QBasic & QB64

A computer's a useless hunk of metal & plastic until somebody feeds it a **program**, which is a list of commands teaching the computer how to perform a task. A person who writes a program is called a **programmer**. Now you'll learn how to write programs, so you become a programmer.

You learned to buy & use programs such as Microsoft Office. Now you'll learn how to invent your own programs, so you can become the computer's master and make it do whatever you wish, not limited to the creations of other programmers.

Programming the computer can be easy. You'll write your own programs just a few minutes from now, when you reach page 508. Then on your résumé you can brag you're a "programmer." As you read farther, you'll learn how to become a *good* programmer, by writing programs that are more sophisticated.

Learning to program is fun, an adventure that expands your mind and turns you into a brilliant thinker.

> You learn the secret of computer life: how to take a computer — that hunk of metal and plastic — and teach it new skills by feeding it programs you invent. Your teaching and programs turn the computer into a thinking organism. You can teach the computer to become as smart as you and even imitate your personality. You become the computer's God, able to make the computer do anything you wish. Ah, the power!

To program the computer, feed it a list of commands written in a **computer language**. Each computer language is a small part of English. The easiest popular computer language is **Basic**. Two kinds of Basic are popular:

> One kind, **classic Basic**, was invented long ago and is extremely simple. We'll start with that. It consists of words such as PRINT, INPUT, IF, and THEN. You'll learn classic Basic's most popular versions: **QBasic** and **QB64**.
>
> Next, you'll learn the other kind of Basic, called **Visual Basic**, which is slightly harder but more powerful: it lets you teach the computer to create windows & buttons and handle mouse clicks.

Later, I'll explain computer languages that are harder to learn but have extra features.

Basic was invented by 2 Dartmouth College professors (John Kemeny & Tom Kurtz) in 1964 and improved afterwards. Basic consists of words such as PRINT, INPUT, IF, and THEN. I'll explain how to program the computer by using those Basic words.

Different computers speak different **dialects** of Basic. The most popular dialect was invented in 1975 by a 19-year-old kid, Bill Gates. Since he developed software for microcomputers, he called himself **Microsoft** and called his Basic dialect **Microsoft Basic**.

Since Microsoft Basic is so wonderful, all popular computer companies paid him to make their computers understand Microsoft Basic. IBM, Apple, and *hundreds* of other computer companies all had to pay off Bill. Microsoft Basic became so popular that he had to hire hundreds of employees to help him fill all the orders. Microsoft Incorporated became a multi-billion-dollar company, and Bill became a famous billionaire, the wealthiest person in the world.

Over the years, Bill improved Microsoft Basic. Some computers use old versions of Microsoft Basic; other computers use his latest improvements.

One of the most popular versions of Microsoft Basic is **QBasic**. It's popular because it works well and most people got it at no charge: free!

QBasic expects your operating system is MS-DOS. You can force QBasic to run with some versions of Windows, and you can even download QBasic free from some Websites (by Microsoft and others), but Microsoft's taken steps to discourage you from doing so.

This chapter explains QB64 (pronounced "Q B sixty-four"), which imitates QBasic and runs well if you have Windows. You can download a free copy of QB64 from **QB64.net**. QB64 was invented in Sydney, Australia by a guy whose name is "Rob" but whose nickname is "Galleon Dragon." **After reading this chapter, you can advance to Visual Basic**, which is explained in the next chapter and harder.

QB64's commands are explained on these pages:

Command	What the computer will do	Page	Similar to
`BEEP`	hum for a quarter of a second	541	`SOUND, PLAY`
`CASE "fine"`	if SELECTed is "fine", do indented lines	522	`SELECT, IF`
`CIRCLE (100, 100), 40`	draw a circle at (100, 100) with radius 40	540	`LINE, PAINT`
`CLS`	clear the screen, so it becomes all black	508	`LOCATE`
`COMMON SHARED x`	make all procedures share x's box	558	`DIM SHARED`
`DATA meat, potatoes`	use this list of data: meat, potatoes	528	`READ, RESTORE`
`DIM SHARED y$(20)`	make y$ be 20 strings the procedures share	558	`COMMON, SUB`
`DIM x$(7)`	make x$ be a list of 7 strings	553	`x =`
`DO`	do the indented lines below, repeatedly	514	`DO UNTIL, LOOP`
`ELSE`	do indented lines when IF conditions false	522	`IF, ELSEIF`
`ELSEIF age < 100 THEN`	do lines when earlier IFs false & age<100	522	`IF, ELSE`
`END`	skip the rest of the program	517	`STOP`
`END IF`	make this the bottom of an IF statement	522	`IF, ELSE`
`END SELECT`	make this the bottom of SELECT statement	522	`SELECT, CASE`
`END SUB`	make this the bottom of a SUB procedure	557	`SUB`
`EXIT DO`	skip down to the line that's under LOOP	525	`DO, LOOP`
`FOR x = 1 TO 20`	repeat the indented lines, 20 times	525	`NEXT, DO`
`GOTO 10`	skip to line 10 of the program	516	`DO, EXIT DO`
`IF y < 18 THEN PRINT "m"`	if y is less than 18, print an "m"	521	`ENDIF, ELSE`
`INPUT "What name"; n$`	ask "What name?" and get answer n$	519	`x =`
`LINE (0, 0)-(100, 100)`	draw a line from (0, 0) to (100, 100)	540	`PSET, CIRCLE`
`LOCATE 3, 7`	move to the screen's 3rd line, 7th position	539	`PRINT, CLS`
`LOOP`	make this the bottom line of a DO loop	514	`LOOP UNTIL`
`LOOP UNTIL guess$ = "p"`	do the loop repeatedly, until guess$ is "p"	525	`LOOP, DO UNTIL`
`LPRINT 2 + 2`	print, onto paper, the answer to 2 + 2	512	`PRINT`
`MID$(a$, 2)="owl"`	change the middle of a$ to "owl"	551	`x =`
`NEXT`	make this the bottom line of a FOR loop	525	`FOR`
`PAINT (100, 101)`	fill in the shape that surrounds (100, 101)	540	`LINE, CIRCLE`
`PLAY "c d g# b- a"`	play this music: C, D, G sharp, B flat, A	541	`SOUND, BEEP`
`PSET (100, 100)`	make pixel (100, 100) turn white	540	`SCREEN, LINE`
`PRINT 4 + 2`	print the answer to 4 + 2	508	`PRINT USING`
`PRINT USING "##.#"; x`	print x, rounded to one decimal place	542	`PRINT`
`RANDOMIZE TIMER`	make random numbers be unpredictable	547	`x =`
`READ a$`	get a string from the DATA and call it a$	528	`DATA, RESTORE`
`RESTORE 10`	skip to line 10 of the DATA	530	`READ, DATA`
`SCREEN 12`	let you draw pictures	539	`PSET, WIDTH`
`SELECT CASE a$`	analyze a$ to select a case from list below	522	`END SELECT, IF`
`SOUND 440, 18.2`	make a sound of 440 hertz, for 1 second	541	`PLAY, BEEP`
`SLEEP`	pause until you press a key	513	`FOR`
`STOP`	skip rest of program; close the black window	531	`END`
`SUB insult`	make the lines below define "insult"	557	`END SUB`
`WIDTH 40`	make the characters wide, 40 per line	515	`SCREEN`
`x = 47`	make x stand for the number 47	517	`INPUT`
`'Zoo program is fishy`	ignore this comment	534	`PRINT`

QB64's functions are explained on these pages:

Function	Meaning	Value	Page	Similar to
ABS(-3.89)	absolute value of -3.89	3.89	545	SGN
ASC("A")	Ascii code number for "A"	65	551	CHR$
ATN(1) / degrees	arctangent of 1, in degrees	45	552	TAN
CHR$(164)	character whose code# is 164	"ñ"	550	ASC
CINT(3.89)	round to nearest integer	4	545	INT, FIX
COS(60 * degrees)	cosine of 60 degrees	.5	552	SIN, TAN
DATE$	today's date	varies	545	TIME$
EXP(1)	e raised to the first power	2.718282	544	LOG, SQR
FIX(3.89)	erase digits after decimal point	3	545	INT, CINT
INSTR("needed", "ed")	position of "ed" in "needed"	3	552	other INSTR
INSTR(4,"needed","ed")	search from the 4th character	5	552	other INSTR
INT(3.89)	round down to a lower integer	3	546	FIX, CINT
LCASE$("We love")	lower case; uncapitalize	"we love"	551	UCASE$
LEFT$("smart", 2)	left 2 characters of "smart"	"sm"	551	RIGHT$, MID$
LEN("smart")	length of "smart"	5	551	RIGHT$, MID$
LOG(2.718282)	logarithm base e	1	544	EXP
LTRIM$(" Sue Smith")	delete beginning spaces	"Sue Smith"	551	RTRIM$
MID$("smart", 2)	begin at the 2nd character	"mart"	551	other MID$
MID$("smart", 2, 3)	begin at the 2nd take 3	"mar"	552	other MID$
RIGHT$("smart", 2)	rightmost 2 characters	"rt"	551	LEFT$, MID$
RND	random decimal	varies	546	TIMER
RTRIM$("Sue Smith ")	delete ending spaces	"Sue Smith"	551	LTRIM$
SGN(-3.89)	sign of -3.89	-1	546	ABS, FIX
SIN(30 * degrees)	sine of 30 degrees	.5	552	COS, TAN
SQR(9)	square root of 9	3	544	EXP, LOG
STR$(81.4)	turn 81.4 into a string	" 81.4"	552	VAL
STRING$(5, "b")	a string of 5 b's	"bbbbb"	552	other STRING$
STRING$(5, 98)	98th Ascii character, 5 times	"bbbbb"	552	other STRING$
TAN(45 * degrees)	tangent of 45 degrees	1	553	ATN
TIME$	current time of day	varies	545	TIMER, DATE$
TIMER	# of seconds since midnight	varies	545	TIME$, DATE$
UCASE$("We love")	capitalize "We love"	"WE LOVE"	551	LCASE$
VAL("52.6")	remove the quotation marks	52.6	552	STR$

Fun

Let's have fun programming! If you have any difficulty, phone me at 603-666-6644 (day or night) for free help.

Get QB64

Here's how to copy QB64 (version 1.000) from the Internet to a Windows 10 computer, free (using Microsoft Edge).

Go to QB64.net. Click "Download (.zip)".

The computer sends a compressed copy of QB64 from the Internet to your computer. That takes about 2 minutes (depending on your Internet connection's speed).

When the screen's bottom says "finished downloading", tap the "Open" button.

If your computer complains you didn't pay for WinZip (probably because you bought a Toshiba laptop that unfortunately includes the annoying WinZip program), delete WinZip by doing this: right-click the Windows Start button then click "Control Panel" then "Programs and Features" then right-click "WinZip" (which you'll see when you scroll down) then click Uninstall then Yes then Yes again then the X (at the screen's top-right corner) then X again then start over (by doing the previous paragraph again).

Tap "Extract all". Type "C:\QB64" and press Enter.

The computer says "Copying 8,578 items".

The computer expands (uncompresses) QB64. That takes about 10 minutes (depending on your computer's speed).

Then the word "Copying" disappears. Close all windows, so you can start fresh.

Start QB64

You can start QB64 (version 1.000) by doing this:

Tap the File Explorer button (the picture of a yellow manila folder at the screen's bottom) then "This PC" (at the screen's left edge). Double-click the "(C:)" (which is at the screen's middle and has some letters before it) then "QB64" then "qb64" then "qb64" again.

Type your program

Now you're ready to type your first program!

For example, type this program:

```
CLS
PRINT 4 + 2
```

Here's how. Type CLS, then press the Enter key at the end of that line. Type PRINT 4 + 2 (and remember to hold down the Shift key to type the symbol +), then press the Enter key at the end of that line.

Notice that you must press the Enter key at the end of each line.

A **program** is a list of commands that you want the computer to obey. The sample program you typed contains two commands. The first command (**CLS**) tells the computer to **CLear the Screen**, so the computer will erase the screen and the screen will become blank: entirely black! The next command (**PRINT 4 + 2**) tells the computer to do some math: it tells the computer to compute 4 + 2, get the answer (6), and print the answer on the screen.

Run your program

To make the computer obey the program you wrote, press the F5 key. (Exception: if the "F5" is blue or tiny or on a new computer by Microsoft, HP, Lenovo, or Toshiba, press the F5 key *while holding down the Fn key*, which is left of the Space bar.)

That tells the computer to **run** the program: the computer will run through the program and obey all the commands in it.

While the computer is running your program, you see a small black window.

The CLS command makes sure the computer clears that window, so it becomes all blank, all black.

Then the computer obeys the PRINT 4 + 2 command. The computer prints this answer onto the black window:

```
 6
```

Congratulations! You've written your first program! You've programmed the computer to compute the answer to 4 + 2! You've become a programmer! Now you can put on your résumé: "programmer!"

When you finish admiring the computer's answer, close the black window, by clicking its X button (or pressing the Enter key).

Faster typing

While typing the program, **you don't have to capitalize computer words** such as CLS and PRINT: the computer will capitalize them automatically when you press Enter at the end of the line.

While typing that program, put a blank space after the word PRINT to separate the "PRINT" from the 4. But **you don't need to put spaces next to the + sign**, since the computer will automatically insert those spaces when you press Enter at the end of the line.

Instead of typing "PRINT" or "print", you can type just a question mark. When you press the Enter key at the end of the line, the computer will replace the question mark by the word PRINT, and the computer will put a blank space after it.

So **instead of typing PRINT 4 + 2, you can type just this:**

```
?4+2
```

Think of the question mark as standing for this word:

```
What's
```

If you want to ask the computer "What's 4+2", type this:

```
?4+2
```

When you run the program, the computer will print the answer, 6.

CLS optional

The program's top line (CLS) tells the computer to erase the screen before printing the answer (6).

If you forget to make the program's top line say CLS, don't worry!

The CLS line was required by QBasic but not by QB64. QB64 will automatically do CLS at your program's top, even if you forgot to write CLS. In QB64, typing CLS is optional. So in this book, I won't bother to write CLS at the program's top anymore.

Edit your program

After you've typed your program, try typing another one. For example, create a program that makes the computer print the answer to 79 + 2. To do that, make this program appear on the screen:

```
PRINT 79 + 2
```

To make that program appear, just edit the program you typed previously (which said PRINT 4 + 2). To edit, do this:

Move to the character you want to change (which was the 4) by using the arrow keys (or clicking that character with the mouse). Then undelete that character (4) by pressing the Delete key. Then type the characters you want instead (79).

While editing, use these tricks….

To delete a character:
move the cursor (blinking underline) to that character by using the arrow keys (or clicking that character with the mouse), then press the Delete key.

To delete SEVERAL characters:
move to the first character you want to delete, then hold down the Delete key awhile.

To delete AN ENTIRE LINE:
drag across that line then press the Delete key.

To INSERT A NEW LINE between two lines:
move to the beginning of the lower line, then press the Enter key.

If you've edited the program successfully, the screen shows just the new program —

```
PRINT 79 + 2
```

and you don't see the old program anymore.

When you've finished editing the program, run it by pressing the F5 key. Then the computer will print the answer:

```
 81
```

Fix your errors

What happens if you misspell a computer word, such as CLS or PRINT? For example, what happens if you accidentally say PRIMPT instead of PRINT?

Here's the result:

The blue window's bottom says "Syntax error". If the error isn't in the line you're typing, the bad line is highlighted in red. Fix the error.

Math

This command makes the computer add 4 + 2:

```
PRINT 4 + 2
```

Put that command into a program (whose top line should be CLS). When you run the program (by pressing Shift with F5), the computer will print the answer:

```
 6
```

If you want to subtract 3 from 7, type this command instead:

```
PRINT 7 - 3
```

(When typing the minus sign, do *not* press the Shift key.) The computer will print:

```
 4
```

You can use decimal points and negative numbers. For example, if you type this —

```
PRINT -26.3 + 1
```

the computer will print:

```
-25.3
```

Multiplication To multiply, use an asterisk. So to multiply 2 by 6, type this:

```
PRINT 2 * 6
```

The computer will print:

```
 12
```

Division To divide, use a slash. So to divide 8 by 4, type this:

```
PRINT 8 / 4
```

The computer will print:

```
 2
```

To divide 2 by 3, type this:

```
PRINT 2 / 3
```

The computer will print:

```
 .6666667
```

Avoid commas Do *not* put commas in big numbers. To write four million, do *not* write 4,000,000; instead, write 4000000.

The symbol # If you type a long number (such as 7000000000 or 273.85429), the computer might automatically put the symbol # afterwards. That's the computer's way of reminding itself that the number is long and must be treated extra carefully!

E notation If the codddmputer's answer is huge (more than a million) or tiny (less than .01), the computer might print an E in the answer. The E means "move the decimal point".

For example, suppose the computer says the answer to a problem is:

```
 8.516743E+12
```

The E means, "move the decimal point". The plus sign means, "towards the right". Altogether, **the E+12 means "move the decimal point towards the right, 12 places."** So look at 8.516743 and move the decimal point towards the right, 12 places; you get 8516743000000.

So when the computer says the answer is 8.516743E+12, the computer really means the answer is 8516743000000, approximately. The exact answer might be 8516743000000.2 or 8516743000000.79 or some similar number, but the computer prints just an approximation.

Suppose your computer says the answer to a problem is:

```
 9.23E-06
```

After the E, the minus sign means, "towards the *left*". So look at 9.23 and move the decimal point towards the left, 6 places. You get:
.00000923

So when the computer says the answer is 9.23E-06, the computer really means the answer is:
.00000923

You'll see E notation rarely: the computer uses it just if an answer is huge (many millions) or tiny (tinier than .01). But when the computer *does* use E notation, remember to move the decimal point!

D notation If the answer's a long number, the computer usually prints a D instead of an E. Like the E, the D means "move the decimal point".

Use decimals for big answers **In any problem whose answer might be bigger than 32 thousand, type a decimal point (or use E or D notation).**

For example, if you want to multiply 200 by 300, you should put a decimal point after the 200 or 300.

If you accidentally say just "PRINT 200 * 300" without any decimal points, QB64 prints the right answer anyway (60000) but QBasic complains by saying "Overflow".

If you want to multiply 54000 by 40000, put a decimal point after the 54000 or 40000:

If you accidentally say just "PRINT 54000 * 40000" without any decimal points, QBasic complains by saying "Overflow" but QB64 accidentally prints this instead:

```
-2134967296
```

Fix your program by inserting a decimal point, like this —

```
PRINT 54000 * 40000.0
```

or like this —

```
PRINT 54000 * 40000.
```

or using E notation like this:

```
PRINT 54000 * 4E4
```

Then when you run the program, QBasic and QB64 will print a right answer. For example, QB64 will print:

```
 2.16E+09
```

The highest number The highest number the computer can handle well is about 1E38, which is 1 followed by 38 zeros, like this:

```
100000000000000000000000000000000000000
```

If you try to go much higher, the computer will either use D notation (which goes up to about 1D308) or gripe.

If the computer wants to gripe about a number being too big, QBasic says "Overflow" but QB64 says "1.#INF" instead (which means "infinity").

The tiniest decimal The tiniest decimal the computer can handle easily is about 1E-38, which is a decimal point followed by 38 digits, 37 of which are zeros, like this:

```
.00000000000000000000000000000000000001
```

If you try to go much tinier, the computer will either say 0 or use D notation (which goes down to about 1D-323).

Order of operations What does "2 plus 3 times 4" mean? The answer depends on whom you ask.

To a clerk, it means "start with 2 plus 3, then multiply by 4"; that makes 5 times 4, which is 20. But to a scientist, "2 plus 3 times 4" means something different: it means "2 plus three fours", which is 2 + 4 + 4 + 4, which is 14.

Since computers were invented by scientists, computers think like scientists. If you type —

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

the computer will think you mean "2 plus three fours", so it will do 2 + 4 + 4 + 4 and print this answer:

```
 14
```

The computer will *not* print the clerk's answer, which is 20. So if you're a clerk, tough luck!

Scientists and computers follow this rule: **do multiplication and division before addition and subtraction**. So if you type —

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

the computer begins by hunting for multiplication and division. When it finds the multiplication sign between the 3 and the 4, it multiplies 3 by 4 and gets 12, like this:

```
PRINT 2 + 3 * 4
          \ /
           12
```

So the problem becomes 2 + 12, which is 14, which the computer prints.

For another example, suppose you type:

```
PRINT 10 - 2 * 3 + 72 / 9 * 5
```

The computer begins by doing all the multiplications and divisions. So it does 2 * 3 (which is 6) and does 72 / 9 * 5 (which is 8 * 5, which is 40), like this:

```
PRINT 10 - 2 * 3 + 72 / 9 * 5
           \ /     \ /
            6       40
```

So the problem becomes 10 - 6 + 40, which is 44, which is the answer the computer prints.

You can use parentheses the same way as in algebra. For example, if you type —

```
PRINT 5 - (1 + 1)
```

the computer will compute 5 - 2 and print:

```
 3
```

You can put parentheses inside parentheses. If you type —

```
PRINT 10 - (5 - (1 + 1))
```

the computer will compute 10 - (5 - 2), which is 10 - 3, and will print:

```
 7
```

Strings

Let's make the computer fall in love. Let's make it say, "I love you".

Type this program:

```
PRINT "I love you"
```

Here's how to type the second line:

Begin by typing the word PRINT. Then type a blank space (by pressing the Space bar). Then type a quotation mark, but be careful: **to type the quotation mark, you must hold down the Shift key.** Then type these words: *I love you*. Then type another quotation mark. At the end of that line, press the Enter key.

When you run the program, the computer will obey your command; it will print:

```
I love you
```

You can change the computer's personality. For example, if you give this command —

```
PRINT "I hate you"
```

the computer will reply:

```
I hate you
```

Notice that **to make the computer print a message, you must put the message between quotation marks**. The quotation marks make the computer copy the message without worrying about what the message means. For example, if you misspell "I love you", and type —

```
PRINT "aieee luf ya"
```

the computer will still copy the message (without worrying about what it means); the computer will print:

```
aieee luf ya
```

Faster typing Instead of typing —

```
PRINT "I love you"
```

you can type just this:

```
?"I love you
```

At the end of that line, when you press the Enter key, the computer will automatically do three things:

The computer will change the question mark to the word PRINT. The computer will put a blank space after PRINT (and before the quotation mark). The computer will put a quotation mark at the line's end (to match the other quotation mark).

Jargon The word "joy" consists of 3 characters: j and o and y. Programmers say that the word "joy" is a **string** of 3 characters.

A **string** is any collection of characters, such as "joy" or "I love you" or "aieee luf ya" or "76 trombones" or "GO AWAY!!!" or "xypw exr///746". The computer will print whatever string you wish, but remember to **put the string in quotation marks**.

Strings versus numbers The computer can handle two types of expressions: **strings** and **numbers**. Put strings (such as "joy" and "I love you") in quotation marks. Numbers (such as 4 + 2) do *not* go in quotation marks.

Accidents Suppose you accidentally put the number 2 + 2 in quotation marks, like this:

```
PRINT "2 + 2"
```

The quotation marks make the computer think "2 + 2" is a string instead of a number. Since the computer thinks "2 + 2" is a string, it copies the string without analyzing what it means; the computer will print:

```
2 + 2
```

It will *not* print 4.

Suppose you want the computer to print the word "love" but you accidentally forget to put the string "love" in quotation marks, and type this instead:

```
PRINT love
```

Since you forgot the quotation marks, the computer thinks *love* is a number instead of a string but doesn't know which number, since the computer doesn't know the meaning of love. Whenever the computer is confused, it either gripes at you or prints a zero. In this particular example, when you run the program the computer will print a zero, like this:

```
 0
```

So if you incorrectly tell the computer to proclaim its love, it will say zero.

Longer programs You can program the computer say it's madly in love with you!

Let's make the computer say:

```
I love you.
You turned me on.
Let's get married!
```

To make the computer say all that, just run this program:

```
PRINT "I love you."
PRINT "You turned me on."
PRINT "Let's get married!"
```

To run that program, type it and then press Shift with F5. Try it!

To have even more fun, run this program:

```
PRINT "I long"
PRINT 2 + 2
PRINT "U"
```

It makes the computer print "I long", then print the answer to 2+2 (which is 4), then print "U". So altogether, the computer prints:

```
I long
 4
U
```

Yes, the computer says it longs for you!

Tricky printing

Printing can be tricky! Here are the tricks.

Indenting Suppose you want the computer to print this letter onto the screen:

```
Dear Joan,
  Thank you for the beautiful
necktie.  Just one problem--
I don't wear neckties!
              Love,
              Fred-the-Hippie
```

This program prints it:

```
PRINT "Dear Joan,"
PRINT "  Thank you for the beautiful"
PRINT "necktie.  Just one problem--"
PRINT "I don't wear neckties!"
PRINT "              Love,"
PRINT "              Fred-the-Hippie"
```

In the program, each line contains 2 quotation marks. **To make the computer indent a line, put blank spaces AFTER the first quotation mark.**

Blank lines Life consists sometimes of joy, sometimes of sorrow, and sometimes of a numb emptiness. To express those feelings, run this program:

Program	What the computer will do
`PRINT "joy"`	Print "joy".
`PRINT`	Print blank empty line, under "joy".
`PRINT "sorrow"`	Print "sorrow".

Altogether, the computer will print:

```
joy

sorrow
```

Semicolons Run this program:

```
PRINT "fat";
PRINT "her"
```

The top line, which makes the computer print "fat", ends with a semicolon. **The semicolon makes the computer print the next item on the same line**; so the computer will print "her" on the same line, like this:

```
father
```

This program gives you some food for thought:

```
PRINT "I love to eat her";
PRINT "ring for dinner";
PRINT "you are the most beautiful fish in the whole sea!"
```

The program says to print three phrases. Because of the semicolons, the computer tries to print all the phrases onto a single line; but those phrases are too long to all fit on the same line simultaneously! So the computer prints just the first two phrases onto the line and prints the third phrase underneath, like this:

```
I love to eat herring for dinner
you are the most beautiful fish in the whole sea!
```

The next program shows what happens to an evil king on a boat:

```
PRINT "sin"; "king"
```

The computer will print "sin", and will print "king" on the same line, like this:

```
sinking
```

Notice that in a PRINT statement, you can type several items (such as "sin" and "king"). You're supposed to type a semicolon between each pair of items; but if you forget to type a semicolon, the computer will type it for you automatically when you press the Enter key at the end of the line. The computer will also automatically put a blank space after each semicolon.

