + 1
50   IF I = 11 THEN 70
60   GOTO 30
70   PRINT "THE SUM OF THE FIRST"
75   PRINT "10 INTEGERS IS:";
80   PRINT SUM
90   END
```

Two variables are used in this program: SUM and I. The variable SUM accumulates the sum of the first 10 integers as we keep adding them—it is the equivalent of a subtotal on a calculator. I is the integer that is being added to SUM.

Recall that a variable must have a value the first time it is used. Thus, before we use SUM and I in a formula, we must set their values to an *initial* value (0 and 1, respectively). This is accom-

"How about something a little more complex?"
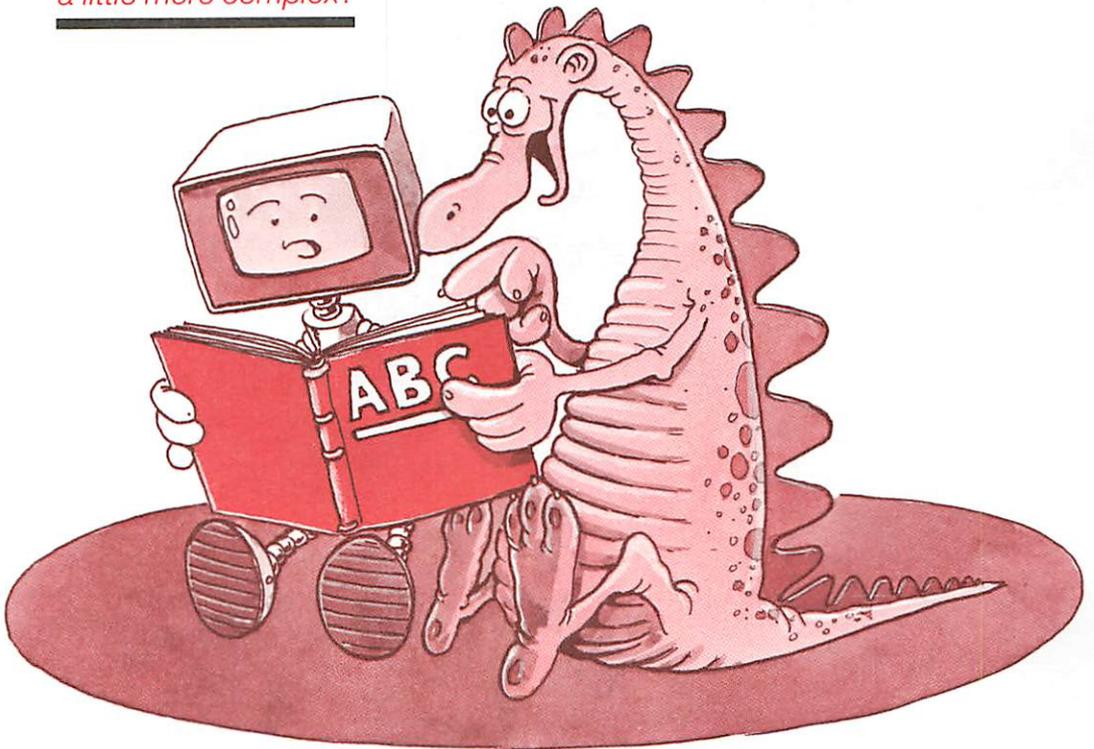
plished by statements 10 and 20. These statements are called *initialization* statements.

The next statement is:

```
30   SUM = SUM + I
```

This statement adds the value of the current integer I to the current SUM. When this statement is executed for the first time, the value of SUM is 0 and the value of I is 1. As a result this statement assigns the value $0 + 1 = 1$ to SUM. Following execution of that statement, SUM contains the value 1.

The next statement is:

```
40   I = I + 1
```

The current value of I is 1. The result of this statement is to give I the new value, 2. This is the counter technique: I is incremented by one in order to generate the next integer. At the same time, the value of I indicates how many integers have been added so far. In other words, I is used as the current integer and as a counter.

So, all we have left to do is to go back to statement 30 and keep adding integers:

```
50   GOTO 30
```

Wrong. This program will (in theory) never stop (actually it will once the value of SUM becomes larger than the maximum allowed by your interpreter). This is not what we want. We want the program to stop after executing the loop ten times. We must introduce a *test* instruction. Here it is:

```
50   IF I = 11 THEN 70
```

Once I reaches the value 11, statement 70 is executed and the program stops. This is called *exiting* from the loop. Let's now verify that the value 11 (rather than 10) is indeed correct in statement 50. If we write:

```
50   IF I = 10 THEN 70
```

It does not work. Once I reaches the value 10, SUM contains the sum of 1 through 9 only. The loop should be executed one more time.

Remember that each loop contains a counter. You should always carefully check the value of the counter that causes exit from the loop. In our example, as long as I is not equal to 11, the loop will be reentered:

```
60   GOTO 30
```

Once I reaches the value 11, the first ten numbers will have been added. This is because in our program the addition (SUM = SUM + I) takes place before the incrementation (I = I + 1). The final

"Remember me?"

"Got you again!"

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three statements in the program are the *exit* from the loop:

```
70  PRINT "THE SUM OF THE FIRST";
75  PRINT "10 INTEGERS IS:  ";
80  PRINT SUM
90  END
```

Here is a sample run of this program:

```
THE SUM OF THE FIRST
10 INTEGERS IS: 55
```
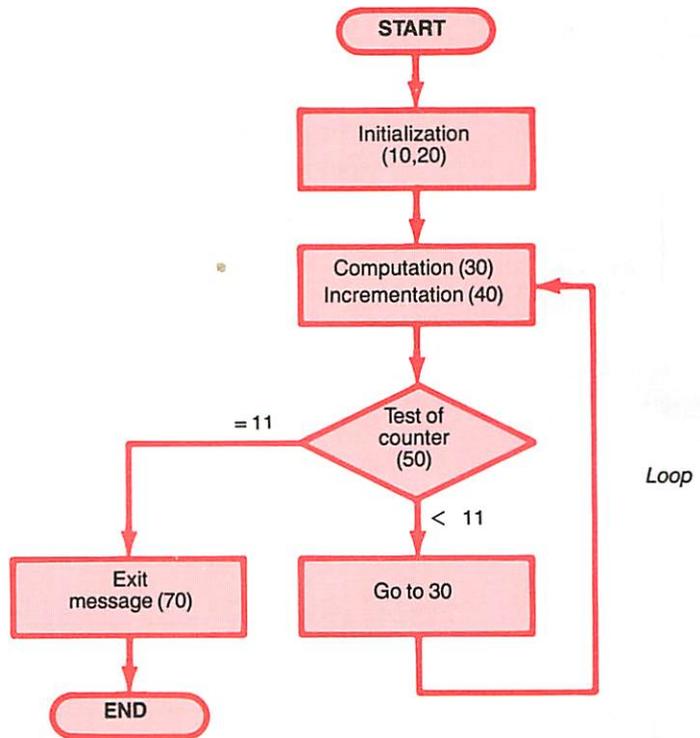

Figure 7.1 Flow control in the Integer SUM Program

The illustration in Figure 7.1 shows the flow of control in the program. The numbers in parentheses are the statement numbers. This diagram is called a *flowchart*. We will discuss the subject of flowcharts in detail in Chapter 8. For now, simply note the general organization of the program: initialization, computation plus incrementation, test, and exit. All program segments with loops perform these functions.

Variations

Let's now play with our integer addition program and sharpen our programming skills. This will demonstrate the many alternatives

that can be used to write a program. For example, on line 50 we could have written:

```
50   IF I > 10 THEN 70
```

and the result would be the same (when I reaches the value 11, it is greater than 10). Also, we could have written:

```
40   IF I = 10 THEN 70
50   I = I + 1
```

instead of:

```
40   I = I + 1
50   IF I = 11 THEN 70
```

With this change, I is tested first, then incremented. Note that this time I is tested for the value 10 (instead of 11).

We could also have written:

```
50   IF I > 11 THEN 30
60   REM
```

You can verify that these versions are indeed correct. All these variations are valid and equivalent. Even such a short program as the SUM program can be written in many equivalent ways. There is no unique way to write a program. Just like in a spoken language, you can express the same concept in many different ways.

This short program has illustrated the use of a loop and the use of a counter variable. We have also examined the typical phases involved in such a program: initialization, computation, incrementation, test, and exit. In view of the frequent use of loops in programs, a special statement has been provided to facilitate their use in BASIC. This is the FOR . . . NEXT statement.

The FOR . . . NEXT Statement

The FOR . . . NEXT statements automate much of the programming required for a loop. We will explain their use and operation by using actual examples.

Here is one way we can rewrite our addition program using these new statements:

```
1    REM * INTEGER ADDITION – VER 2 *
10   SUM = 0
20   FOR I = 1 TO 10
30   SUM = SUM + I
40   NEXT I
50   PRINT "THE SUM OF THE FIRST"
60   PRINT "10 INTEGERS IS:";
65   PRINT SUM
70   END
```

Note that this program has two less instructions than the first one. It is shorter and more readable. Let's examine it in detail. The first executable statement initializes SUM to zero:

```
10  SUM = 0
```

The next statement is the FOR instruction:

```
20  FOR I = 1 TO 10
```

This instruction has several roles:

- ► It marks the beginning of the automatic loop. (This is where the loop starts.)

- ► It specifies that I (the counter variable) starts with the initial value 1 when this statement is first executed. This eliminates the need for an initialization statement for I.

- ► I is incrementated by 1 (up to a maximum value of 10) every time the statement is reactivated by a matching NEXT statement. An automatic test is performed, and when I exceeds the value 10, the loop is no longer executed, and the statement following the NEXT is executed instead. (This is the loop exit).

The body of the loop simply contains the accumulation of the sum:

```
30  SUM = SUM + I
```

The NEXT statement:

```
40  NEXT I
```

marks the end of the loop and causes reactivation of the FOR. This replaces two statements in the previous version:

```
40  I = I + 1
60  GOTO 30
```

Every time NEXT I is executed, the program jumps to the beginning of the loop , i.e., the FOR statement. When FOR is activated:

- ► I is incremented by 1
- ► the new value of I is automatically compared to 10.

As long as I does not exceed 10, execution proceeds. The looping stops when I equals 10, and NEXT is reached. At this point, exit occurs, and statement 50 (following the NEXT) is executed. This sequence is illustrated in Figure 7.2 (a flowchart).

Figure 7.2 shows that the FOR statement automates three tasks:

- ► initialization of the counter variable (I is set to 1 initially)
- ► incrementation of the counter variable (I is incremented by 1 each time)
- ► test of the counter variable against a maximum value (I is compared to 10).
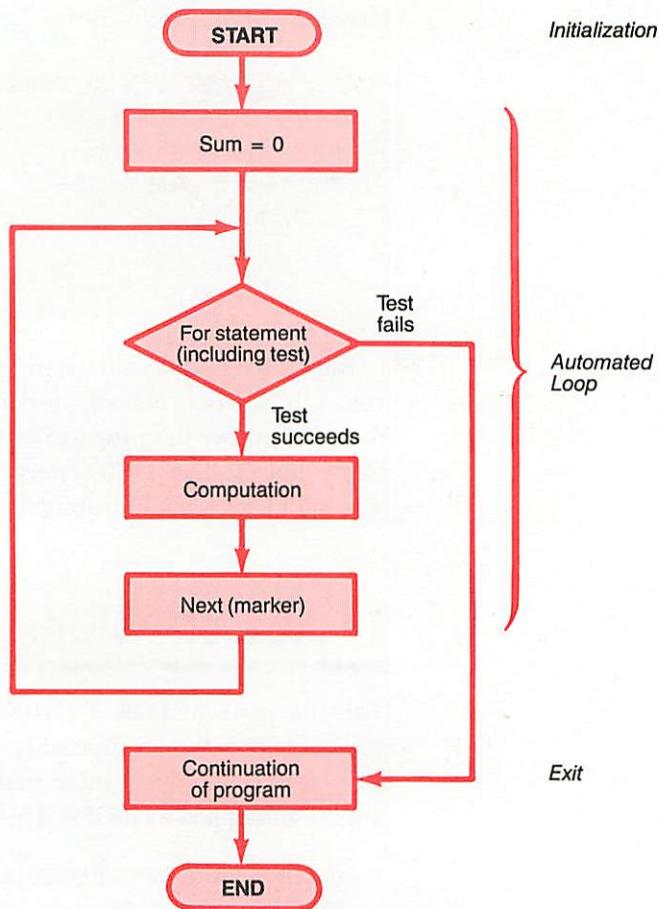
Figure 7.2: Automatic looping with FOR . . . NEXT

The NEXT statement simply marks the end of the loop and causes a "GOTO the FOR" statement.

FOR . . . NEXT is a convenience statement. You do not have to use it, but you will probably find it very valuable. It simplifies loop design and clarifies the program. We will now give practical examples to illustrate the use of the FOR . . . NEXT statement and the use of automated loops.

Sum of the First N Integers

We will compute the sum of the first N integers. This time the user specifies the value of N at the keyboard. Here is the program:

```
10  REM * SUM OF FIRST N INTEGERS *
20  SUM = 0
25  PRINT "I WILL ADD THE FIRST N";
30  PRINT "INTEGERS. TYPE N:"
35  INPUT N
40  FOR I = 1 TO N
50  SUM = SUM + I
60  NEXT I
65  PRINT "THE SUM OF THE FIRST"
70  PRINT N; "INTEGERS IS";
75  PRINT SUM
80  END
```

Here is a sample run:

```
I WILL ADD THE FIRST N
INTEGERS. TYPE N:? 5
THE SUM OF THE FIRST
   5 INTEGERS IS 15
```

You should understand the program readily. This time, we loop from 1 to N, where N is supplied at the keyboard (statement 35). You can improve this program by validating the input: N should be greater than 1. The BASIC interpreter will automatically verify that N is an integer when executing the FOR statement. Try fooling it.

Tables of Values

Using the powerful FOR . . . NEXT statement, we will show how easy it is to automate computations and print tables of values. Here is a table of squares (a number multiplied by itself) and cubes (a number multiplied by itself and multiplied by itself again):

```
10   REM TABLE OF SQUARES AND CUBES
20   REM FOR THE FIRST 10 INTEGERS
30   FOR I = 1 TO 10
40   PRINT I; I ^ 2; I ^ 3
50   NEXT I
60   END
```

Here is the result:

```
1      1       1
2      4       8
3      9       27
4      16      64
5      25      125
6      36      216
7      49      343
8      64      512
9      81      729
10     100     1000
```

Let's take a closer look at statement 40:

```
40   PRINT I; I ^ 2; I ^ 3
```

$I \char94 2$ means I to the power 2, i.e., $I * I$. For example, if $I = 2$, then $I \char94 2 = 2 \times 2 = 4$. Similarly, $I \char94 3$ means I to the power 3, i.e., $I * I * I$. If $I = 4$, then $I \char94 3 = 4 \times 4 \times 4 = 64$.

As an exercise you could rewrite this program to display the sum of the squares and cubes of the first N integers, where N is read at the keyboard. We learned how to do this in the previous section.

Lines of Stars

Here is a simple program that prints N lines of stars, where N is a number you specify at the keyboard:

```
10   REM * LINES OF STARS *
20   PRINT "I WILL DISPLAY"
25   PRINT "LINES OF STARS"
30   PRINT "HOW MANY LINES : "
35   INPUT N
40   REM N IS # OF LINES
50   FOR I = 1 TO N
60   PRINT "* * * * * * * * * * * * * * * *"
70   NEXT I
80   END
```

And here is a sample run of this program:

```
I WILL DISPLAY
LINES OF STARS
HOW MANY LINES :
? 6
* * * * * * * * * * * * * * * *
* * * * * * * * * * * * * * * *
* * * * * * * * * * * * * * * *
* * * * * * * * * * * * * * * *
* * * * * * * * * * * * * * * *
* * * * * * * * * * * * * * * *
```

Again, every time an input is supplied by the user, it is a good idea to validate it in order to avoid strange program behavior. We expect that the person using this program will supply a positive number. Let's assume you want no more than 20 lines of stars. You would tell the user in an appropriate PRINT statement, and use two validation statements like:

```
IF (N <  1) GOTO 20
IF (N > 20) GOTO 20
```

Advanced Looping

The FOR . . . NEXT statement offers two advanced facilities that we have not yet described:

► You can increment the counter by any integer value, such as 2, 3, 4, or even −1 (rather than just incrementing by 1). This is called the *variable step* feature.

► You can create a loop within another loop. Such loops are called *nested loops*.

Let us examine these two techniques.

*Be careful
when looping*
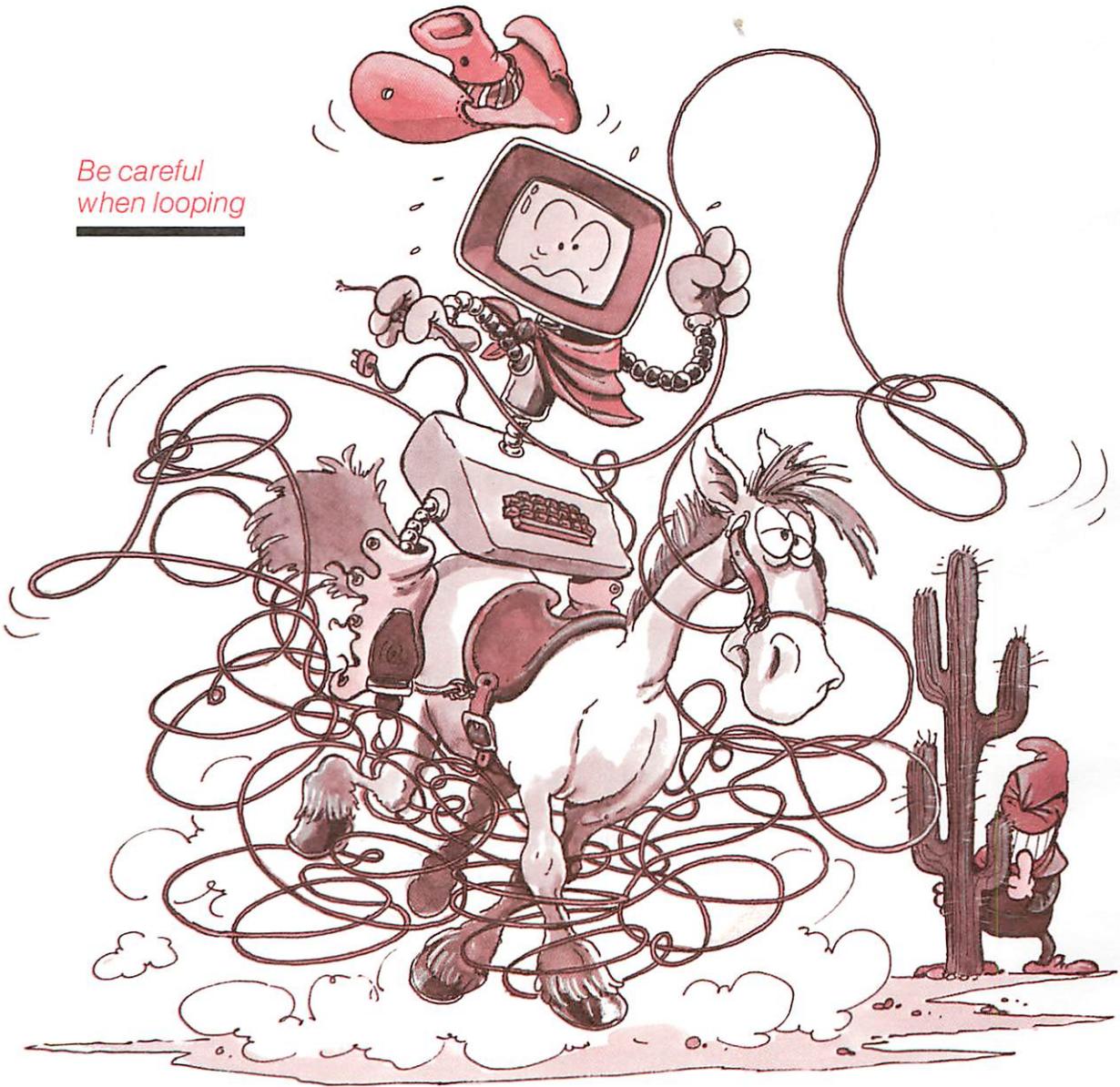
Variable Step

Here is an example of variable step:

    FOR I = 1 TO 5 STEP 2

Every time the loop is re-entered I will be incremented by 2. You could even write:

    FOR I = 10 TO −5 STEP −1

using a *negative step* increment. Because the upper limit for the counter variable (−5 here) is less than the starting value (10), it is a "negative step" for the interpreter. The value of I will be decreased by 1 each time. The first value of I will be 10. The next will be 9; the next 8, etc. The last one will be −5. In other words, I will take the following values in turn: 10, 9, 8, 7, 6, 5, 4, 3, 2, 1, 0, −1, −2, −3, −4, −5. Negative step is another convenience feature that you may want to use.

Your variable may use step increases

Nested Loops

The nested loop technique is an important and powerful facility used to automate complex processing. A nested loop is created whenever you use a FOR . . . NEXT group of statements within a loop; that is, whenever you use another FOR . . . NEXT group of statements.

In general, you may use as many statements as you wish between the FOR and the NEXT statements. Specifically, you may even include another loop within these statements. When this takes place it is called a nested loop. This concept is illustrated in Figure 7.3.

When using nested loops, notice how the program becomes more difficult to read. To remedy this, you are encouraged to use *indentation*. Indentation is another program clarification technique. Figure 7.4 shows an indented version of the program of Figure 7.3.

	STATEMENT	STATEMENT
	STATEMENT	STATEMENT
	STATEMENT	STATEMENT
	FOR	**FOR**
	STATEMENT	STATEMENT
	STATEMENT	STATEMENT
	FOR	**FOR**
	STATEMENT	STATEMENT
	STATEMENT	STATEMENT
	NEXT	**NEXT**
	STATEMENT	STATEMENT
	NEXT	**NEXT**
	STATEMENT	STATEMENT
	STATEMENT	STATEMENT
	STATEMENT	STATEMENT
	END	**END**
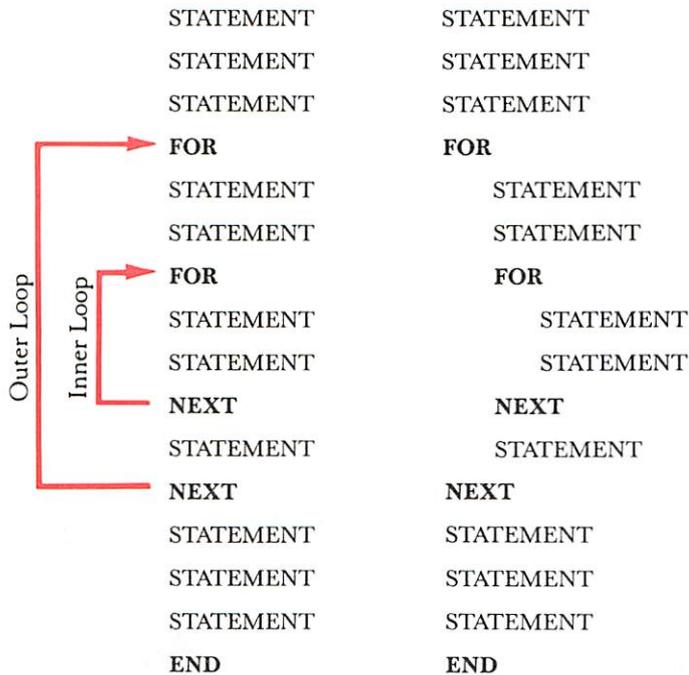
Figure 7.3: A nested loop   **Figure 7.4:** An indented program

You can nest loops to any level, up to a maximum number depending on the amount of memory you have. However, you may not overlap loops. The following loops are legal:
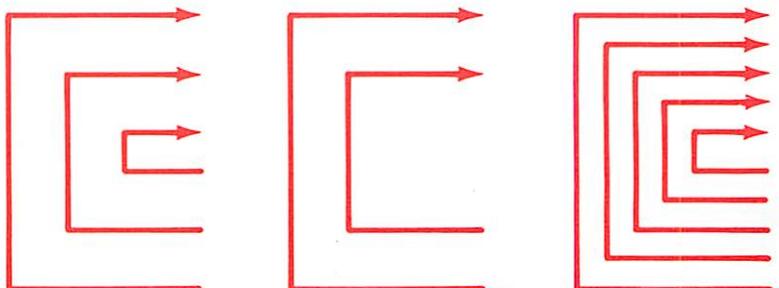
The following are not legal:
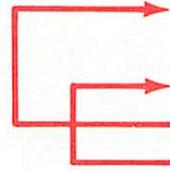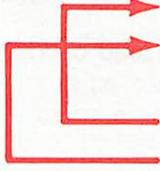
Don't overlap loops!
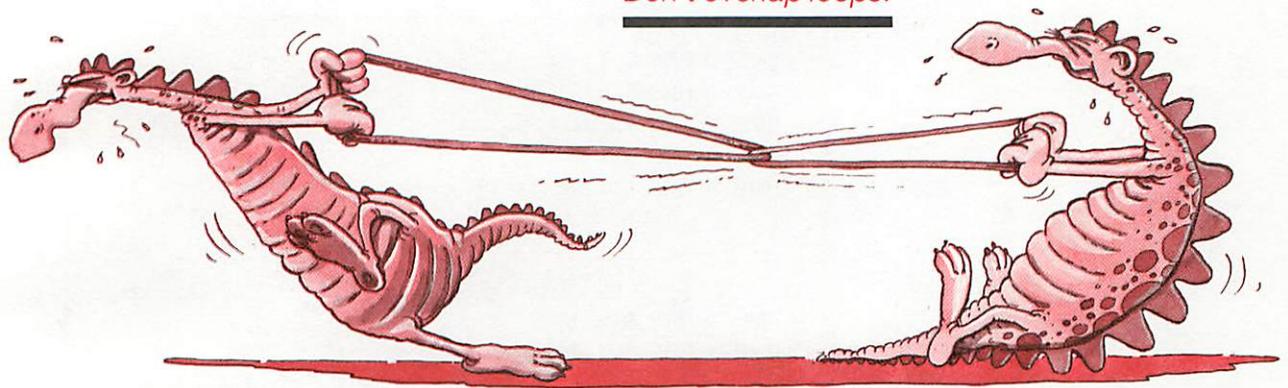
In addition, you may not jump (i.e, specify a GOTO) from a point *inside* the outer loop to a point inside the inner one:
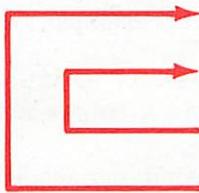
Correct nesting
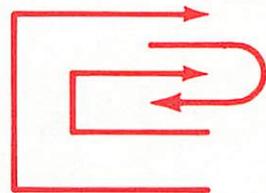
Illegal jumping
(with IF or GOTO)

However, you may jump out of the inner loop:
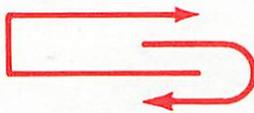
Correct jumping
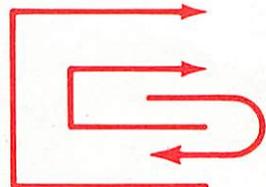
Correct jumping

Here is an example of a nested loop. This program displays accelerated time in minutes and hours:

```
10  REM * SIMULATED CLOCK *
20  FOR HOUR = 0 TO 23
30  FOR MINUTE = 0 TO 59
40  PRINT "TIME:";
45  PRINT HOUR;  "HRS &";
50  PRINT MINUTE;  "MIN"
55  NEXT MINUTE
60  NEXT HOUR
70  PRINT "END OF THE DAY"
80  END
```

Here is a portion of the run:

```
TIME: 0 HRS & 0 MIN
TIME: 0 HRS & 1 MIN
TIME: 0 HRS & 2 MIN
TIME: 0 HRS & 3 MIN
TIME: 0 HRS & 4 MIN
          .
          .
          .
TIME: 0 HRS & 59 MIN
TIME: 1 HRS & 0 MIN
```

Additional Features

As a final note, decimal values and expressions are allowed in the FOR statement. For example, the following are valid:

```
FOR MEASURE = 0.1 TO 13.5 STEP 0.2
FOR INTEGER = N TO (N * 2) STEP 1
```

This practice is not recommended; and we will not use these advanced features here.

Summary

Loops are used extensively to automate the repetition of a program segment. The FOR . . . NEXT statement is used to automate loops in BASIC. In most cases, the FOR . . . NEXT statement can replace several other BASIC statements. In this chapter, we have examined typical uses of the FOR . . . NEXT statement, including nested loops, and we have developed several advanced programs. Now that you have learned all the basic programming techniques, you are almost ready to start writing your own programs. In the next chapter we will explain how you can get started.

Exercises

7-1: Display the first 5 integers on a line (4 statements).

7-2: Write a program that reads the time in hours and minutes at the keyboard and displays it as follows:

Input:	3 *(hours),*	3 *(minutes)*
Display:	H H H	*(3 letters)*
	M M M	*(3 letters)*

7-3: What is the counter variable in a loop?

7-4: Can you jump into the middle of a loop?

7-5: Display a table that converts ounces to grams (1 ounce = 28 grams).

7-6: Compute the sum of the first N odd integers—where N is supplied at the keyboard—and display it for each integer.

7-7: Read scores for five students that each took four tests, graded 0 to 10. Display the grades, then the total and average for each.

7-8: Display a sales tax table for prices of $1 to $100 in $1 increments. Supply the tax rate at the keyboard.

Creating a
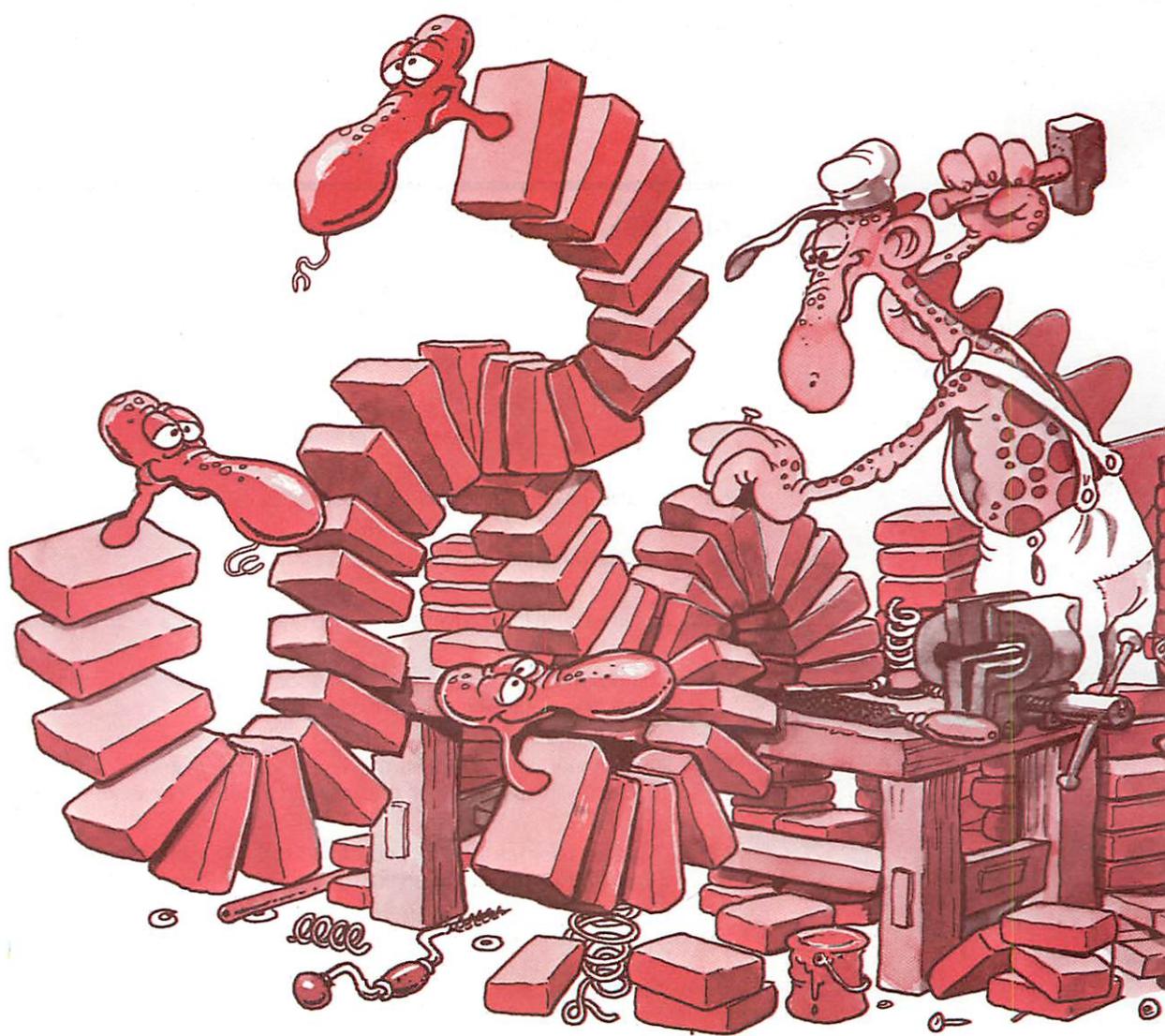
8

Programming involves designing a program that automates a task. So far, we have written several short programs. We have done so without any intermediate steps—directly writing a sequence of BASIC statements. This technique is fine for very simple programs, but it does not work well for complex ones.

In this chapter, we will learn the correct way to create a program.

This is a five-step process:

1. Specify the sequence of steps involved in solving the problem. This is called designing the *algorithm*.

2. Draw a diagram showing the sequence of events and the logical steps. This is called drawing the *flowchart*.

3. Write the program in BASIC. This is called *coding*.

4. Verify and test the program. This is called *debugging*.

5. Clarify and document the program. This is called *documenting*.

So far, we have only learned and practiced steps 2 and 5. But this sequence will work only for short programs. Before we proceed to long programs, let's study the complete sequence involved in program development.
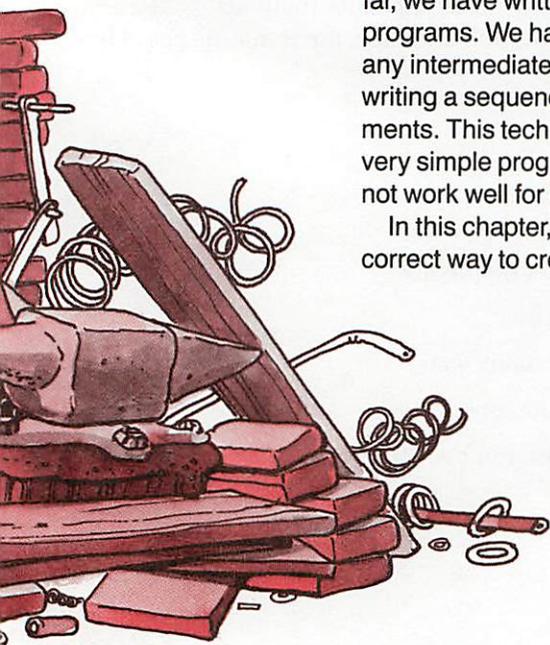
Algorithm Design

We want to design a program that will solve a given problem or automate a task. So far, we have designed programs to solve simple problems. The sequence of steps required to solve each problem was generally obvious, so there was almost no design phase. In the general case, however, given a problem we must first design a solution. In order to write programs, this solution must be specified as a sequence of steps. This sequence of steps is called an *algorithm*. Formally, an algorithm is defined as a step-by-step specification of the solution to a problem. Technically, an algorithm must also terminate—it should not go on indefinitely. An algorithm that does not stop is called an *error!*

Here is a simple problem: let's convert a weight measured in ounces into its equivalent in grams. Recall that one ounce is equivalent to 28.35 grams. The solution is obvious: we multiply the weight in ounces by 28.35. This is a simple one-step algorithm.

Let's now examine a slightly more complex problem: let's read a number at the keyboard and test that it is within a certain range. We will accept the number as being valid if it falls in the range between 0 and 100. The sequence of steps involved in solving this problem is the following:

1. Read the number.

2. Check to see if it is greater than zero. If so, proceed; if not, reject the number.

3. Check to see if it is less than 100. If yes, accept the number; if not, reject it.

This is a 3-step algorithm.

In practice, most problems are more complicated, and their solutions require longer and more complex algorithms. Here are several everyday examples of algorithms. You can find many more in your cookbook, or in your car or appliance manuals.

Let's examine an algorithm for boiling a three-minute egg. Here are the steps:

1. Take a pan

2. Fill it with water

3. Turn on the stove

4. Place the pan of water on the stove

5. Bring the water to a boil

6. Place an egg in the boiling water

7. Start the three-minute timer

8. When the timer rings, remove the egg

9. Turn off the stove.
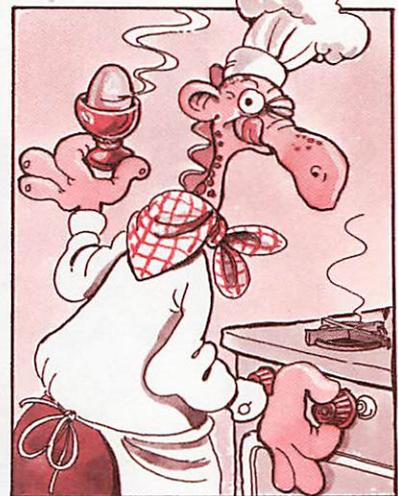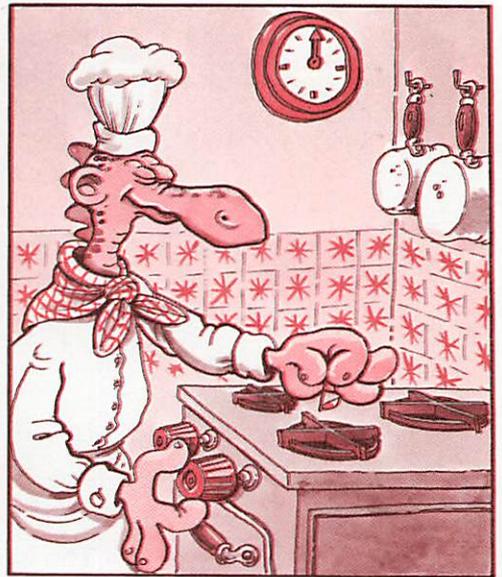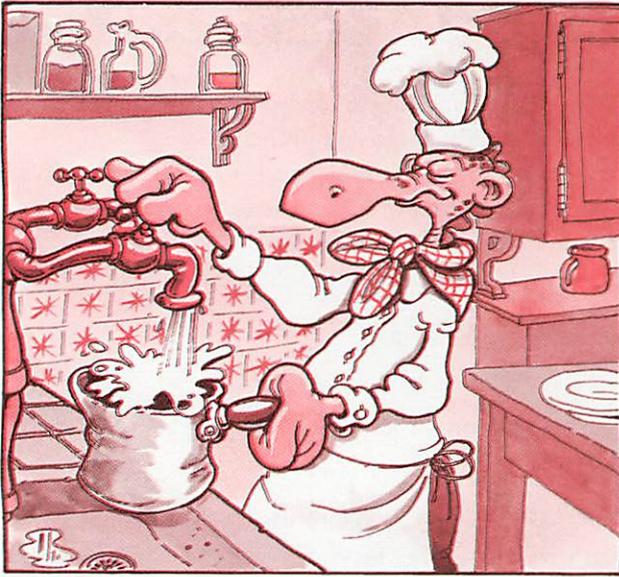
"I'll demonstrate the three-minute egg algorithm."

This algorithm looks straightforward, but if it were to be executed as a program by a computerized robot, it would have to be much more precise. For example, we would need to specify exactly which pan to use, as well as the precise amount of water to put in the pan.

Many algorithms presented in everyday books assume that the user has a specific cultural or technical background; and they are therefore generally incomplete. In other words, they assume that a user can fill in the blanks. Unfortunately, this is precisely why so many manuals are so difficult to comprehend!

We will not make the same mistake here. Our algorithms will be completely specified in order to become useable programs.

Here is one last example: an algorithm for starting a car. If we assume that the car works perfectly, the algorithm is quite simple:

1. Insert the key in the ignition.

2. Turn the key all the way to the right.

3. Release pressure on the key while applying gentle pressure on the gas pedal.

However, we know that it is possible that a car may not start. This is because there are other factors involved, such as temperature, or the mechanical condition of the engine. Preparing a complete algorithm for starting a car under all conditions would require several pages—if we are to take into account everything that could possibly go wrong.

Starting a car is
an interesting algorithm

In everyday life we can often simplify the steps of an algorithm. But, in a computer program we may not. An algorithm has to be correct and complete.

When designing an algorithm for a computer solution, you must be thorough and anticipate every reasonable case that may arise, or your program may eventually fail. Successful programming requires a special attitude: you must continuously challenge everything you do, always assuming that it could be wrong or incomplete.

Never assume an input will be reasonable. Check it and verify it. Always allow for the possibility of errors. We will illustrate these considerations later in this chapter when we examine an actual case study.

In summary, in order to automate the solution to a problem by writing a computer program, start by preparing an algorithm. The final algorithm should be perfect—although, in the beginning it rarely is. In fact, you will probably design an approximate solution (i.e., a rough algorithm) in the beginning and then continue to refine the algorithm as you go along, until it reaches the state you consider to be perfection. Always make sure your algorithm is complete before you start actually writing instructions.

Remember, the algorithm is supposed to work!
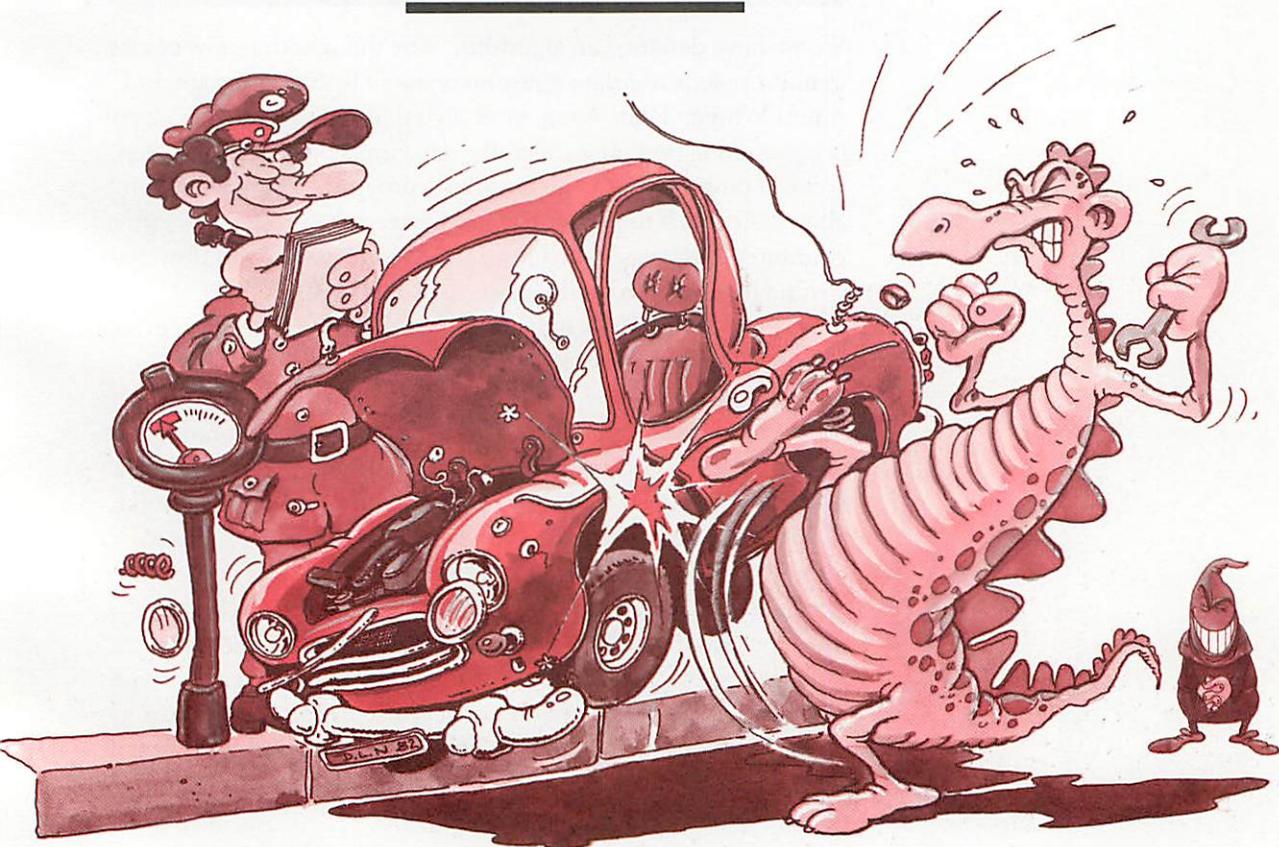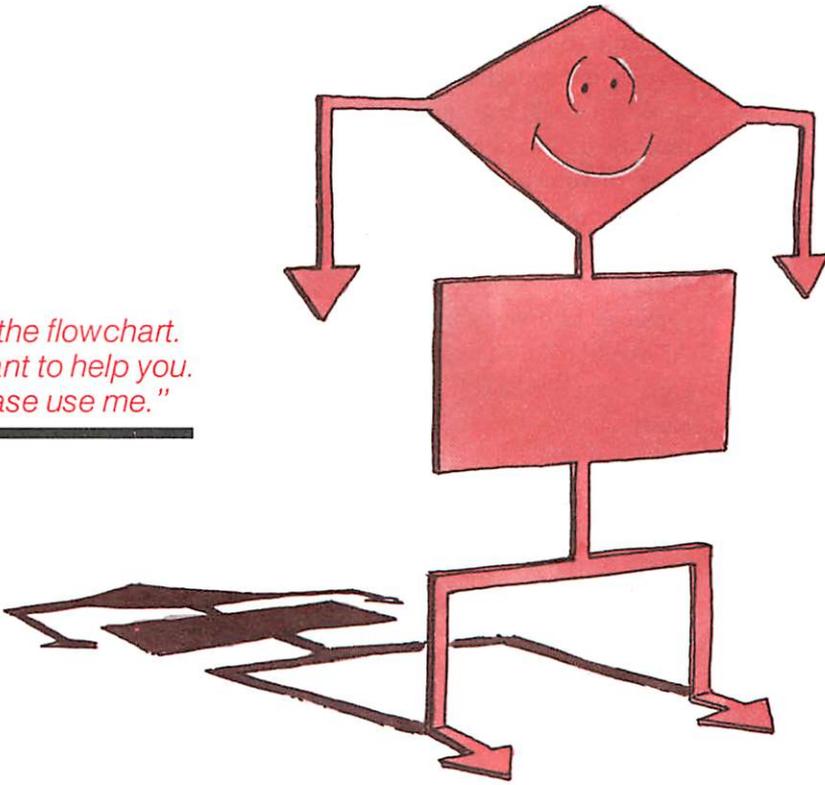
Flowcharting

So, we have designed an algorithm. The thought that now comes to mind is: let's translate it promptly into a BASIC program and run it! Wrong. There is one more step that may save you hours of programming time: it is called flowcharting. If you skip this step, you will probably not write a working program, and you will probably waste much time later trying to correct the program—with no guarantee of success. By contrast, once you have a good flowchart, writing the program is one easy step away.

A flowchart is simply a diagram showing the sequence of events. Figure 8.1 shows a flowchart of the steps involved in boiling a 3-minute egg.

As you can see, this flowchart is a graphic representation of the algorithm we have already presented. In this case, each box in the flowchart represents one step of the algorithm. The purpose of a flowchart is to show the sequence of the steps over time. Later, once you become familiar with flowcharting, you may even skip the algorithm design step and begin directly with flowcharting, since the flowchart is just a representation of the algorithm.

In the case of an algorithm as simple as the one for preparing a 3-minute egg, the flowchart is not very useful and could be dispensed with. The true value of a flowchart becomes apparent when you begin designing more complex algorithms that involve numerous choices and decisions.
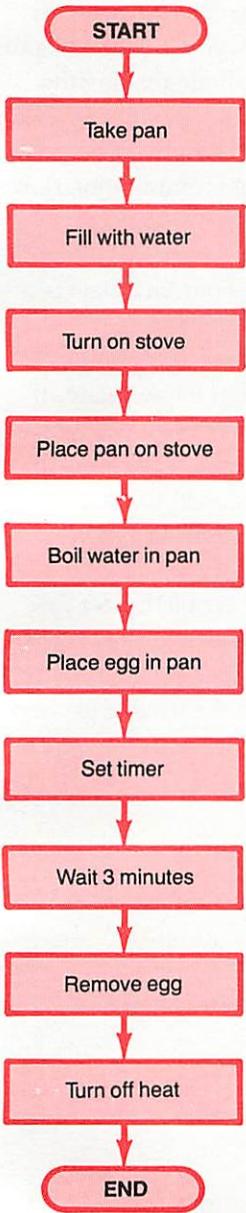
Figure 8.1
Boiling a 3-minute egg
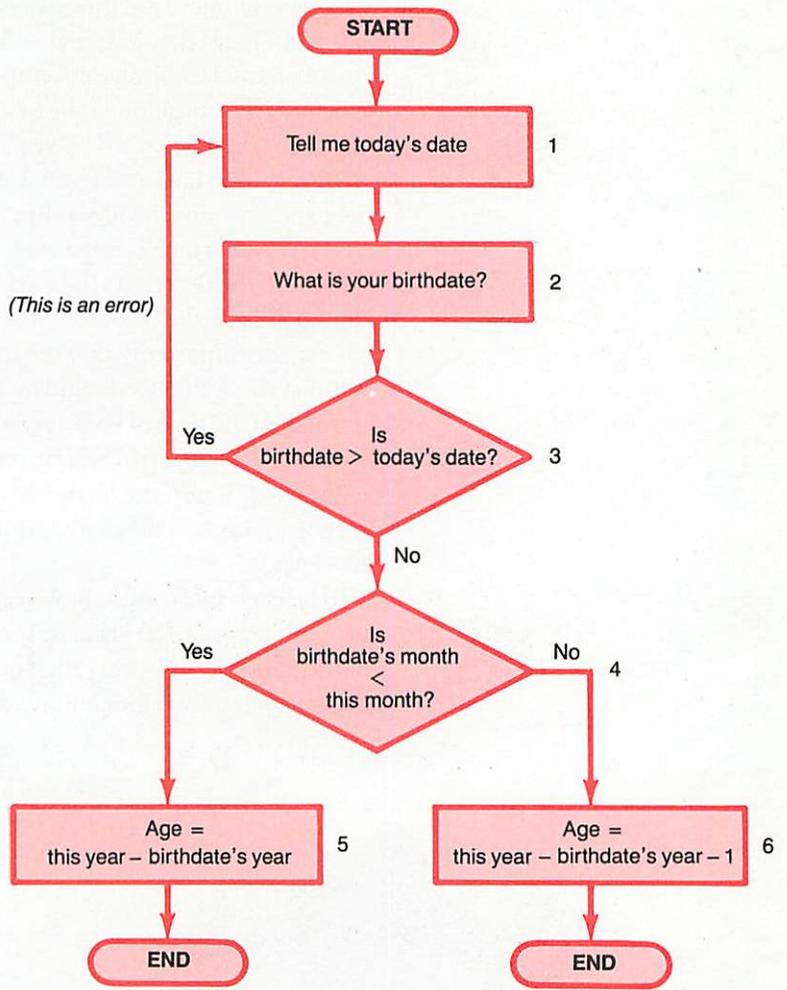
Figure 8.2 Age Computation flowchart
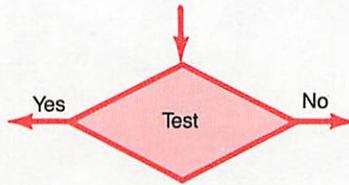
Figure 8.3 Diamond symbol

Let's now design a new program that asks for your birthdate and the current date, and then computes your age. The algorithm is obvious. The flowchart is shown in Figure 8.2. The diamond-shaped boxes in the flowchart indicate a test, i.e., a choice in the sequence. At this point, to facilitate converting the flowchart into a program, make sure that each choice has only *two* results: "yes" or "no." Label the arrows accordingly. Now examine Figure 8.2 and verify that each arrow coming out of the diamond-shaped boxes is labeled either "yes" or "no," depending on the result of the test (see Figure 8.3).

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In general, there are three ways the arrows can be drawn, as shown in Figure 8.4. You may select any way you prefer. The purpose of your selection should simply be to facilitate reading the flowchart. The position of the yes and the no arrows may be freely exchanged; in other words, "yes" can be on the right if you prefer.

Let's now go back to Figure 8.2 and the age computation flowchart and examine the algorithm it represents.

First, today's date is requested. This step corresponds to the first box in the flowchart (labeled 1). Second your birthdate is requested. This is the box labeled as 2 on the flowchart.

Next, we must verify that the birthdate supplied is reasonable. We must check that the birthdate is earlier than today's date. If the value of the date of your birthdate is greater than the value of today's date, an error will be recognized and the process will be restarted. If not, the birthdate will be presumed valid. This step corresponds to the diamond shaped box (labeled 3) on the flowchart.