Spaces after numbers Try typing this command:

```
PRINT -3; "is my favorite number"
```

Whenever the computer prints a NUMBER, it prints a blank space afterwards; so the computer will print a blank space after -3, like this:

```
-3 is my favorite number
 ↑
space
```

Spaces before positive numbers This command tells what to put in your coffee:

```
PRINT 7; "do"; "nuts"
```

The computer prints 7 and "do" and "nuts". Since 7 is a number, the computer prints a blank space after the 7. **The computer prints another blank space BEFORE every number that's positive**; so the computer prints another blank space before the 7, like this:

```
 7 donuts
↑ ↑
spaces
```

Hey, if you're feeling cool, maybe this command expresses your feelings:

```
PRINT "the temperature is"; 4 + 25; "degrees"
```

The computer prints "the temperature is", then 4 + 25 (which is 29), then "degrees". Since 29 is a positive number, the computer prints a blank space before and after the 29:

```
the temperature is 29 degrees
                  ↑  ↑
                spaces
```

Fix the negative numbers Use this command if you're even colder:

```
PRINT "the temperature is"; 4 - 25; "degrees"
```

The computer prints "the temperature is", then 4 - 25 (which is -21), then "degrees". Since -21 is a number, the computer prints a space after it; but since -21 is *not* positive, the computer does *not* print a space before it. The computer prints:

```
the temperature is-21 degrees
                  ↑   ↑
              no space  space
```

Yuk! That looks ugly! It would look prettier if there were a space before the -21. To insert a space, put the space inside quotation marks:

```
PRINT "the temperature is "; 4 - 25; "degrees"
                          ↑
          inserted space, before the quotation mark
```

Then the computer will print:

```
the temperature is -21 degrees
                   ↑
              inserted space
```

Multiple calculations By using semicolons, you can make the computer do many calculations at once.

For example, this command makes the computer do 6+2, 6-2, 6*2, and 6/2, all at once:

```
PRINT 6 + 2; 6 - 2; 6 * 2; 6 / 2
```

That makes the computer print the four answers:

```
 8  4  12  3
```

The computer prints spaces between the answers, because the computer prints a space after every number (and an additional space before every number that's positive).

Print on paper If you say LPRINT instead of PRINT, the computer will try print on paper instead of on your screen.

For example, if you want the computer to compute 2+2 and print the answer on paper, type this program:

```
LPRINT 2 + 2
```

While typing that program, make sure you type "LPRINT". Although "PRINT" can be abbreviated by typing "?", "LPRINT" can*not* be abbreviated by typing "L?"; you must type the word "LPRINT" in full.

When you run that program, the computer will compute 2 + 2 and print this answer onto paper:

```
 4
```

Here are peculiarities:

The printer might pause a minute before printing. Be patient. Also, if you try to do zoned printing using commas (which I'll explain later), the printer might not space the answers correctly.

If you say PRINT 2 + 2, the computer prints the answer (4) onto the screen. If you say LPRINT 2 + 2, the computer tries to print 4 onto paper instead. If you want to print the answer onto the screen *and also onto paper*, say PRINT *and also LPRINT*, like this:

Program	What the computer will do
`PRINT 2 + 2`	Print the answer (4) onto the screen.
`LPRINT 2 + 2`	Print the answer (4) onto paper.

File menu

If you **tap the Alt key and then the F key** (or click "File" by using the mouse), you see this **File menu**:

QB64	QBasic
New	New
Open	Open
Save	Save
Save As	Save As
Update	Print
Exit	Exit

Save If you want the computer to copy the program onto your hard disk, choose **Save** from the File menu, by pressing the S key (or click "Save" by using the mouse).

If you haven't invented a name for the program yet, the computer will say "File Name" and wait for you to invent a name. Invent any name you wish. For example, the name can be JOE or SUE or LOVER or POEM4U. Pick a name that reminds you of the program's purpose. Here are details:

The computer assumes you want the name to be "untitled.bas". Erase that name (by holding down the Backspace key), then type whatever name you want instead. When you finish typing the name, press the Enter key. The computer automatically adds ".bas" to the end of it (which means "basic") and copies your program to drive C's qb64 folder.

Exception: if the name you invented was already used by another program, the computer asks you, "Overwrite?" Press the Y key if you want the new program to replace the old program, so the old program disappears. If you do *not* want the new program to replace the old program, press N instead of Y, then invent a *different* name for your new program.

Suppose you're creating a program that's so long it takes you several hours to type. You'll be upset if, after several hours of typing, your town suddenly has a blackout that makes the computer forget what you typed. To protect yourself against such a calamity, choose Save from the File menu every 15 minutes. Then if your town has a blackout, you'll lose just a few minutes of work; the rest of your work will have already been saved on the disk. Saving your program every 15 minutes protects you against blackouts and also "computer malfunction" and any careless errors you might make.

New When you've finished inventing and saving a program, **here's how to erase everything in the blue window, so you can start writing a different program instead**: choose **New** from the File menu, by pressing the N key (or click "New" by the mouse).

If you didn't save the program you worked on, the computer asks, "Save it now?" If you want to save the program you worked on, press the Y key; if you do *not* want to save the program you worked on, press the N key instead.

Here's a faster way to erase everything in the blue window:

While holding down the Ctrl key, tap the A key. Then press the Delete key.

Open If you saved a program onto the hard disk (drive C), here's how to use it again: choose **Open** from the File menu (by pressing the letter O).

The computer shows you an alphabetical list of Basic programs on the hard disk. (If the list is too long to fit on the screen, the computer shows you the list's beginning.)

Then say which program you want, by choosing one of these methods.…

Typist method Type the name of the program you want (such as "joe"), then press Enter.

List method In the alphabetical list of Basic programs, click which one you want.

All lines of that program will appear on the screen.

Exception: if a different program has been on the screen and you didn't save it, the computer will ask, "Save it now?" If you want to save that program, press the Y key; if you do *not* want to save that program, press the N key instead.

Escape key If you change your mind and wish you hadn't requested the File menu, press the **Escape key** (which says "Esc" on it). The File menu will disappear.

Save As Here's how to create a program called JOE then create a variant of it called JOE2.

First, type the JOE program and save it. Then do this:

Edit that program. Choose **Save As** from the File menu, by pressing the A key (or click "Save As" by using the mouse). Put "JOE2" into the File Name box. Press Enter.

Update If you choose **Update** from that menu (by clicking "Update"), QB64 checks immediately whether QB64.net has a newer version of QB64. Usually it says "No new updates available"; to reply, press Enter.

You don't have to bother choosing Update, since the computer checks for updates each time you start QB64. The computer automatically installs any updates it finds.

Exit When you've finished using QB64, close the QB64 window (by clicking its X button).

(If you didn't save the program you worked on, the computer asks, "Save it now?" If you want to save the program you worked on, press the Y key; if you do *not* want to save the program you worked on, press the N key instead.)

Then the computer will exit from QB64.

Become an expert

Congratulations! You've learned how to program!

C'mon, write some programs! It's easy! Try it. You'll have lots of fun!

A person who writes a program is called a **programmer**. Congratulations: *you're* a programmer!

Write *several* programs like the ones I've shown you already. Then you can put on your résumé that you have "a wide variety of programming experience", and you can talk your way into a programming job!

The rest of this chapter explains how to become a *good* programmer.

Practice Programming the computer is like driving a car: **the only way to become an expert is to put your hands on that mean machine and try it yourself**.

If you have a computer, put this book next to the computer's keyboard. At the end of each paragraph, type the examples and look, look, see the computer run! Invent your own variations: try typing different numbers and strings. Invent your own programs: make the computer print your name or a poem; make it solve problems from your other courses and the rest of your life. The computer's a fantastic toy. Play with it.

If you're a student, don't wait for your instructor to give lectures and assign homework. *Act now.* You'll learn more from handling the computer than from lectures or readings. Experience counts.

Hang around your computer. Communicate with it every day. At first, that will be even harder than talking with a cat or a tree, because the computer belongs to a different species, a different kingdom; but keep trying. Get to know it as well as you know your best friend.

If you're taking a French course, you might find French hard; and if you're taking a computer course, you might find computers hard also. But even a stupid 3-year-old French kid can speak French, and even kindergarten kids can program the computer. They have just one advantage over you: practice!

Be bold In science fiction, computers blow up; in real life, they never do. No matter what keys you press, no matter what commands you type, you won't hurt the computer. The computer is invincible! So go ahead and experiment. If it doesn't like what you type, it will gripe at you, but so what?

Troubles When you try using the computer, you'll have trouble — because you're making a mistake, or the computer is broken, or the computer is weird and works differently from the majority computers discussed in this book. (Each computer has its own "personality", its own quirks.)

Whenever you have trouble, laugh about it, and say, "Oh, boy! Here we go again!" (If you're Jewish, you can say all that more briefly, in one word: "Oy!") Then get some help.

Get help For help with your computer, read this book! For further help, read the manuals that came with your computer or ask the genie who got you the computer (your salesperson or parent or boss or teacher or friend).

If you're sitting near computers in your office, school, or home, and other people are nearby, ask them for help. They'll gladly answer your questions because they like to show off and because the way *they* got to know the answers was by asking.

Computer folks like to explain computers, just as priests like to explain religion. You're joining a cult! Even if you don't truly believe in "the power and glory of computers", at least you'll get a few moments of weird fun. Just play along with the weird computer people, boost their egos, and they'll help you get through your initiation rite. Assert yourself and **ask questions**. "Shy guys finish last." To get your money's worth from a computer course, ask your teacher, classmates, lab assistants, and other programmers lots of questions!

Your town probably has a **computer club**. (To find out, ask the local schools and computer stores.) Join the club and tell the members you'd like help with your computer. Probably some computer hobbyist will help you.

Call me anytime at **603-666-6644**: I'll help you, free!

Going & stopping

You can control how your computer goes and stops.

SLEEP

If you say SLEEP, the computer will take a nap:

```
PRINT "I'm going to take a nap."
SLEEP
PRINT "Thanks for waking me up."
```

The top line makes the computer announce:

```
I'm going to take a nap.
```

The next line says SLEEP, which makes the computer take a nap. The computer will continue sleeping until you wake it up by pressing a key on the keyboard. (Press any key, such as Enter.) Then the computer, woken up, will finish running the rest of the program, whose bottom line makes it say:

```
Thanks for waking me up.
```

Valentine's Day This program lets the computer gripe about how humans treated it on Valentine's Day:

```
PRINT "Valentine's Day, you didn't bring me flowers!"
PRINT "I won't speak until you gimme roses!"
PRINT "Bring them, then touch one of my keys."
SLEEP
PRINT "It's great to wake up and smell the roses!"
```

Lines 1-3 make the computer say:

```
Valentine's Day, you didn't bring me flowers!
I won't speak until you gimme roses!
Bring them, then touch one of my keys.
```

The next line (SLEEP) makes the upset computer go to sleep and refuse to talk to humans, until a human presses a key. When a human finally presses a key, the computer wakes up and says:

```
It's great to wake up and smell the roses!
```

Timed pause Instead of letting the computer sleep a long time, you can set an alarm clock so the computer will be forced to wake up soon. For example, if you say SLEEP 6 (instead of just SLEEP), the computer will sleep for just 6 seconds.

That's how to make the computer pause for 6 seconds. Give that 6-second pause before you reveal the punch line of a joke:

```
PRINT "Human, your intelligence is amazing!  You must be an M.D.";
SLEEP 6
PRINT "--Mentally Deficient!"
```

That program makes the computer print the joke's setup ("Human, your intelligence is amazing! You must be an M.D."), then pause for 6 seconds, then reveal the joke's punch line, so the screen finally shows:

```
Human, your intelligence is amazing!  You must be an M.D.--Mentally Deficient!
```

SLEEP 6 makes the computer sleep until it gets woken up by either the alarm clock (after 6 seconds) or the human (by pressing a key). If you want the computer to pause for 10 seconds instead of 6, say SLEEP 10 instead of SLEEP 6.

The number after the word SLEEP can be 6 or 10 or any other positive whole number, but not a decimal. (If you say SLEEP 5.9, the computer will round the 5.9 and sleep for 6 seconds instead.)

This program makes the computer brag, then confess:

```
PRINT "We computers are smart for three reasons."
PRINT "The first is our VERY GOOD MEMORY."
PRINT "The other two reasons… ";
SLEEP 10
PRINT "I forgot."
```

The computer begins by bragging:

```
We computers are smart for three reasons.
The first is our VERY GOOD MEMORY.
The other two reasons…
```

But then the computer pauses for 10 seconds and finally admits:

```
I forgot.
```

This program makes the computer change its feelings, in surprising ways:

```
PRINT "I'm up";
SLEEP 3
PRINT "set!  I want to pee";
SLEEP 4
PRINT "k at you";
SLEEP 5
PRINT "r ma";
SLEEP 6
PRINT "nual.";
```

The computer will print —

```
I'm up
```

then pause 3 seconds and change it to —

```
I'm upset!  I want to pee
```

then pause 4 seconds and change it to —

```
I'm upset!  I want to peek at you
```

then pause 5 seconds and change it to —

```
I'm upset!  I want to peek at your ma
```

then pause 6 seconds and change it to:

```
I'm upset!  I want to peek at your manual.
```

Experiment: invent your *own* jokes, and make the computer pause before printing the punch lines.

Speed-reading test This program tests how fast you can read:

```
PRINT "If you can read this, you read quickly."
SLEEP 1
CLS
```

When you run that program, the computer makes the screen display this message:

```
If you can read this, you read quickly.
```

Then the computer pauses for 1 second (because of the SLEEP 1), then erases the screen (CLS). So the message appears on the screen for just 1 second before being erased!

If you manage to read that entire message in just 1 second, you're indeed a fast reader!

But don't stop at that first success! For the ultimate challenge, try running this program:

```
PRINT "Mumbling morons make my mom miss murder mysteries Monday morning."
SLEEP 2
CLS
```

That makes the computer display this tongue-twister —

```
Mumbling morons make my mom miss murder mysteries Monday morning.
```

then pause for 2 seconds, then erase the screen. During the 2 seconds while that tongue-twister appears on the screen, can you recite the entire twister out loud? Try it! If you don't recite it properly, you'll sound like a mumbling moron yourself!

DO...LOOP

This program makes the computer print the word "love" once:

```
PRINT "love"
```

This fancier program makes the computer print the word "love" *three* times:

```
PRINT "love"
PRINT "love"
PRINT "love"
```

When you run that program, the computer will print:

```
love
love
love
```

Let's make the computer print the word "love" *many* times. To do that, we must make the computer do this line many times:

```
PRINT "love"
```

To make the computer do the line many times, say "DO" above the line and say "LOOP" below it, so the program looks like this:

```
DO
    PRINT "love"
LOOP
```

Between the words DO and LOOP, the line being repeated (PRINT "love") should be indented. The computer will indent that line for you automatically, when you press the Enter key at that line's end.

When you run that program, the computer will PRINT "love" many times, so it will print:

```
love
love
love
love
love
love
love
love
love
etc.
```

The computer will print "love" on every line of your screen's window.

But even when the screen's window is full of "love", the computer won't stop: the computer will try to print even more loves onto your screen! The computer will lose control of itself and try to devote its entire life to making love! The computer's mind will spin round and round, always circling back to the thought of making love again!

Since the computer's thinking keeps circling back to the same thought, the computer is said to be in a **loop**. In that program, the **DO** means "do what's underneath & indented"; the **LOOP** means "loop back and do it again". The lines that say DO and LOOP — and the lines between them — form a loop, which is called a **DO loop**.

To stop the computer's lovemaking madness, you must give the computer a "jolt" that will put it out of its misery and get it out of the loop. To jolt the computer out of the program, **abort** the program. To abort the program, close the black window (by clicking its X button). That makes the computer stop running your program; it will **break out of your program**; it will **abort your program** and show you the blue screen so you can edit the program.

In that program, since the computer tries to go round and round the loop forever, the loop is called **infinite**. The only way to stop an infinite loop is to abort it.

Semicolon For more lovely fun, put a semicolon after "love", so the program looks like this:

```
DO
    PRINT "love";
LOOP
```

The semicolon makes the computer print "love" *next to* "love", so the screen looks like this:

```
lovelovelovelovelovelovelovelovelovelovelovelovelovelovelovelovelovelove
lovelovelovelovelovelovelovelovelovelovelovelovelovelovelovelovelovelove
lovelovelovelovelovelovelovelovelovelovelovelovelovelovelovelovelovelove
etc.
```

If you put a space after love, like this —

```
DO
    PRINT "love ";
LOOP
```

the computer will put a space after each love:

```
love love love love love love love love love love love love love love love
love love love love love love love love love love love love love love love
love love love love love love love love love love love love love love love
etc.
```

Bigger DO loop Run this program:

```
DO
    PRINT "dog";
    PRINT "cat";
LOOP
```

Lines 2 & 3 (which say PRINT "dog" and PRINT "cat") make the computer print "dog" and then print "cat" next to it. Since those lines are between the words DO and LOOP, the computer does them repeatedly — PRINT "dog", then PRINT "cat", then PRINT "dog" again, then PRINT "cat" again — so the screen looks like this:

```
dogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcat
dogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcat
dogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcat
etc.
```

The computer will keep printing "dog" and "cat" until you abort the program.

Blinking Let's make the screen say "Stop pollution!" and make that message blink.

To do that, flash "Stop pollution!" onto the screen for 2 seconds, then turn that message off for 1 second (so the screen is blank), then flash that message on again. Here's the program:

```
WIDTH 40
DO
    PRINT "Stop pollution!"
    SLEEP 2
    CLS
    SLEEP 1
LOOP
```

The top line (WIDTH 40) makes sure all characters appear dramatically huge.

Lines 3 & 4 (which say PRINT "Stop pollution!" and SLEEP 2) flash the message "Stop pollution!" onto the screen and keep it on the screen for 2 seconds. The next pair of lines (CLS and SLEEP 1) make the screen become blank for 1 second. Since those lines are all between the words DO and LOOP, the computer does them repeatedly — flash message then blank, flash message then blank, flash message then blank — so your screen becomes a continually flashing sign.

The screen will keep flashing until you abort the program.

Instead of saying "Stop pollution!", edit that program so it flashes your favorite phrase instead, such as "Save the whales!" or "Marry me!" or "Keepa youse hands offa my computer!" or "Jesus saves — America spends!" or "In God we trust — all others pay cash" or "Please wait — Dr. Doom will be with you shortly" or "Let's rock!" or whatever else turns you on. Make the computer say whatever you feel emotional about. Like a dog, the computer imitates its master's personality. If your computer acts "cold and heartless", it's because *you* are!

In the program, you typed just a few lines; but since the bottom line said LOOP, the computer does an infinite loop. By saying LOOP, you can make the computer do an infinite amount of work. Moral: **the computer can turn a finite amount of human energy into an infinite amount of good**. Putting it another way: **the computer can multiply your abilities by infinity**.

Line numbers

You can number the lines in your program. For example, instead of typing —

```
DO
    PRINT "love"
LOOP
```

you can type:

```
1 DO
    2 PRINT "love"
3 LOOP
```

Then when you're discussing your program with another programmer, you can talk about "line 2" instead of having to talk about "the line in the middle of the DO loop".

Selective numbering You can number just the lines you're planning to discuss.

For example, if you're planning to discuss just lines 1 and 3, you can number just those lines:

```
1 DO
    PRINT "love"
3 LOOP
```

Or if you prefer, number them like this:

```
1 DO
    PRINT "love"
2 LOOP
```

Decimal numbers Here's a simple program:

```
1 CLS
2 PRINT "Life's a blast!"
```

Suppose you want to edit it and insert an extra numbered line between 1 and 2. You can give the extra line a decimal number, such as 1.5:

```
1 CLS
1.5 PRINT "I hope..."
2 PRINT "Life's a blast!"
```

Number by tens Instead of making line numbers be 1, 2, 3, etc., make the line numbers be 10, 20, 30, etc., like this:

```
10 CLS
20 PRINT "Life's a blast!"
```

Then you can insert an extra line without using decimals:

```
10 CLS
15 PRINT "I hope..."
20 PRINT "Life's a blast!"
```

GOTO

This program makes the computer print the words "dog" and "cat" repeatedly:

```
DO
    PRINT "dog";
    PRINT "cat";
LOOP
```

It makes the computer print:

```
dogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcat
dogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcat
dogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcatdogcat
etc.
```

This program does the same thing:

```
10 PRINT "dog";
PRINT "cat";
GOTO 10
```

The top line (which is numbered 10) makes the computer print "dog". The next line makes the computer print "cat". The bottom line makes the computer GO back TO line 10, so the computer will print "dog" again, then "cat again", then GO back TO line 10 again, then print "dog" again, then "cat" again, etc. The computer will print "dog" and "cat" repeatedly, until you abort the program.

This program does the same thing:

```
joe: PRINT "dog";
PRINT "cat";
GOTO joe
```

The top line (named "joe") makes the computer print "dog". The next line makes the computer print "cat". The bottom line makes the computer GO back TO the line named "joe". In that program, "joe" is called the second line's **label**.

One word "GOTO" is one word. You're supposed to type "GOTO", not "GO TO". If you accidentally type "GO TO" instead of "GOTO", here's what happens when you press the Enter key at the end of that line: the computer will gripe by saying "Syntax error".

Skip ahead Did you ever dream about having a picnic in the woods? This program expresses that dream:

```
PRINT "Let's munch"
PRINT "sandwiches under"
PRINT "the trees!"
```

It makes the computer print:

```
Let's munch
sandwiches under
the trees!
```

Let's turn that dream into a nightmare where we all become giant termites. To do that, insert the shaded items:

```
PRINT "Let's munch"
GOTO 10
PRINT "sandwiches under"
10 PRINT "the trees!"
```

The computer begins by printing "Let's munch". Then the computer does GOTO 10, which makes the computer GO skip down TO line 10, which prints "the trees!" So the program makes the computer print just this:

```
Let's munch
the trees!
```

Is GOTO too powerful? The word GOTO gives you great power: if you say GO back TO line 10, the computer will create a loop (as if you'd said DO...LOOP); if you say GO skip down TO line 10, the computer will skip over several lines of your program.

Since the word GOTO is so powerful, programmers fear it! Programmers know that the slightest error in using that powerful word will make the programs act very bizarre! Programmers feel more comfortable using milder words instead (such as DO...LOOP), which are safer and rarely get botched up. Since the word GOTO is scary, many computer teachers prohibit students from using it, and many companies fire programmers who say GOTO instead of DO...LOOP.

But saying GOTO is fine when you've learned how to control the power! Though I'll usually say DO...LOOP instead of GOTO, I'll say GOTO in certain situations where saying DO...LOOP would be awkward.

Life as an infinite loop

A program that makes the computer do the same thing again and again forever is an infinite loop.

Some humans act just like computers. Those humans do the same thing again and again.

> Every morning they GOTO work, and every evening they GOTO home. GOTO work, GOTO home, GOTO work, GOTO home,… Their lives are sheer drudgery. They're caught in an infinite loop.

Go to your bathroom, get your bottle of shampoo, and look at the instructions on the back. A typical bottle has three instructions:

```
Lather.
Rinse.
Repeat.
```

Those instructions say to lather, then rinse, then repeat — which means to lather again, then rinse again, then repeat again — which means to lather again, then rinse again, then repeat again.… If you follow those instructions, you'll never finish washing your hair! The instructions are an infinite loop! The instructions are a program: they program you to use lots of shampoo! That's how infinite loops help sell shampoo.

END

To make the computer skip the bottom part of your program, say END:

```
PRINT "She smells"
END
PRINT "of perfume"
```

When you run that program (by pressing the F5 key), the computer will print "She smells" and then end, without printing "of perfume".

Suppose you write a program that prints a long message, and you want to run the program several times (so several of your friends get the message). If one of your friends would be offended by the end of your message, send that friend an *abridged* message! Here's how: put END above the part of the message that you want the computer to omit — or skip past that part by saying GOTO.

Multi-statement line

In your program, **a line can contain several statements separated by colons**, like this:

```
CLS: PRINT "I dream": PRINT "of you"
```

When you run that program, the computer will CLear the Screen, then PRINT "I dream", then PRINT "of you". Altogether, the computer will print:

```
I dream
of you
```

If you want to number the line, put the number at the far left, like this:

```
10 CLS: PRINT "I dream": PRINT "of you"
```

Variables

A letter can stand for a number. For example, x can stand for the number 47, as in this program:

```
x = 47
PRINT x + 2
```

The top line says x stands for the number 47. In other words, x is a name for the number 47.

The bottom line says to print x + 2. Since x is 47, the x + 2 is 49; so the computer will print 49. That's the only number the computer will print; it will not print 47.

Jargon

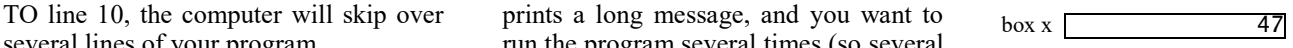
A letter that stands for a number is called a **numeric variable**. In that program, x is a numeric variable; it stands for the number 47. The **value** of x is 47.

In that program, the statement "x = 47" is called an **assignment statement**, because it **assigns** 47 to x.

A variable is a box

When you run that program, here's what happens inside the computer.

The computer's random-access memory (RAM) consists of electronic boxes. When the computer encounters the line "x = 47", the computer puts 47 into box x, like this:



Then when the computer encounters the line "PRINT x + 2", the computer prints what's in box x, plus 2; so the computer prints 49.

Faster typing

Instead of typing —

```
x = 47
```

you can type just this:

```
x=47
```

At the end of that line, when you press the Enter key, the computer will automatically put spaces around the equal sign.

Since the computer automatically capitalizes computer words (such as CLS), automatically puts spaces around symbols (such as + and =), and lets you type a question mark instead of the word PRINT, you can type just this:

```
cls
x=47
?x+2
```

When you press Enter at the end of each line, the computer will automatically convert your typing to this:

```
CLS
x = 47
PRINT x + 2
```

More examples

Here's another example:

```
y = 38
PRINT y - 2
```

The top line says y is a numeric variable that stands for the number 38.

The bottom line says to print y - 2. Since y is 38, the y - 2 is 36; so the computer will print 36.

Example:

```
b = 8
PRINT b * 3
```

The top line says b is 8. The bottom line says to print b * 3, which is 8 * 3, which is 24; so the computer will print 24.

One variable can define another:

```
n = 6
d = n + 1
PRINT n * d
```

The top line says n is 6. The next line says d is n + 1, which is 6 + 1, which is 7; so d is 7. The bottom line says to print n * d, which is 6 * 7, which is 42; so the computer will print 42.

Changing a value

A value can change:

```
k = 4
k = 9
PRINT k * 2
```

The top line says k's value is 4. The next line changes k's value to 9, so the bottom line prints 18.

When you run that program, here's what happens inside the computer's RAM. The top line (k = 4) makes the computer put 4 into box k:

box k [4]

The next line (k = 9) puts 9 into box k. The 9 replaces the 4:

box k [9]

That's why the bottom line (PRINT k * 2) prints 18.

Hassles

When writing an equation (such as x = 47), here's what you must put before the equal sign: the name of just one box (such as x). So **before the equal sign, put one variable**:

```
Allowed:     d = n + 1  (d is one variable)
Not allowed: d - n = 1  (d-n is two variables)
Not allowed: 1 = d - n  (1 is not a variable)
```

The variable on the left side of the equation is the only one that changes. For example, the statement d = n + 1 changes the value of d but not n. The statement b = c changes the value of b but not c:

```
b = 1
c = 7
b = c
PRINT b + c
```

The third line changes b, to make it equal c; so b becomes 7. Since both b and c are now 7, the bottom line prints 14.

"b = c" versus "c = b" Saying "b = c" has a different effect from "c = b". That's because "b = c" changes the value of b (but not c); saying "c = b" changes the value of c (but not b).

Compare these programs:

```
b = 1          b = 1
c = 7          c = 7
b = c          c = b
PRINT b + c    PRINT b + c
```

In the left program (which you saw before), the third line changes b to 7, so both b and c are 7. The bottom line prints 14.

In the right program, the third line changes c to 1, so both b and c are 1. The bottom line prints 2.

While you run those programs, here's what happens inside the computer's RAM. For both programs, the second and third lines do this:

box b [1]

box c [7]

In the left program, the fourth line makes the number in box b become 7 (so both boxes contain 7, and the bottom line prints 14). In the right program, the fourth line makes the number in box c become 1 (so both boxes contain 1, and the bottom line prints 2).

When to use variables

Here's a practical example of when to use variables.

Suppose you're selling something that costs $1297.43, and you want to do these calculations:

```
multiply   $1297.43 by 2
multiply   $1297.43 by .05
add        $1297.43 to $483.19
divide     $1297.43 by 37
```

To do those four calculations, you could run this program:

```
PRINT 1297.43 * 2; 1297.43 * .05; 1297.43 + 483.19; 1297.43 / 37
```

But that program's silly, since it contains the number 1297.43 four times. This program's briefer, because it uses a variable:

```
c = 1297.43
PRINT c * 2; c * .05; c + 483.19; c / 37
```

So **whenever you need to use a number several times, turn the number into a variable**, which will make your program briefer.

String variables

A string is any collection of characters, such as "I love you". Each string must be in quotation marks.

A letter can stand for a string — if you put a dollar sign after the letter, like this:

```
g$ = "down"
PRINT g$
```

The top line says g$ stands for the string "down". The bottom line prints:

```
down
```

In that program, g$ is a variable. Since it stands for a string, it's called a **string variable**.

Every string variable must end with a dollar sign. The dollar sign is supposed to remind you of a fancy S, which stands for String. The second line is pronounced, "g String is down".

If you're paranoid, you'll love this program:

```
t$ = "They're laughing at you!"
PRINT t$
PRINT t$
PRINT t$
```

The top line says t$ stands for the string "They're laughing at you!" The later lines make the computer print:

```
They're laughing at you!
They're laughing at you!
They're laughing at you!
```

Spaces between strings

Examine this program:

```
s$ = "sin"
k$ = "king"
PRINT s$; k$
```

The bottom line says to print "sin" and then "king", so the computer will print:

```
sinking
```

Let's make the computer leave a space between "sin" and "king", so the computer prints:

```
sin king
```

To make the computer leave that space, choose one of these methods.…

Method 1 Instead of saying s$ = "sin", make s$ include a space:

```
s$ = "sin "
```

Method 2 Instead of saying k$ = "king", make k$ include a space:

```
k$ = " king"
```

Method 3 Instead of saying —

```
PRINT s$; k$
```

say to print s$ then a space then k$:

```
PRINT s$; " "; k$
```

Nursery rhymes

The computer can recite nursery rhymes:

```
p$ = "Peas porridge "
PRINT p$; "hot!"
PRINT p$; "cold!"
PRINT p$; "in the pot,"
PRINT "Nine days old!"
```

The top line says p$ stands for "Peas porridge ". The later lines make the computer print:

```
Peas porridge hot!
Peas porridge cold!
Peas porridge in the pot,
Nine days old!
```

This program prints a fancier rhyme:

```
h$ = "Hickory, dickory, dock! "
m$ = "THE MOUSE (squeak! squeak!) "
c$ = "THE CLOCK (tick! tock!) "
PRINT h$
PRINT m$; "ran up "; c$
PRINT c$; "struck one"
PRINT m$; "ran down"
PRINT h$
```

Lines 1-3 define h$, m$, and c$. The later lines make the computer print:

```
Hickory, dickory, dock!
THE MOUSE (squeak! squeak!) ran up THE CLOCK (tick! tock!)
THE CLOCK (tick! tock!) struck one
THE MOUSE (squeak! squeak!) ran down
Hickory, dickory, dock!
```

Undefined variables

If you don't define a numeric variable, the computer assumes it's zero:

```
PRINT r
```

Since r hasn't been defined, the line prints zero.

The computer doesn't look ahead:

```
PRINT j
j = 5
```

When the computer encounters the top line (PRINT j), it doesn't look ahead to find out what j is. As of the top line, j is still undefined, so the computer prints zero.

If you don't define a string variable, the computer assumes it's blank:

```
PRINT f$
```

Since f$ hasn't been defined, the "PRINT f$" makes the computer print a line that says nothing; the line the computer prints is blank.

Long variable names

A numeric variable's name can be a letter (such as x) or a longer combination of characters, such as:

```
profit.in.2001.before.November.promotion
```

For example, you can type:

```
profit.in.2001.before.November.promotion = 3497.18
profit.in.2001 = profit.in.2001.before.November.promotion + 6214.27
PRINT profit.in.2001
```

The computer will print:

```
 9711.45
```

The variable's name can be quite long: up to 40 characters!

The first character in the name must be a letter. The remaining characters can be letters, digits, or periods.

The name must not be a word that has a special meaning to the computer. For example, the name cannot be "print".

If the variable stands for a string, the name can have up to 40 characters, followed by a dollar sign, making a total of 41 characters, like this:

```
my.job.in.2001.before.November.promotion$
```

Beginners are usually too lazy to type long variable names, so beginners use variable names that are short. But when you become a pro and write a long, fancy program containing hundreds of lines and hundreds of variables, you should use long variable names to help you remember each variable's purpose.

In this book, I'll use short variable names in short programs (so you can type those programs quickly) but long variable names in long programs (so you can keep track of which variable is which).

Programmers employed at Microsoft capitalize each word's first letter and omit the periods. So instead of writing —

```
my.job.in.2001.before.November.promotion$
```

those programmers write:

```
MyJobIn2001BeforeNovemberPromotion$
```

That's harder to read; but since Microsoft's chairman is Bill Gates, who's the richest person in America, he can do whatever he pleases!

INPUT

Humans ask questions; so to turn the computer into a human, you must make it ask questions too. **To make the computer ask a question, use the word INPUT.**

This program makes the computer ask for your name:

```
INPUT "What is your name"; n$
PRINT "I adore anyone whose name is "; n$
```

When the computer sees that INPUT line, the computer asks "What is your name?" then waits for you to answer the question. Your answer will be called n$. For example, if you answer Maria, then n$ is Maria. The bottom line makes the computer print:

```
I adore anyone whose name is Maria
```

When you run that program, here's the whole conversation that occurs between the computer and you; I've underlined the part typed by you.…

```
Computer asks for your name: What is your name? Maria
Computer praises your name: I adore anyone whose name is Maria
```

Try that example. Be careful! When you type the INPUT line, make sure you type the two quotation marks and the semicolon. You don't have to type a question mark: when the computer runs your program, it will automatically put a question mark at the end of the question.

Just for fun, run that program again and pretend you're somebody else.…

```
Computer asks for your name: What is your name? Bud
Computer praises your name:  I adore anyone whose name is Bud
```

When the computer asks for your name, if you say something weird, the computer will give you a weird reply.…

```
Computer asks:   What is your name? none of your business!
Computer replies: I adore anyone whose name is none of your business!
```

College admissions

This program prints a letter, admitting you to the college of your choice:

```
INPUT "What college would you like to enter"; c$
PRINT "Congratulations!"
PRINT "You have just been admitted to "; c$
PRINT "because it fits your personality."
PRINT "I hope you go to "; c$; "."
PRINT "           Respectfully yours,"
PRINT "           The Dean of Admissions"
```

When the computer sees the INPUT line, the computer asks "What college would you like to enter?" and waits for you to answer. Your answer will be called c$. If you'd like to be admitted to Harvard, you'll be pleased.…

```
Computer asks you:   What college would you like to enter? Harvard
Computer admits you: Congratulations!
                     You have just been admitted to Harvard
                     because it fits your personality.
                     I hope you go to Harvard.
                               Respectfully yours,
                               The Dean of Admissions
```

You can choose any college you wish:

```
Computer asks you:   What college would you like to enter? Hell
Computer admits you: Congratulations!
                     You have just been admitted to Hell
                     because it fits your personality.
                     I hope you go to Hell.
                               Respectfully yours,
                                The Dean of Admissions
```

That program consists of three parts:

1. The computer begins by asking you a question ("What college would you like to enter?"). The computer's question is called the **prompt**, because it prompts you to answer.

2. Your answer (the college's name) is called **your input**, because it's information that you're *putting into* the computer.

3. The computer's reply (the admission letter) is called the **computer's output**, because it's the final answer that the computer puts out.

INPUT versus PRINT

The word INPUT is the opposite of the word PRINT.

The word PRINT makes the computer print information out. The word INPUT makes the computer take information in.

What the computer prints out is called the **output**. What the computer takes in is called **your input**.

Input and Output are collectively called **I/O**, so the INPUT and PRINT statements are called **I/O statements**.

Once upon a time

Let's make the computer write a story, by filling in the blanks:

Once upon a time, there was a youngster named _____ (your name)

who had a friend named _____ (friend's name).

_____ (your name) wanted to _____ (verb (such as "pat")) _____ (friend's name),

but _____ (friend's name) didn't want to _____ (verb (such as "pat")) _____ (your name)!

Will _____ (your name) _____ (verb (such as "pat")) _____ (friend's name)?

Will _____ (friend's name) _____ (verb (such as "pat")) _____ (your name)?

To find out, come back and see the next exciting episode

of _____ (your name) and _____ (friend's name)!

To write the story, the computer must ask for your name, your friend's name, and a verb. To make the computer ask, your program must say INPUT:

```
INPUT "What is your name"; y$
INPUT "What's your friend's name"; f$
INPUT "In 1 word, say something you can do to your friend"; v$
```

Then make the computer print the story:

```
PRINT "Here's my story...."
PRINT "Once upon a time, there was a youngster named "; y$
PRINT "who had a friend named "; f$; "."
PRINT y$; " wanted to "; v$; " "; f$; ","
PRINT "but "; f$; " didn't want to "; v$; " "; y$; "!"
PRINT "Will "; y$; " "; v$; " "; f$; "?"
PRINT "Will "; f$; " "; v$; " "; y$; "?"
PRINT "To find out, come back and see the next exciting episode"
PRINT "of "; y$; " and "; f$; "!"
```

Here's a sample run:

```
What's your name? Dracula
What's your friend's name? Madonna
In 1 word, say something you can do to your friend? bite
Here's my story....
Once upon a time, there was a youngster named Dracula
who had a friend named Madonna.
Dracula wanted to bite Madonna,
but Madonna didn't want to bite Dracula!
Will Dracula bite Madonna?
Will Madonna bite Dracula?
To find out, come back and see the next exciting episode
of Dracula and Madonna!
```

Here's another run:

```
What's your name? Superman
What's your friend's name? King Kong
In 1 word, say something you can do to your friend? tickle
Here's my story....
Once upon a time, there was a youngster named Superman
Who had a friend named King Kong.
Superman wanted to tickle King Kong,
but King Kong didn't want to tickle Superman!
Will Superman tickle King Kong?
Will King Kong tickle Superman?
To find out, come back and see the next exciting episode
of Superman and King Kong!
```

Try it: put in your own name, the name of your friend, and something you'd like to do to your friend.

Contest

The following program prints a certificate saying you won a contest. Since the program contains many variables, it uses long variable names to help you remember which variable is which:

```
INPUT "What's your name"; you$
INPUT "What's your friend's name"; friend$
INPUT "What's the name of another friend"; friend2$
INPUT "Name a color"; color$
INPUT "Name a place"; place$
INPUT "Name a food"; food$
INPUT "Name an object"; object$
INPUT "Name a part of the body"; part$
INPUT "Name a style of cooking (such as baked or fried)"; style$
PRINT
PRINT "Congratulations, "; you$; "!"
PRINT "You've won the beauty contest, because of your gorgeous "; part$; "."
PRINT "Your prize is a "; color$; " "; object$
PRINT "plus a trip to "; place$; " with your friend "; friend$
PRINT "plus--and this is the best part of all--"
PRINT "dinner for the two of you at "; friend2$; "'s new restaurant,"
PRINT "where "; friend2$; " will give you ";
PRINT "all the "; style$; " "; food$; " you can eat."
PRINT "Congratulations, "; you$; ", today's your lucky day!"
PRINT "Now everyone wants to kiss your award-winning "; part$; "."
```

Here's a sample run:

```
What's your name? Long John Silver
What's your friend's name? the parrot
What's the name of another friend? Jim
Name a color? gold
Name a place? Treasure Island
Name a food? rum-soaked coconuts
Name an object? chest of jewels
Name a part of the body? missing leg
Name a style of cooking (such as baked or fried)? barbecued

Congratulations, Long John Silver!
You've won the beauty contest, because of your gorgeous missing leg.
Your prize is a gold chest of jewels
plus a trip to Treasure Island with your friend the parrot
plus--and this is the best part of all--
dinner for the two of you at Jim's new restaurant,
where Jim will give you all the barbecued rum-soaked coconuts you can eat.
Congratulations, Long John Silver, today's your lucky day!
Now everyone wants to kiss your award-winning missing leg.
```

Numeric input

This program makes the computer predict your future:

```
PRINT "I predict what'll happen to you in the year 2020!"
INPUT "In what year were you born"; y
PRINT "In the year 2020, you'll turn"; 2020 - y; "years old."
```

Here's a sample run:

```
I predict what'll happen to you in the year 2020!
In what year were you born? 1962
In the year 2020, you'll turn 58 years old.
```

Suppose you're selling tickets to a play. Each ticket costs $2.79. (You decided $2.79 would be a nifty price, because the cast has 279 people.) This program finds the price of multiple tickets:

```
INPUT "How many tickets"; t
PRINT "The total price is $"; t * 2.79
```

This program tells you how much the "oil crisis" costs you, when you drive your car:

```
INPUT "How many miles do you want to drive"; m
INPUT "How many pennies does a gallon of gas cost"; p
INPUT "How many miles-per-gallon does your car get"; r
PRINT "The gas for your trip will cost you $"; m * p / (r * 100)
```

Here's a sample run:

```
How many miles do you want to drive? 400
How many pennies does a gallon of gas cost? 204.9
How many miles-per-gallon does your car get? 31
The gas for your trip will cost you $ 26.43871
```

Conversion

This program converts feet to inches:

```
INPUT "How many feet"; f
PRINT f; "feet ="; f * 12; "inches"
```

Here's a sample run:

```
How many feet? 3
 3 feet = 36 inches
```

Trying to convert to the metric system? This program converts inches to centimeters:

```
INPUT "How many inches"; i
PRINT i; "inches ="; i * 2.54; "centimeters"
```

Nice day today, isn't it? This program converts the temperature from Celsius to Fahrenheit:

```
INPUT "How many degrees Celsius"; c
PRINT c; "degrees Celsius ="; c * 1.8 + 32; "degrees Fahrenheit"
```

Here's a sample run:

```
How many degrees Celsius? 20
 20 degrees Celsius = 68 degrees Fahrenheit
```

See, you can write the *Guide* yourself! Just hunt through any old math or science book, find any old formula (such as f = c * 1.8 + 32), and turn it into a program.

Conditions

Here's how to restrict the computer, so it performs certain lines only under certain conditions.…

IF

Let's write a program so that if the human is less than 18 years old, the computer will say:

```
You are still a minor.
```

Here's the program:

```
INPUT "How old are you"; age
IF age < 18 THEN PRINT "You are still a minor"
```

The top line makes the computer ask "How old are you" and wait for the human to type an age. Since **the symbol for "less than" is "<"**, the bottom line says: if the age is less than 18, then print "You are still a minor".

Go ahead! Run that program! The computer begins the conversation by asking:

```
How old are you?
```

Try saying you're 12 years old, by typing a 12, so the screen looks like this:

```
How old are you? 12
```

When you finish typing the 12 and press the Enter key at the end of it, the computer will reply:

```
You are still a minor
```

Try running that program again, but this time try saying you're 50 years old instead of 12, so the screen looks like this:

```
How old are you? 50
```

When you finish typing the 50 and press the Enter key at the end of it, the computer will *not* say "You are still a minor". Instead, the computer will say nothing — since we didn't teach the computer how to respond to adults yet!

In that program, the most important line says:

```
IF age < 18 THEN PRINT "You are still a minor"
```

That line contains the words IF and THEN. **Whenever you say IF, you must also say THEN**. Do *not* put a comma before THEN. What comes between IF and THEN is called the **condition**; in that example, the condition is "age < 18". If the condition is true (if age is really less than 18), the computer does the **action**, which comes after the word THEN and is:

```
PRINT "You are still a minor"
```

ELSE

Let's teach the computer how to respond to adults.

Here's how to program the computer so that if the age is less than 18, the computer will say "You are still a minor", but if the age is *not* less than 18 the computer will say "You are an adult" instead:

```
INPUT "How old are you"; age
IF age < 18 THEN PRINT "You are still a minor" ELSE PRINT "You are an adult"
```

In programs, **the word "ELSE" means "otherwise"**. That program's bottom line means: if the age is less than 18, then print "You are still a minor"; otherwise (if the age is *not* less than 18), print "You are an adult". So the computer will print "You are still a minor" or else print "You are an adult", depending on whether the age is less than 18.

Try running that program! If you say you're 50 years old, so the screen looks like this —

```
How old are you? 50
```

the computer will reply by saying:

```
You are an adult
```

Multi-line IF

If the age is less than 18, here's how to make the computer print "You are still a minor" and also print "Ah, the joys of youth":

```
IF age < 18 THEN PRINT "You are still a minor": PRINT "Ah, the joys of youth"
```

Here's a more sophisticated way to say the same thing:

```
IF age < 18 THEN
    PRINT "You are still a minor"
    PRINT "Ah, the joys of youth"
END IF
```

That sophisticated way (in which you type 4 short lines instead of a single long line) is called a **multi-line IF** (or a **block IF**).

In a multi-line IF:

The top line must say IF and THEN (with nothing after THEN).

The middle lines should be indented; they're called the **block** and typically say PRINT.

The bottom line must say END IF.

In the middle of a multi-line IF, you can say ELSE:

```
IF age < 18 THEN
    PRINT "You are still a minor"
    PRINT "Ah, the joys of youth"
ELSE
    PRINT "You are an adult"
    PRINT "We can have adult fun"
END IF
```

That means: if the age is less than 18, then print "You are still a minor" and "Ah, the joys of youth"; otherwise (if age *not* under 18) print "You are an adult" and "We can have adult fun".

ELSEIF

Let's say this:

If age is under 18, print "You're a minor".
If age is *not* under 18 but is under 100, print "You're a typical adult".
If age is *not* under 100 but is under 125, print "You're a centenarian".
If age is *not* under 125, print "You're a liar".

Here's how:

```
IF age < 18 THEN
    PRINT "You're a minor"
ELSEIF age < 100 THEN
    PRINT "You're a typical adult"
ELSEIF age < 125 THEN
    PRINT "You're a centenarian"
ELSE
    PRINT "You're a liar"
END IF
```

One word "ELSEIF" is one word. Type "ELSEIF", not "ELSE IF". If you accidentally type "ELSE IF", the computer will gripe.

SELECT

Let's turn your computer into a therapist!

To make the computer ask the patient, "How are you?", begin the program like this:

```
INPUT "How are you"; a$
```

Make the computer continue the conversation by responding this way:

If the patient says "fine", print "That's good!"
If the patient says "lousy" instead, print "Too bad!"
If the patient says anything else instead, print "I feel the same way!"

To accomplish all that, you can use a multi-line IF:

```
IF a$ = "fine" THEN
    PRINT "That's good!"
ELSEIF a$ = "lousy" THEN
    PRINT "Too bad!"
ELSE
    PRINT "I feel the same way!"
END IF
```

Instead of typing that multi-line IF, you can type this **SELECT statement** instead, which is briefer and simpler:

```
SELECT CASE a$
    CASE "fine"
        PRINT "That's good!"
    CASE "lousy"
        PRINT "Too bad!"
    CASE ELSE
        PRINT "I feel the same way!"
END SELECT
```

Like a multi-line IF, a SELECT statement consumes several lines. The top line of that SELECT statement tells the computer to analyze a$ and SELECT one of the CASEs from the list underneath. That list is indented and says:

In the case where a$ is "fine", print "That's good!"
In the case where a$ is "lousy", print "Too bad!"
In the case where a$ is anything else, print "I feel the same way!"

Every SELECT statement's bottom line must say END SELECT.

Complete program Here's a complete program:

```
INPUT "How are you"; a$
SELECT CASE a$
    CASE "fine"
        PRINT "That's good!"
    CASE "lousy"
        PRINT "Too bad!"
    CASE ELSE
        PRINT "I feel the same way!"
END SELECT
PRINT "I hope you enjoyed your therapy.  Now you owe $50."
```

The top line makes the computer ask the patient, "How are you?" The next several lines are the SELECT statement, which makes the computer analyze the patient's answer and print "That's good!" or "Too bad!" or else "I feel the same way!"

Regardless of what the patient and computer said, that program's bottom line always makes the computer end the conversation by printing:

```
I hope you enjoyed your therapy.  Now you owe $50.
```

In that program, try changing the strings to make the computer print smarter remarks, become a better therapist, and charge even more money.

Error trap This program makes the computer discuss human sexuality:

```
10 INPUT "Are you male or female"; a$
SELECT CASE a$
    CASE "male"
        PRINT "So is Frankenstein!"
    CASE "female"
        PRINT "So is Mary Poppins!"
    CASE ELSE
        PRINT "Please say male or female!"
        GOTO 10
END SELECT
```

The top line (which is numbered 10) makes the computer ask, "Are you male or female?"

The remaining lines are a SELECT statement that analyzes the human's response. If the human claims to be "male", the computer prints "So is Frankenstein!" If the human says "female" instead, the computer prints "So is Mary Poppins!" If the human says anything else (such as "not sure" or "super-male" or "macho" or "none of your business"), the computer does the CASE ELSE, which makes the computer say "Please say male or female!" and then go back to line 10, which makes the computer ask again, "Are you male or female?"

In that program, the CASE ELSE is called an **error handler** (or **error-handling routine** or **error trap**), since its only purpose is to handle human error (a human who says neither "male" nor "female"). Notice that the error handler begins by printing a gripe message ("Please say male or female!") and then lets the human try again (GOTO 10).

In QBasic, the GOTO statements are used rarely: they're used mainly in error handlers, to let the human try again.

Let's extend that program's conversation. If the human says "female", let's make the computer say "So is Mary Poppins!", then ask "Do you like her?", then continue the conversation this way:

```
If human says "yes", make computer say "I like her too. She is my mother."
If human says "no", make computer say "I hate her too. She owes me a dime."
If human says neither "yes" nor "no", make computer handle that error.
```

To accomplish all that, insert the shaded lines into the program:

```
10 INPUT "Are you male or female"; a$
SELECT CASE a$
    CASE "male"
        PRINT "So is Frankenstein!"
    CASE "female"
        PRINT "So is Mary Poppins!"
        20 INPUT "Do you like her"; b$
        SELECT CASE b$
            CASE "yes"
                PRINT "I like her too.  She is my mother.  "
            CASE "no"
                PRINT "I hate her too.  She owes me a dime."
            CASE ELSE
                PRINT "Please say yes or no!"
                GO TO 20
        END SELECT
    CASE ELSE
        PRINT "Please say male or female!"
        GOTO 10
END SELECT
```

Weird programs The computer's abilities are limited only by your own imagination — and your weirdness. Here are some weird programs from weird minds.…

Like a human, the computer wants to meet new friends. This program makes the computer show its true feelings:

```
10 INPUT "Are you my friend"; a$
SELECT CASE a$
    CASE "yes"
        PRINT "That's swell."
    CASE "no"
        PRINT "Go jump in a lake."
    CASE ELSE
        PRINT "Please say yes or no."
        GO TO 10
END SELECT
```

When you run that program, the computer asks "Are you my friend?" If you say "yes", the computer says "That's swell." If you say "no", the computer says "Go jump in a lake."