To be even more refined, we could also reject birthdates that result in an age of 150 years or more, since they are unlikely to be valid. However, accepting such birthdates does not create serious adverse effects; therefore it may not be worth the trouble to check for them.

The flowchart is the reflection of the algorithm
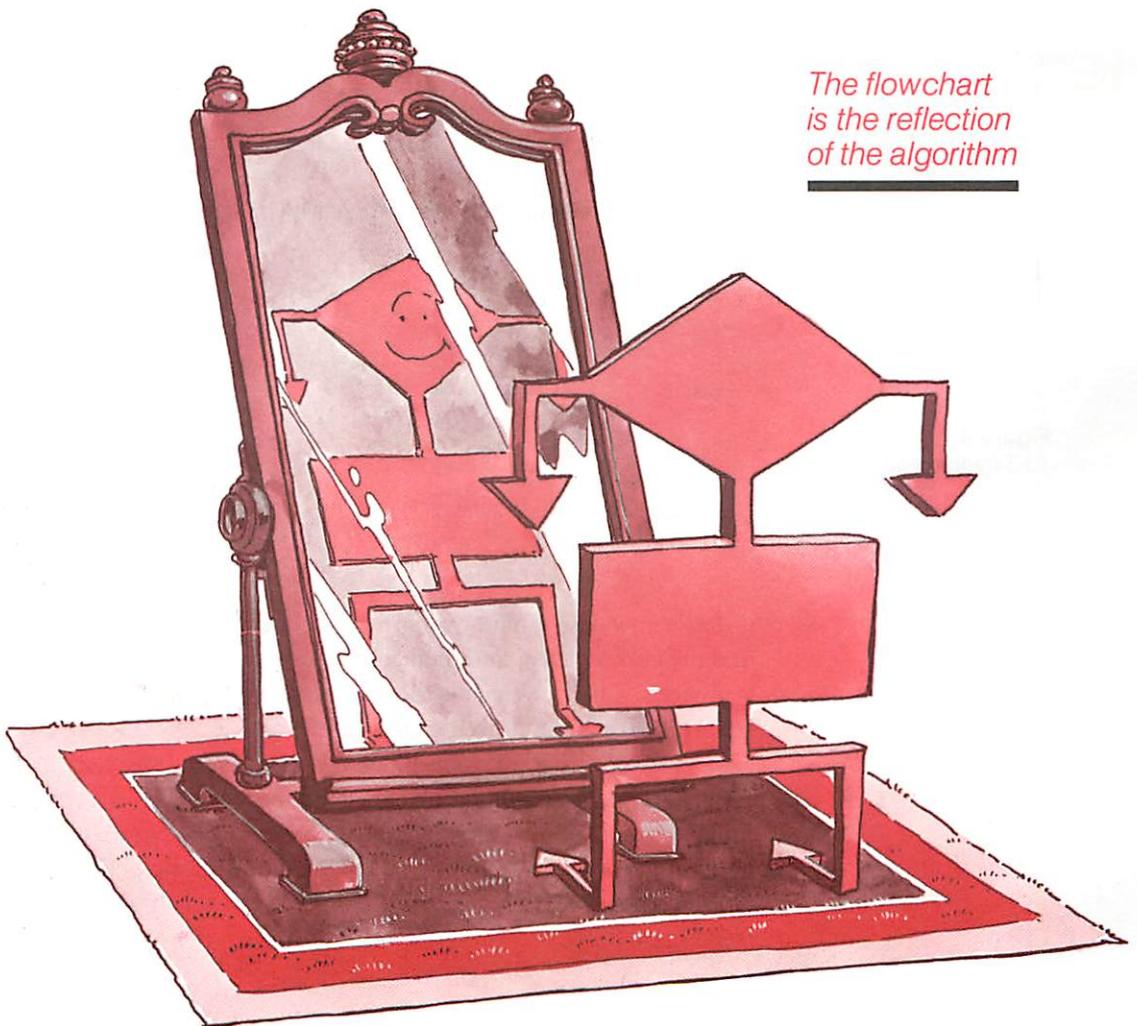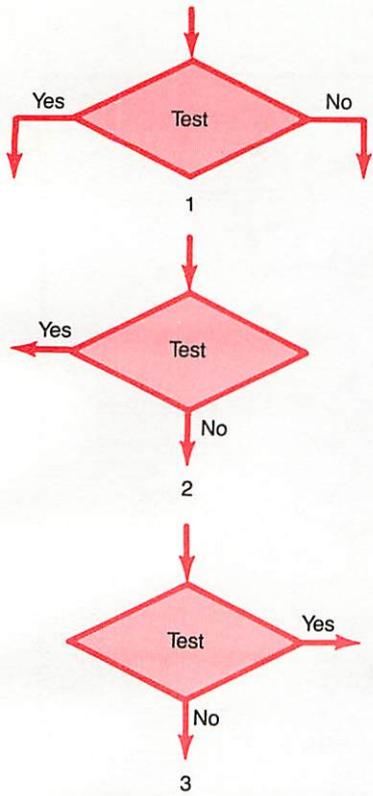
Figure 8.4 The three ways to draw arrows
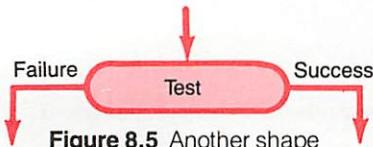
Figure 8.5 Another shape for a decision box
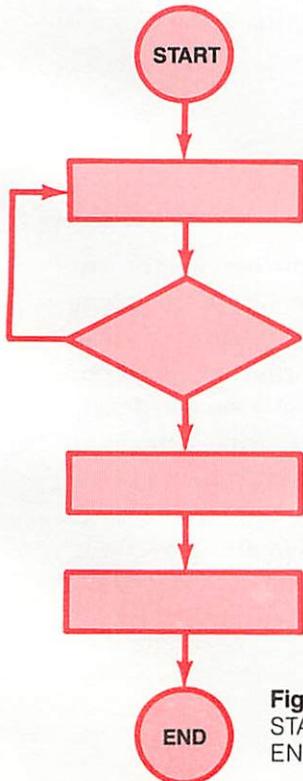
Figure 8.6 START and END symbols
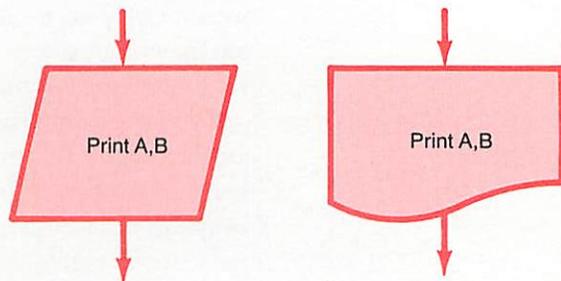
In box 4 on the flowchart, we determine whether the month of your birthday is less than today's month. If so, your birthday has passed for this year, and your age may be computed (in box 5 of the flowchart) as the difference of the current year and the year of your birthday. For example, if you were born in February 1946 and we are in March 1983, your age is $1983 - 1946 = 37$.

Otherwise (this is box 6 on the flowchart), your age is computed as the current year minus your birthdate's year, minus 1. For example, if you were born in June 1942 and we are in March 1983, your age is $1983 - 1942 - 1 = 40$. To keep this example simple, we will not check for the day of the month. We'll add this improvement later.

The steps of the algorithm should now be clear. Let's examine the flowchart symbols.

The Symbols in the Flowchart

In a flowchart, rectangular boxes are used for computations and direct actions that do not involve a choice, such as input or display. Diamond-shaped boxes are used for tests or choices. They must always have at least two arrows coming out of them. Finally, each algorithm must have a beginning and an end. This is denoted by the labels START (or BEGIN) and END.

The symbols used in flowcharts are not uniformly standardized. Many standards have been proposed but none has gained universal acceptance. The rectangular box is always used. The diamond-shaped box, however, may be replaced by one with rounded edges, as shown in Figure 8.5. In addition, the START and END symbols can be placed in a small circle, as shown in Figure 8.6. Finally, some special symbols may be used to indicate the use of specific peripherals. For example, a PRINT operation may appear in one of two ways, as shown in Figure 8.7.

In practice you need not worry about the symbols. A flowchart is simply a way of conveniently visualizing an algorithm (especially when it contains many choices). You may even use different symbols if you wish. However, it is better to use common ones so that your programs may be more easily shared with others, and so that you can read and follow other flowcharts more easily.

Figure 8.7 Symbols for PRINT
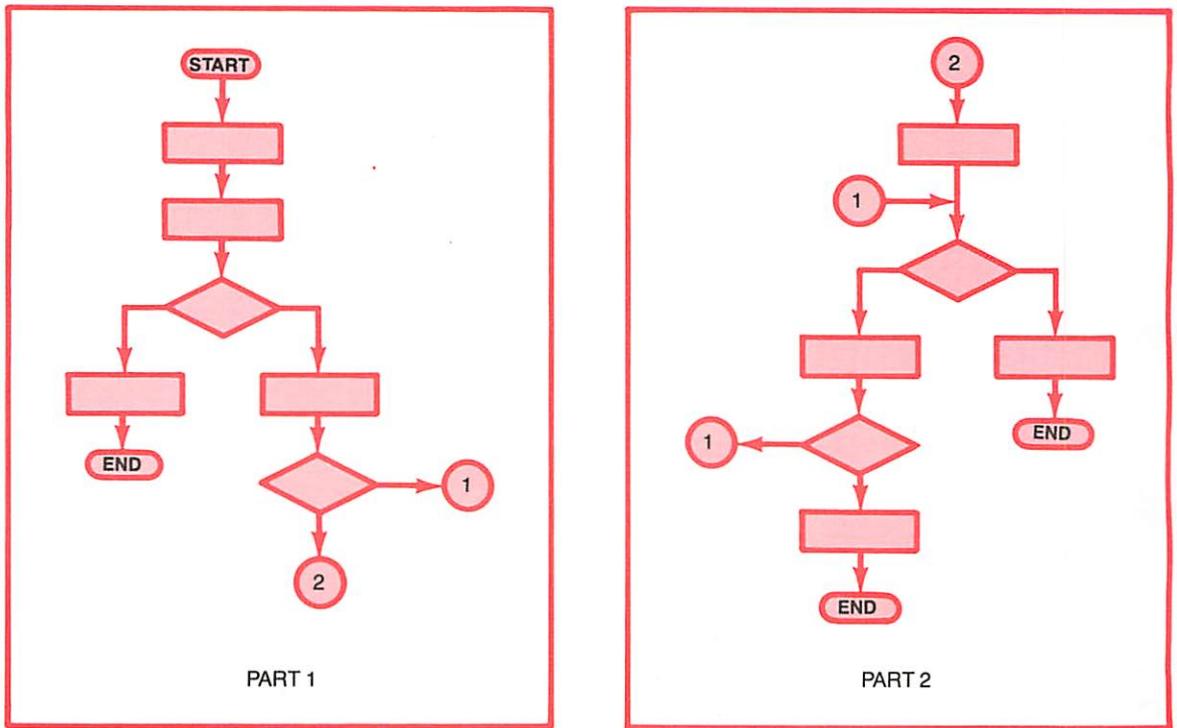
Figure 8.8 Cutting a flowchart

Cutting the Flowchart

Here is one more useful convention. If a flowchart spreads out over several pages, you can cut it into pieces. Label each cut arrow with a number or name, and make sure you have matching entry points to the flowcharts on the other pages. Figure 8.8 shows an example of using numbers to connect arrows.

Refining the Flowchart

The instructions placed in the boxes of the flowchart may be written as you please. They are not BASIC statements. When writing your flowchart for the first time, you may write instructions that are somewhat vague, such as "tell me your birthdate?"; later on, you may refine the statements contained in the boxes and design a more detailed chart that will be easier to translate into a program.

If you feel that the instructions in the boxes are sufficiently precise for you to write an equivalent program, you need not change them any further. If you feel, however, that they are too vague or complex to be translated directly into a program, then you should replace them with a sequence of more-detailed instructions.

As an example, you may recall that the flowchart in Figure 8.2 checks for the month of your birthdate, but not the day, when determining whether your birthday has already occurred this month. Let's refine it so that it checks for the month and the day. The corresponding segment of the initial (rough) flowchart appears in Figure 8.9. The new or refined flowchart is shown in Figure 8.10.
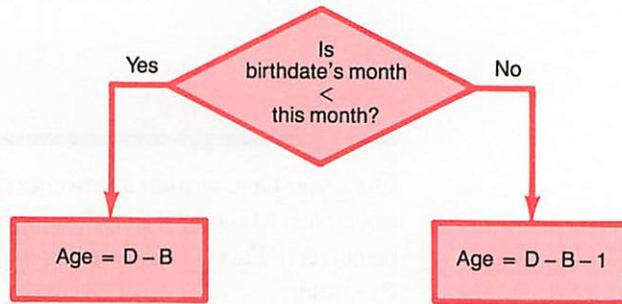
Figure 8.9 A rough algorithm
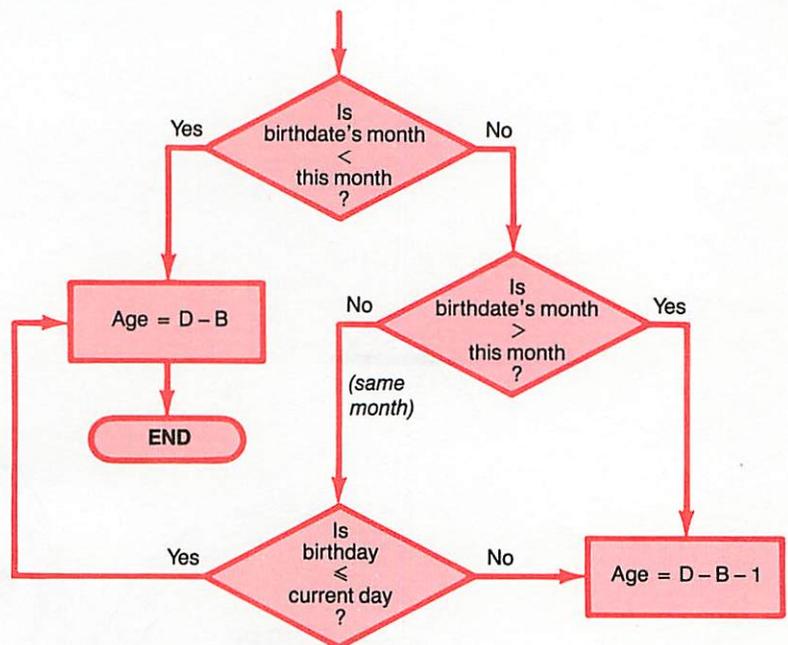
Figure 8.10 A refined flowchart

In practice most people do not write out the algorithm; they proceed directly to the flowcharting phase. This is fine. However, sometimes experienced (and not-so-experienced) programmers skip the flowcharting phase as well, and start by writing the *program* on paper. This is highly dangerous and error prone. I strongly recommend that you always draw a flowchart before writing any program. Later on as you become an expert programmer, you may be able to dispense with the detailed flowchart, and draw only a rough one.

Hand Testing

Once you have written a flowchart, test it by trying out actual examples. Make sure that the result is correct or at least appears to be correct. This is called testing *by hand,* as opposed to using the computer.

For example, go back to the age computation flowchart in Figure 8.2 and supply today's date and your own birthdate, as indicated. Does it give you the correct age? If so, things look good.

If you skip flowcharting, you'll probably run into problems
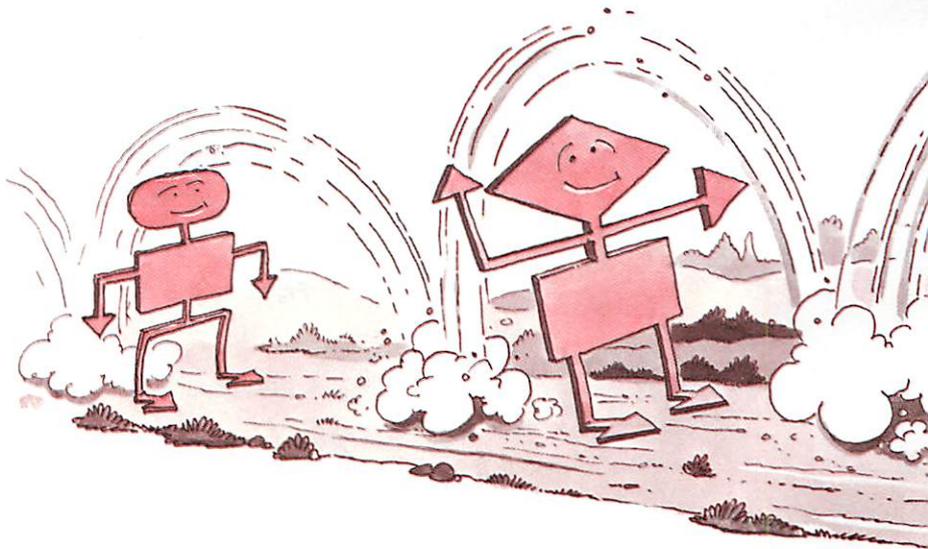
If not, there is an error. Now, try it again with different values, using birthdates that fall before and after today's date. Does it still work? If so, the algorithm is probably correct. If not, there is an error. Hand testing is a quick way to insure that there is no obvious mistake.

Having written a flowchart that seems to work, we have now accomplished all of the preliminary steps required before writing an actual program. Let us now write the program.

Coding

Writing program instructions is called *coding*. *Programming* normally refers to the entire sequence required to create a program: designing the algorithm, flowcharting, coding, debugging, and testing. Coding involves translating the contents of the flowchart boxes into program instructions expressed in a programming language—in this case, expressed in BASIC.

This is what we have learned so far: we have learned how to translate statements, formulas, tests, and conditions into BASIC instructions.

The key to easy coding is to write a detailed enough flowchart so that you can easily code each box of the flowchart into a few simple BASIC instructions. Generally, in the early stages of programming, each box in a flowchart is translated into just a few BASIC instructions, say one or two; i.e., there is a straightforward equivalence between boxes and instructions. Later as your programming skills and experience grow, you may be able to write "looser" flowcharts where each box is coded into many BASIC instructions.

Despite appearances, the coding phase is often the one that requires the least time in the program development sequence. Testing the program usually requires much longer than the actual coding. That is why it is so important to write a good flowchart—so that you can minimize errors and testing time.

When coding a program, remember to make your program accurate, clear, and readable, so that it will work quickly and can be tested or modified easily.
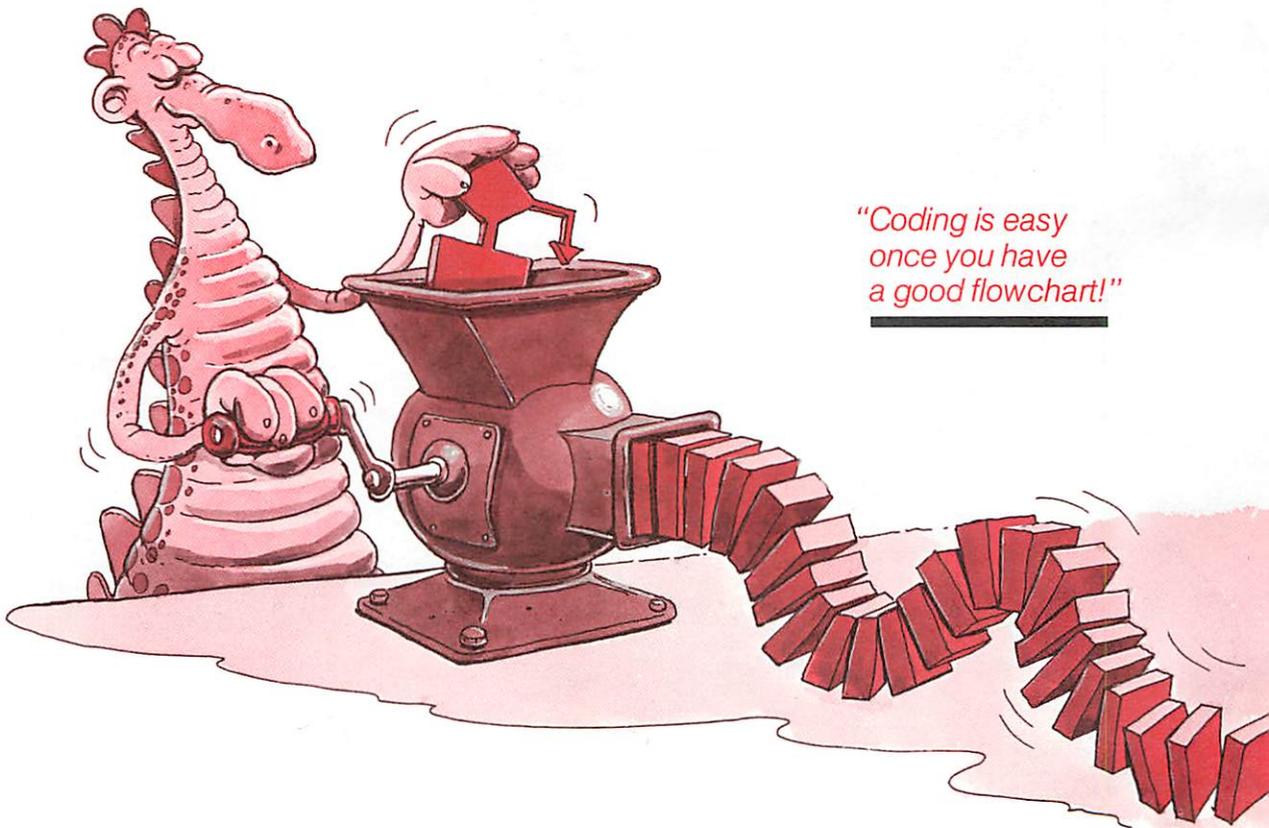
"Coding is easy once you have a good flowchart!"

Make it Accurate

Write your program instructions with utmost care since any error in the placement of a punctuation sign or symbol will probably make the program fail.

Make it Clear

Use variable names that are easy to remember. Leave intervals or even gaps in your sequence of instruction numbers in case you might have to insert other instructions in between. Use remarks (the REM statement) liberally throughout the program to clarify what it does.

So now you have designed an algorithm, drawn a flowchart, and written the corresponding program. And you seriously expect it to work. Don't. Sorry. In the majority of cases, *programs do not work the first time.* It usually takes several attempts or lots of experience before a program of any length will run correctly. This is the topic of the next phase.

Watch out for bugs!
Make it accurate;
make it clean.
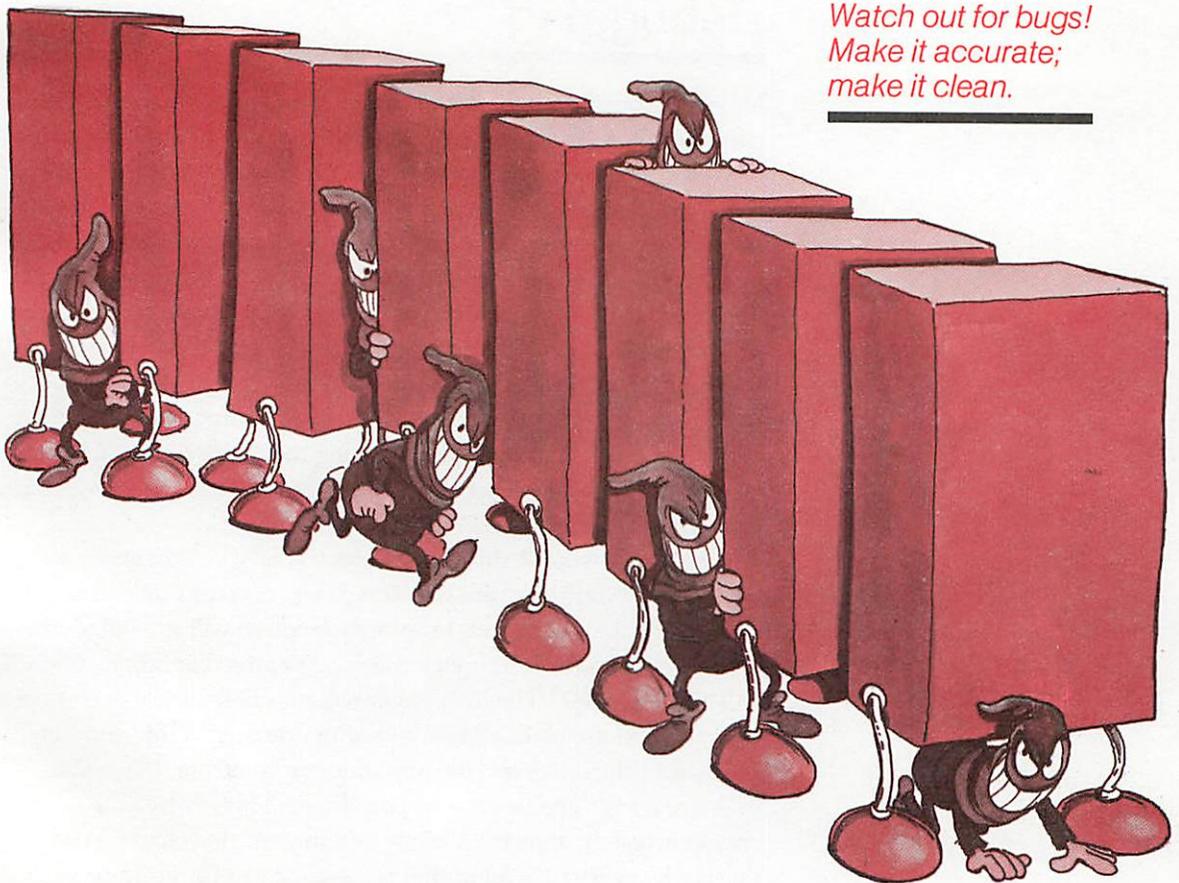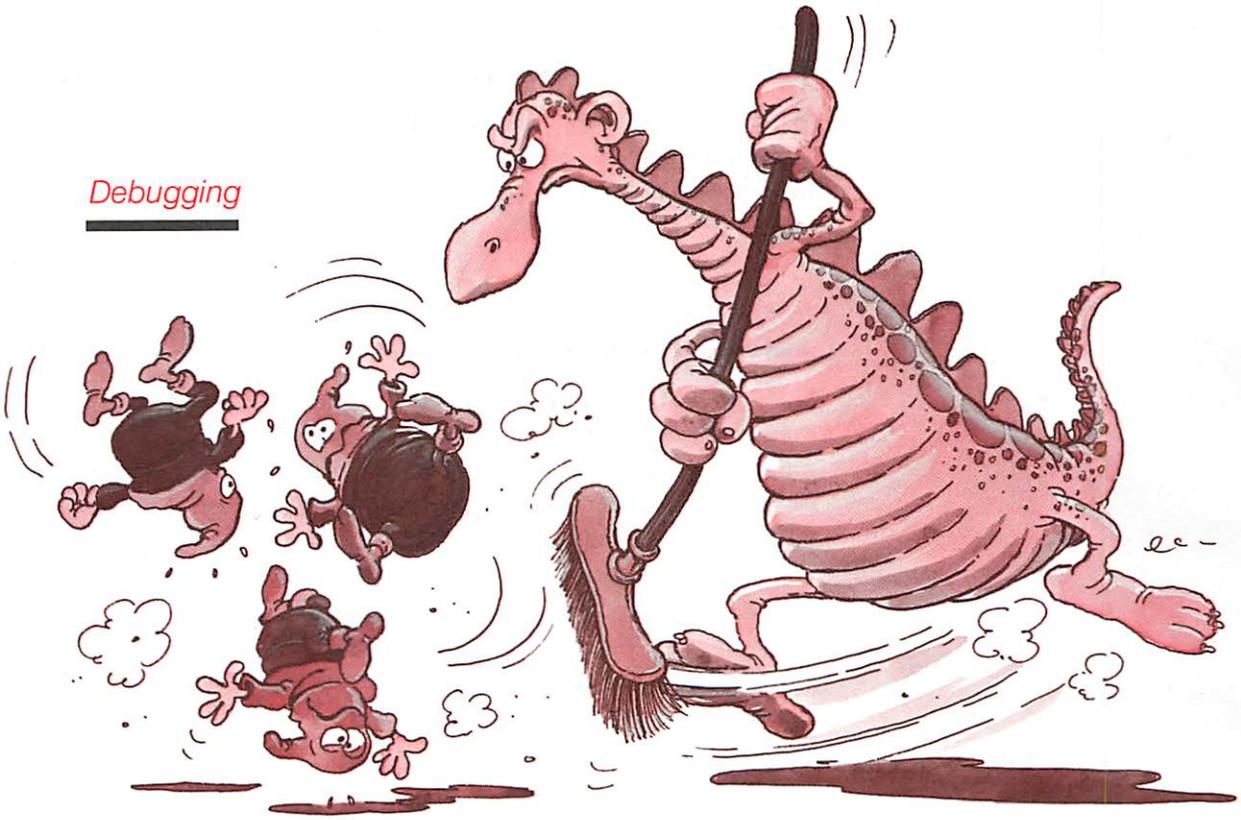
Debugging

You have coded your flowchart into a BASIC program. Your program is still on paper. You should now type it into your computer's memory, type RUN, and make sure that it works. This is called *testing* and *debugging*. Errors in a program are called *bugs*. Removing the bugs in a program is called *debugging*. Every time you find an error, you must correct it, then run the program again. Even if you have been careful and thorough in writing your program, a long program will seldom run correctly the first time. This is because it is so easy to misplace a character or even an entire instruction along the way. Even the best programmers must spend a considerable amount of time debugging their programs. So do not be surprised if you must correct your program several times before it finally runs correctly.

Fortunately, your BASIC interpreter will help you diagnose some problems. If your program contains a type of error that can be detected by the interpreter, program execution will stop after you type RUN, and the interpreter will give you the diagnostic "CAN'T DO THAT IN 84." The interpreter will mostly help you detect *syntax errors* (the use of illegal symbols or operations). Unfortunately, it will not help you detect the most dangerous errors, the *logical* or *design errors*. That is your responsibility. This is why you should invest the time to carefully design your flowcharts. Also, this is why every time a number is supplied to a program or

generated by it, you should validate that number by checking its range. In the event that your program contains a logical flaw, this technique will help you isolate the program section that contains the error.

Usually, in the case of a simple program, a few typographical errors will be detected by the BASIC interpreter. You will then correct them and your program will work. You should still make sure that it works correctly by testing it for various cases or values; your program might contain logical flaws. In most cases, however, you will determine that your program works correctly.

Practical Hints

Here is a practical hint: you should insert additional PRINT statements throughout your program to verify key values throughout. This will help you detect strange values and isolate the instructions that caused them. Here is a sample PRINT you might insert:

```
1235  PRINT "TEST FOR AVERAGE VALUE IS   ";
1240  PRINT AVERAGE
```

Then, once the program works, you can remove these extra PRINT statements. This technique is called *tracing* a variable.

As another practical hint, any time that your program stops, either on its own or because the interpreter stopped it, you should use the *immediate execution mode* to verify the value of various variables in your program. For example, you might type:

```
>PRINT AVERAGE
```

then:

```
>PRINT SUM
```

to check the current values of these two variables.

The key to successful debugging is experience and a lot of prevention. Next time, spend more time on the program design and the flowchart, and you will spend less time debugging.

So your program now works correctly. You think it is correct; and you do not want to touch it any more. However, an error might be found later, or you might use the program again or share it with someone else. In order to make a program reuseable, one more step is required: you should document the program while you remember what it does.

Documentation

You have just finished designing and coding a program. You are thoroughly familiar with its operation and with what each instruction does. You will be surprised to discover how quickly you will forget what the program does and how difficult it may be to read or understand your own program later on. If you intend to reuse your program or to correct errors found at a future date, it is vital that you clarify the program promptly and completely. This means clarifying the program itself, as well as documenting everything that might require an explanation, on paper or as REMarks within the program.

Here is a summary of the techniques we have described for clarifying the program:

Use a clear layout: Separate sections with blank lines or empty statements. Use alignments or indentations for clarity. You may want to use line numbers that all have the same length. This way all program statements will be aligned vertically. In addition, every time you use a FOR . . . NEXT statement, it is a good idea to indent the block of instructions that are enclosed between the FOR and the NEXT.

Also, use blanks liberally to clarify complex instructions, in particular those containing mathematical expressions. Use parentheses to clarify the results of a computation.

Explain what you do: Use REM statements to explain formulas, tests, names, or conventions. It is also a good idea to provide a short written explanation for any methods or techniques you are using which are not obvious or are not described by PRINT statements within the program.

Clean up flowcharts: Produce one clean flowchart or set of flowcharts that correspond exactly to your program. Often, during the debugging process, last minute changes are made directly to the program. Make sure they are reflected on the original flowchart or else you may find it very difficult to change or correct your program later on.

Renumber your lines: Often, in the process of correcting the program, i.e., in the debugging phase, you will need to insert

Document your program
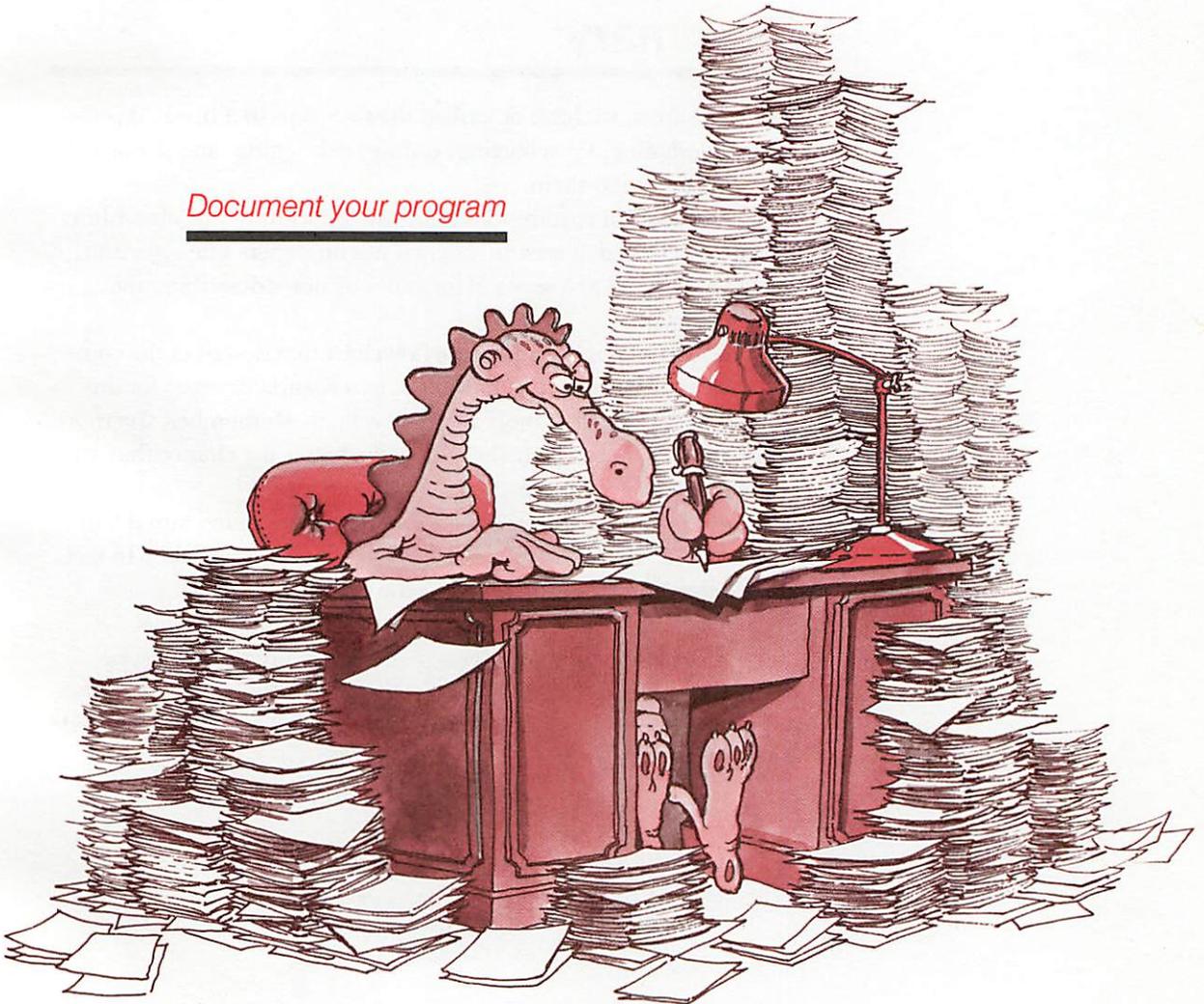
additional statements. Once you think your program is correct, it is a good idea to renumber the lines so that all line numbers are spaced regularly. This will facilitate later changes to the program. You can use the TI BASIC command RESEQUENCE to do this. This is a convenience, not a requirement.

Summary

In this chapter, we have described the five steps to a finished program: designing, flowcharting, coding, debugging, and documenting. Let us review them.

Each program requires designing an algorithm. The algorithm must be designed at least mentally if not on paper. The algorithm may be sketched as a series of formulas or notes describing the essential steps.

The next step is designing the flowchart that describes the complete sequence of events. Consider it as a mandatory step for any program that involves more than a few lines. Remember, the more carefully you design your flowchart, the better the chance that your program will be correct.

The next step is coding. The flowchart is translated into BASIC instructions. Practice will speed-up this phase considerably. In fact, the coding phase quickly becomes the shortest phase.

Then comes testing and debugging. This phase is always required and is often the longest phase. Each program must be carefully checked out.

Finally, the quality of the documentation will facilitate or impede the later use of, and changes to, the program.

Exercises

8-1: Describe the five phases of program development.

8-2: What is the difference between coding and programming?

8-3: What is the purpose of debugging?

8-4: How do you trace a variable?

8-5: Why renumber a program after making many changes?

8-6: What is a flowchart?

8-7: Write a flowchart to start your car or operate an appliance.

8-8: What are the advantages of a clearly-written program?

8-9: Describe the techniques that can be used to clarify a program.
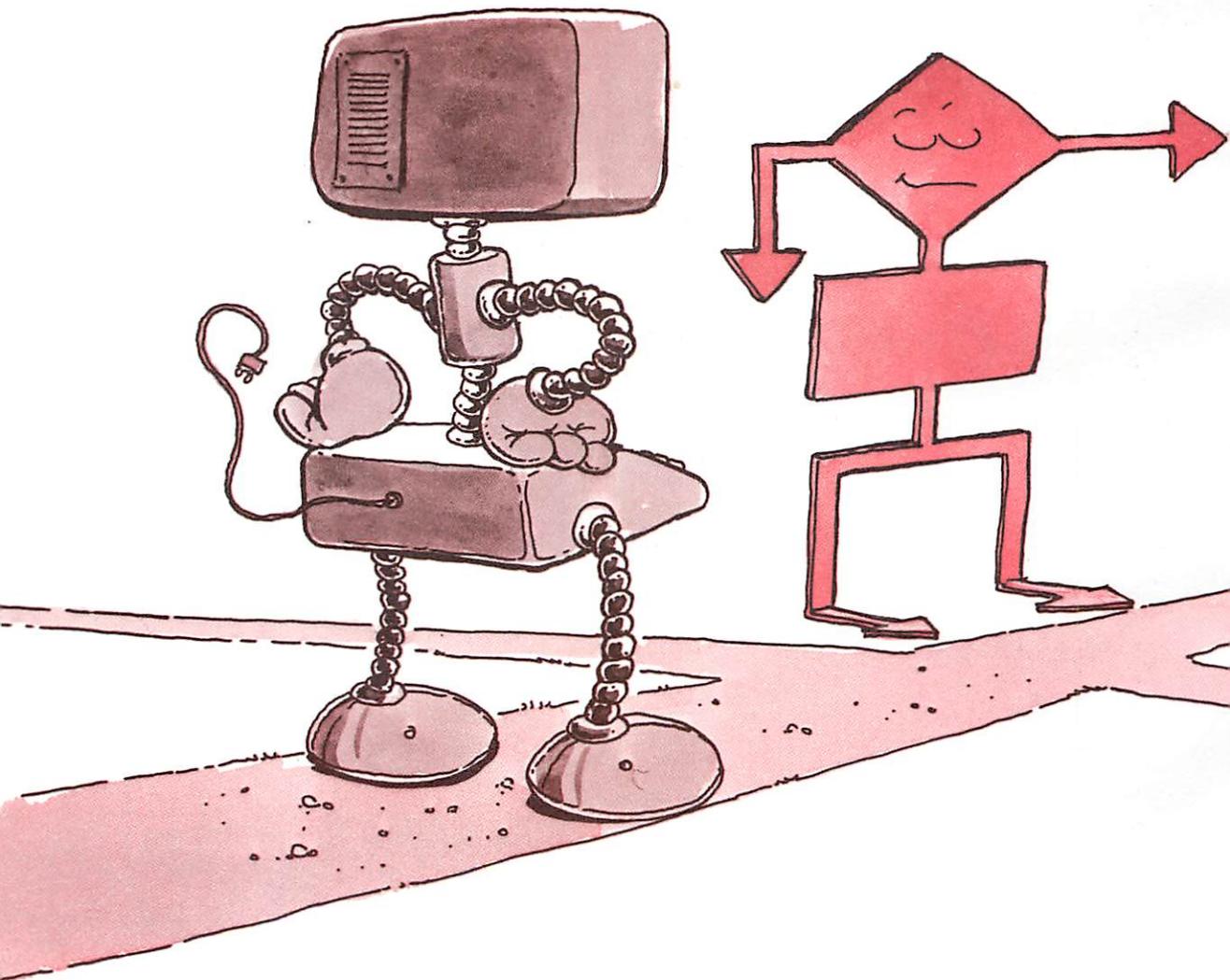
9

We will now develop a complete program and describe each step in turn. Here is the problem to be solved:

We need to write a program that will automatically convert a weight expressed in ounces into its equivalent value in grams. This program should either convert a number typed at the keyboard, or print a weight conversion table for those numbers between two specified values.

Designing the Algorithm

The rough sequence of steps that we will follow to solve this problem is quite straightforward: We will ask the user what he or she wants (a single conversion or a table of values) and then perform the action requested. This is our rough algorithm. Let us refine it.

One ounce equals 28.35 grams. The conversion from ounces to grams is therefore accomplished by the following formula:

$$W_{grams} = W_{ounces} \times 28.35$$

or, in short:

$$W_g = W_{oz} \times 28.35$$

Here is the basic algorithm:

▶ Specify either single conversion or table
▶ If conversion, request weight in ounces
▶ Convert to grams (using the formula above) and display result
▶ END
▶ If table, request maximum weight in ounces
▶ Convert to grams and display results up to the limit
▶ END

In practice, there is no need to write out the algorithm, as long as you prepare a flowchart.

Flowcharting

In preparing the flowchart, we must first know whether the user wants the program to perform a single conversion or display a table of values. Here is the corresponding flowchart element:
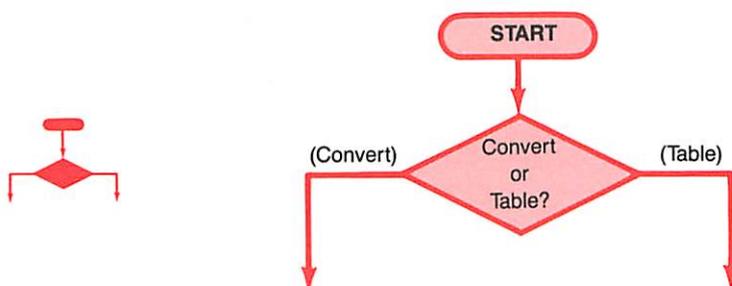
This is a decision box, with two possible outcomes (i.e., branches): CONVERT and TABLE.

Let's first examine CONVERT: The user wants to convert a single weight from ounces to grams. We must request the value of the weight. Here is the corresponding flowchart entry:

(Convert)

```
Request weight
(in ounces)
```
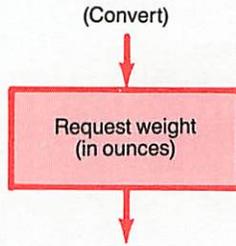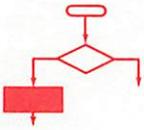
We could now convert this value into grams. However, let's refine the flowchart immediately. As a precaution, we will validate the value supplied by the user, by checking whether it is reasonable or not. Here is the way our flowchart looks with this validation added:

START

Convert or Table?

(Convert)