The most inventive programmers are kids. A sixth-grade girl wrote this program, to test your honesty:

```
PRINT "FKGJDFGKJ*#K$JSLF*/#$()$&(IKJNHBGD52:?./KSDJK$E(EF$#/JIK(*"
PRINT "FASDFJKL:JFRFVFJUNJI*&()JNE$#SKI#(!SERF HHW NNWAZ MAME !!!"
PRINT "ZBB%%%%%##)))))FESDFJK DSFE N.D.JJUJASD EHWLKD******"
10 INPUT "Do you understand what I said"; a$
SELECT CASE a$
    CASE "no"
        PRINT "Sorry to have bothered you."
    CASE "yes"
        PRINT "SSFJSLFKDJFL++++45673456779XSDWFEF/#$&**()--!!ZZXX"
        PRINT "###EDFHTG NVFDF MKJK ==+--*$&% #RHFS SES DOPE DSBS"
        INPUT "Okay, what did I say"; b$
        PRINT "You are a liar, a liar, a big fat liar!"
    CASE ELSE
        PRINT "Please say yes or no."
        GO TO 10
END SELECT
```

When you run that program, lines 1-3 print nonsense. Then the computer asks whether you understand that stuff. *If you're honest* and answer "no", the computer will apologize. But *if you pretend that you understand the nonsense* and answer "yes", the computer will print more nonsense, challenge you to translate it, wait for you to fake a translation, and then scold you for lying.

Fancy IF conditions

A Daddy wrote a program for his 5-year-old son, John. When John runs the program and types his name, the computer asks "What's 2 and 2?" If John answers 4, the computer says "No, 2 and 2 is 22". If he runs the program again and answers 22, the computer says "No, 2 and 2 is 4". No matter how many times he runs the program and how he answers the question, the computer says he's wrong. But when Daddy runs the program, the computer replies, "Yes, Daddy is always right".

Here's how Daddy programmed the computer:

```
INPUT "What's your name"; n$
INPUT "What's 2 and 2"; a
IF n$ = "Daddy" THEN PRINT "Yes, Daddy is always right": END
IF a = 4 THEN PRINT "No, 2 and 2 is 22" ELSE PRINT "No, 2 and 2 is 4"
```

Different relations You can make the IF clause very fancy:

IF clause	Meaning
`IF b$ = "male"`	If b$ is "male"
`IF b = 4`	If b is 4
`IF b < 4`	If b is less than 4
`IF b > 4`	If b is greater than 4
`IF b <= 4`	If b is less than or equal to 4
`IF b >= 4`	If b is greater than or equal to 4
`IF b <> 4`	If b is not 4
`IF b$ < "male"`	If b$ is a word that comes before "male" in dictionary
`IF b$ > "male"`	If b$ is a word that comes after "male" in dictionary

In the IF statement, the symbols =, <, >, <=, >=, and <> are called **relations**.

When writing a relation, mathematicians and computerists habitually **put the equal sign last**:

Right	Wrong
<=	=<
>=	=>

When you press the Enter key at the end of the line, the computer will automatically put your equal signs last: the computer will turn any "=<" into "<="; it will turn any "=>" into "<=".

To say "not equal to", say "less than or greater than", like this: <>.

OR The computer understands the word OR. For example, here's how to say, "If x is either 7 or 8, print the word *wonderful*":

```
IF x = 7 OR x = 8 THEN PRINT "wonderful"
```

That example is composed of two conditions: the first condition is "x = 7"; the second condition is "x = 8". Those two conditions combine, to form "x = 7 OR x = 8", which is called a **compound condition**.

If you use the word OR, put it between two conditions.

Right: `IF x = 7 OR x = 8 THEN PRINT "wonderful"`
Right because "x = 7" and "x = 8" are conditions.

Wrong: `IF x = 7 OR 8 THEN PRINT "wonderful"`
Wrong because "8" is not a condition.

AND The computer understands the word AND. Here's how to say, "If p is more than 5 and less than 10, print *tuna fish*":

```
IF p > 5 AND p < 10 THEN PRINT "tuna fish"
```

Here's how to say, "If s is at least 60 and less than 65, print *you almost failed*":

```
IF s >= 60 AND s < 65 THEN PRINT "you almost failed"
```

Here's how to say, "If n is a number from 1 to 10, print *that's good*":

```
IF n >= 1 AND n <= 10 THEN PRINT "that's good"
```

Can a computer be President?

To become President of the United States, you need 4 basic skills:

First, you must be a **good talker**, so you can give effective speeches saying "Vote for me!", express your views, and make folks do what you want.

But even if you're a good talker, you're useless unless you're also a **good listener**. You must be able to listen to people's needs and ask, "What can I do to make you happy and get you to vote for me?"

But even if you're a good talker and listener, you're still useless unless you can **make decisions**. Should you give more money to poor people? Should you bomb the enemy? Which actions should you take, and under what conditions?

But even if you're a good talker and listener and decision maker, you still need one more trait to become President: you must be able to take the daily grind of politics. You must, again and again, shake hands, make compromises, and raise funds. You must have the **patience to put up with the repetitive monotony** of those chores.

So altogether, to become President you need to be a good talker and listener and decision maker and also have the patience to put up with monotonous repetition.

Those are exactly the 4 qualities the computer has!

The word **PRINT** turns the computer into a good speech-maker. By using the word PRINT, you can make the computer write whatever speech you wish.

The word **INPUT** turns the computer into a good listener. By using the word INPUT, you can make the computer ask humans lots of questions, to find out who the humans are and what they want.

The word **IF** turns the computer into a decision maker. The computer can analyze the IF condition, determine whether that condition is true, and act accordingly.

Finally, the word **GOTO** enables the computer to perform loops, which the computer will repeat patiently.

So by using the words PRINT, INPUT, IF, and GOTO, you can make the computer imitate any intellectual human activity. Those 4 magic words — PRINT, INPUT, IF, and GOTO — are the only concepts you need, to write whatever program you wish!

Yes, you can make the computer imitate the President of the United States, do your company's payroll, compose a beautiful poem, play a perfect game of chess, contemplate the meaning of life, act as if it's falling in love, or do whatever other intellectual or emotional task you wish, by using those 4 magic words. The only question is: how? This book teaches you how, by showing you many examples of programs that do those remarkable things.

What programmers believe Yes, we programmers believe that all of life can be explained and programmed. We believe all of life can be reduced to just those four concepts: PRINT, INPUT, IF, and GOTO. Programming is the ultimate act of scientific reductionism: programmers reduce all of life scientifically to just four concepts.

The words that the computer understands are called **keywords**. The four essential keywords are PRINT, INPUT, IF, and GOTO.

The computer also understands extra keywords, such as CLS, LPRINT, WIDTH, SLEEP, DO (and LOOP), END, SELECT (and CASE), and words used in IF statements (such as THEN, ELSE, ELSEIF, OR, AND). Those extra keywords aren't necessary: if they hadn't been invented, you could still write programs without them. But they make programming easier.

A QBasic programmer is a person who translates an ordinary English sentence (such as "act like the President" or "do the payroll") into a series of QBasic statements, using keywords such as PRINT, INPUT, IF, GOTO, CLS, etc.

The mysteries of life Let's dig deeper into the mysteries of PRINT, INPUT, IF, GOTO, and the extra keywords. The deeper we dig, the more you'll wonder: are *you* just a computer, made of flesh instead of wires? Can everything *you* do be explained in terms of PRINT, INPUT, IF, and GOTO?

By the time you finish this book, you'll know!

Exiting a DO loop

This program plays a guessing game, where the human tries to guess the computer's favorite color, which is pink:

```
10 INPUT "What's my favorite color"; guess$
IF guess$ = "pink" THEN
    PRINT "Congratulations!  You discovered my favorite color."
ELSE
    PRINT "No, that's not my favorite color.  Try again!"
    GOTO 10
END IF
```

The INPUT line asks the human to guess the computer's favorite color; the guess is called guess$.

If the guess is "pink", the computer prints:

```
Congratulations!  You discovered my favorite color.
```

But if the guess is *not* "pink", the computer will instead print "No, that's not my favorite color" and then GO back TO line 10, which asks the human again to try guessing the computer's favorite color.

END Here's how to write that program without saying GOTO:

```
DO
    INPUT "What's my favorite color"; guess$
    IF guess$ = "pink" THEN
        PRINT "Congratulations!  You discovered my favorite color."
        END
    END IF
    PRINT "No, that's not my favorite color.  Try again!"
LOOP
```

That new version of the program contains a DO loop. That loop makes the computer do this repeatedly: ask "What's my favorite color?" and then PRINT "No, that's not my favorite color."

The only way to stop the loop is to guess "pink", which makes the computer print "Congratulations!" and END.

EXIT DO Here's another way to write that program without saying GOTO:

```
DO
    INPUT "What's my favorite color"; guess$
    IF guess$ = "pink" THEN EXIT DO
    PRINT "No, that's not my favorite color.  Try again!"
LOOP
PRINT "Congratulations!  You discovered my favorite color."
```

That program's DO loop makes the computer do this repeatedly: ask "What's my favorite color?" and then PRINT "No, that's not my favorite color."

The only way to stop the loop is to guess "pink", which makes the computer EXIT from the DO loop; then the computer proceeds to the line underneath the DO loop. That line prints:

```
Congratulations!  You discovered my favorite color.
```

LOOP UNTIL Here's another way to program the guessing game:

```
DO
    PRINT "You haven't guessed my favorite color yet!"
    INPUT "What's my favorite color"; guess$
LOOP UNTIL guess$ = "pink"
PRINT "Congratulations!  You discovered my favorite color."
```

That program's DO loop makes the computer do this repeatedly: say "You haven't guessed my favorite color yet!" and then ask "What's my favorite color?"

The LOOP line makes the computer repeat the indented lines again and again, UNTIL the guess is "pink". When the guess is "pink", the computer proceeds to the line underneath the LOOP and prints "Congratulations!".

The LOOP UNTIL's condition (guess$ = "pink") is called the **loop's goal**. The computer does the loop repeatedly, until the loop's goal is achieved. Here's how:

The computer does the indented lines, then checks whether the goal is achieved yet. If the goal is *not* achieved yet, the computer does the indented lines again, then checks again whether the goal is achieved. The computer does the loop again and again, until the goal is achieved. Then the computer, proud at achieving the goal, does the program's **finale**, which consists of any lines under the LOOP UNTIL line.

Saying —

```
LOOP UNTIL guess$ = "pink"
```

is just a briefer way of saying this pair of lines:

```
    IF guess$ = "pink" THEN EXIT DO
LOOP
```

FOR...NEXT

Let's make the computer print every number from 1 to 20, like this:

```
 1
 2
 3
 4
 5
 6
 7
etc.
 20
```

Here's the program:

```
FOR x = 1 TO 20
    PRINT x
NEXT
```

The top line (FOR x = 1 TO 20) says that x will be every number from 1 to 20; so x will be 1, then 2, then 3, etc. The line underneath, which is indented, says what to do about each x; it says to PRINT each x.

Whenever you write a program that contains the word FOR, you must say NEXT; so the bottom line says NEXT.

The indented line, which is between the FOR line and the NEXT line, is the line that the computer will do repeatedly; so the computer will repeatedly PRINT x. The first time the computer prints x, the x will be 1, so the computer will print:

```
 1
```

The next time the computer prints x, the x will be 2, so the computer will print:

```
 2
```

The computer will print every number from 1 up to 20.

When men meet women

Let's make the computer print these lyrics:

```
I saw 2 men
meet 2 women.
Tra-la-la!

I saw 3 men
meet 3 women.
Tra-la-la!

I saw 4 men
meet 4 women.
Tra-la-la!

I saw 5 men
meet 5 women.
Tra-la-la!

They all had a party!
Ha-ha-ha!
```

To do that, type these lines —

```
The first line of each verse:      PRINT "I saw"; x; "men"
The second line of each verse:     PRINT "meet"; x; "women."
The third line of each verse:      PRINT "Tra-la-la!"
Blank line under each verse:       PRINT
```

and make x be every number from 2 up to 5:

```
FOR x = 2 TO 5
    PRINT "I saw"; x; "men"
    PRINT "meet"; x; "women."
    PRINT "Tra-la-la!"
    PRINT
NEXT
```

At the end of the song, print the closing couplet:

```
FOR x = 2 TO 5
    PRINT "I saw"; x; "men"
    PRINT "meet"; x; "women."
    PRINT "Tra-la-la!"
    PRINT
NEXT
PRINT "They all had a party!"
PRINT "Ha-ha-ha!"
```

That program makes the computer print the entire song.

Here's an analysis:

```
                          FOR X = 2 TO 5
The computer will do the      PRINT "I saw"; x; "men"
indented lines repeatedly,    PRINT "meet"; x; "women."
for x=2, x=3, x=4, and x=5.   PRINT "Tra-la-la!"
                              PRINT
                          NEXT
Then the computer will    PRINT "They all had a party!"
print this couplet once.  PRINT "Ha-ha-ha!"
```

Since the computer does the indented lines repeatedly, those lines form a loop. Here's the general rule: **the statements between FOR and NEXT form a loop**. The computer goes round and round the loop, for x=2, x=3, x=4, and x=5. Altogether, it goes around the loop 4 times, which is a finite number. Therefore, the loop is **finite**.

If you don't like the letter x, choose a different letter. For example, you can choose the letter i:

```
FOR i = 2 TO 5
    PRINT "I saw"; i; "men"
    PRINT "meet"; i; "women."
    PRINT "Tra-la-la!"
    PRINT
NEXT
PRINT "They all had a party!"
PRINT "Ha-ha-ha!"
```

When using the word FOR, most programmers prefer the letter i; most programmers say "FOR i" instead of "FOR x". Saying "FOR i" is an "old tradition". Following that tradition, the rest of this book says "FOR i" (instead of "FOR x"), except in situations where some other letter feels more natural.

Print the squares

To find the **square** of a number, multiply the number by itself. The square of 3 is "3 times 3", which is 9. The square of 4 is "4 times 4", which is 16.

Let's make the computer print the square of 3, 4, 5, etc., up to 20, like this:

```
The square of 3 is 9
The square of 4 is 16
The square of 5 is 25
The square of 6 is 36
The square of 7 is 49
etc.
The square of 20 is 400
```

To do that, type this line —

```
    PRINT "The square of"; i; "is"; i * i
```

and make i be every number from 3 up to 20, like this:

```
FOR i = 3 TO 20
    PRINT "The square of"; i; "is"; i * i
NEXT
```

Count how many copies

This program, which you saw before, prints "love" on every line of your screen:

```
DO
    PRINT "love"
LOOP
```

That program prints "love" again and again, until you abort the program by pressing Ctrl with PAUSE/BREAK.

But what if you want to print "love" just 20 times? This program prints "love" just 20 times:

```
FOR i = 1 TO 20
    PRINT "love"
NEXT
```

As you can see, FOR...NEXT resembles DO...LOOP but is smarter: while doing FOR...NEXT, the computer counts!

Count to midnight

This program makes the computer count to midnight:

```
FOR i = 1 TO 11
    PRINT i
NEXT
PRINT "midnight"
```

The computer will print:

```
 1
 2
 3
 4
 5
 6
 7
 8
 9
 10
 11
midnight
```

Semicolon Let's put a semicolon at the end of the indented line:

```
FOR i = 1 TO 11
    PRINT i;
NEXT
PRINT "midnight"
```

The semicolon makes the computer print each item on the same line, like this:

```
 1  2  3  4  5  6  7  8  9  10  11 midnight
```

If you want the computer to press the Enter key before "midnight", insert a PRINT line:

```
FOR i = 1 TO 11
    PRINT i;
NEXT
PRINT
PRINT "midnight"
```

That extra PRINT line makes the computer press the Enter key just before "midnight", so the computer will print "midnight" on a separate line, like this:

```
 1  2  3  4  5  6  7  8  9  10  11
midnight
```

Nested loops Let's make the computer count to midnight 3 times, like this:

```
 1  2  3  4  5  6  7  8  9  10  11
midnight
 1  2  3  4  5  6  7  8  9  10  11
midnight
 1  2  3  4  5  6  7  8  9  10  11
midnight
```

To do that, put the entire program between the words FOR and NEXT:

```
FOR j = 1 TO 3
    FOR i = 1 TO 11
        PRINT i;
    NEXT
    PRINT
    PRINT "midnight"
NEXT
```

That version contains a loop inside a loop: the loop that says "FOR i" is inside the loop that says "FOR j". The j loop is called the **outer loop**; the i loop is called the **inner loop**. The inner loop's variable must differ from the outer loop's. Since we called the inner loop's variable "i", the outer loop's variable must *not* be called "i"; so I picked the letter j instead.

Programmers often think of the outer loop as a bird's nest, and the inner loop as an egg *inside the nest*. So programmers say the inner loop is **nested in** the outer loop; the inner loop is a **nested loop**.

Abnormal exit

Earlier, we programmed a game where the human tries to guess the computer's favorite color, pink. Here's a fancier version of the game, in which the human gets just 5 guesses:

```
PRINT "I'll give you 5 guesses...."
FOR i = 1 TO 5
    INPUT "What's my favorite color"; guess$
    IF guess$ = "pink" THEN GO TO 10
    PRINT "No, that's not my favorite color."
NEXT
PRINT "Sorry, your 5 guesses are up!  You lose."
END
10 PRINT "Congratulations!  You discovered my favorite color."
PRINT "It took you"; i; "guesses."
```

Line 2 warns the human that just 5 guesses are allowed. The FOR line makes the computer count from 1 to 5; to begin, i is 1. The INPUT line asks the human to guess the computer's favorite color; the guess is called guess$.

If the guess is "pink", the computer jumps down to the line numbered 10, prints "Congratulations!", and tells how many guesses the human took. But if the guess is *not* "pink", the computer will print "No, that's not my favorite color" and go on to the NEXT guess.

If the human guesses 5 times without success, the computer proceeds to the line that prints "Sorry… You lose."

For example, if the human's third guess is "pink", the computer prints:

```
Congratulations!  You discovered my favorite color.
It took you 3 guesses.
```

If the human's very first guess is "pink", the computer prints:

```
Congratulations!  You discovered my favorite color.
It took you 1 guesses.
```

Saying "1 guesses" is bad grammar but understandable.

That program contains a FOR...NEXT loop. The FOR line says the loop will normally be done five times. The line below the loop (which says to PRINT "Sorry") is the loop's **normal exit**. But if the human happens to input "pink", the computer jumps out of the loop early, to line 10, which is the loop's **abnormal exit**.

STEP

The FOR statement can be varied:

Statement	Meaning
`FOR i = 5 TO 17 STEP .1`	The i will go from 5 to 17, counting by tenths. So i will be 5, then 5.1, then 5.2, etc., up to 17.
`FOR i = 5 TO 17 STEP 3`	The i will be every 3rd number from 5 to 17. So i will be 5, then 8, then 11, then 14, then 17.
`FOR i = 17 TO 5 STEP -3`	The i will be every 3rd number from 17 down to 5. So i will be 17, then 14, then 11, then 8, then 5.

To count down, you *must* use the word STEP. To count from 17 down to 5, give this instruction:

```
FOR i = 17 TO 5 STEP -1
```

This program prints a rocket countdown:

```
FOR i = 10 TO 1 STEP -1
    PRINT i
NEXT
PRINT "Blast off!"
```

The computer will print:

```
 10
 9
 8
 7
 6
 5
 4
 3
 2
 1
Blast off!
```

This statement is tricky:

```
FOR i = 5 TO 16 STEP 3
```

It says to start i at 5, and keep adding 3 until it gets past 16. So i will be 5, then 8, then 11, then 14. The i won't be 17, since 17 is past 16. The first value of i is 5; the last value is 14.

In the statement FOR i = 5 TO 16 STEP 3, the **first value** or **initial value** of i is 5, the **limit value** is 16, and the **step size** or **increment** is 3. The i is called the **counter** or **index** or **loop-control variable**. Although the limit value is 16, the **last value** or **terminal value** is 14.

Programmers usually say "FOR i", instead of "FOR x", because the letter i reminds them of the word **index**.

Round-off errors

If the step size is a decimal, the computer might make small errors (called round-off errors), which can add up to a result that's very wrong.

For example, suppose you say:

```
FOR i = 5 TO 17 STEP .1
```

That means you want the last few values of i to be 16.8, 16.9, and 17; but the computer will accidentally make the step size be slightly *more* than .1, so the computer's last few values of i will be about 16.80003 and 16.90003. The computer will refuse to do the next number (which would be about 17.0003), since you said not to go past 17; so the last i will be 16.90003, which isn't at all what you wanted for the last value!

To make the last i be about 17, make the limit value be slightly *more* than 17, like this —

```
FOR i = 5 TO 17.01 STEP .1
```

or, better yet, avoid a decimal step size by using this pair of lines instead:

```
FOR j = 50 TO 170
    i = j / 10
```

That makes i indeed be 5 then 5.1 then 5.2, etc., up to 17.

DATA...READ

Let's make the computer print this message:

```
I love meat
I love potatoes
I love lettuce
I love tomatoes
I love honey
I love cheese
I love onions
I love peas
```

That message concerns this list of food: meat, potatoes, lettuce, tomatoes, honey, cheese, onions, peas. That list doesn't change: the computer continues to love those foods throughout the entire program.

A list that doesn't change is called DATA. So in the message about food, the DATA is meat, potatoes, lettuce, tomatoes, honey, cheese, onions, peas.

Whenever a problem involves DATA, put the DATA at the program's top, under just CLS, like this:

```
DATA meat,potatoes,lettuce,tomatoes,honey,cheese,onions,peas
```

You must tell the computer to READ the DATA:

```
DATA meat,potatoes,lettuce,tomatoes,honey,cheese,onions,peas
READ a$
```

That READ line makes the computer read the first datum ("meat") and call it a$. So a$ is "meat".

Since a$ is "meat", this shaded line makes the computer print "I love meat":

```
DATA meat,potatoes,lettuce,tomatoes,honey,cheese,onions,peas
READ a$
PRINT "I love "; a$
```

Hooray! We made the computer handle the first datum correctly: we made the computer print "I love meat".

To make the computer handle the rest of the data (potatoes, lettuce, etc.), tell the computer to READ and PRINT the rest of the data, by putting the READ and PRINT lines in a loop. Since we want the computer to READ and PRINT all 8 data items (meat, potatoes, lettuce, tomatoes, honey, cheese, onions, peas), put the READ and PRINT lines in a loop that gets done 8 times, by making the loop say "FOR i = 1 TO 8":

```
DATA meat,potatoes,lettuce,tomatoes,honey,cheese,onions,peas
FOR i = 1 TO 8
    READ a$
    PRINT "I love "; a$
NEXT
```

Since that loop's main purpose is to READ the data, it's called a **READ loop**.

When writing that program, make sure the FOR line's last number (8) is the number of data items. If the FOR line accidentally says 7 instead of 8, the computer won't read or print the 8th data item. If the FOR line accidentally says 9 instead of 8, the computer will try to read a 9th data item, realize that no 9th data item exists, and gripe by saying:

```
Out of DATA
```

Then click "No".

Let's make the computer end by printing "Those are the foods I love", like this:

```
I love meat
I love potatoes
I love lettuce
I love tomatoes
I love honey
I love cheese
I love onions
I love peas
Those are the foods I love
```

To make the computer print that ending, put a PRINT line at the end of the program:

```
DATA meat,potatoes,lettuce,tomatoes,honey,cheese,onions,peas
FOR i = 1 TO 8
    READ a$
    PRINT "I love "; a$
NEXT
PRINT "Those are the foods I love"
```

End mark

When writing that program, we had to count the DATA items and put that number (8) at the end of the FOR line.

Here's a better way to write the program, so you don't have to count the DATA items:

```
DATA meat,potatoes,lettuce,tomatoes,honey,cheese,onions,peas
DATA end
DO
    READ a$: IF a$ = "end" THEN EXIT DO
    PRINT "I love "; a$
LOOP
PRINT "Those are the foods I love"
```

The second line (DATA end) is called the **end mark**, since it marks the end of the DATA. The READ line means:

```
READ a$ from the DATA;
but if a$ is the "end" of the DATA, then EXIT from the DO loop.
```

When the computer exits from the DO loop, the computer prints "Those are the foods I love". So altogether, the entire program makes the computer print:

```
I love meat
I love potatoes
I love lettuce
I love tomatoes
I love honey
I love cheese
I love onions
I love peas
Those are the foods I love
```

The routine that says:

```
IF a$ = "end" THEN EXIT DO
```

is called the **end routine**, because the computer does that routine

when it reaches the end of the DATA.

Henry the Eighth Let's make the computer print this nursery rhyme:

```
I love ice cream
I love red
I love ocean
I love bed
I love tall grass
I love to wed

I love candles
I love divorce
I love kingdom
I love my horse
I love you
Of course, of course,
For I am Henry the Eighth!
```

If you own a jump rope, have fun: try to recite that poem while skipping rope!

This program makes the computer recite the poem:

```
DATA ice cream,red,ocean,bed,tall grass,to wed
DATA candles,divorce,my kingdom,my horse,you
DATA end
DO
    READ a$: IF a$ = "end" THEN EXIT DO
    PRINT "I love "; a$
    IF a$ = "to wed" THEN PRINT
LOOP
PRINT "Of course, of course,"
PRINT "For I am Henry the Eighth!"
```

Since the data's too long to fit on a single line, I've put part of the data in the top line and the rest in line 2. Each line of data must begin with the word DATA. In each line, put commas between the items. Do *not* put a comma at the end of the line.

The program resembles the previous one. The new line (IF a$ = "to wed" THEN PRINT) makes the computer leave a blank line underneath "to wed", to mark the first verse's bottom.

Pairs of data

Let's throw a party! To make the party yummy, let's ask each guest to bring a kind of food that resembles the guest's name. For example, let's have Sal bring salad, Russ bring Russian dressing, Sue bring soup, Tom bring turkey, Winnie bring wine, Kay bring cake, and Al bring Alka-Seltzer.

Let's send all those people invitations, in this form:

```
Dear _____,
      person's name

   Let's party in the clubhouse at midnight!

Please bring _____.
                food
```

Here's the program:

```
DATA Sal,salad,Russ,Russian dressing,Sue,soup,Tom,turkey
DATA Winnie,wine,Kay,cake,Al,Alka-Seltzer
DATA end,end
DO
    READ person$, food$: IF person$ = "end" THEN EXIT DO
    LPRINT "Dear "; person$; ","
    LPRINT "     Let's party in the clubhouse at midnight!"
    LPRINT "Please bring "; food$; "."
    LPRINT CHR$(12);
LOOP
PRINT "I've finished writing the letters."
```

The DATA comes in pairs. For example, the first pair consists of "Sal" and "salad"; the next pair consists of "Russ" and "Russian dressing". Since the DATA comes in pairs, you must make the end mark also be a pair (DATA end,end).

Since the DATA comes in pairs, the READ line says to READ a pair of data (person$ and food$). The first time that the computer encounters the READ line, person$ is "Sal"; food$ is "salad". Then the LPRINT lines print this message onto paper:

```
Dear Sal,
     Let's party in the clubhouse at midnight!
Please bring salad.
```

The LPRINT CHR$(12) makes the computer eject the paper from the printer.

Then the computer comes to the word LOOP, which sends the computer back to the word DO, which sends the computer to the READ line again, which reads the next pair of DATA, so person$ becomes "Russ" and food$ becomes "Russian dressing". The LPRINT lines print onto paper:

```
Dear Russ,
     Let's party in the clubhouse at midnight!
Please bring Russian dressing.
```

The computer prints similar letters to all the people.

After all people have been handled, the READ statement comes to the end mark (DATA end,end), so that person$ and food$ both become "end". Since person$ is "end", the IF statement makes the computer EXIT DO, so the computer prints this message onto the screen:

```
I've finished writing the letters.
```

In that program, you need *two* ends to mark the data's ending, because the READ statment says to read two strings (person$ and food$).

Debts Suppose these people owe you things:

Person	What the person owes
Bob	$537.29
Mike	a dime
Sue	2 golf balls
Harry	a steak dinner at Mario's
Mommy	a kiss

Let's remind those people of their debt, by writing them letters, in this form:

```
Dear _____,
      person's name

   I just want to remind you...

that you still owe me _____.
                      debt
```

To start writing the program, begin by saying CLS and then feed the computer the DATA. The final program is the same as the previous program, except for the part I've shaded:

```
DATA Bob,$537.29,Mike,a dime,Sue,2 golf balls
DATA Harry,a steak dinner at Mario's,Mommy,a kiss
DATA end,end
DO
    READ person$, debt$: IF person$ = "end" THEN EXIT DO
    LPRINT "Dear "; person$; ","
    LPRINT "     I just want to remind you..."
    LPRINT "that you still owe me "; debt$; "."
    LPRINT CHR$(12);
LOOP
PRINT "I've finished writing the letters."
```

Triplets of data

Suppose you're running a diet clinic and get these results:

Person	Weight before	Weight after
Joe	273 pounds	219 pounds
Mary	412 pounds	371 pounds
Bill	241 pounds	173 pounds
Sam	309 pounds	198 pounds

This program makes the computer print a nice report:

```
DATA Joe,273,219,Mary,412,371,Bill,241,173,Sam,309,198
DATA end,0,0
DO
    READ person$, weight.before, weight.after
    IF person$ = "end" THEN EXIT DO
    PRINT person$; " weighed"; weight.before;
    PRINT "pounds before attending the diet clinic"
    PRINT "but weighed just"; weight.after; "pounds afterwards."
    PRINT "That's a loss of"; weight.before - weight.after; "pounds."
    PRINT
LOOP
PRINT "Come to the diet clinic!"
```

The top line contains the DATA, which comes in triplets. The first triplet consists of Joe, 273, and 219. Each triplet includes a string (such as Joe) and two numbers (such as 273 and 219), so line 3's end mark also includes a string and two numbers: it's the word "end" and two zeros. (If you hate zeros, you can use other numbers instead; but most programmers prefer zeros.)

The READ line says to read a triplet: a string (person$) and two numbers (weight.before and weight.after). The first time the computer comes to the READ statement, the computer makes person$ be "Joe", weight.before be 273, and weight.after be 219. The PRINT lines print this:

```
Joe weighed 273 pounds before attending the diet clinic
but weighed just 219 pounds afterwards.
That's a loss of 54 pounds.

Mary weighed 412 pounds before attending the diet clinic
but weighed just 371 pounds afterwards.
That's a loss of 41 pounds.

Bill weighed 241 pounds before attending the diet clinic
but weighed just 173 pounds afterwards.
That's a loss of 68 pounds.

Sam weighed 309 pounds before attending the diet clinic
but weighed just 198 pounds afterwards.
That's a loss of 111 pounds.

Come to the diet clinic!
```

RESTORE

Examine this program:

```
DATA love,death,war
10 DATA chocolate,strawberry
READ a$
PRINT a$
RESTORE 10
READ a$
PRINT a$
```

The first READ makes the computer read the first datum (love), so the first PRINT makes the computer print:

```
love
```

The next READ would normally make the computer read the next datum (death); but the **RESTORE 10 tells the READ to skip ahead to DATA line 10**, so the READ line reads "chocolate" instead. The entire program prints:

```
love
chocolate
```

So saying "RESTORE 10" makes the next READ skip ahead to DATA line 10. If you write a new program, saying "RESTORE 20" makes the next READ skip ahead to DATA line 20. Saying just "RESTORE" makes the next READ skip back to the beginning of the *first* DATA line.

Continents This program prints the names of the continents:

```
DATA Europe,Asia,Africa,Australia,Antarctica,North America,South America
DATA end
DO
    READ a$: IF a$ = "end" THEN EXIT DO
    PRINT a$
LOOP
PRINT "Those are the continents."
```

That program makes the computer print this message:

```
Europe
Asia
Africa
Australia
Antarctica
North America
South America
Those are the continents.
```

Let's make the computer print that message *twice*, so the computer prints:

```
Europe
Asia
Africa
Australia
Antarctica
North America
South America
Those are the continents.

Europe
Asia
Africa
Australia
Antarctica
North America
South Ameruca
Those are the continents.
```

To do that, put the program in a loop saying "FOR i = 1 TO 2", like this:

```
DATA Europe,Asia,Africa,Australia,Antarctica,North America,South America
DATA end
FOR i = 1 TO 2
    DO
        READ a$: IF a$ = "end" THEN EXIT DO
        PRINT a$
    LOOP
    PRINT "Those are the continents."
    PRINT
    RESTORE
NEXT
```

After that program says to PRINT "Those are the continents", the program says to PRINT a blank line and then RESTORE. The word RESTORE makes the READ go back to the beginning of the DATA, so the computer can READ and PRINT the DATA a second time without saying "Out of DATA".

Search loop

Let's make the computer translate colors into French. For example, if the human says "red", we'll make the computer say the French equivalent, which is:

```
rouge
```

Let's make the computer begin by asking "Which color interests you?", then wait for the human to type a color (such as "red"), then reply:

```
In French, it's rouge
```

The program begins simply:

```
INPUT "Which color interests you"; request$
```

Next, we must make the computer translate the requested color into French. To do so, feed the computer this English-French dictionary:

English	French
white	blanc
yellow	jaune
orange	orange
red	rouge
green	vert
blue	bleu
brown	brun
black	noir

That dictionary becomes the data:

```
DATA white,blanc,yellow,jaune,orange,orange,red,rouge
DATA green,vert,blue,bleu,brown,brun,black,noir
INPUT "Which color interests you"; request$
```

The data comes in pairs; each pair consists of an English word (such as "white") followed by its French equivalent ("blanc"). To make the computer read a pair, say:

```
READ english$, french$
```

To let the computer look at *all* the pairs, put that READ statement in a DO loop. Here's the complete program:

```
DATA white,blanc,yellow,jaune,orange,orange,red,rouge
DATA green,vert,blue,bleu,brown,brun,black,noir
INPUT "Which color interests you"; request$
DO
    READ english$, french$
    IF english$ = request$ THEN EXIT DO
LOOP
PRINT "In French, it's "; french$
```

Since the READ line is in a DO loop, the computer does the READ line repeatedly. So the computer keeps READing pairs of DATA, until the computer find the pair of DATA that the human requested. For example, if the human requested "red", the computer keeps READing pairs of DATA until it finds a pair whose English word matches the requested word ("red"). When the computer finds that match, the english$ is equal to the request$, so the IF line makes the computer EXIT DO and PRINT:

```
In French, it's rouge
```

So altogether, when you run the program the chat can look like this:

```
Which color interests you? red
In French, it's rouge
```

Here's another sample run:

```
Which color interests you? brown
In French, it's brun
```

Here's another:

```
Which color interests you? pink
Out of DATA
```

The computer says "Out of DATA" because it can't find "pink" in the DATA.

Avoid "Out of DATA" Instead of saying "Out of DATA", let's make the computer say "I wasn't taught that color". To do that, put an end mark at the end of the DATA; and when the computer reaches the end mark, make the computer say "I wasn't taught that color":

```
DATA white,blanc,yellow,jaune,orange,orange,red,rouge
DATA green,vert,blue,bleu,brown,brun,black,noir
DATA end,end
INPUT "Which color interests you"; request$
DO
    READ english$, french$
    IF english$ = "end" THEN PRINT "I wasn't taught that color": END
    IF english$ = request$ THEN EXIT DO
LOOP
PRINT "In French, it's "; french$
```

In that program, the DO loop's purpose is to *search* through the DATA, to find DATA that matches the INPUT. Since the DO loop's purpose is to search, it's called a **search loop**.

The typical search loop has these characteristics:

It starts with DO and ends with LOOP.
It says to READ a pair of data.

It includes an error trap saying what to do IF you reach the "end" of the data because no match found.

It says that IF you find a match (english$ = request$) THEN EXIT the DO loop.
Below the DO loop, say what to PRINT when the match is found.
Above the DO loop, put the DATA and tell the human to INPUT a search request.

Auto rerun At the end of the program, let's make the computer automatically rerun the program and translate another color.

To do that, make the program's bottom say GO back TO the INPUT line:

```
DATA white,blanc,yellow,jaune,orange,orange,red,rouge
DATA green,vert,blue,bleu,brown,brun,black,noir
DATA end,end
10 INPUT "Which color interests you"; request$
RESTORE
DO
    READ english$, french$
    IF english$ = "end" THEN PRINT "I wasn't taught that color": GOTO 10
    IF english$ = request$ THEN EXIT DO
LOOP
PRINT "In French, it's "; french$
GOTO 10
```

The word RESTORE, which is above the search loop, makes sure that the computer's search through the DATA always starts at the DATA's beginning.

Press Q to quit That program repeatedly asks "Which color interests you" until the human aborts the program. But what if the human's a beginner who hasn't learned how to abort?

Let's permit the human to stop the program more easily by pressing just the Q key to quit:

```
DATA white,blanc,yellow,jaune,orange,orange,red,rouge
DATA green,vert,blue,bleu,brown,brun,black,noir
DATA end,end
10 INPUT "Which color interests you (press q to quit)"; request$
IF request$ = "q" THEN END
RESTORE
DO
    READ english$, french$
    IF english$ = "end" THEN PRINT "I wasn't taught that color": GOTO 10
    IF english$ = request$ THEN EXIT DO
LOOP
PRINT "In French, it's "; french$
GOTO 10
```

END or STOP That program's shaded line ends by saying END. Instead of saying END, try saying STOP.

While the program is running, here's what the computer does when it encounters END or STOP:

STOP makes the program stop *immediately*. It closes the black window, so you see the blue window and the program's lines.

END makes the computer say "Press any key to continue" and wait for the human to press a key (such as Enter). When the human finally presses a key, the black window closes, so you see the blue window and program's lines.

Helpful hints

Here are some hints to help you master programming.

Variables & constants

A **numeric constant** is a simple number, such as:

```
0       1       2       8       43.7       -524.6       .003
```

Another example of a numeric constant is 1.3E5, which means, "take 1.3, and move its decimal point 5 places to the right".

A numeric constant does not contain any arithmetic. For example, since 7+1 contains arithmetic (+), it's *not* a numeric constant. 8 is a numeric constant, even though 7+1 isn't.

A **string constant** is a simple string, in quotation marks:

```
"I love you"    "76 trombones"    "Go away!!!"    "xypw exr///746"
```

A **constant** is a numeric constant or a string constant:

```
0     8     -524.6     1.3E5     "I love you"     "xypw exr///746"
```

A **variable** is something that stands for something else. If it stands for a string, it's called a **string variable** and ends with a dollar sign, like this:

```
a$       b$       y$       z$       my.job.before.promotion$
```

If the variable stands for a number, it's called a **numeric variable** and lacks a dollar sign, like this:

```
a        b        y        z        profit.before.promotion
```

So all these are variables:

```
a$ b$ y$ z$ my.job.before.promotion$ a b y z profit.before.promotion
```

Expressions A **numeric expression** is a numeric constant (such as 8) or a numeric variable (such as b) or a combination of them, such as 8+z, or 8*a, or z*a, or 8*2, or 7+1, or even z*a-(7+z)/8+1.3E5*(-524.6+b). A **string expression** is a string constant (such as "I love you") or a string variable (such as a$) or a combination. An **expression** is a numeric expression or a string expression.

Statements At the end of a GOTO statement, the line number must be a numeric constant.

Right:	`GOTO 100`	(100 is a numeric constant.)
Wrong:	`GOTO n`	(n is not a numeric constant.)

The INPUT statement's prompt must be a string constant.

Right:	`INPUT "What is your name; n$`	("What is your name" is a constant.)
Wrong:	`INPUT q$; n$`	(q$ is not a constant.)

In a DATA statement, you must have constants.

Right:	`DATA 8, 1.3E5`	(8 and 1.3E5 are constants.)
Wrong:	`DATA 7+1, 1.3E5`	(7+1 is not a constant.)

In the DATA statement, if the constant is a string, you can omit the quotation marks (unless the string contains a comma or a colon).

```
Right:      DATA "Joe","Mary"
Also right: DATA Joe,Mary
```

Here are the forms of popular statements:

General form	Example
`PRINT` *list of expressions*	`PRINT "Temperature is"; 4 + 25; "degrees"`
`LPRINT` list of expressions	`LPRINT "Temperature is"; 4 + 25; "degrees"`
`SLEEP` *numeric expression*	`SLEEP 3 + 1`
`GOTO` *line number or label*	`GOTO 10`
variable `=` *expression*	`x = 47 + 2`
`INPUT` *string constant*`;` *variable*	`INPUT "What is your name"; n$`
`IF` *condition* `THEN` *list of statements*	`IF a >= 18 THEN PRINT "You": PRINT "vote"`
`SELECT CASE` *expression*	`SELECT CASE a + 1`
`DATA` *list of constants*	`DATA Joe,273,219,Mary,412,371`
`READ` *list of variables*	`READ n$, b, a`
`RESTORE` *line number or label*	`RESTORE 10`
`FOR` *numeric variable* `=` *numeric expression* `TO` *numeric expression* `STEP` *numeric expression*	`FOR I = 59 + 1 TO 100 + n STEP 2 + 3`

Debugging

If you write and run your own program, it probably won't work.

Your first reaction will be to blame the computer. Don't!

The probability is 99.99% that the fault is yours. Your program contains an error. An error is called a **bug**. Your next task is to **debug** the program, which means get the bugs out.

Bugs are common; top-notch programmers make errors all the time. If you write a program that works perfectly on the first run and doesn't need debugging, it's called a **gold-star program** and means you should have tried writing a harder one instead!

It's easy to write a program that's nearly correct but hard to find the little bug fouling it up. Most time you spend at the computer will be devoted to debugging.

Debugging can be fun. Hunting for the bug is like going on a treasure hunt – or solving a murder mystery. Pretend you're Sherlock Holmes. Your mission: to find the bug and squish it! When you squish it, have fun: yell out, "Squish!"

How can you tell when a roomful of programmers is happy? Answer: when you hear continual cries of "Squish!"

To find a bug, use three techniques:

Inspect the program.
Trace the computer's thinking.
Shorten the program.

Here are the details.…

Inspect the program Take a good, hard look at the program. If you stare hard enough, maybe you'll see the bug.

Usually, the bug will turn out to be just a typing error, a **typo**. For example.…

Maybe you typed the letter O instead of zero? Zero instead of the letter O?

Typed I instead of 1? Typed 1 instead of I?

Pressed the Shift key when you weren't supposed to? Forgot to press it?

Typed an extra letter? Omitted a letter?

Typed a line you thought you hadn't? Omitted a line?

You must **put quotation marks around each string, and a dollar sign after each string variable**:

```
Right: a$ = "jerk"
Wrong: a$ = jerk
Wrong: a = "jerk"
```

Here are 3 reasons why the computer might **print too much**:

1. You forgot to insert the word END or EXIT DO into your program.

2. Into a DO loop or FOR loop, you inserted a PRINT line that should be *outside* the loop.

3. When you started typing the program, you forgot to choose New from the File menu; so the computer is including part of the previous program.

Trace the computer's thinking If you've inspected the program thoroughly and *still* haven't found the bug, the next step is to **trace** the computer's thinking. **Pretend you're the computer. Do what your program says.** Do you find yourself printing the same wrong answers the computer printed? If so, why? To help your analysis, **make the computer print everything it's thinking** while it's running your program. For example, suppose your program uses the variables b, c, and x$. Insert lines such as these into your program:

```
10 PRINT "I'm at line 10.  The values are"; b; c; x$
20 PRINT "I'm at line 20.  The values are"; b; c; x$
```

Then run the program. Those extra lines tell you what the computer is thinking about b, c, and x$ and also tell you how many times the computer reached lines 10 and 20. For example, if the computer prints what you expect in line 10 but prints strange values in line 20 (or doesn't even get to line 20), you know the bug occurs after line 10 but before line 20.

Here's a good strategy. Halfway down your program, insert a line that says to print all the values. Then run your program. If the line you inserted prints the correct values, you know the bug lies underneath that line; but if the line prints *wrong* values (or if the computer never reaches that line), you know the bug lies *above* that line. In either case, you know which half of your program contains the bug. In that half of the program, insert more lines, until you finally zero in on the line containing the bug.

Shorten the program When all else fails, shorten the program.

Hunting for a bug in a program is like hunting for a needle in a haystack: the job is easier if the haystack is smaller. So make your program shorter: delete the last half of your program. Then run the shortened version. That way, you'll find out whether the first half of your program is working the way it's supposed to. When you've perfected the first half of your program, tack the second half back on.

Does your program contain **a statement whose meaning you're not completely sure of**? Check the meaning by reading a book or asking a friend; or **write a tiny experimental program that contains the statement**, and see what happens when you run it.

Hint: before you shorten your program (or write tiny experimental ones), **save the original version** (by choosing Save from the File menu), even though it contains a bug. After you've played with the shorter versions, retrieve the original (by choosing Open from the File menu) and fix it.

To write a long, correct program easily, write a short program first and debug it, then add a few more lines and debug them, add a few more lines and debug them, etc. So start with a small program, perfect it, then gradually add perfected extras so you *gradually* build a perfected masterpiece. If you try to compose a long program all at once – instead of building it from perfected pieces – you'll have nothing more than a master*mess* – full of bugs.

Moral: to build a large masterpiece, start with a *small* masterpiece. To build a program so big that it's a skyscraper, begin by laying a good foundation; double-check the foundation before you start adding the program's walls and roof.

Error messages

If the computer can't obey your command, the computer will print an **error message**. The following error message are the most common.…

Syntax errors If you say "prind" instead of "print", the computer will say:

```
Syntax error
```

That means the computer hasn't the faintest idea of what you're talking about!

If the computer says you have a syntax error, it's usually because you spelled a word wrong, or forgot a word, or used a word the computer doesn't understand. It can also result from wrong punctuation: check your commas, semicolons, and colons. It can also mean your DATA statement contains a string but your READ statement says to read a number instead; to fix that problem, change the READ statement by putting a dollar sign at the end of the variable's name.

If you try to say PRINT 5 + 2 but forget to type the 2, the computer will say:

```
Expected variable/value after +
```

If you type a left parenthesis but forget to type the right parenthesis that matches it, the computer will say:

```
Missing )
```

If you accidentally type extra characters (or an unintelligible word) at the end of the line, the computer will say:

```
Expected operator
```

Numeric errors If the answer to a calculation is a bigger number than the computer can handle, the computer will say:

```
1.#INF
```

To help the computer handle bigger numbers, remember to put a decimal point in any problem whose answer might be bigger than 32 thousand.

If you try to divide by zero, the computer will say:

```
1.#INF
```

Logic errors Some commands come in pairs.

The words **DO and LOOP** form a pair. If you say DO but no line says LOOP, the computer will gripe by saying:

```
DO without LOOP
```

If you say LOOP but no line says DO, the computer will say:

```
PROGRAM FLOW ERROR!
```

The words **FOR and NEXT** form another pair. If part of the pair is missing, the computer will say —

```
FOR without NEXT
```

or:

```
NEXT without FOR
```

If a line's first word is **SELECT**, you're supposed to have a line below saying END SELECT. If you say SELECT but no line says END SELECT, the computer will say:

```
SELECT CASE without END SELECT
```

If you say END SELECT but no line's first word is SELECT, the computer will say:

```
END SELECT without SELECT CASE
```

Between the SELECT and END SELECT lines, you're supposed to have several lines saying CASE. If you say CASE but no line's first word is SELECT, the computer will say:

```
CASE without SELECT CASE
```

If you say **GOTO 10**, the computer tries to find a line numbered 10. If you say GOTO joe, the computer tries to find a line named joe. If there's no line numbered 10 or no line named joe, the computer will say:

```
Label not defined
```

Here are other messages about unmatched pairs, involving **IF**:

```
ELSE without IF
END IF without IF
IF without END IF
```

If you say **READ** but the computer can't find any more DATA to read (because the computer has read all the DATA already), the computer will say:

```
Out of DATA
```

The computer handles 2 major **types** of info: numbers & strings. If you feed the computer the wrong type of info – if you feed it a number when you should have fed it a string, or you feed it a string when you should have fed it a number – the computer will say:

```
Illegal string-number conversion
```

When you feed the computer a string, you must put the string in quotation marks, and put a dollar sign after the string's variable. If you forget to type the string's quotation marks or dollar sign, the computer won't realize it's a string; the computer will think you're trying to type a number instead; and if a number would be inappropriate, the computer will give that gripe. So when the computer gives that gripe, it usually means you forgot a quotation mark or a dollar sign.

Pause key

Magicians often say, "The hand is quicker than the eye." The computer's the ultimate magician: the computer can print info on the screen much faster than you can read it.

When the computer is printing faster than you can read, tap the **Pause key**, if you can find it. (It's typically the last key in the top row. Some notebook computers have no Pause key at all. On some notebook computers, you must tap the Pause key *while holding down the Fn key*.) Then the computer will pause, to let you read what's on the screen.

When you've finished reading what's on the screen and want the computer to stop pausing, press the Enter key. Then the computer will continue printing rapidly, where it left off.

If your eyes are as slow as mine, you'll need to use the Pause key often! You'll want the computer to pause while you're running a program containing many PRINT statements (or a PRINT statement in a loop).

Apostrophe

Occasionally, jot a note to remind yourself what your program does and what the variables stand for. Slip the note into your program by putting an apostrophe before it:

```
'This program is a dumb example, written by Russy-poo.
'It was written on Halloween, under a full moon.
c = 40 'because Russ has 40 computers
h = 23 'because 23 of his computers are haunted
PRINT c - h 'That is how many computers are unhaunted.
```

When you run the program, **the computer ignores everything that's to the right of an apostrophe**. So the computer ignores lines 1 & 2; in lines 3 & 4, the computer ignores the "because…"; in the bottom line, the computer ignores the comment about being unhaunted. Since c is 40, and h is 23, the bottom line makes the computer print:

```
 17
```

Everything to the right of an apostrophe is called a **comment** (or **remark**). While the computer runs the program, it ignores the comments. But the comments remain part of the program; they appear on the blue screen with the rest of the program. Though the comments appear in the program, they don't affect the run.

Loop techniques

Here's a strange program:

```
x = 9
x = 4 + x
PRINT x
```

The second line (x = 4 + x) means: the new x is 4 plus the old x. So the new x is 4 + 9, which is 13. The bottom line prints:

```
 13
```

Let's look at that program more closely. The top line (x = 9) puts 9 into box x:

box x `9`

When the computer sees the next line (x = 4 + x), it examines the equation's right side and sees the 4 + x. Since x is 9, the 4 + x is 4 + 9, which is 13. So the line "x = 4 + x" means x = 13. The computer puts 13 into box x:

box x `13`

The program's bottom line prints 13.

Here's another weirdo:

```
b = 6
b = b + 1
PRINT b * 2
```

The second line (b = b + 1) says the new b is "the old b plus 1". So the new b is 6 + 1, which is 7. The bottom line prints:

```
 14
```

In that program, the top line says b is 6; but the next line increases b, by adding 1 to b; so b becomes 7. Programmers say that b has been **increased** or **incremented**. In the third line, the "1" is called the **increase** or the **increment**.

The opposite of "increment" is **decrement**:

```
j = 500
j = j - 1
PRINT j
```

The top line says j starts at 500; but the next line says the new j is "the old j minus 1", so the new j is 500 - 1, which is 499. The bottom line prints:

```
 499
```

In that program, j was **decreased** (or **decremented**). In the third line, the "1" is called the **decrease** (or **decrement**).

Counting Suppose you want the computer to count, starting at 3, like this:

```
 3
 4
 5
 6
 7
 8
etc.
```

This program does it, by a special technique:

```
c = 3
DO
    PRINT c
    c = c + 1
LOOP
```

In that program, c is called the **counter**, because it helps the computer count.

The top line says c starts at 3. The PRINT line makes the computer print c, so the computer prints:

```
 3
```

The next line (c = c + 1) increases c by adding 1 to it, so c becomes 4. The LOOP line sends the computer back to the PRINT line, which prints the new value of c:

```
 4
```

Then the computer comes to the "c = c + 1" again, which increases c again, so c becomes 5. The LOOP line sends the computer back again to the PRINT line, which prints:

```
 5
```

The program's an infinite loop: the computer will print 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, and so on, forever, unless you abort it.

Here's the general procedure to make the computer count:

Start c at some value (such as 3).

Then write a DO loop.