```
Request weight
(in ounces)
```

Reasonable?

No → Diagnostic

Yes
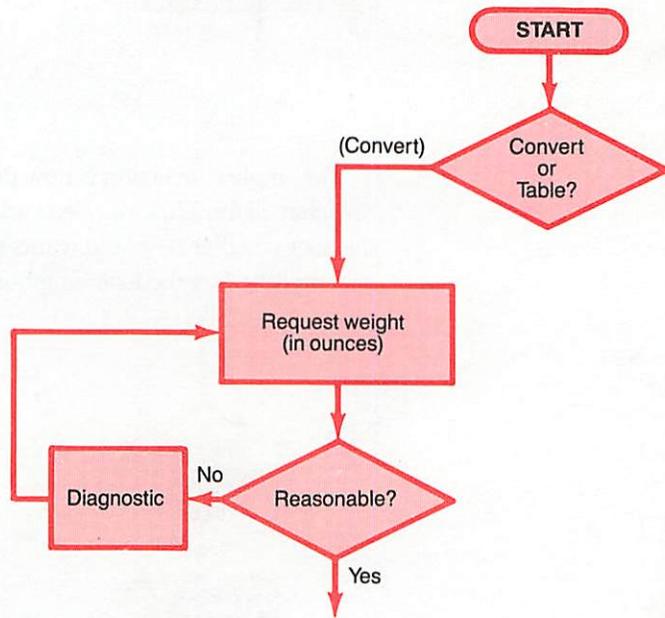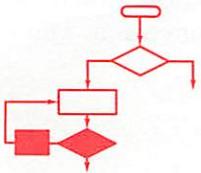
Note that we have added a box to check whether the input is reasonable. If the input is reasonable, we proceed. If not, a diagnostic, such as "UNREASONABLE INPUT, TRY AGAIN" is issued, and the program requests another value for the weight.

We now have a validated value for the weight. Let's convert it into grams. This is accomplished by the following:

$$W_g = W_{oz} \times 28.35$$
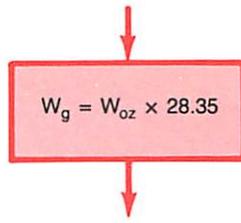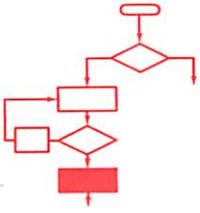
We can now display the results. This is accomplished by the following box:

Print W_g
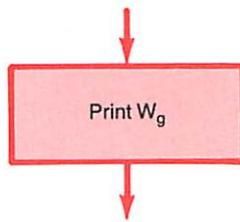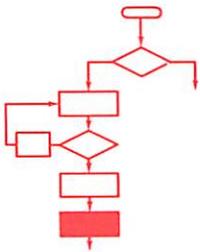
The single conversion is now done. We could end this part of the flowchart here. However, let's add a convenience feature and ask the user whether he or she wants to do another conversion. This is accomplished by the following box:

START

Yes

One more conversion?

No

END
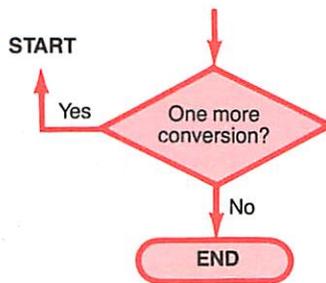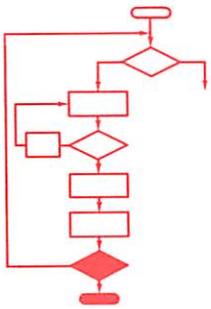
The START symbol on the left arrow indicates that this arrow will be connected back to the beginning of the flowchart. At this point, our flowchart looks like this:
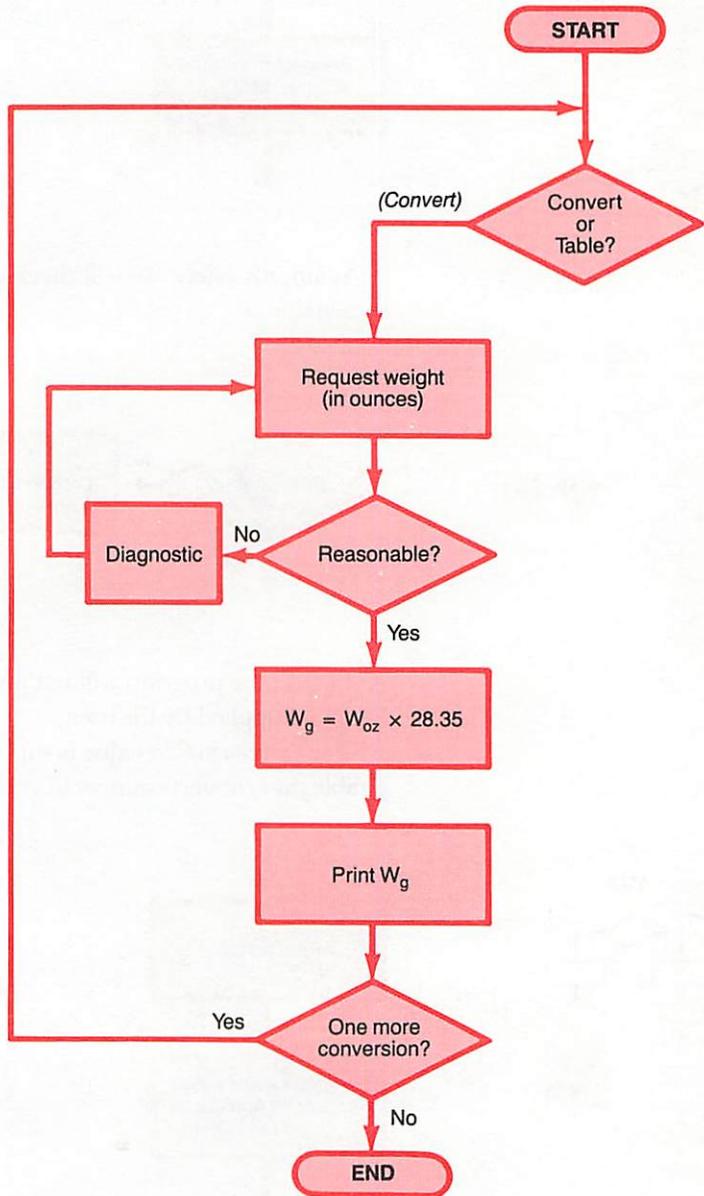
Let us now go back to our first decision box and examine what happens when the user wants to display a table of values. This is the TABLE option at the top of the flowchart.

We must know the maximum value to be converted. This is accomplished by the following box:

(Table)

Request maximum number of ounces (MAX)
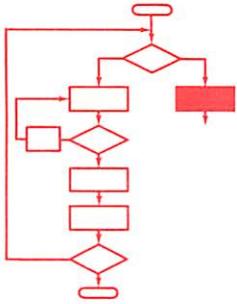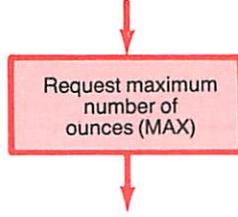
Again, for safety, we will check whether this number is reasonable:

Reasonable? — No → Diagnostic

Yes
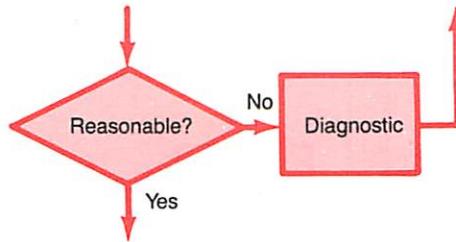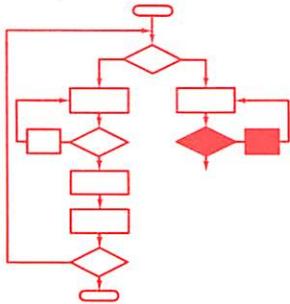
As before, the program will not proceed until a reasonable value of MAX is supplied by the user.

Once a reasonable value is supplied, we can proceed and display a table that converts ounces to grams, up to the desired limit:

Print header

Print values of weight in ounces and grams up to MAX
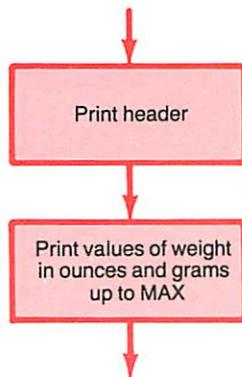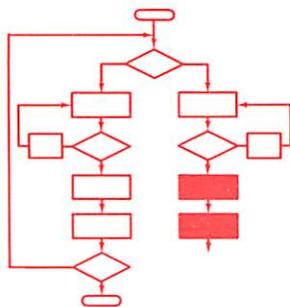
Finally, let's add the same convenience feature that we used in the single conversion case and ask the user whether he or she would like to perform one more conversion:

One more conversion? — Yes

No

END

148
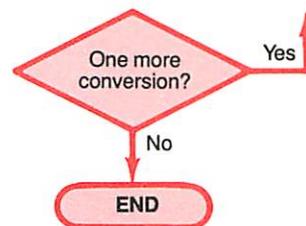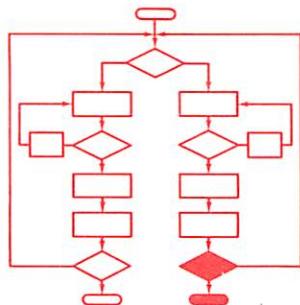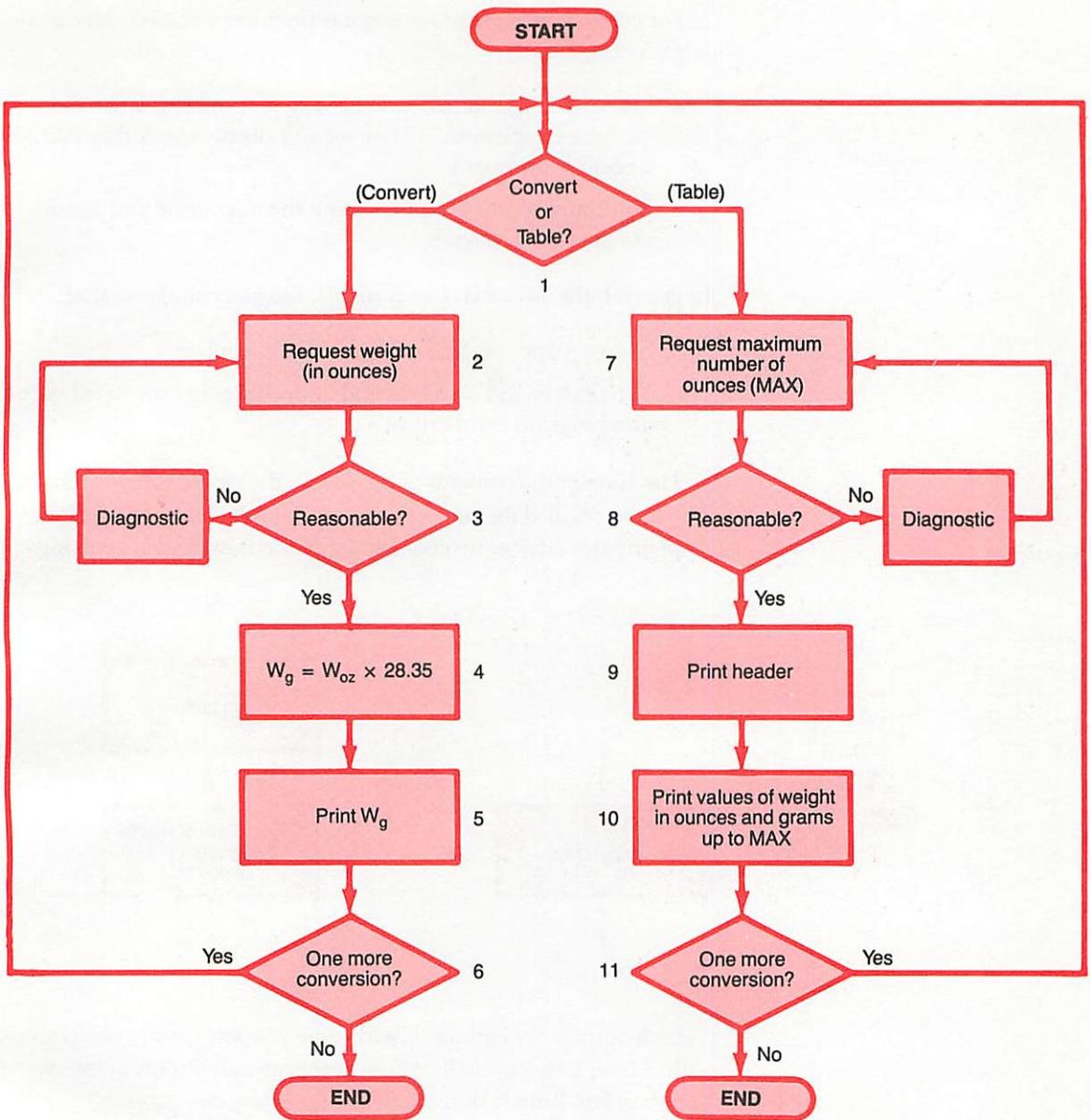
Figure 9.1
Weight Conversion flowchart

Figure 9.1 shows the complete flowchart. This flowchart is typical. The contents of the boxes are somewhat "loosely" written. Some boxes in the flowchart will be coded into just one or two BASIC instructions, while others will require many more. However, it is the sequence that counts. The fact that some boxes may be more detailed than others does not matter. Remember that the flowchart sequence must be exact, but the details may be written in any manner that is convenient for you. There is no need to spend a lot of time optimizing the contents of the boxes, as long as you feel you can code from it in a straightforward manner.

The flowchart must simply be clear and easy to read. A clear, well-organized flowchart improves your chances of writing a correct program.

For completeness, here are some refinements or alternatives you might consider:

- ► You could explain in detail the way you will check the weight for "reasonableness." (Here we will simply check that WOZ is a positive number.)
- ► You could be more explicit about the diagnostic and about much of the dialogue.

In general, the advice is: *keep it simple.* Do just enough so that:

1. The sequence of steps is correct and complete.

2. You understand each box and know roughly how to convert it into program instructions.

The simpler the contents of the boxes, the clearer the flowchart. The more detailed the contents of the boxes, the easier the coding. Applying this advice, we could simplify the flowchart by writing:
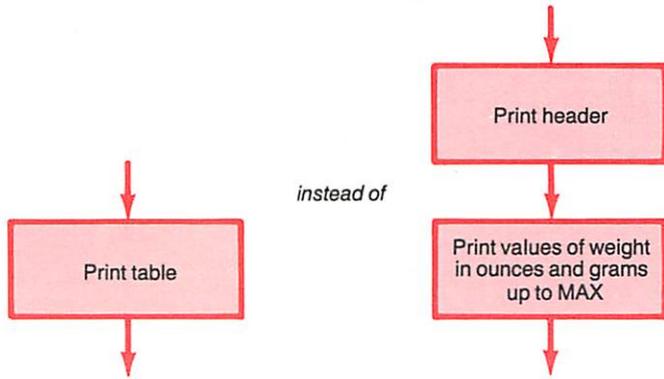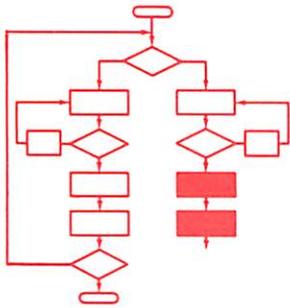
Both options are correct. Use the one you feel most comfortable with. Here, I decided to hint at the programming steps involved and therefore I made the contents of the box more explicit.

You can always rewrite the contents of a box, or for that matter any part of your flowchart, on a separate piece of paper to facilitate the coding, or to try out an alternative.

Now that we have a flowchart, let's try it out by hand with actual numbers, to make sure it works. This hand-checking process is obvious, so let's proceed.

Coding

We will now write a program that corresponds to our flowchart. Let's code each box of the flowchart into the corresponding BASIC instructions.

Here is box 1 of the flowchart:

(Convert)   Convert or Table?   (Table)

Here are the corresponding program instructions:

```
100   REM * OUNCES TO GRAMS *
110   REM THIS PROGRAM PERFORMS A DIRECT CONVERSION
120   REM OR PRINTS A TABLE OF VALUES
130   REM 1ST, SPECIFY MODE: DIRECT OR TABLE
140   PRINT "I WILL CONVERT"
145   PRINT "OUNCES TO GRAMS"
150   PRINT "IF YOU WANT TO CONVERT";
155   PRINT "VALUES DIRECTLY, TYPE V";
160   PRINT "IF YOU WANT A TABLE"
165   PRINT "OF VALUES, TYPE T"
170   PRINT "YOUR CHOICE   (V OR T)"
180   INPUT CHOICE$
190   IF CHOICE$ = "V" THEN 300
200   REM LINE 300 IS VALUE CONVERSION
210   IF CHOICE$ = "T" THEN 500
220   REM LINE 500 IS TABLE CONVERSION
230   REM INPUT MUST BE V OR T
240   PRINT "V OR T PLEASE:"
250   GOTO 170
```

As you become more experienced, you may be able to go directly from box 1 of the flowchart to the corresponding program instructions. However, at the beginning, you will need to write down the detailed version of the flowchart first.

Here is the detailed version of box 1:
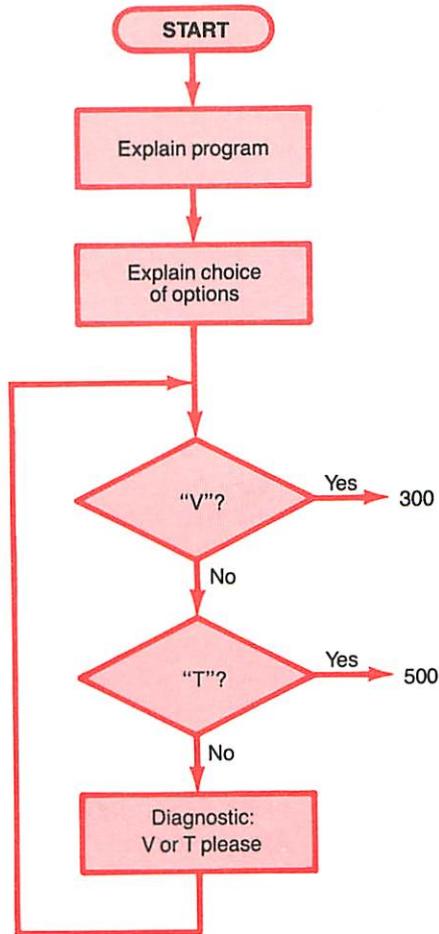
Looking at this detailed version, note how closely the flowchart corresponds with the BASIC instructions. In addition, note that we have introduced a *validity test* for CHOICE$. We aren't going to simply assume that the user will cooperate and type "V" or "T". Check it. **Remember:** every time you request an input, you should validate it.
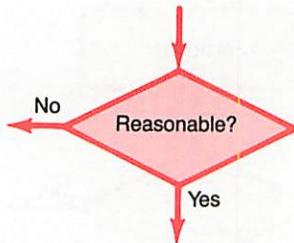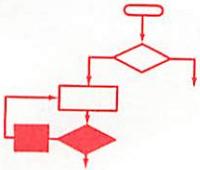
The rest is simpler. Let's convert box 2:
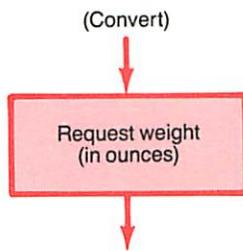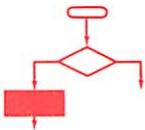
The corresponding instructions are:

```
300   REM * VALUE CONVERSION *
310   PRINT "TYPE THE WEIGHT"
315   PRINT "IN OUNCES..."
320   INPUT WOZ
```

Here is box 3:

Here is its program equivalent:

```
330   IF WOZ < 0 THEN 310
340   REM WEIGHT MUST BE POSITIVE
350   REM ERROR MESSAGE COULD BE PUT HERE
```

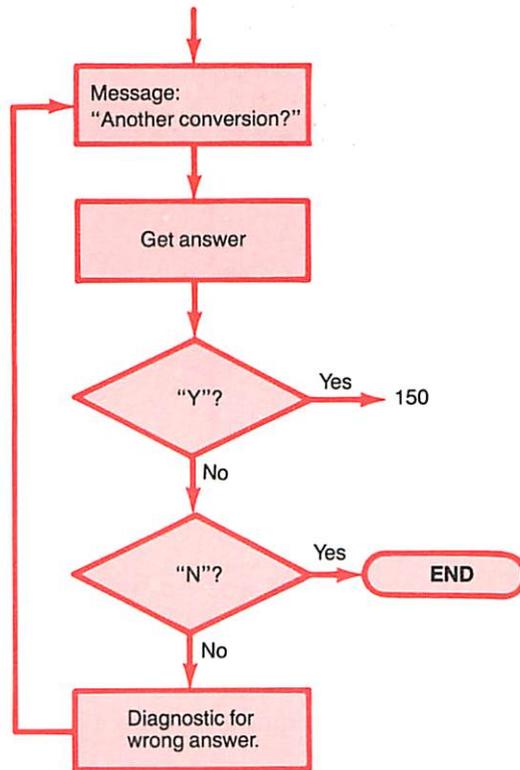The equivalent of box 4 is:

```
360   WG = WOZ * 28.35
```

And for box 5:

```
370   PRINT WOZ; "OUNCES ARE EQUAL TO"
375   PRINT WG; "GRAMS"
```

And for box 6:

```
410   PRINT "ANOTHER CONVERSION?"
415   PRINT "Y FOR YES, N FOR NO:"
420   INPUT AGAIN$
430   IF AGAIN$ = "Y" THEN 150
440   IF AGAIN$ = "N" THEN 660
450   REM INPUT WAS NOT Y OR N. TELL USER
460   PRINT "Y OR N PLEASE"
470   GOTO 380
```

If the above is not clear to you, here is the equivalent detailed flowchart:

Let's now look at the right part of the flowchart in Figure 9.1. Here is the equivalent of box 7:

```
520  PRINT "I WILL DISPLAY A"
525  PRINT "CONVERSION TABLE"
530  PRINT "OF OUNCES TO GRAMS"
540  PRINT "NUMBER OF OUNCES:"
550  INPUT MAX
```

And for box 8:

```
560  REM CHECK FOR MAX 1 OR MORE
570  IF MAX < 1 THEN 610
```

For clarity, let's skip a line on the display, before we print the table:

```
580  PRINT
```

Remember: that's an empty PRINT. It displays a blank line. Now here is the equivalent of box 9:

```
590  PRINT "OUNCES",  "GRAMS"
```

Note that we use a comma rather than a semicolon for a pleasant spacing of the columns.
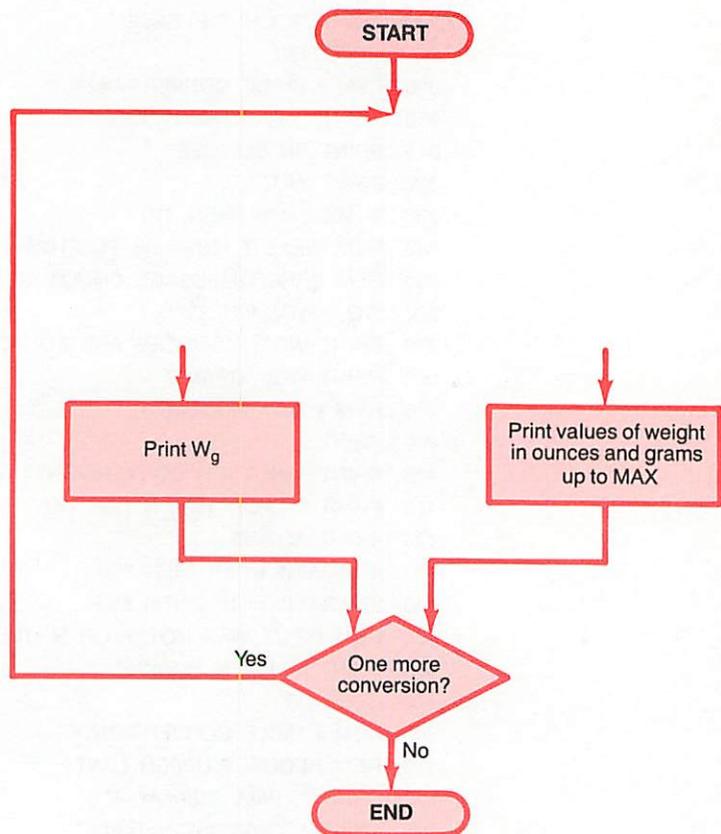
And here is box 10:

```
600   I = 1
610   PRINT I,   I * 28.35
620   I = I + 1
630   IF I < = MAX  THEN  610
```

Finally, here is box 11:

```
650   GOTO  380
```

Box 11 is the same as box 6, so we can simplify our program by jumping (GOTO) to the instructions for box 6.

Here is the corresponding (corrected) flowchart:

The complete program is shown on the following page.