In the DO loop, make the computer use c (such as by saying PRINT c) and increase c (by saying c = c + 1).

To read the printing more easily, put a semicolon at the end of the PRINT statement:

```
c = 3
DO
    PRINT c;
    c = c + 1
LOOP
```

The semicolon makes the computer print horizontally:

```
 3  4  5  6  7  8  etc.
```

This program makes the computer count, starting at 1:

```
c = 1
DO
    PRINT c;
    c = c + 1
LOOP
```

The computer will print 1, 2, 3, 4, etc.

This program makes the computer count, starting at 0:

```
c = 0
DO
    PRINT c;
    c = c + 1
LOOP
```

The computer will print 0, 1, 2, 3, 4, etc.

Quiz Let's make the computer give this quiz:

What's the capital of Nevada?
What's the chemical symbol for iron?
What word means `brother or sister'?
What was Beethoven's first name?
How many cups are in a quart?

To make the computer score the quiz, we must tell it the correct answers:

Question	Correct answer
What's the capital of Nevada?	Carson City
What's the chemical symbol for iron?	Fe
What word means `brother or sister'?	sibling
What was Beethoven's first name?	Ludwig
How many cups are in a quart?	4

So feed the computer this DATA:

```
DATA What's the capital of Nevada,Carson City
DATA What's the chemical symbol for iron,Fe
DATA What word means 'brother or sister',sibling
DATA What was Beethoven's first name,Ludwig
DATA How many cups are in a quart,4
```

In the DATA, each pair consists of a question and an answer. To make the computer READ the DATA, tell the computer to READ a question and an answer, repeatedly:

```
DO
    READ question$, answer$
LOOP
```

Here's the complete program:

```
DATA What's the capital of Nevada,Carson City
DATA What's the chemical symbol for iron,Fe
DATA What word means 'brother or sister',sibling
DATA What was Beethoven's first name,Ludwig
DATA How many cups are in a quart,4
DATA end,end
DO
    READ question$, answer$: IF question$ = "end" THEN EXIT DO
    PRINT question$;
    INPUT "??"; response$
    IF response$ = answer$ THEN
        PRINT "Correct!"
    ELSE
        PRINT "No, the answer is:  "; answer$
    END IF
LOOP
PRINT "I hope you enjoyed the quiz!"
```

The lines underneath READ make the computer PRINT the question, wait for the human to INPUT a response, and check IF the human's response matches the correct answer. Then the computer will either PRINT "Correct!" or PRINT "No" and reveal the correct answer. When the computer reaches the end of the DATA, the computer does an EXIT DO and prints "I hope you enjoyed the quiz!"

Here's a sample run, where I've underlined the parts typed by the human:

```
What's the capital of Nevada??? Las Vegas
No, the answer is:  Carson City
What's the chemical symbol for iron??? Fe
Correct!
What word means 'brother or sister'??? I give up
No, the answer is:  sibling
What was Beethoven's first name??? Ludvig
No, the answer is:  Ludwig
How many cups are in a quart??? 4
Correct!
I hope you enjoyed the quiz!
```

To give a quiz about different topcs, change the DATA.

Let's make the computer count how many questions the human answered correctly. To do that, we need a counter. As usual, let's call it c:

```
DATA What's the capital of Nevada,Carson City
DATA What's the chemical symbol for iron,Fe
DATA What word means 'brother or sister',sibling
DATA What was Beethoven's first name,Ludwig
DATA How many cups are in a quart,4
DATA end,end
c = 0
DO
    READ question$, answer$: IF question$ = "end" THEN EXIT DO
    PRINT question$;
    INPUT "??"; response$
    IF response$ = answer$ THEN
        PRINT "Correct!"
        c = c + 1
    ELSE
        PRINT "No, the answer is:  "; answer$
    END IF
LOOP
PRINT "I hope you enjoyed the quiz!"
PRINT "You answered"; c; "of the questions correctly."
```

At the program's beginning, the human hasn't answered any questions correctly yet, so the counter begins at 0 (by saying "c = 0"). Each time the human answers a question correctly, the computer does "c = c + 1", which increases the counter. The program's bottom line prints the counter, by printing a message such as:

```
You answered 2 of the questions correctly.
```

It would be nicer to print —

```
You answered 2 of the 5 questions correctly.
Your score is 40 %
```

or, if the quiz were changed to include 8 questions:

```
You answered 2 of the 8 questions correctly.
Your score is 25 %
```

To make the computer print such a message, we must make the computer count how many questions were asked. So we need another counter. Since we already used c to count the number of correct answers, let's use q to count the number of questions asked. Like c, q must start at 0; and we must increase q, by adding 1 each time another question is asked:

```
DATA What's the capital of Nevada,Carson City
DATA What's the chemical symbol for iron,Fe
DATA What word means 'brother or sister',sibling
DATA What was Beethoven's first name,Ludwig
DATA How many cups are in a quart,4
DATA end,end
q = 0
c = 0
DO
    READ question$, answer$: IF question$ = "end" THEN EXIT DO
    PRINT question$;
    q = q + 1
    INPUT "??"; response$
    IF response$ = answer$ THEN
        PRINT "Correct!"
        c = c + 1
    ELSE
        PRINT "No, the answer is:  "; answer$
    END IF
LOOP
PRINT "I hope you enjoyed the quiz!"
PRINT "You answered"; c; "of the"; q; "questions correctly."
PRINT "Your score is"; c / q * 100; "%"
```

Summing Let's make the computer imitate an adding machine, so a run looks like this:

```
Now the sum is 0
What number do you want to add to the sum? 5
Now the sum is 5
What number do you want to add to the sum? 3
Now the sum is 8
What number do you want to add to the sum? 6.1
Now the sum is 14.1
What number do you want to add to the sum? -10
Now the sum is 4.1
etc.
```

Here's the program:

```
s = 0
DO
    PRINT "Now the sum is"; s
    INPUT "What number do you want to add to the sum"; x
    s = s + x
LOOP
```

The top line starts the sum at 0. The PRINT line prints the sum. The INPUT line asks the human what number to add to the sum; the human's number is called x. The next line (s = s + x) adds x to the sum, so the sum changes. The LOOP line sends the computer back to the PRINT line, which prints the new sum. The program's an infinite loop, which you must abort.

Here's the general procedure to make the computer find a sum:

Start s at 0.

Then write a DO loop.

In the DO loop, make the computer use s (such as by saying PRINT s) and increase s (by saying s = s + the number to be added).

Checking account If your bank's nasty, it charges you 20¢ to process each good check you write, a $25 penalty for each check that bounces, and pays no interest on money you've deposited.

This program makes the computer imitate such a bank.…

```
s = 0
DO
    PRINT "Your checking account contains"; s
    1 INPUT "Press d (to make a deposit) or c (to write a check)"; a$
    SELECT CASE a$
        CASE "d"
            INPUT "How much money do you want to deposit"; d
            s = s + d
        CASE "c"
            INPUT "How much money do you want the check for"; c
            c = c + .2
            IF c <= s THEN
                PRINT "Okay"
                s = s - c
            ELSE
                PRINT "That check bounced!"
            s = s - 25
            END IF
        CASE ELSE
            PRINT "Please press d or c"
            GOTO 1
    END SELECT
LOOP
```

In that program, the total amount of money in the checking account is called the sum, s. The top line (s = 0) starts that sum at 0. The first PRINT line prints the sum. The next line asks the human to press "d" (to make a deposit) or "c" (to write a check).

If the human presses "d" (to make a deposit), the computer asks "How much money do you want to deposit?" and waits for the human to type an amount to deposit. The computer adds that amount to the sum in the account (s = s + d).

If the human presses "c" (to write a check), the computer asks "How much money do you want the check for?" and waits for the human to type the amount on the check. The computer adds the 20¢ check-processing fee to that amount (c = c + .2). Then the computer reaches the line saying "IF c <= s", which checks whether the sum s in the account is big enough to cover the check (c). If c <= s, the computer says "Okay" and processes the check, by subtracting c from the sum in the account. If the check is too big, the computer says "That check bounced!" and decreases the sum in the account by the $25 penalty.

That program is nasty to customers:

For example, suppose you have $1 in your account, and you try to write a check for 85¢. Since 85¢ + the 20¢ service charge = $1.05, which is more than you have in your account, your check will bounce, and you'll be penalized $25. That makes your balance become *negative* $24, and the bank will demand *you* pay the *bank* $24 — just because you wrote a check for 85¢!

Another nuisance is when you leave town permanently and want to close your account. If your account contains $1, you can't get your dollar back! The most you can withdraw is 80¢, because 80¢ + the 20¢ service charge = $1.

That nasty program makes customers hate the bank — and hate the computer! The bank should make the program friendlier. Here's how:

To stop accusing the customer of owing money, the bank should change any negative sum to 0, by inserting this line just under the word DO:

```
IF s < 0 THEN s = 0
```

Also, to be friendly, the bank should ignore the 20¢ service charge when deciding whether a check will clear. So the bank should eliminate the line saying "c = c + .2". On the other hand, if the check *does* clear, the bank should impose the 20¢ service charge afterwards, by changing the "s = s - c" to "s = s - c - .2".

So if the bank is kind, it will make all those changes. But some banks complain that those changes are *too* kind! For example, if a customer whose account contains just 1¢ writes a million-dollar check (which bounces), the new program charges him just 1¢ for the bad check; $25 might be more reasonable.

Moral: **the hardest thing about programming is choosing your goal — deciding what you WANT the computer to do**.

Series Let's make the computer add together all the numbers from 7 to 100, so that the computer finds the sum of this series: 7 + 8 + 9 + ... + 100. Here's how.

```
Start the sum at 0:                    s = 0
Make i go from 7 to 100:               FOR i = 7 TO 100
Increase sum, by adding each i to it:      s = s + i
                                       NEXT
Print the final sum (which is 5029): PRINT s
```

Let's make the computer add together the *squares* of all the numbers from 7 to 100, so that the computer finds the sum of this series: (7 squared) + (8 squared) + (9 squared) +… + (100 squared). Here's how:

```
s = 0
FOR i = 7 TO 100
    s = s + i * i
NEXT
PRINT s
```

It's the same as the previous program, except that indented line says to add i*i instead of i. The bottom line prints the final sum, which is 338259.

Data sums This program adds together the numbers in the data:

```
DATA 5, 3, 6.1, etc.
DATA 0
s = 0
DO
    READ x: IF x = 0 THEN EXIT DO
    s = s + x
LOOP
PRINT s
```

The DATA line contains the numbers to be added. The DATA 0 is an end mark. The line saying "s = 0" starts the sum at 0. The READ statement reads an x from the data. The next line (s = s + x) adds x to the sum. The LOOP line makes the computer repeat that procedure for every x. When the computer has read all the data and reaches the end mark (0), the x becomes 0; so the computer will EXIT DO and PRINT the final sum, s.

Pretty output

Here's how to make your output prettier.

Zones

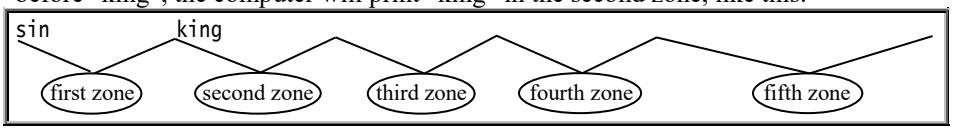
The screen is divided into 5 wide columns, called **zones**. The leftmost zone is called **zone 1**; the rightmost zone is called **zone 5**.

Zones 1, 2, 3, and 4 are each 14 characters wide. Zone 5 is extra-wide: it's 24 characters wide. So altogether, the width of the entire screen is 14+14+14+14+24, which is 80 characters. The screen is 80 characters wide.

A comma makes the computer jump to a new zone. Here's an example:

```
PRINT "sin", "king"
```

The computer will print "sin" and "king" on the same line; but because of the comma before "king", the computer will print "king" in the second zone, like this:



Here are the words of a poet who drank too much and is feeling spaced out:

```
PRINT "love", "cries", "out"
```

The computer will print "love" in the first zone, "cries" in the second zone, and "out" in the third zone, so the words are spaced out like this:

```
love          cries         out
```

This program's even spacier:

```
PRINT "love", "cries", "out", "to", "me", "at", "night"
```

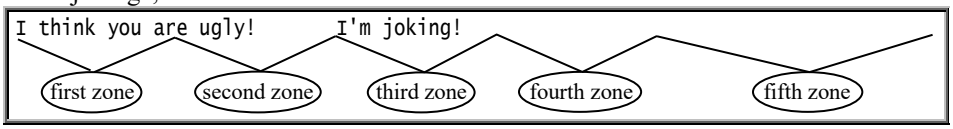
The computer will print "love" in the first zone, "cries" in the second, "out" in the third, "to" in the fourth, "me" in the fifth, and the remaining words below, like this:

```
love          cries         out           to            me
at            night
```

This program tells a bad joke:

```
PRINT "I think you are ugly!", "I'm joking!"
```

The computer will print "I think you are ugly!", then jump to a new zone, then print "I'm joking", like this:



When you combine commas with semicolons, you can get weird results:

```
PRINT "eat", "me"; "at"; "balls", "no"; "w"
```

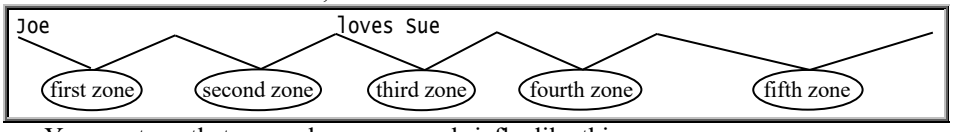
That line contains commas and semicolons. A comma makes the computer jump to a new zone, but a semicolon does *not* make the computer jump. The computer will print "eat", then jump to a new zone, then print "me" and "at" and "balls", then jump to a new zone, then print "no" and "w". Altogether, the computer will print:

```
eat           meatballs     now
```

Skip a zone You can make the computer skip over a zone:

```
PRINT "Joe", " ", "loves Sue"
```

The computer will print "Joe" in the first zone, a blank space in the second zone, and "loves Sue" in the third zone, like this:



You can type that example even more briefly, like this:

```
PRINT "Joe", , "loves Sue"
```

Loops This program makes the computer greet you:

```
DO
  PRINT "hello",
LOOP
```

The computer will print "hello" many times. Each time will be in a new zone, like this:

```
hello         hello         hello         hello         hello
hello         hello         hello         hello         hello
hello         hello         hello         hello         hello
etc.
```

Tables This program prints a list of words and their opposites:

```
PRINT "good", "bad"
PRINT "black", "white"
PRINT "grandparent", "grandchild"
PRINT "he", "she"
```

The top line makes the computer print "good", then jump to the next zone, then print "bad". Altogether, the computer will print:

```
good          bad
black         white
grandparent   grandchild
he            she
```

The first zone contains a column of words; the second zone contains the opposites. Altogether, the computer's printing looks like a table. So **whenever you want to make a table easily, use zones, by putting commas in your program**.

Let's make the computer print this table:

```
Number        Square
 3             9
 4             16
 5             25
 6             36
 7             49
 8             64
 9             81
 10            100
```

Here's the program:

```
PRINT "Number", "Square"
FOR i = 3 TO 10
    PRINT i, i * i
NEXT
```

The top line prints the word "Number" at the top of the first column, and the word "Square" at the top of the second. Those words are called the **column headings**. The FOR line says i goes from 3 to 10; to begin, i is 3. The indented line makes the computer print:

```
 3             9
```

The bottom line makes the computer do the same thing for the next i, and for the next i, and for the next; so the computer prints the whole table.

TAB

When the computer puts a line of information on your screen, the leftmost character in the line is said to be at **position 1**. The second character in the line is said to be at **position 2**.

This program makes the computer skip to position 6 and then print "HOT":

```
PRINT TAB(6); "hot"
```

The computer will print:

```
     hot
12345678
```

Here's a fancier example:

```
PRINT TAB(6); "hot"; TAB(13); "buns"
```

The computer will skip to the 6th position, then print "hot", then skip to the 13th position, then print "buns":

```
     HOT    BUNS
12345678    13
```

Diagonal This program prints a diagonal line:

```
FOR i = 1 TO 12
    PRINT TAB(i); "*"
NEXT
```

The FOR line says to do the loop 12 times, so the computer does the indented line. The first time the computer does the indented line, the i is 1, so the computer prints an asterisk at position 1:

```
*
```

The next time, the i is 2, so the computer skips to position 2 and prints an asterisk:

```
 *
```

The next time, the i is 3, so the computer skips to position 3 and prints an asterisk:

```
  *
```

Altogether, the program makes the computer print this picture:

```
*
 *
  *
   *
    *
     *
      *
       *
        *
         *
          *
           *
            *
```

LOCATE

While you're running a program, the black window shows 25 lines of information. The screen's top line is called **line 1**; underneath it is **line 2**; then comes **line 3**; etc. The bottom line is **line 25**.

Each line consists of 80 characters. The leftmost character is at **position 1**; the next character is at **position 2**; etc. The rightmost character is at **position 80**.

In the black window, the computer will print wherever you wish.

For example, to make the computer print the word "drown" so that "drown" begins at line 3's 7th position, type this:

```
LOCATE 3, 7: PRINT "drown"
```

The computer will print the word's first letter (d) at line 3's 7th position. The computer will print the rest of the word afterwards.

You'll see the first letter (d) at line 3's 7th position, the next letter (r) at the next position (line 3's 8th position), the next letter (o) at the next position (line 3's 9th position), etc.

Middle of the screen Since the black window's top line is 1 and the bottom line is 25, **the middle line is 13**. Since the screen's leftmost position is 1 and the rightmost position is 80, **the middle positions are 40 and 41**.

To make the computer print the word "Hi" in the middle of the black window, tell the computer to print at the middle line (13) and the middle positions (40 and 41):

```
LOCATE 13, 40: PRINT "Hi"
```

Bottom line Whenever the computer finishes running a program, the computer prints this message on the black screen's bottom line:

```
Press any key to continue
```

Then the computer waits for you to press the Enter key, which makes the screen turn blue and show the lines of your program.

That message, "Press any key to continue", is the only message that the computer wants to print on the bottom line.

To force the computer to print anything else on the bottom line, do this: say LOCATE, mention line 25, put a semicolon at the end of the PRINT statement (to prevent the computer from pressing the Enter key, which would disturb the rest of the screen), and say SLEEP (to make the computer pause awhile so you can admire the printing). For example, this program prints an "x" at the black window's bottom right corner:

```
LOCATE 25, 80: PRINT "x";
SLEEP
```

Pixels

The image on the black window's screen is called the **picture**. If you stare at the picture closely, you'll see the picture's composed of thousands of tiny dots. Each dot, which is a tiny rectangle, is called a **picture's element**, or **pic's el**, or **pixel**, or **pel**.

Coordinates The dot in the black window's top left corner is called **pixel (0,0)**. Just to the right of it is pixel (1,0). Then comes pixel (2,0), etc.

Underneath pixel (0,0) is pixel (0,1). Farther down is pixel (0,2).

Here are the positions of the pixels:

pixel (0,0)	pixel (1,0)	pixel (2,0)	pixel (3,0)	pixel (4,0)	etc.
pixel (0,1)	pixel (1,1)	pixel (2,1)	pixel (3,1)	pixel (4,1)	etc.
pixel (0,2)	pixel (1,2)	pixel (2,2)	pixel (3,2)	pixel (4,2)	etc.
pixel (0,3)	pixel (1,3)	pixel (2,3)	pixel (3,3)	pixel (4,3)	etc.

Each pixel's name consists of two numbers in parentheses. The first number is the **X coordinate**; the second number is the **Y coordinate**. For example, if you're talking about pixel (4,3), its X coordinate is 4; its Y coordinate is 3.

The X coordinate tells how far to the right the pixel is. The Y coordinate tells how far down. So **pixel (4,3) is the pixel that's 4 to the right and 3 down.**

On the computer, the Y coordinate measures how far *down*, not up. If you've read old-fashioned math books in which the Y coordinate measured how far up, you'll have to reverse your thinking!

Screen modes How many pixels are on the screen? The answer depends on which **screen mode** you choose.

For most purposes, the best screen mode is **screen mode 12**.

In screen mode 12, the X coordinate goes from 0 to 639, and the Y coordinate goes from 0 to 479, so the pixel at the window's bottom right corner is pixel (639,479). Since you have 640 choices for the X coordinate (numbered from 0 to 639) and 480 choices for the Y coordinate (numbered from 0 to 479), that mode is called a **640-by-480 mode**.

In screen mode 12, the computer can display 16 colors simultaneously.

Screen mode 13 gives you more colors but fewer pixels:

In screen mode 13, the X coordinate goes from 0 to 319, and the Y coordinate goes from 0 to 199, so the pixel at the window's bottom right corner is pixel (319,199). Since you have 320 choices for the X coordinate (numbered from 0 to 639) and 200 choices for the Y coordinate (numbered from 0 to 479), that mode is called a **320-by-200 mode**.

In screen mode 13, the computer can display 256 colors simultaneously.

Since mode 13 has fewer pixels, its drawings look crude.

Each pixel is a tiny rectangular dot.

QB64 Each pixel is a perfect square, whose width is the same as its height.

QBasic In screen mode 12, each pixel is a perfect square, whose width is the same as its height: on a typical 15-inch screen, each pixel's width and height are about a 60^{th} of an inch. In screen mode 13, each pixel is slightly taller than it is wide, so each pixel looks like a little tower.

There's also a **screen mode 0**, which works on all computers and **produces just text** (no graphics).

To give commands about pixels, begin by telling the computer which screen mode you want. For example, if you want screen mode 12, say:

```
SCREEN 12
```

When you give such a SCREEN command, the computer automatically clears the window so the whole window becomes black. You do *not* have to say CLS.

PSET This program makes the window become entirely black then makes pixel (100,100) turn white:

```
SCREEN 12
PSET (100, 100)
```

In that program, the PSET (100, 100) makes pixel (100,100) turn white. The word "PSET" means "pixel set": "PSET (100, 100)" means "set the pixel (100,100) to white".

LINE This program draws a white line from pixel (0,0) to pixel (100,100):

```
SCREEN 12
LINE (0, 0)-(100, 100)
```

This program draws a white line from pixel (0,0) to pixel (100,100), then draws a white line from that pixel (100,100) to pixel (120,70):

```
SCREEN 12
LINE (0, 0)-(100, 100)
LINE -(120, 70)
```

CIRCLE This program draws a white circle whose center is pixel (100,100) and whose radius is 40 pixels:

```
SCREEN 12
CIRCLE (100, 100), 40
```

In screen mode 12, each pixel is a perfect square, and the computer draws the circle easily. The circle's radius is 40 pixels; the circle's diameter (width) is 80 pixels.

If you switch to screen mode 13 (by saying SCREEN 13), each pixel is a tower instead of a square, so a "circle that's 80 pixels wide and 80 pixels high" would be taller than wide and look like a tall oval. To make sure your "circle of radius 40" looks pretty, the computer cheats: the computer makes the circle's width be 80 pixels but makes the circle's height be fewer than 80 pixels, so that the circle's height is the same number of *inches* as the width.

Avoid the bottom When your program finishes, the bottom of the screen automatically shows this advice:

```
Press any key to continue
```

To prevent that advice from covering up your drawing, position your drawing near the *top* of the screen (avoiding the bottom), or else make your program's bottom line say "SLEEP" so the computer will pause and let you admire the drawing before the advice covers it.

PAINT After drawing a shape's outline (by using dots, lines, and circles), you can fill in the shape's middle, by telling the computer to PAINT the shape.

Here's how to PAINT a shape that you've drawn (such as a circle or a house). Find a pixel that's in the middle of the shape and that's still black; then tell the computer to PAINT, starting at that pixel. For example, if pixel (100, 101) is inside the shape and still black, say:

```
PAINT (100, 101)
```

Colors In screen mode 12, you can use these 16 colors:

0. black	8. light black (gray)
1. blue	9. light blue
2. green	10. light green
3. cyan (greenish blue)	11. light cyan (aqua)
4. red	12. light red (pink)
5. magenta (purplish red)	13. light magenta
6. brown	14. light brown (yellow)
7. cream (yellowish white)	15. light cream (pure white)

Screen mode 13 gives you the 16 colors used in screen mode 12 — and many more colors, too! Here's the spectrum:

```
  0 through   7: black, blue, green, cyan, red, magenta, brown, cream
  8 through  15: same colors as above, but lighter
 16 through  31: shades of gray (from dark to light)
 32 through  55: color blends (from blue to red to green to blue again)
 56 through  79: same color blends, but lighter
 80 through 103: same color blends, but even lighter
104 through 175: same as 32 through 103, but darker
176 through 247: same as 104 through 175, but even darker
248 through 255: black
```

Normally, the PSET, LINE, CIRCLE, and PAINT commands draw in yellowish white (cream). If you prefer a different color, **put the color's number at the end of the command**. Put a comma before the color's number.

For example, if you want to draw a line from (0,0) to (100,0) using color #2, type this:

```
LINE (0, 0)-(100, 0), 2
```

When you give a PAINT command, you must make its color be the same color as the outline you're filling in.

Boxes If you type —

```
LINE (0, 0)-(100, 100), 2
```

the computer draws a line from pixel (0,0) to (100,100) using color #2.

If you put the letter B at the end of the LINE command, like this —

```
LINE (0, 0)-(100, 100), 2, B
```

the computer will draw a box instead of a line. One corner of the box will be at pixel (0,0); the opposite corner will be at (100,100); and the box will be drawn using color 2.

If you put BF at the end of the LINE command, like this —

```
LINE (0, 0)-(100, 100), 2, BF
```

the computer will draw a box and also fill it in, by painting its interior.

Return to text mode When you finish drawing pictures, you can return to text mode by saying:

```
SCREEN 0
```

If you were using screen mode 13, say this instead:

```
SCREEN 0
WIDTH 80
```

The "WIDTH 80" makes sure the screen will display 80 characters per line instead of 40.

Sounds

To produce sounds, you can say BEEP, SOUND, or PLAY. BEEP appeals to business executives; SOUND appeals to doctors and engineers; and PLAY appeals to musicians.

BEEP If your program says —

```
BEEP
```

the computer will beep. The beep lasts for about a quarter of a second. Its frequency ("pitch") is about 875 hertz. (The beep's length and frequency might be slightly higher or lower, depending on which computer you have.)

You can say BEEP in the middle of your program. For example, you can tell the computer to BEEP if a person enters wrong data.

This program makes the computer act as a priest and perform a marriage ceremony:

```
10 INPUT "Do you take this woman to be your lawful wedded wife"; a$
IF a$ <> "I do" THEN BEEP: PRINT "Try again!": GO TO 10
20 INPUT "Do you take this man to be your lawful wedded husband"; a$
IF a$ <> "I do" THEN BEEP: PRINT "Try again!": GO TO 20
PRINT "I now pronounce you husband and wife."
```

The top line makes the computer ask the groom, "Do you take this woman to be your lawful wedded wife?" If the groom doesn't say "I do", the next line makes the computer beep, say "Try again!", and repeat the question. Line 20 does the same thing to the bride. The bottom line congratulates the couple for answering correctly and getting married.

SOUND If your program says —

```
SOUND 440, 18.2
```

the computer will produce a sound. In that command, the 440 is the frequency ("pitch"), measured in hertz (cycles per second); so the sound will be a musical note whose pitch is 440 hertz. (That note happens to be "the A above middle C").

If you replace the 440 by a lower number, the sound will have a lower pitch; if you replace the 440 by a higher number, the sound will have a higher pitch.

The lowest pitch that the computer can sing is 37. If you try to go below 37, the computer will gripe by saying:

```
Illegal function call
```

The highest pitch that the computer can sing is 32767, but human ears aren't good enough to hear a pitch that high.

When you were a baby, you could probably hear up to 20000. As you get older, your hearing gets worse, and you can't hear such high notes. Today, the highest sound you can hear is probably somewhere around 14000. To find out, give yourself a hearing test, by running this program:

```
DO
    INPUT "What pitch would you like me to play"; p
    SOUND p, 18.2
LOOP
```

When you run that program, begin by inputting a low pitch (such as 37). Then input a higher number, then an even higher number, until you finally pick a number so high you can't hear it. (When trying that test, put your ear close to the computer's speaker, which is in the computer's front left corner.) When you've picked a number too high for you to hear, try a slightly lower number. Keep trying different numbers, until you find the highest number you can hear.

Have a contest with your friends: find out which of your friends can hear best.

If you run that program every year, you'll see that your hearing gets gradually worse. For example, when I was 36 years old, the highest pitch I could hear was about 14500, but I can't hear that high anymore. How about *you*?

In those examples, the 18.2 makes the computer produce the sound for 1 second. **If you want the sound to last longer — so it lasts 2 seconds — replace the 18.2 by 18.2*2.** For 10 seconds, say 18.2*10. (That's because the computer's metronome beats 18.2 times per second.)

PLAY If your program says —

```
PLAY "c d g# b- a"
```

the computer will play the note C, then D, then G sharp, then B flat, then A.

In the PLAY command, the computer ignores the spaces; so if you wish, you can write:

```
PLAY "cdg#b-a"
```

The computer can play in seven octaves, numbered from 0 to 6. Octave 0 consists of very bass notes; octave 6 consists of very high-pitched notes. In each octave, the lowest note is a C: the notes in an octave are C, C#, D, D#, E, F, F#, G, G#, A, A#, and B. "Middle C" is at the beginning of octave 2. Normally, the computer plays in octave 4. **To make the computer switch to octave 3, type the letter "o" followed by a 3**, like this:

```
PLAY "o3"
```

After giving that command, anything else you PLAY will be in octave 3, until you change octaves again.

You can use the symbol ">" to mean "go up an octave", and you can use the symbol "<" to mean "go down an octave". For example, if you say —

```
PLAY "g > c d < g"
```

the computer will play the note G, then go up an octave to play C and D in that higher octave, then go down to the original octave to play G again.

The lowest note the computer can play (the C in octave 0) is called "note 1". The highest note the computer can play (the B in octave 6) is called "note 84". **To make the computer play note 84, you can type this:**

```
PLAY "n84"
```

To make the computer play its lowest note (1), then its middle note (42), then its highest note (84), type this:

```
PLAY "n1 n42 n84"
```

Besides playing with pitches, **you can play with rhythms ("lengths" of notes).** Normally each note is a "quarter note". **To make the computer switch to eighth notes (which are faster), type this:**

```
PLAY "L8"
```

Besides using L8 for eighth notes, you can use L16 for sixteenth notes (which are even faster), L32 for thirty-second notes (which are super-fast), and L64 for sixty-fourth notes (which are super-super-fast). For long notes, you can use L2 (which gives a half note) or L1 (which gives a whole note). You can use any length from L1 to L64. You can even use in-between lengths, such as L7 or L23 (though such rhythms are hard to stamp your foot to).

If you put a period after a note, the computer will multiply the note's length by 1½.

For example, suppose you say:

```
PLAY "L8 c e. d"
```

The C will be an 8th note, E will be 1½ times as long as an 8th note, and D will be an 8th note. Musicians call that E a **dotted eighth note**.

If you put *two* periods after a note (like this: e..), the computer will multiply the note's length by 1¾. Musicians say the note is **double dotted**.

If you put *three* periods after a note (like this: e...), the computer will multiply the note's length by 1⅞.

To make the computer pause ("rest") for an eighth note, put a p8 into the music string.

Normally, the computer plays 120 quarter notes per minute; but you can change that tempo. To switch to 150 quarter notes per minute, say:

```
PLAY "t150"
```

You can switch to any tempo from 32 to 255. The 32 is very slow; 255 is very fast. In musical terms, 40=larghissimo, 50=largo, 63=larghetto, 65=grave, 68=lento, 71=adagio, 76=andantino, 92=andante, 114=moderato, 120=allegretto, 144=allegro, 168=vivace, 188=presto, and 208=prestissimo.

You can combine all those musical commands into a single PLAY statement. For example, to set the tempo to 150, the octave to 3, the length to 8 (which means an eighth note), and then play C and D, and then change the length to 4 and play E, type this:

```
PLAY "t150 o3 L8 c d L4 e"
```

PRINT USING

Suppose you want to add $12.47 to $1.03. The correct answer is $13.50. This almost works:

```
PRINT 12.47 + 1.03
```

It makes the computer print:

```
 13.5
```

But instead of 13.5, we should try to make the computer print 13.50.

This command forces the computer to print 13.50:

```
PRINT USING "##.##"; 12.47 + 1.03
```

The "##.##" is called the **picture** or **image** or **format**: it says to print two characters, then a decimal point, then two digits. The computer will print:

```
13.50
```

This command puts that answer into a sentence:

```
PRINT USING "You spent ##.## at our store"; 12.47 + 1.03
```

The computer will print:

```
You spent 13.50 at our store
```

Rounding This program makes the computer divide 300 by 7 but round the answer to two decimal places:

```
PRINT USING "##.##"; 300 / 7
```

When the computer divides 300 by 7, it gets 42.85714, but the format rounds the answer to 42.86. The computer will print:

```
42.86
```

Multiple numbers Every format (such as "###.##") is a string. You can replace the format by a string variable:

```
a$ = "###.##"
PRINT USING a$; 247.91
PRINT USING a$; 823
PRINT USING a$; 7
PRINT USING a$; -5
PRINT USING a$; -80.3
```

The computer will print:

```
247.91
823.00
  7.00
 -5.00
-80.30
```

When the computer prints that column of numbers, notice that the computer prints the decimal points underneath each other so that they line up. So **to make decimal points line up, say PRINT USING instead of just PRINT**.

To print those numbers *across* instead of down, say this:

```
PRINT USING "###.##"; 247.91; 823; 7; -5; -80.3
```

It makes the computer print 247.91, then 823.00, etc., like this:

```
247.91823.00  7.00 -5.00-80.30
```

Since the computer prints those numbers so close together, they're hard to read. To make the computer insert extra space between the numbers, widen the format by putting a fourth "#" before the decimal point:

```
PRINT USING "####.##"; 247.91; 823; 7; -5; -80.3
```

Then the computer will print:

```
 247.91 823.00   7.00  -5.00 -80.30
```

If you say —

```
PRINT USING "My ## pals drank ###.# pints of gin"; 24; 983.5
```

the computer will print:

```
My 24 pals drank 983.5 pints of gin
```

Oversized numbers Suppose you say:

```
PRINT USING "###.##"; 16238.7
```

The computer tries to print 16238.7 by using the format "###.##". But since that format allows just three digits before the decimal point, the format isn't large enough to fit 16238.7. So the computer must disobey the format. But the computer also prints a percent sign, which means, "Warning! I am disobeying you!" Altogether, the computer prints:

```
%16238.70
```

Final semicolon At the end of the PRINT USING statement, you can put a semicolon:

```
PRINT USING "##.##"; 13.5;
PRINT "credit"
```

The top line makes the computer print 13.50. The semicolon at the top line's end makes the computer print "credit" on the same line, like this:

```
13.50credit
```

Advanced formats Suppose you're running a high-risk business. On Monday, your business runs badly: you *lose* $27,931.60, so your "profit" is *minus* $27,931.60. On Tuesday, your business does slightly better than break-even: your net profit for the day is $8.95.

Let's make the computer print the word "profit", then the amount of your profit (such as -$27,931.60 or $8.95), then the word "ha" (because you're cynical about how your business is going).

You can do that printing in several ways. Let's explore them.…

If you say —

```
a$ = "profit######.##ha"
PRINT USING a$; -27931.6
PRINT USING a$; 8.95
```

the computer will print:

```
profit-27931.60ha
profit     8.95ha
```

If you change the format to "profit###,###.##ha", the computer will **insert a comma** if the number is large:

```
profit-27,931.60ha
profit      8.95ha
```

If you change the format to "profit+#####.##ha", the computer will **print a plus sign** in front of any positive number:

```
profit-27931.60ha
profit    +8.95ha
```

To print a negative number, the computer normally prints a minus sign *before* the number. That's called a **leading minus**. You can make the computer put the minus sign *after* the number instead; that's called a **trailing minus**. For example, if you change the format to "profit######.##-ha", the computer will **print a minus sign AFTER a negative number** (and no minus after a positive number), like this:

```
profit27931.60-ha
profit    8.95 ha
```

Normally, a format begins with ##. If you begin with $$ instead (like this: "profit$$#####.##ha"), the computer will **print a dollar sign** before the digits:

```
profit-$27931.60ha
profit     $8.95ha
```

If you begin with ** (like this: "profit**#####.##ha"), the computer will **print asterisks** before the number:

```
profit*-27931.60ha
profit******8.95ha
```

If you begin with **$ (like this: "profit**$#####.##ha"), the computer will print asterisks and a dollar sign:

```
profit*-$27931.60ha
profit******$8.95ha
```

When you're printing a paycheck, use the asterisks to prevent the employee from enlarging his salary. Since the asterisks protect the check from being altered, they're called **check protection**.

You can combine several techniques into a single format. For example, you can combine the comma, the trailing minus, and the **$ (like this: "profit**$##,###.##-ha"), so that the computer will print:

```
profit**$27,931.60-ha
profit*******$8.95 ha
```

If you change the format to "profit##.#####^^^^ha", the computer will **print numbers by using E notation**:

```
profit-2.79316E+04ha
profit 8.95000E+00ha
```

Fancy calculations

You can do fancy calculations — easily!

Exponents

Try typing this program:

```
PRINT 4 ^ 3
```

To type the symbol ^, do this: while holding down the SHIFT key, tap this key:

```
^
6
```

That symbol (^) is called a **caret**.

In that program, **the "4 ^ 3" makes the computer use the number 4, three times**. The computer will multiply together those three 4's, like this: 4 times 4 times 4. Since "4 times 4 times 4" is 64, the computer will print:

```
 64
```

In the expression "4 ^ 3", the 4 is called the **base**; the 3 is called the **exponent**.

Here's another example:

```
PRINT 10 ^ 6
```

The "10 ^ 6" makes the computer use the number 10, six times. The computer will multiply together those six 10's (like this: 10 times 10 times 10 times 10 times 10 times 10) and print the answer:

```
 1000000
```

Here's another example:

```
PRINT 3 ^ 2
```

The "3 ^ 2" makes the computer use the number 3, two times. The computer will multiply together those two 3's (like this: 3 times 3) and print the answer:

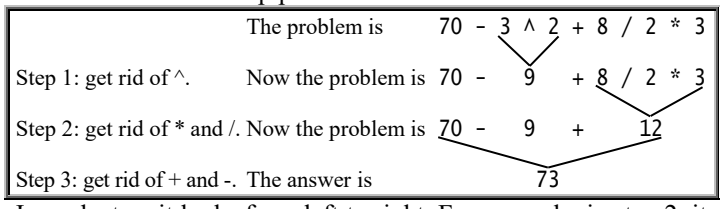
```
 9
```

Order of operations The symbols +, -, *, /, and ^ are all called **operations**.

To solve a problem, the computer uses the three-step process taught in algebra and the "new math". For example, suppose you say:

```
PRINT 70 - 3 ^ 2 + 8 / 2 * 3
```

The computer will *not* begin by subtracting 3 from 70; instead, it will use the three-step process:



In each step, it looks from left to right. For example, in step 2, it sees / and gets rid of it before it sees *.

Speed Though exponents are fun, the computer handles them slowly. For example, the computer handles 3 ^ 2 slower than 3 * 3. So for fast calculations, say 3 * 3 instead of 3 ^ 2.

Square roots What positive number, when multiplied by itself, gives 9? The answer is 3, because 3 times itself is 9.

3 **squared** is 9. 3 is called the **square root** of 9.

To make the computer deduce the square root of 9, type this:

```
PRINT SQR(9)
```

The computer will print 3.

When you tell the computer to PRINT SQR(9), make sure you put the parentheses around the 9.

The symbol SQR is called a **function**. The number in parentheses (9) is called the function's **input** (or **argument** or **parameter**). The answer, which is 3, is called the function's **output** (or **value**).

SQR(9) gives the same answer as 9 ^ .5. The computer handles SQR(9) faster than 9 ^ .5.

Cube roots What number, when multiplied by itself and then multiplied by itself *again*, gives 64? The answer is 4, because 4 times 4 times 4 is 64. The answer (4) is called the **cube root** of 64.

Here's how to make the computer find the cube root of 64:

```
PRINT 64 ^ (1 / 3)
```

The computer will print 4.

EXP The letter "e" stands for a special number, which is approximately 2.718281828459045. You can memorize that number easily, if you pair the digits:

```
2.7 18 28 18 28 45 90 45
```

That weird number is important in calculus, radioactivity, biological growth, and other areas of science. It's calculated by this formula:

$$e = 1 + \frac{1}{1} + \frac{1}{1*2} + \frac{1}{1*2*3} + \frac{1}{1*2*3*4} + \frac{1}{1*2*3*4*5} + \ldots$$

Therefore:

$$e = 1 + 1 + \frac{1}{2} + \frac{1}{6} + \frac{1}{24} + \frac{1}{120} + \ldots$$

EXP(x) means e^x. For example, EXP(3) means e^3, which is e * e * e, which is:

```
2.718281828459045 * 2.718281828459045 * 2.718281828459045
```

EXP(4) means e^4, which is e * e * e * e. EXP(3.1) means $e^{3.1}$, which is more than e^3 but less than e^4.

Here's a practical application. Suppose you put $800 in a savings account, and the bank promises to give you 5% annual interest "compounded continuously". How much money will you have at the end of the year? The answer is 800 * EXP(.05).

Logarithms Here are some powers of 2:

x	2^x
1	2
2	4
3	8
4	16
5	32
6	64

To compute the logarithm-base-2 of a number, find the number in the right-hand column; the answer is in the left column. For example, the logarithm-base-2 of 32 is 5. The logarithm-base-2 of 15 is slightly less than 4.

The logarithm-base-2 of 64 is 6. That fact is written:

$\log_2 64$ is 6

It's also written:

$\frac{\log 64}{\log 2}$ is 6

To make the computer find the logarithm-base-2 of 64, say:

```
PRINT LOG(64) / LOG(2)
```

The computer will print 6.

Here are some powers of 10:

x	10^x
1	10
2	100
3	1000
4	10000
5	100000

The logarithm-base-10 of 100000 is 5. The logarithm-base-10 of 1001 is slightly more than 3.

The logarithm-base-10 of 10000 is 4. That fact is written:

$\log_{10} 10000$ is 4

It's also written:

$\frac{\log 10000}{\log 10}$ is 4

To make the computer do that calculation, say:

```
PRINT LOG(10000) / LOG(10)
```

The computer will print 4.

The logarithm-base-10 is called the **common logarithm**. That's the kind of logarithm used in high school and chemistry. So **if a chemistry book says to find the logarithm of 10000, the book means the logarithm-base-10 of 10000, which is LOG(10000) / LOG(10)**.

What happens if you forget the base, and say just LOG(10000) instead of LOG(10000) / LOG(10)? If you say just LOG(10000), the computer will find the **natural logarithm** of 10000, which is $\log_e 10000$ (where e is 2.718281828459045), which isn't what your chemistry book wants.

Contrasts

The computer's notation resembles that of arithmetic and algebra, but beware of these contrasts.…

Multiplication To make the computer multiply, you must type an asterisk:

Traditional notation	Computer notation
2n	`2 * n`
5(n+m)	`5 * (n + m)`
nm	`n * m`

Exponents Put an exponent in parentheses, if it contains an operation:

Traditional notation	Computer notation
x^{n+2}	`x ^ (n + 2)`
x^{3n}	`x ^ (3 * n)`
$5^{2/3}$	`5 ^ (2 / 3)`
2^{3^4}	`2 ^ (3 ^ 4)`

Fractions Put a fraction's numerator in parentheses, if it contains addition or subtraction:

Traditional notation	Computer notation
$\frac{a+b}{c}$	`(a + b) / c`
$\frac{k-20}{6}$	`(k - 20) / 6`

Put a denominator in parentheses, if it contains addition, subtraction, multiplication, or division:

Traditional notation	Computer notation
$\frac{5}{3+x}$	`5 / (3 + x)`
$\frac{5a^3}{4b}$	`5 * a ^ 3 / (4 * b)`

Mixed numbers A **mixed number** is a number that contains a fraction. For example, 9½ is a mixed number. When you write a mixed number, put a plus sign before its fraction:

Traditional notation	Computer notation
9½	`9 + 1 / 2`

If you're using the mixed number in a further calculation, put the mixed number in parentheses:

Traditional notation	Computer notation
7 - 2¼	`7 - (2 + 1 / 4)`

Clock

If you've set the computer's clock correctly, this program prints the current date & time:

```
PRINT DATE$
PRINT TIME$
```

If you say —

```
PRINT TIMER
```

the computer will tell you how many seconds have elapsed since midnight.

This program makes the computer print the DATE$, TIME$, and TIMER across the top of your screen:

```
PRINT DATE$, TIME$, TIMER
```

The top of your screen will look like this:

```
07-29-1996     18:07:04        65223.85
```

The following program makes the computer look at the clock (and tell you the TIME$), then look at the clock *again* and tell you the new TIME$, then look at the clock *again* and tell you the new TIME$, etc.:

```
DO
  PRINT TIME$
LOOP
```

For example, if the time starts at 18:07:04 (and eventually changes to 18:07:05 and then 18:07:06), the screen will look like this:

```
18:07:04
18:07:04
18:07:04
18:07:05
18:07:05
18:07:05
18:07:05
18:07:05
18:07:06
18:07:06
etc.
```

The program will continue telling you the time until you abort the program.

Stripping

Sometimes the computer prints *too* much info: you wish the computer would print less, to save yourself the agony of reading excess info irrelevant to your needs. Whenever the computer prints too much info about a numerical answer, use ABS, FIX, INT, CINT, or SGN.

ABS removes any minus sign. For example, the ABS of -3.89 is 3.89. So if you say PRINT ABS(-3.89), the computer will print just 3.89.

FIX removes any digits after the decimal point. For example, the FIX of 3.89 is 3. So if you say PRINT FIX(3.89), the computer will print just 3. The FIX of -3.89 is -3.

CINT rounds to the NEAREST integer. For example, the CINT of 3.89 is 4; the CINT of -3.89 is -4.

INT rounds the number DOWN to an integer that's LOWER. For example, the INT of 3.89 is 3 (because 3 is an integer that's lower than 3.89); the INT of -3.89 is -4 (because -4 is lower than -3.89).

SGN removes ALL the digits and replaces them with a 1 — unless the number is 0. For example, the SGN of 3.89 is 1. The SGN of -3.89 is -1. The SGN of 0 is just 0.

ABS, FIX, CINT, INT, and SGN are all called **stripping functions** or **strippers** or **diet functions** or **diet pills**, because they strip away the number's excess fat and reveal just the fundamentals that interest you.

Here are more details about those five functions.…

ABS To find the **absolute value** of a negative number, just omit the number's minus sign. For example, the absolute value of -7 is 7.

The absolute value of a positive number is the number itself. For example, the absolute value of 7 is 7. The absolute value of 0 is 0.

To make the computer find the absolute value of -7, type this:

```
PRINT ABS(-7)
```

The computer will print:

```
 7
```

Like SQR, ABS is a function: you must put parentheses after the ABS.

Since ABS omits the minus sign, ABS turns negative numbers into positive numbers. Use ABS whenever you insist that an answer be positive.

For example, ABS helps solve math & physics problems about "distance", since the "distance" between two points is always a positive number and cannot be negative.

This program computes the distance between two numbers:

```
PRINT "I will find the distance between two numbers."
INPUT "What's the first number"; x
INPUT "What's the second number"; y
PRINT "The distance between those numbers is"; ABS(x - y)
```

When you run that program, suppose you say that the first number is 4 and the second number is 7. Since x is 4, and y is 7, the distance between those two numbers is ABS(4 - 7), which is ABS(-3), which is 3.

If you reverse those two numbers, so that x is 7 and y is 4, the distance between them is ABS(7 - 4), which is ABS(3), which is still 3.

FIX An **integer** is a number that has no decimal point. For example, these are integers: 17, 238, 0, and -956.

If a number contains a decimal point, the simplest way to turn the number into an integer is to delete all the digits after the decimal point. That's called the **FIX** of the number.

For example, the FIX of 3.89 is 3. So if you say PRINT FIX (3.89), the computer will print just 3.

The FIX of -3.89 is -3. The FIX of 7 is 7. The FIX of 0 is 0.

CINT A more sophisticated way to turn a number into an integer is to *round* the number to the *nearest* integer. That's called **CINT** (which means "Convert to INTeger"). For example, the CINT of 3.9 is 4 (because 3.9 is closer to 4 than to 3).

Like FIX, CINT deletes all the digits after the decimal point; but if the digit just after the decimal point is 5, 6, 7, 8, or 9, CINT "rounds up" by adding 1 to the digit before the decimal point.

Here are more examples:

```
CINT(3.9) is 4     CINT(-3.9) is -4
CINT(3.1) is 3     CINT(-3.1) is -3
CINT(3.5) is 4     CINT(-3.5) is -4
```

The highest number CINT can produce is 32767. If you try to go higher than 32767 or lower than -32768, the computer will gripe by saying "Overflow".

To explore the mysteries of rounding, run this program:

```
INPUT "What's your favorite number"; x
PRINT CINT(x)
```

The top line asks you to type a number x. The bottom line prints your number, but rounded to the nearest integer. For example, if you type 3.9, the bottom line prints 4.

INT Like FIX and CINT, **INT** turns a number into an integer. Though INT is slightly harder to understand than FIX and CINT, INT is more useful!

INT rounds a number *down* to an integer that's *lower*. For example:

```
The INT of 3.9 is 3 (because 3 is an integer that's lower than 3.9).
The INT of -3.9 is -4 (because a temperature of -4 is lower and colder than a temperature of -3.9).
The INT of 7 is simply 7.
```

To explore further the mysteries of rounding, run this program:

```
INPUT "What's your favorite number"; x
PRINT "Your number rounded down is"; INT(x)
PRINT "Your number rounded up is"; -INT(-x)
PRINT "Your number rounded to the nearest integer is"; INT(x + .5)
```

The top line asks you to type a number x.

The next line prints your number rounded *down*. For example, if you input 3.9, the computer prints 3.

The next line, PRINT -INT(-x), prints your number rounded *up*. For example if you input 3.9, the computer prints 4.

The bottom line prints your number rounded to the *nearest* integer. For example, if you input 3.9, the computer will print 4.

Here's the rule: if x is a number, **INT(x) rounds x down; -INT(-x) rounds x up; INT(x + .5) rounds x to the nearest integer**.

Here's why **INT is usually better than CINT and FIX**:

To round x to the nearest integer, you can say either CINT(x) or INT(x + .5). Alas, CINT(x) handles just numbers from -32768 to 32767. But INT(x + .5) can handle *any* number!

Another advantage of INT is that it works in *all* versions of Basic. Even the oldest, most primitive versions of Basic understand INT. Alas, CINT and FIX work in just a *few* versions of Basic, such as QBasic. To make sure your programs work on *many* computers, use INT rather than CINT or FIX.

In the rest of this book, I'll emphasize INT.

Rounding down and rounding up are **useful in the supermarket:**

Suppose some items are marked "30¢ each", and you have just two dollars. How many can you buy? Two dollars divided by 30¢ is 6.66667; rounding *down* to an integer, you can buy 6.

Suppose some items are marked "3 for a dollar", and you want to buy just one of them. How much will the supermarket charge you? One dollar divided by 3 is 33.3333¢; rounding *up* to an integer, you will be charged 34¢.

By using INT, **you can do fancier kinds of rounding:**

to round x to the nearest thousand, ask for `INT(x / 1000 + .5) * 1000`
to round x to the nearest thousandth, ask for `INT(x / .001 + .5) * .001`

This program rounds a number, so that it will have just a *few* digits after the decimal point:

```
INPUT "What's your favorite number"; x
INPUT "How many digits would you like after its decimal point"; d
b = 10 ^ -d
PRINT "Your number rounded is"; INT(x / b + .5) * b
```

Here's a sample run:

```
What's your favorite number? 4.28631
How many digits would you like after its decimal point? 2
Your number rounded is 4.29
```

SGN If a number is negative, its **sign** is -1. For example, the sign of -546 is -1.