```
100  REM *OUNCES TO GRAMS *
110  REM THIS PROGRAM PERFORMS DIRECT CONVERSION
120  REM OR PRINTS A TABLE OF VALUES
130  REM 1ST, SPECIFY MODE: DIRECT OR TABLE
140  PRINT "I WILL CONVERT"
145  PRINT "OUNCES TO GRAMS"
150  PRINT "IF YOU WANT TO CONVERT";
155  PRINT "VALUES DIRECTLY, TYPE V";
160  PRINT "IF YOU WANT A TABLE"
165  PRINT "OF VALUES, TYPE T"
170  PRINT "YOUR CHOICE (V OR T)"
180  INPUT CHOICE$
190  IF CHOICE$ = "V" THEN 300
200  REM LINE 300 IS VALUE CONVERSION
210  IF CHOICE$ = "T" THEN 500
220  REM LINE 500 IS TABLE CONVERSION
230  REM INPUT MUST BE V OR T
240  PRINT "V OR T PLEASE: "
250  GOTO 170
300  REM * VALUE CONVERSION *
310  PRINT "TYPE THE WEIGHT"
315  PRINT "IN OUNCES..."
320  INPUT WOZ
330  IF WOZ < 0 THEN 310
340  REM WEIGHT MUST BE POSITIVE
350  REM ERROR MESSAGE COULD BE PUT HERE
360  WG = WOZ * 28.35
370  PRINT WOZ; "OUNCES ARE EQUAL TO"
380  PRINT WG; "GRAMS"
390  REM * EXIT MODULE *
400  PRINT
410  PRINT "ANOTHER CONVERSION?"
415  PRINT "Y FOR YES, N FOR NO:"
420  INPUT AGAIN$
430  IF AGAIN$ = "Y" THEN 150
440  IF AGAIN$ = "N" THEN 660
450  REM INPUT WAS NOT Y OR N. TELL USER
460  PRINT "Y OR N PLEASE"
470  GOTO 390
500  REM * TABLE CONVERSION *
510  REM REQUEST UPPER LIMIT
520  PRINT "I WILL DISPLAY A"
525  PRINT "CONVERSION TABLE"
530  PRINT "OF OUNCES TO GRAMS"
540  PRINT "NUMBER OF OUNCES:"
550  INPUT MAX
560  REM CHECK FOR MAX 1 OR MORE
570  IF MAX < 1 THEN 610
580  PRINT
590  PRINT "OUNCES",  "GRAMS"
600  I = 1
610  PRINT I,  I * 28.35
620  I = I + 1
```

```
630   IF I <= MAX THEN 610
640   REM I IS NOW > MAX, END OF TABLE
650   GOTO 390
660   END
```

There are improvements that could be made to this program. For example, more REMs could be added before instructions 300, 390, and 500 to clarify the program visually. You could also replace instructions 600 to 630 with a FOR . . . NEXT statement. This might improve readability, but it is hardly worth the trouble.

Remember: any change you make to a working program may introduce new bugs—change your program only if there is a clear benefit.

We now have a complete program. Let's try it out.

Remember: any change you make may introduce new bugs!
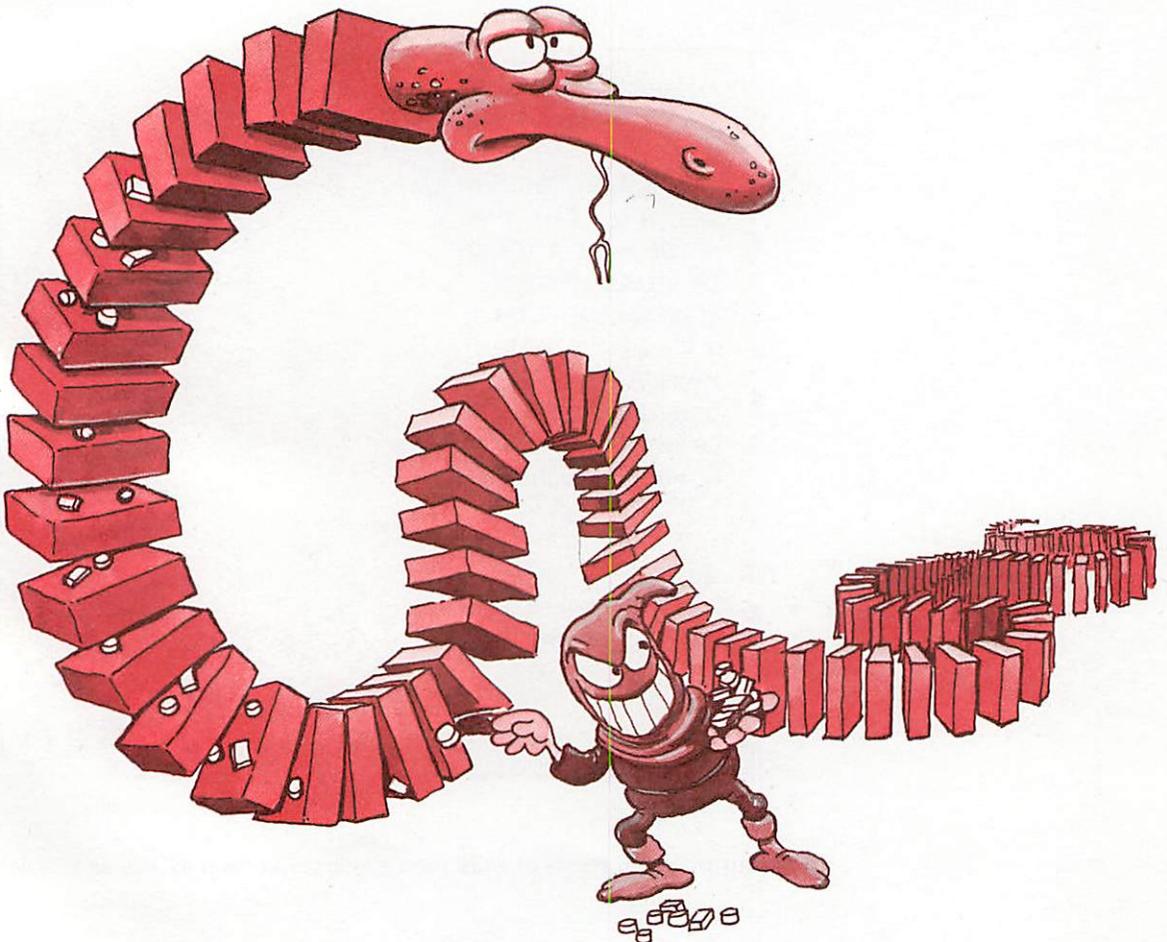
Testing

Let's run the program. Here is a sample run:

```
I WILL CONVERT
OUNCES TO GRAMS
IF YOU WANT TO CONVERT
VALUES DIRECTLY, TYPE V
IF YOU WANT A TABLE
OF VALUES, TYPE T
YOUR CHOICE (V OR T)
? V
TYPE THE WEIGHT
IN OUNCES. . .
? 3
  3 OUNCES ARE EQUAL TO
  85.05 GRAMS
```

Here is another one:

```
ANOTHER CONVERSION?
Y FOR YES, N FOR NO:
? Y
IF YOU WANT TO CONVERT
VALUES DIRECTLY, TYPE V
IF YOU WANT A TABLE
OF VALUES, TYPE T
YOUR CHOICE (V OR T)
? T
I WILL DISPLAY A
CONVERSION TABLE
OF OUNCES TO GRAMS
NUMBER OF OUNCES:
? 4

OUNCES       GRAMS
   1         28.35
   2         56.7
   3         85.05
   4         113.4
```

Our program seems to work for a single conversion as well as a table.

Let's try to fool it:

```
ANOTHER CONVERSION?
Y FOR YES, N FOR NO:
? Y
IF YOU WANT TO CONVERT
VALUES DIRECTLY, TYPE V
IF YOU WANT A TABLE
OF VALUES, TYPE T
YOUR CHOICE (V OR T)
? D
V OR T PLEASE
YOUR CHOICE (V OR T)
? V
TYPE THE WEIGHT
IN OUNCES...
? 7
 7 OUNCES ARE EQUAL TO
 198.45 GRAMS
```

Let's try the repeat option:

```
ANOTHER CONVERSION?
Y FOR YES, N FOR NO:
? Y
IF YOU WANT TO CONVERT
VALUES DIRECTLY, TYPE V
IF YOU WANT A TABLE
OF VALUES, TYPE T
YOUR CHOICE (V OR T)
? V
TYPE THE WEIGHT
IN OUNCES...
? 85
 85 OUNCES ARE EQUAL TO
 2409.75 GRAMS

ANOTHER CONVERSION?
Y FOR YES, N FOR NO:
? Y
IF YOU WANT TO CONVERT
VALUES DIRECTLY, TYPE V
IF YOU WANT A TABLE
OF VALUES, TYPE T
YOUR CHOICE (V OR T)
? V
TYPE THE WEIGHT
IN OUNCES...
? 2.5
 2.5 OUNCES ARE EQUAL TO
 70.875 GRAMS
```

Let's try and fool it again:

```
ANOTHER CONVERSION?
Y FOR YES, N FOR NO:
? Y
IF YOU WANT TO CONVERT
VALUES DIRECTLY, TYPE V
IF YOU WANT A TABLE
OF VALUES, TYPE T
YOUR CHOICE (V OR T)
? V
TYPE THE WEIGHT
IN OUNCES...
? -5
TYPE THE WEIGHT
IN OUNCES...
? ■
```

Well, it seems to work. But you should really try it several more times before you are completely satisfied with it.

In this case, we have been very careful—and very lucky. Our program worked right the first time.

Summary

In this chapter we have illustrated the complete sequence involved in writing a program that solves a given problem. You should now close this book, write your own flowchart, and convert it into a working program.

The key to successful programming is practice.

Exercises

9-1: Add to this program the option of converting grams to ounces.

9-2: Expand the program to include distance conversion.

        1 meter = 39.37079 inches.

        1 km = 0.62138 mile.

        1 inch = 25.3995 mm

        1 foot = 30.479 cm
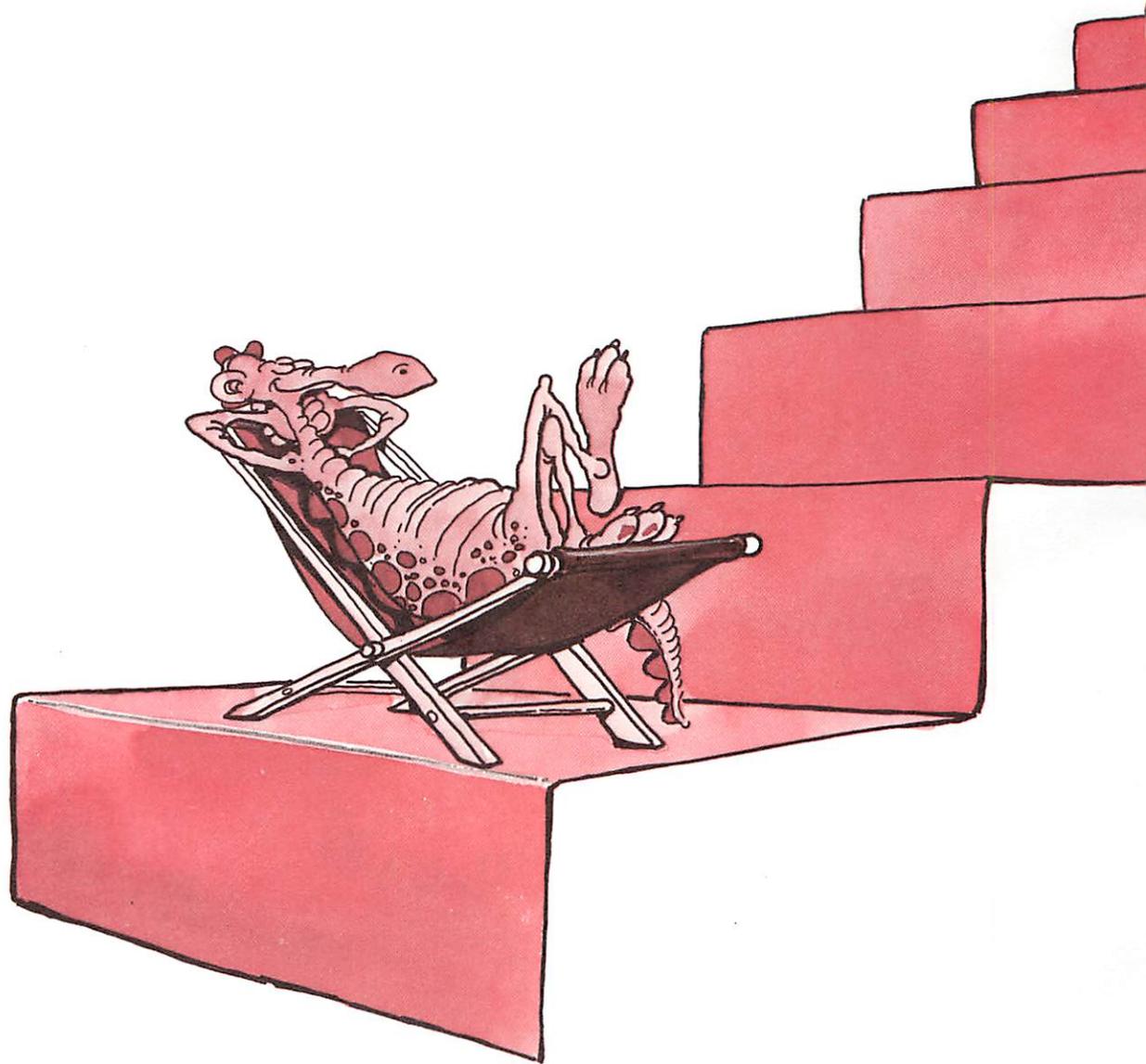
        1 yard = 0.91438 m

        1 mile = 1609.3149 m

9-3: Expand the program to include temperature conversion.
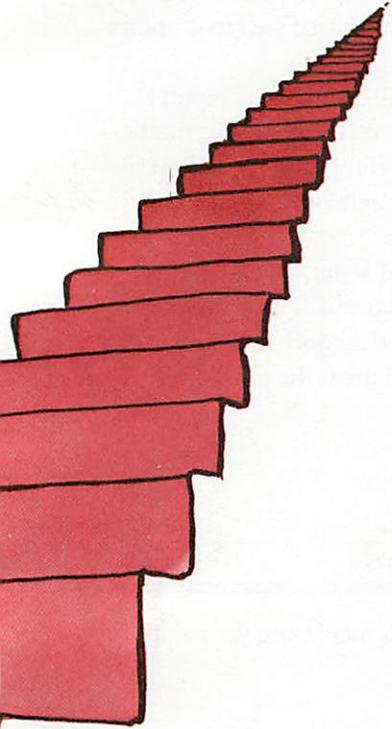
$$C = (F - 32) \times 5/9$$

$$F = (9/5) \times C - 32$$

9-4: Suggest additional ways to improve or clarify our final program.

xt Step

10

You have now learned how to write your own BASIC programs. In this chapter, we will examine the next step you can take towards improving your programming skills. We will review what you can do with BASIC, and then describe the additional skills and techniques that can help you more easily write complex programs.

What You Can Do with BASIC

You can write a BASIC program to automate most tasks, unless they require very precise mathematical computations, complex decision-making, or a very fast response (such as real-time process control). You will find that BASIC is well suited to simple business applications, such as data processing, mailing lists, and common financial computations. TI BASIC also lends itself well to graphics and games.

Other typical application areas for BASIC include computer-assisted education, personal and business record-keeping, mathematical and technical computations with a limited degree of precision, and many more. Applications are generally limited mostly by one's programming skills.

With the knowledge you have acquired so far, you should be able to write a wide variety of BASIC programs. However, as you progress, you will want to improve your skills and use more powerful and convenient programming tools. This is the topic of the next sections.
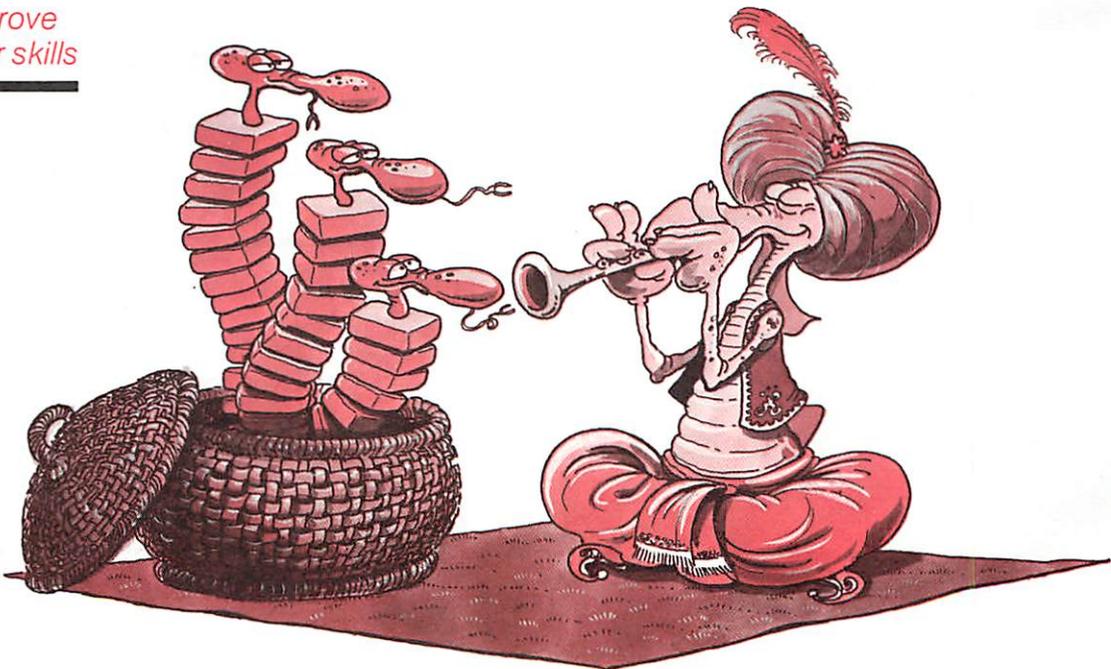
Improving Your Skills

You can take three essential steps towards increasing your skills in BASIC:

1. Gain more practice
2. Obtain a better knowledge of the complete resources of TI BASIC
3. Learn additional programming techniques.

Let us review each step in turn.

*Improve
your skills*

More Practice

The key to programming effectiveness is practice: write as many programs as possible, and get them to work. Develop good programming habits by following all the recommendations presented in this book. If your programs work consistently after just a few tries, you may be well on your way to becoming a disciplined and effective programmer. If they do not, watch your habits, or perhaps read parts of this book again, and then practice some more. **Remember:** there is no way you can become a good programmer unless you write many programs. This book will get you started, but it can never be a substitute for actual experience.

Specific BASIC Features

Your TI BASIC interpreter provides specific capabilities, including statements, commands, shorthand facilities, extensions to "standard BASIC" (such as graphics and sound), and an operating environment (including disk or cassette storage commands, file facilities, an editor program, and more). You can enhance your programming ability by learning these additional features and facilities. In the next section we will describe the additional BASIC statements found in TI BASIC. Facilities such as graphics, sound, and files are specific to your computer and your interpreter. You will gain by learning about them.

Additional Techniques

Once you develop longer programs (say, longer than one page), you will want to learn the usual techniques for solving common problems, such as ordering items, sorting them, formatting data, filing, and creating data structures. These topics are covered in programming books.

More BASIC

Your TI BASIC interpreter offers a fairly "standardized" set of facilities, plus many extensions. The facilities offered by TI BASIC include everything we have studied so far, plus six types of statements. We will present a brief overview of each of these additional

types. You will want to study them on your own or with a more advanced book. They are:

1. **Functions:** Functions are either *built-in* or *user-defined* expressions that operate on a given variable and perform a specific computation or action. TI BASIC provides some built-in functions (such as ABS, COS, EXP, RND, SGN, SIN, SQR, INT, and TAN). These functions will automatically perform common tasks.

Study more

(Additional functions can be defined by the user. Let's examine a few of the typical built-in functions:)

► The INT function computes the integer part of a decimal number by dropping the fractional part of the number. For example, INT(1.234) yields the value 1.

► Similarly, ABS computes the absolute value. For example, ABS (−5.2) is 5.2.

► The SQR function computes the square root of a number. For example, SQR(4) yields the value 2.

Functions may also be defined by the user. A user-defined function is essentially a formula written by the user that has a name, operates on a variable, and can be used in the program many times. Then every time the name of the function is used, the formula is computed with the current value of the variable. This is very convenient shorthand notation.

Here is an example of a user-defined function that computes 2% of X:

```
10   DEF FNA(X) = X * 2 / 100
```

And here is one way of using this function:

```
20   PRINT FNA(50)
```

This will print the value 1.

Let's look at these statements more closely. FN means function. FNA is function A, i.e., the name of the function. X is the "dummy" variable. X does not have a value when the DEFinition is written. The actual value or variable is substituted for X at the time the function is used; for example, it could appear as FNA(50).

2. **Subroutines:** A subroutine is a group of instructions within a BASIC program that has its own name and can be used repeatedly by simply writing that name. Then every time the name of the subroutine is used in the body of the program, all the instructions within the subroutine are executed. Subroutines are convenient for executing a program segment repeatedly, without having to repeat the instructions in the program every time they are required.

Here is an example of a subroutine:

```
500   REM THIS IS SUBROUTINE AVERAGE
510   PRINT "I WILL COMPUTE THE AVERAGE OF A AND B"
520   PRINT "A = "; A; "B = ";   B
530   AVERAGE = (A + B) / 2
540   PRINT "THE AVERAGE IS  ";
550   PRINT AVERAGE
560   RETURN
```

Provided A and B have been assigned a value, this subroutine can be called by an instruction like:

```
50  GOSUB 500
```

It can then be used again later in the program with an instruction such as:

```
170  GOSUB 500
```

and it will yield a different value, if A and B are different. Using subroutines will clarify your program, shorten it, and save you time. You can also build a library of common subroutines and use them in various programs. However, be careful with variable names and statement numbers!

3. **String Operators:** String operators allow you to manipulate text conveniently by operating on strings of characters. Operations on strings include modifying them, measuring them, connecting them together, cutting them, inserting text to the left, the right, or at any given position, substituting characters, and comparing strings of characters. These operators are useful for word and text processing applications.

4. **Data Structures:** BASIC allows subscripted variables with either one or two subscripts. These variables correspond to mathematical vectors and matrices, or arrays. The use of subscripted variables allows you to set up structures like lists, and then conveniently refer to any element within the list. For example, the elements of a list named CLIENT can be referred to as: CLIENT[1], CLIENT[2], etc.; and you can print all ten values by writing:

```
50  FOR N = 1 TO 10
60  PRINT CLIENT[N]
70  NEXT N
```

You can compare two consecutive elements by writing:

```
100  IF CLIENT[K] < CLIENT[K + 1] THEN 500
```

This is a great convenience.

5. **Files:** TI BASIC provides facilities for storing and/or retrieving data from disk files. These facilities are described in the manufacturer's documentation.

6. **Additional Resources:** Additional resources that are available with the TI BASIC interpreter include the ON . . . GOTO and READ . . . DATA statements. You should explore these facilities with your TI-99/4A manual, as they will make programming easier.

Also, shorthand facilities are available; for example, you are allowed to type:

?25 * 32

thus providing a convenient feature for using your computer as a pocket calculator.

In addition, a tabulation facility (TAB) is provided for ease in setting up printed tables.

Finally, remember that there are commands to generate graphics, produce sound effects, and facilitate editing—for example, there are commands that allow you to modify your program and the files it creates—as well as aid in the running and debugging of a program. Such facilities include screen control, the ability to set up break points at which the program will stop automatically, tracing the values of selected variables during execution, and slowing or accelerating the speed of your display.

Conclusion

The purpose of this book has been to teach you quickly and effectively how to write your first TI BASIC programs. If you have become truly interested in BASIC, you will now want to learn more. Your next step should be to work through all the exercises and develop some of your own programs.

As you progress, you will want to learn more advanced techniques. A list of programming books is presented at the end of this book.

I hope that you agree that learning BASIC can be easy and enjoyable, and I hope that your desire now is to do and learn more. I would appreciate hearing from you if you have any suggestions for possible improvements to this book.

Appendix A

**Answers
to Selected
Exercises**

2

2-2:

```
10  PRINT "AAAAA"
20  PRINT "BBBB"
30  PRINT "CCC"
40  PRINT "DD"
50  PRINT "E"
```

2-4: **a.** In BASIC, a label is a line number, and it must precede each statement that is part of a program.

b. The deferred execution mode is the normal mode in which a program is entered. BASIC statements are typed with line numbers, and memorized by the computer for later execution.

c. Immediate execution is the mode in which a statement is typed without a line number and executed immediately. This is also called calculator mode.

d. An empty statement is a statement that does nothing. Typically it is a line number or label that appears alone—without anything else on the same line—or with "REM."

e. A cursor is a special visual symbol on the screen (such as a square or underline) that shows your current position. It generally blinks to enhance its visibility.

f. The control or CTRL key, when pressed at the same time as an alphabetic key, will issue a specific command. Control keys make it easier to issue frequently used commands to the computer, since only two keys have to be pressed.

g. A key pad is a keyboard. It is generally a small special-purpose set of keys positioned to the right of the main keyboard, which are used for numeric calculations and cursor positioning.

h. A reserved word is a name that has a specific meaning to BASIC. It may not be used as a variable by the programmer.

h. A prompt is a character or message generated by a program that indicates that the program expects the user to enter information. TI BASIC uses the prompt > to mean "type your next instruction." The prompt "?" means "give me an input."

2-6: Yes, but this seems a cumbersome way to do it, since if you desire to run the program again, you must type in the statements again. Also, conditional branches (to be covered later) will not work properly when typed in this way.

2-8: Yes, BASIC will insert each statement in its proper place within the program so that all the labels are in numeric order.

2-10: No: you must type:

    PRINT "EXAMPLE"

2-12: To erase statement 20 in a program, type an empty statement with the label 20.

3

3-2:

    PRINT 1 + (½) * (1/(1 + (½)))

or

    PRINT 1 + .5 / (1 + .5)

3-4:

    PRINT 100 * 1.6

3-6:

    PRINT 350 / 55

4

4-1:

```
10  INPUT A, B, C, D
20  SUM = A + B + C + D
30  AVG = SUM / 4
40  PROD = A * B * C * D
50  PRINT SUM, AVG, PROD
60  END
```

4-2:

a = no	e = yes	i = yes
b = yes	f = yes	j = no
c = no	g = no	k = yes
d = yes	h = no	l = yes

4-4:

```
10   PRINT "GIVE THE NAME OF AN OBJECT ";
20   INPUT O$
30   PRINT "GIVE ME THE NAME OF A PIECE OF FURNITURE ";
40   INPUT F$
50   PRINT "GIVE ME THE NAME OF A FRIEND ";
60   INPUT P$
70   PRINT
80   PRINT "DOES YOUR FRIEND   "; P$;  " HAVE A  ";  O$;
         " ON A  ";  F$;  "?"
90   END
```

4-6: b, c, f are valid.

5

5-2:

a = yes	d = yes
b = yes	e = no
c = yes	f = no

5-5: A = 3

6

6-1: The IF statement allows the program to make decisions, thus changing its behavior according to variations in input data or computed values.

6-2:

a = yes	e = no
b = yes	f = yes
c = yes	g = yes
d = yes	

6-3: Yes.

6-4: A program loop repeatedly executes a part of a program. In order to prevent an infinite loop (a loop that will not stop repeating) a test should always be made within the loop, which, when successful, allows the program to jump out of the loop.

7

```
10    PRINT "HOURS, MINUTES :";
15    INPUT HOURS, MINUTES
20    REM VALIDATE INPUT
25    IF HOURS <  0 THEN 50
30    IF HOURS >  72 THEN 50
35    IF MINUTES <  0 THEN 50
40    IF MINUTES >  60 THEN 50
45    GOTO 60
50    PRINT "INCORRECT, TRY AGAIN"
55    GOTO 10
60    REM PRINT LINE OF H'S
70    IF HOURS = 0 THEN 110
80    FOR A = 1 TO HOURS
90    PRINT "H";
100   NEXT A
110   PRINT
120   REM PRINT LINE OF M'S
130   IF MINUTES = 0 THEN 170
140   FOR A = 1 TO MINUTES
150   PRINT "M";
160   NEXT A
170   PRINT
180   END
```

7-4: A jump can be made into a loop not run by FOR . . . NEXT statements.

7-6:

```
10    PRINT "PROGRAM TO SUM ODD INTEGERS"
20    PRINT "TO A USER-ENTERED VALUE"
25    INPUT "HIGHEST ODD INTEGER TO SUM ";
30    INPUT VALUE
35    REM TEST FOR VALID INPUT
40    REM
45    IF VALUE >  0 THEN 50
50    IF VALUE <  10000 THEN 55
55    IF INT(VALUE / 2) <  VALUE / 2 THEN 90
60    PRINT "BAD NUMBER . . . TRY AGAIN"
70    GOTO 25
80    REM DO TABLE
90    PRINT "NUMBER", "SUM"
100   PRINT
110   FOR N = 1 TO VALUE STEP 2
120   SUM  =  SUM + N
130   PRINT N, SUM
140   NEXT N
150   END
```

7-8:

```
10   PRINT "TAX RATE IN PERCENT ";
15   INPUT TAX
20   IF TAX < 1 THEN 10
25   IF TAX > 100 THEN 10
30   PRINT "PRICE ", "TAX ", "PRICE + TAX "
40   FOR PRICE = 1 TO 100
50   PRINT PRICE; PRICE * TAX / 100; PRICE + PRICE *
     TAX / 100
60   NEXT PRICE
70   END
```

8

8-2: Coding is one step of programming. Programming involves algorithm design, flowcharting, coding, debugging, and documenting.

8-4: A variable is traced by inserting PRINT statements to show the value of the variable at critical points in the program. Somtimes a TRACE command is provided by the interpreter to facilitate this.

8-6: A flowchart is a symbolic diagram showing the sequence of events occurring during the execution of a program.

8-8: Clearly written programs are easy to understand, and thus easy to modify. This allows the programmer who created the program, as well as other programmers, to easily change it.

Appendix B

TI BASIC Reserved Words

This list will help you avoid using illegal names for variables.

ABS	END	OLD	SEG$
APPEND	EOF	ON	SEQUENTIAL
ASC	EXP	OPEN	SGN
ATN	FIXED	OPTION	SIN
BASE	FOR	OUTPUT	SQR
BREAK	GO	PERMANENT	STEP
BYE	GOSUB	POS	STOP
CALL	GOTO	PRINT	STR$
CHR$	IF	RANDOMIZE	SUB
CLOSE	INPUT	READ	TAB
CON	INT	REC	TAN
CONTINUE	INTERNAL	RELATIVE	THEN
COS	LEN	REM	TO
DATA	LET	RES	TRACE
DEF	LIST	RESEQUENCE	UNBREAK
DELETE	LOG	RESTORE	UNTRACE
DIM	NEW	RETURN	UPDATE
DISPLAY	NEXT	RND	VAL
EDIT	NUM	RUN	VARIABLE
ELSE	NUMBER	SAVE	

Appendix C

**BASIC
Glossary**

algorithm A sequence of steps that specify the solution to a given problem.

alphanumeric The set of alphabetic and numeric characters.

assignment The operation of giving a value to a variable, which is indicated by the " = " symbol in BASIC.

BASIC *Beginners All-Purpose Symbolic Instruction Code.* A high-level programming language designed for ease in learning.

binary A numbering system that uses only two digits: 0 and 1.

bit A contraction of the words binary digit. A bit may take the value 0 or 1.

bug Program error. Bugs should be prevented rather than cured.

byte A group of eight bits.

chip An integrated circuit that resides on a small silicon square mounted on a plastic or ceramic package.

coding The act of converting an algorithm or a flowchart into a sequence of program statements. This is one of the stages of the programming process.

command A reserved word used to perform a specific housekeeping chore, such as clearing the screen, starting a program, or accessing files. Specifying a command activates a specialized program inside the computer to perform the chore.

computer An enclosure containing at least a central processing unit, a memory, basic interfaces that allow it to communicate with the outside world, and a power supply. The enclosure may also include a keyboard, a screen, and disk drives. A computer is capable of storing programs and executing them. It communicates with the outside world by means of input/output devices. The usual input device is a keyboard. The usual output device is a screen and may also be a printer. Additional memory is usually provided in the form of disk units or cassette recorders.

CPU *Central Processing Unit.* An electronic module in charge of fetching, decoding, and executing in the proper sequence instructions stored in the memory. On most small computers, the CPU and the memory reside on a single circuit board or "card." The CPU normally uses a microprocessor chip and a few other components.

CRT *A Cathode Ray Tube.* A television-like screen.

cursor A symbol used to indicate the current position at which a character will be displayed on the screen. Often a blinking square or underline. Specialized keys are generally available to conveniently position the cursor on the screen.

data Any text or numbers on which a program can operate.

debugging Action of removing the bugs from a program. Debugging may be arduous and all efforts should be used to design a correct program so that it has as few bugs as possible.

disk Magnetic medium on which data and programs can be stored. On disk, information is organized in files that can be retrieved by name. Disks can store a large amount of data and are a common mass memory device used with small computers.

disk drive The mechanism used to read and write from a disk.

diskette A floppy disk, i.e., an 8" or 5-1/4" soft disk designed to provide inexpensive storage for programs and data.

double precision Number that has twice as many digits as in the normal representation. Each interpreter represents numbers with a set number of digits. Double precision is usually required for scientific computations or business calculations that involve large numbers or extensive computations.

editor Program designed to facilitate the entering and modifying of text. Used to remove errors or make changes while typing in a program.

empty statement A statement that does nothing. For example, the statement

    10   REM

can be used to provide a space in the program and enhance readability.

endless loop A loop that has no exit point and executes forever. This is a common error made by programmers when no test condition is included in the loop or when the test always succeeds (or always fails). Breaking out of an endless loop requires the use of a special escape character—often CTRL C.

expression A combination of operands or variables separated by operators. An expression represents a formula and performs a specific calculation. When an expression is evaluated by the interpreter at execution time, it results in a value.

file A collection of information that has been given a name. A program is usually stored on a disk as a file.

fixed point number An integer, i.e., whole number, where the decimal point is in a fixed position to the right of the last digit.

floating point number A decimal number. A fixed number of digits is used internally to represent any number; and as operations are performed on the number, the position of the decimal point floats to the left or the right.

flowchart Symbolic visual representation of an algorithm.

graphics Pictures, figures, or drawings displayed on the screen, generally using a pattern of small adjacent dots. The use of color enhances the appearance of graphics.

hardware The equipment, including the computer, the disks, and any other items, that make up a computer system. *Contrast with:* software (i.e., the instruction or the programs).

high-level language A programming language designed to facilitate giving instructions to the computer. BASIC is a high-level language.

IC An *Integrated Circuit*.

initialization The phase (in a program) during which initial values are assigned to the variables. Every loop requires an initialization phase.

instruction A valid order given to the interpreter that will affect the data being operated on. Each instruction preceded by a line number is part of a program. (Commands do not affect the values of the data. They perform housekeeping chores or facilitate designing or using a program.)

integrated circuit Also called IC. An electronic circuit with many transistors and logic functions realized on a small piece of silicon.

interface Electronic circuits that allow the connection of a specific device to the computer. A disk, a printer, and a recorder require specific interfaces.

interpreter The program in charge of translating the instructions of a programming language (say BASIC) into the binary language of the computer and executing them. Once the interpreter has been installed on the computer, the computer appears to understand BASIC instructions.

I/O *Input/Output*, i.e., the communications to and from the computer.

jump Branching to, i.e., executing an instruction out of sequence.

K 1024, read as "K" or kilo. K is used to denote memory size, usually in bytes.

label A line number in BASIC.

loading Transferring data or a program into the computer's internal memory.

logical A variable or expression that takes the value true or false.

logical expression A combination of operands or variables separated by relational operators (= , > , etc.). The value of a logical expression is either true or false.

loop A sequence of program instructions that executes repeatedly until a specified event occurs, usually until a variable reaches a given value.

machine language The binary language that the computer understands directly, i.e., a limited set of instructions that manipulate binary information inside the CPU and the memory.

memory Medium that stores information. The internal memory usually resides on the same board as the CPU and stores programs and data as bytes. Mass memory units are cassettes and disks.

microcomputer A computer that uses a microprocessor as its central processing unit.

microprocessor An integrated circuit that implements most of the function of a CPU on a single chip. A contemporary microprocessor incorporates sometimes tens of thousands of transistors within a single chip and may even incorporate the memory.

monitor A minimal program required to operate a computer system. The monitor reads characters from the keyboard, displays them on the screen, and performs the basic data transfers between the keyboard, screen, and common peripherals.

MPU *Microprocessor unit*. A chip.

nested loop Loop embedded within another loop.

non-resident A program that is normally not in the permanent memory (the ROM) of the computer. A non-resident program may be stored on a cassette or diskette.

operating system A house-keeping program that provides extensive facilities for performing all common data transfers and data processing required to conveniently use the resources of a computer system. The operating system manages disk files, performs format conversions, and starts and stops programs.

operator A symbol representing any valid operation on values (i.e., + (add), * (multiply), etc.).

peripheral Device connected to a computer, such as a printer, a disk drive or a terminal.

program Sequence of instructions to be executed by the computer. Each program is written in a specific computer language and must be loaded into the computer's memory in order to be executed.

RAM *Random Access Memory*. The read/write (modifiable) portion of the computer's memory (the rest being ROM).

relational operator A logical operator that establishes a size relationship between values.

reserved word A word that has a pre-defined meaning for the BASIC interpreter. It may not be used by the programmer as a variable name.

resident A program that is stored permanently in the computer's memory, i.e., in ROM.

ROM *Read-Only Memory*. This memory may not be changed by the programmer. It generally contains part or all of the monitor and sometimes a simple BASIC interpreter.

RUN Command that starts execution of a BASIC program.

software The programs.

statement A BASIC instruction or a command, that is part of a program.

string A sequence of characters (*contrast with:* a number). In BASIC, the name of a variable is different, depending on whether it contains a string or a number. For example, WORD$ is a string variable, while NUMBER is a numeric variable.

syntax A set of rules that defines the acceptable instructions of a computer language. BASIC has a simple syntax. The interpreter always checks for, and indicates, syntax errors.

terminal Combination of a screen and a keyboard, or a printer and a keyboard, used to communicate conveniently with a computer.

variable Memory location that has a name and may take successive values over time. BASIC distinguishes between string variables and numeric variables. The name of a string variable must end with a $.

Index

The SYBEX Library

More Books on BASIC

FIFTY BASIC EXERCISES
by J. P. Lamoitier
232 pp., 90 illustr., Ref. 0-056
Teaches BASIC by actual practice, using graduated exercises drawn from everyday applications. All programs written in Microsoft BASIC.

BASIC EXERCISES FOR THE APPLE®
by J. P. Lamoitier
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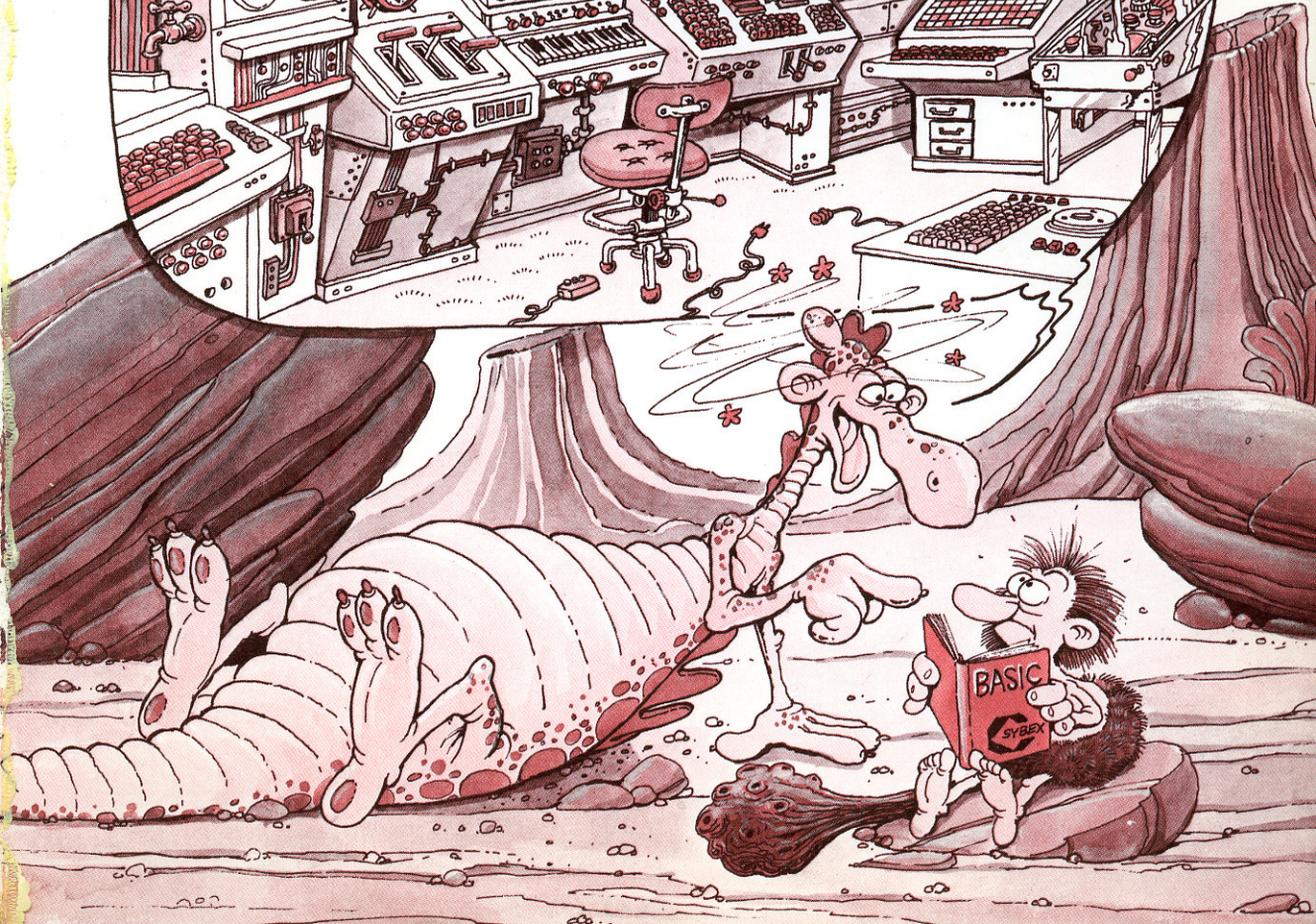Tel: 1/347-30-20, Telex: 211801

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