If a number is positive, its **sign** is +1. For example the sign of 8231 is +1.

The **sign** of 0 is 0.

The computer's abbreviation for "sign" is "SGN". So if you say —

```
PRINT SGN(-546)
```

the computer will print the sign of -546; it will print -1.

If you say —

```
PRINT SGN(8231)
```

the computer will print the sign of 8231; it will print 1.

If you say —

```
PRINT SGN(0)
```

the computer will print the sign of 0; it will print 0.

SGN is the opposite of ABS. Let's see what both functions do to -7.2. ABS removes the minus sign, but leaves the digits:

```
ABS(-7.2) is 7.2
```

SGN removes the digits, but leaves the minus sign:

```
SGN(-7.2) is -1
```

The Latin word for *sign* is **signum**. Most mathematicians prefer to talk in Latin — they say "signum" instead of "sign" — because the English word "sign" sounds too much like the trigonometry word "sine". So mathematicians call SGN the **signum function**.

Random numbers

Usually, the computer is predictable: it does exactly what you say. But sometimes, you want the computer to be *un*predictable.

For example, if you're going to play a game of cards with the computer and tell the computer to deal, you want the cards dealt to be unpredictable. If the cards were predictable — if you could figure out exactly which cards you and the computer would be dealt — the game would be boring.

In many other games too, you want the computer to be unpredictable, to "surprise" you. Without an element of surprise, the game would be boring.

Being unpredictable increases the pleasure you derive from games — and from art. To make the computer act artistic, and create a new *original* masterpiece that's a "work of art", you need a way to make the computer get a "flash of inspiration". Flashes of inspiration aren't predictable: they're surprises.

Here's how to make the computer act unpredictably.…

RND is a RaNDom decimal, bigger than 0 and less than 1. For example, it might be .6273649 or .9241587 or .2632801. Every time your program mentions RND, the computer concocts another decimal:

```
PRINT RND
PRINT RND
PRINT RND
```

The computer prints:

```
 .7055475
 .533424
 .5795186
```

The first time your program mentions RND, the computer chooses its favorite decimal, which is .7055475. Each succeeding time your program mentions RND, the computer uses the previous decimal to concoct a new one. It uses .7055475 to concoct .533424, which it uses to concoct .5795186. The process by which the computer concocts each new decimal from the previous one is weird enough so we humans cannot detect any pattern.

This program prints lots of decimals — and pauses a second after each decimal, so you have a chance to read it:

```
DO
    PRINT RND
    SLEEP 1
LOOP
```

About half the decimals will be less than .5, and about half will be more than .5.

Most of the decimals will be less than .9. In fact, about 90% will be.

About 36% of the decimals will be less than .36; 59% will be less than .59; 99% will be less than .99; 2% will be less than .02; a quarter of them will be less than .25; etc. You might see some decimal twice, though most of the decimals will be different from each other. When you get tired of running that program and seeing decimals, abort the program (by pressing Ctrl with Pause/Break).

If you run that program again, you'll get exactly the same list of decimals again, in the same order.

RANDOMIZE TIMER If you'd rather see a different list of decimals, say **RANDOMIZE TIMER** at program's top:

```
RANDOMIZE TIMER
DO
  PRINT RND
  SLEEP 1
LOOP
```

When the computer sees RANDOMIZE TIMER, the computer looks at the clock and manipulates the time's digits to produce the first value of RND.

So the first value of RND will be a number that depends on the time of day, instead of the usual .7055475. Since the first value of RND will be different than usual, so will the second, and so will the rest of the list.

Every time you run the program, the clock will be different, so the first value of RND will be different, so the whole list will be different — unless you run the program at exactly the same time the next day, when the clock is the same. But since the clock is accurate to a tiny fraction of a second, the chance of hitting the same time is extremely unlikely.

Love or hate? Who loves ya, baby? This program tries to answer that question:

```
RANDOMIZE TIMER
DO
    INPUT "Type the name of someone you love..."; name$
    IF RND < .67 THEN
        PRINT name$; " loves you, too"
    ELSE
        PRINT name$; " hates your guts"
    END IF
LOOP
```

The RANDOMIZE TIMER line makes the value of RND depend on the clock. The INPUT line makes the computer wait for the human to type a name. Suppose he types Suzy. Then name$ is "Suzy". The IF line says there's a 67% chance that the computer will print "Suzy loves you, too", but there's a 33% chance the computer will instead print "Suzy hates your guts". The words DO and LOOP make the computer do the routine again and again, until the human aborts the program. The run might look like this:

```
Type the name of someone you love...? Suzy
Suzy loves you, too
Type the name of someone you love...? Joan
Joan hates your guts
Type the name of someone you love...? Alice
Alice loves you, too
Type the name of someone you love...? Fred
Fred loves you, too
Type the name of someone you love...? Uncle Charlie
Uncle Charlie hates your guts
```

Coin flipping This program makes the computer flip a coin:

```
RANDOMIZE TIMER
IF RND < .5 THEN PRINT "heads" ELSE PRINT "tails"
```

The IF line says there's a 50% chance that the computer will print "heads"; if the computer does *not* print "heads", it will print "tails".

Until you run the program, you won't know which way the coin will flip; the choice is random. Each time you run the program, the computer will flip the coin again; each time, the outcome is unpredictable.

Here's how to let the human bet on whether the computer will say "heads" or "tails":

```
RANDOMIZE TIMER
10 INPUT "Do you want to bet on heads or tails"; bet$
IF bet$ <> "heads" AND bet$ <> "tails" THEN
    PRINT "Please say heads or tails"
    GOTO 10
END IF
IF RND < .5 THEN coin$ = "heads" ELSE coin$ = "tails"
PRINT "The coin says "; coin$
IF coin$ = bet$ THEN PRINT "You win" ELSE PRINT "You lose"
```

The line numbered 10 makes the computer ask:

```
Do you want to bet on heads or tails?
```

The next line makes sure the human says "heads" or "tails": if the human's answer isn't "heads" and isn't "tails", the computer gripes. The bottom three lines make the computer flip a coin and determine whether the human won or lost the bet.

Here's a sample run:

```
Do you want to bet on heads or tails? heads
The coin says tails
You lose
```

Here's another:

```
Do you want to bet on heads or tails? tails
The coin says tails
You win
```

Here's another:

```
Do you want to bet on heads or tails? tails
The coin says heads
You lose
```

Here's how to let the human use money when betting:

```
RANDOMIZE TIMER
bankroll = 100
3 PRINT "You have"; bankroll; "dollars"
4 INPUT "How many dollars do you want to bet"; stake
IF stake > bankroll THEN PRINT "You don't have that much!  Bet less!": GOTO 4
IF stake < 0 THEN PRINT "You can't bet less than nothing!": GOTO 4
IF stake = 0 THEN PRINT "I guess you don't want to bet anymore": GOTO 20
10 INPUT "Do you want to bet on heads or tails"; bet$
IF bet$ <> "heads" AND bet$ <> "tails" THEN
    PRINT "Please say heads or tails"
    GOTO 10
END IF
IF RND < .5 THEN coin$ = "heads" ELSE coin$ = "tails"
PRINT "The coin says "; coin$
IF coin$ = bet$ THEN
    PRINT "You win"; stake; "dollars"
    bankroll = bankroll + stake
    GOTO 3
END IF
PRINT "You lose"; stake; "dollars"
bankroll = bankroll - stake
IF bankroll > 0 THEN GOTO 3
PRINT "You're broke!  Too bad!"
20 PRINT "Thanks for playing with me!  You were fun to play with!"
PRINT "I hope you play again sometime!"
```

Line 2 (bankroll = 100) gives the human a $100 *bankroll*, so the human starts with $100. Line 3 makes the computer say:

```
You have 100 dollars
```

Line 4 makes the computer ask:

```
How many dollars do you want to bet?
```

The number that the human inputs (the number of dollars that the human bets) is called the human's *stake*. The next three lines (which say "IF stake") make sure the stake is reasonable.

The line numbered 10 gets the human to bet on heads or tails. The next few lines flip the coin, determine whether the human won or lost the bet, and then send the computer back to line 4 for another round (if the human isn't broke yet). The bottom three lines say good-bye to the human.

Here's a sample run:

```
You have 100 dollars
How many dollars do you want to bet? 120
You don't have that much!  Bet less!
How many dollars do you want to bet? 75
Do you want to bet on heads or tails? heads
The coin says tails
You lose 75 dollars
You have 25 dollars
How many dollars do you want to bet? 10
Do you want to bet on heads or tails? tails
The coin says tails
You win 10 dollars
You have 35 dollars
How many dollars do you want to bet? 35
Do you want to bet on heads or tails? tails
The coin says heads
You lose 35 dollars
You're broke!  Too bad!
Thanks for playing with me!  You were fun to play with!
I hope you play again sometime!
```

To make the output prettier, replace line 3 by this group of lines:

```
3 PRINT
PRINT "You have"; bankroll; "dollars!  Here they are:"
FOR i = 1 TO bankroll
    PRINT "$";
NEXT
PRINT
```

Now the run looks like this:

```
You have 100 dollars!  Here they are:
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$$$$$$$$$$$$$
$$$$$$$$$$$$$$$$$$$
How many dollars do you want to bet? 120
You don't have that much!  Bet less!
How many dollars do you want to bet? 75
Do you want to bet on heads or tails? heads
The coin says tails
You lose 75 dollars

You have 25 dollars!  Here they are:
$$$$$$$$$$$$$$$$$$$$$$$$$
How many dollars do you want to bet? 10
Do you want to bet on heads or tails? tails
The coin says tails
You win 10 dollars

You have 35 dollars!  Here they are:
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
How many dollars do you want to bet? 35
Do you want to bet on heads or tails? tails
The coin says heads
You lose 35 dollars
You're broke!  Too bad!
Thanks for playing with me!  You were fun to play with!
I hope you play again sometime!
```

Random integers If you want a random integer from 1 to 10, ask for 1 + INT(RND * 10). Here's why:

```
RND is a decimal, bigger than 0 and less than 1.
So RND * 10 is a decimal, bigger than 0 and less than 10.
So INT(RND * 10) is an integer, at least 0 and no more than 9.
So 1 + INT(RND * 10) is an integer, at least 1 and no more than 10.
```

Guessing game This program plays a guessing game:

```
RANDOMIZE TIMER
PRINT "I'm thinking of a number from 1 to 10."
computer.number = 1 + INT(RND * 10)
10 INPUT "What do you think my number is"; guess
IF guess < computer.number THEN PRINT "Your guess is too low.": GOTO 10
IF guess > computer.number THEN PRINT "Your guess is too high.": GOTO 10
PRINT "Congratulations!  You found my number!"
```

Line 2 makes the computer say:

```
I'm thinking of a number from 1 to 10.
```

The next line makes the computer think of a random number from 1 to 10; the computer's number is called "computer.number". The INPUT line asks the human to guess the number.

If the guess is less than the computer's number, the first IF line makes the computer say "Your guess is too low" and then GOTO 10, which lets the human guess again. If the guess is *greater* than the computer's number, the bottom IF line makes the computer say "Your guess is too high" and then GOTO 10.

When the human guesses correctly, the computer arrives at the bottom line, which prints:

```
Congratulations!  You found my number!
```

Here's a sample run:

```
I'm thinking of a number from 1 toO 10.
What do you think my number is? 3
Your guess is too low.
What do you think my number is? 8
Your guess is too high.
What do you think my number is? 5
Your guess is too low.
What do you think my number is? 6
Congratulations!  You found my number!
```

Dice This program makes the computer roll a pair of dice:

```
RANDOMIZE TIMER
PRINT "I'm rolling a pair of dice"
a = 1 + INT(RND * 6)
PRINT "One of the dice says"; a
b = 1 + INT(RND * 6)
PRINT "The other says"; b
PRINT "The total is"; a + b
```

Line 2 makes the computer say:

```
I'm rolling a pair of dice
```

Each of the dice has 6 sides. The next line, a = 1 + INT(RND * 6), rolls one of the dice, by picking a number from 1 to 6. The line saying "b = 1 + INT(RND * 6)" rolls the other. The bottom line prints the total.

Here's a sample run:

```
I'm rolling a pair of dice
One of the dice says 3
The other says 5
The total is 8
```

Here's another run:

```
I'm rolling a pair of dice
One of the dice says 6
The other says 4
The total is 10
```

Daily horoscope This program predicts what will happen to you today:

```
RANDOMIZE TIMER
PRINT "You will have a ";
SELECT CASE 1 + INT(RND * 5)
    CASE 1
        PRINT "wonderful";
    CASE 2
        PRINT "fairly good";
    CASE 3
        PRINT "so-so";
    CASE 4
        PRINT "fairly bad";
    CASE 5
        PRINT "terrible";
END SELECT
PRINT " day today!"
```

The computer will say —

```
You will have a wonderful day today!
```

or —

```
You will have a terrible day today!
```

or some in-between comment. That's because the SELECT CASE line makes the computer pick a random integer from 1 to 5.

For inspiration, run that program when you get up in the morning. Then notice whether your day turns out the way the computer predicts!

Character codes

You can use these code numbers:

			64	@	96	`	128	Ç	160	á	192	└	224	α
1	☺	33	!	65	A	97	a	129	ü	161	í	193	┴	225	ß
2	☻	34	"	66	B	98	b	130	é	162	ó	194	┬	226	Γ
3	♥	35	#	67	C	99	c	131	â	163	ú	195	├	227	π
4	♦	36	$	68	D	100	d	132	ä	164	ñ	196	─	228	Σ
5	♣	37	%	69	E	101	e	133	à	165	Ñ	197	┼	229	σ
6	♠	38	&	70	F	102	f	134	å	166	ª	198	╞	230	µ
		39	'	71	G	103	g	135	ç	167	º	199	╟	231	τ
8	◘	40	(	72	H	104	h	136	ê	168	¿	200	╚	232	Φ
		41	)	73	I	105	i	137	ë	169	⌐	201	╔	233	Θ
		42	*	74	J	106	j	138	è	170	¬	202	╩	234	Ω
		43	+	75	K	107	k	139	ï	171	½	203	╦	235	δ
		44	,	76	L	108	l	140	î	172	¼	204	╠	236	∞
		45	-	77	M	109	m	141	ì	173	¡	205	═	237	φ
14	♫	46	.	78	N	110	n	142	Ä	174	«	206	╬	238	∈
15	☼	47	/	79	O	111	o	143	Å	175	»	207	╧	239	∩
16	►	48	0	80	P	112	p	144	É	176	░	208	╨	240	≡
17	◄	49	1	81	Q	113	q	145	æ	177	▒	209	╤	241	±
18	↕	50	2	82	R	114	r	146	Æ	178	▓	210	╥	242	≥
19	‼	51	3	83	S	115	s	147	ô	179	│	211	╙	243	≤
20	¶	52	4	84	T	116	t	148	ö	180	┤	212	╘	244	⌠
21	§	53	5	85	U	117	u	149	ò	181	╡	213	╒	245	⌡
22	▬	54	6	86	V	118	v	150	û	182	╢	214	╓	246	÷
23	↨	55	7	87	W	119	w	151	ù	183	╖	215	╫	247	≈
24	↑	56	8	88	X	120	x	152	ÿ	184	╕	216	╪	248	°
25	↓	57	9	89	Y	121	y	153	Ö	185	╣	217	┘	249	•
26	→	58	:	90	Z	122	z	154	Ü	186	║	218	┌	250	·
27	←	59	;	91	[	123	(	155	¢	187	╗	219	█	251	√
		60	<	92	\	124	|	156	£	188	╝	220	▄	252	ⁿ
		61	=	93	]	125	)	157	¥	189	╜	221	▌	253	²
		62	>	94	^	126	~	158	₧	190	╛	222	▐	254	■
		63	?	95	_	127	⌂	159	ƒ	191	┐	223	▀		

Alt key Here's how to type the symbol ñ, whose code number is 164. Hold down the Alt key; and while you keep holding down the Alt key, type 164 *by using the numeric keypad* (the number keys on the far right side of the keyboard). When you finish typing 164, lift your finger from the Alt key, and you'll see ñ on your screen!

The Alt key works for most numbers in that chart but *not* for numbers 8 and 26.

You can use the Alt key in your program. For example, try typing this program:

```
PRINT "In Spanish, tomorrow is mañana"
```

While typing that program, make the symbol ñ by typing 164 on the numeric keypad while holding down the Alt key. When you run that program, the computer will print:

```
In Spanish, tomorrow is mañana
```

CHR$ Here's another way to type the symbol ñ:

```
PRINT CHR$(164)
```

When you run that program, the computer will print the CHaRacter whose code number is 164. The computer will print:

```
ñ
```

This program makes the computer print "In Spanish, tomorrow is mañana":

```
PRINT "In Spanish, tomorrow is ma"; CHR$(164); "ana"
```

That makes the computer print "In Spanish, tomorrow is ma", then print character 164 (which is ñ), then print "ana".

Since character 34 is a quotation mark, **this program prints a quotation mark:**

```
PRINT CHR$(34)
```

Suppose you want the computer to print:

```
Scholars think "Hamlet" is a great play.
```

To make the computer print the quotation marks around "Hamlet", use CHR$(34), like this:

```
PRINT "Scholars think "; CHR$(34); "Hamlet"; CHR$(34); " is a great play."
```

CHR$ works reliably for all numbers in that chart. **This program prints, on your screen, all the symbols in the chart:**

```
FOR i = 1 TO 6: PRINT CHR$(i);: NEXT
PRINT CHR$(8);
FOR i = 14 TO 27: PRINT CHR$(i);: NEXT
FOR i = 33 TO 254: PRINT CHR$(i);: NEXT
```

That chart shows *most* code numbers from 1 to 254 but skips these mysterious code numbers: 7, 9-13, and 28-32. Here's what those mysterious code numbers do….

In a PRINT statement, **CHR$(7) makes the computer beep.** Saying —

```
PRINT CHR$(7);
```

has the same effect as saying:

```
BEEP
```

If you say —

```
PRINT "hot"; CHR$(7); "dog"
```

the computer will print "hot", then beep, then turn the "hot" into "hotdog".

CHR$(9) makes the computer press the Tab key, so your writing is indented. For example, if you say —

```
PRINT "hot"; CHR$(9); "dog"
```

the computer will print "hot", then indent by pressing the TAB key, then print "dog", so you see this:

```
hot     dog
```

CHR$(31) makes the computer move the cursor (the blinking underline) down to the line below. For example, if you say —

```
PRINT "hot"; CHR$(31); "dog"
```

the computer will print "hot", then move down, then print "dog" on the line below, so you see this:

```
hot
   dog
```

You can move the cursor in all four directions:

```
CHR$(28) moves the cursor toward the right
CHR$(29) moves the cursor toward the left
CHR$(30) moves the cursor up
CHR$(31) moves the cursor down
```

CHR$(11) moves the cursor all the way to the screen's top-left corner, which is called the **home position**.

CHR$(32) is a blank space. It's the same as " ".

CHR$(12) erases the entire screen. Saying —

```
PRINT CHR$(12);
```

has the same effect as saying:

```
CLS
```

CHR$(10) and CHR$(13) each make the computer press the Enter key.

ASC The code numbers from 32 to 126 are for characters that you can type on the keyboard easily. Established by a national committee, those code numbers are called the **American Standard Code for Information Interchange**, which is abbreviated **Ascii**, which is pronounced "ass key".

Programmers say, "the Ascii code number for A is 65". If you say —

```
PRINT ASC("A")
```

the computer will print the Ascii code number for "A". It will print:

```
 65
```

If you say PRINT ASC("B"), the computer will print 66. If you say PRINT ASC("b"), the computer will print 97.

If you say PRINT ASC("ñ"), the computer will print 164 (which is the code number for ñ), even though ñ isn't an Ascii character.

String analysis

Let's analyze the word "smart".

Length Since "smart" has 5 characters in it, the **length** of "smart" is 5. If you say —

```
PRINT LEN("smart")
```

the computer will print the LENgth of "smart"; it will print:

```
 5
```

Left, right, middle The left two characters of "smart" are "sm". If you say —

```
PRINT LEFT$("smart", 2)
```

the computer will print:

```
sm
```

Try this program:

```
a$ = "smart"
PRINT LEFT$(a$, 2)
```

The top line says a$ is "smart". The bottom line says to print the left 2 characters of a$, which are "sm". The computer will print:

```
sm
```

If a$ is "smart", here are the consequences.…

LEN(a$) is the LENgth of a$. It is 5.

LEFT$(a$, 2) is the LEFT 2 characters of a$. It is "sm".

RIGHT$(a$, 2) is the RIGHT 2 characters of a$. It is "rt".

MID$(a$, 2) begins in the MIDdle of a$, at the 2nd character. It is "mart".

MID$(a$, 2, 3) begins at 2nd character and includes 3 characters. It is "mar".

You can change a string's middle, like this:

```
a$ = "bunkers"
MID$(a$, 2) = "owl"
PRINT a$
```

The top line says a$ is "bunkers". The MID$ line changes the middle of a$ to "owl"; the change begins at the 2nd character of a$. The bottom line prints:

```
bowlers
```

Here's a variation:

```
a$ = "bunkers"
MID$(a$, 2) = "ad agency"
PRINT a$
```

The top line says a$ is "bunkers". The MID$ line says to change the middle of a$, beginning at the 2nd character of a$. But "ad agency" is too long to become part of "bunkers". The computer uses as much of "ad agency" as will fit in "bunkers". The computer will print:

```
bad age
```

Another variation:

```
a$ = "bunkers"
MID$(a$, 2, 1) = "owl"
PRINT a$
```

The top line says a$ is "bunkers". The MID$ line says to change the middle of a$, beginning at the 2nd character of a$. But the ",1" makes the computer use just 1 letter from "owl". The bottom line prints:

```
bonkers
```

Capitals Capital letters (such as X, Y, and Z) are called **upper-case letters**. Small letters (such as x, y, and z) are called **lower-case letters**.

If you say —

```
PRINT UCASE$("We love America")
```

the computer will print an upper-case (capitalized) version of "We love America"), like this:

```
WE LOVE AMERICA
```

If you say —

```
PRINT LCASE$("We love America")
```

the computer will print a lower-case version of "We love America", like this:

```
we love america
```

Unfortunately, the computer doesn't know how to capitalize an accented letter (such as ñ). For example, suppose you say:

```
PRINT UCASE$("mañana")
```

Since the computer doesn't know how to capitalize the ñ, the computer prints:

```
MAñANA
```

If you say PRINT LCASE$("MAÑANA"), the computer doesn't know how to uncapitalize Ñ, so the computer prints:

```
maÑana
```

This program measures geographical emotions:

```
INPUT "What's the most exciting continent"; a$
IF a$ = "Africa" THEN
    PRINT "Yes, it's the dark continent!"
ELSE
    PRINT "I disagree!"
END IF
```

The top line asks:

```
What's the most exciting continent?
```

Line 2 checks whether the person's answer is "Africa". If the person's answer is "Africa", the computer prints "Yes, it's the dark continent!"; otherwise, the computer prints "I disagree!"

But instead of typing "Africa", what if the person types "africa" or "AFRICA"? We still ought to make the computer print "Yes, it's the dark continent!" Here's how:

```
INPUT "What's the most exciting continent"; a$
IF UCASE$(a$) = "AFRICA" THEN
    PRINT "Yes, it's the dark continent!"
ELSE
    PRINT "I disagree!"
END IF
```

The new version of the IF statement says: if the person's answer, after being capitalized, becomes "AFRICA", then print "Yes, it's the dark continent!" So the computer will print "Yes, it's the dark continent!" even if the person types "Africa" or "africa" or "AFRICA" or "AfRiCa".

Suppose you ask the person a **yes/no question**. If the person means "yes", the person might type "yes" or "Yes" or "YES" or "YES!" or just "y" or just "Y". So instead of saying —

```
IF a$ = "yes"
```

say this:

```
IF UCASE$(LEFT$(a$, 1)) = "Y"
```

That tests whether the first letter of the person's answer, after being capitalized, is "Y".

Trim Some folks accidentally press the Space bar at the beginning or end of a string. For example, instead of typing "Sue", the person might type " Sue" or "Sue ".

You want to get rid of those accidental spaces. Getting rid of them is called **trimming** the string.

The function **LTRIM$** will left-trim the string: it will delete any spaces at the string's beginning (left edge). For example, if a$ is " Sue Smith", LTRIM$(a$) is "Sue Smith".

**RTRIM$** will right-trim the string: it will delete any spaces at the string's end (right edge). If a$ is "Sue Smith ", RTRIM$(a$) is "Sue Smith".

To trim *both* edges of a$ and make the trimmed result be the new a$, say this:

```
a$ = LTRIM$(RTRIM$(a$))
```

Spaces at the string's beginning (which are deleted by LTRIM$) are called **leading spaces**. Spaces at the string's end (which are deleted by RTRIM$) are called **trailing spaces**.

Adding strings You can add strings together, to form a longer string:

```
a$ = "fat" + "her"
PRINT a$
```

The top line says a$ is "father". The bottom line makes the computer print:

```
father
```

Searching in a string You can make the computer search in a string to find another string. To make the computer search IN the STRing "needed" to find "ed", say:

```
PRINT INSTR("needed", "ed")
```

Since "ed" begins at the third character of "needed", the computer will print:

```
 3
```

If you say —

```
PRINT INSTR("needed", "ey")
```

the computer will search in the string "needed" for "ey". Since "ey" is *not* in "needed", the computer will print:

```
 0
```

If you say —

```
PRINT INSTR(4, "needed", "ed")
```

the computer will hunt in the string "needed" for "ed"; but the hunt will begin at the 4th character of "needed". The computer finds the "ed" that begins at the 5th character of "needed". The computer will print:

```
 5
```

String-number conversion This program converts a string to a number:

```
a$ = "52.6"
b = VAL(a$)
PRINT b + 1
```

The top line says a$ is the string "52.6". The next line says b is the numeric VALue of a$, so b is the number 52.6. The bottom line prints:

```
 53.6
```

VAL converts a string to a number. The opposite of VAL is STR$, which converts a number to a string. For example, STR$(-7.2) is the string "-7.2". STR$(81.4) is the string " 81.4", in which the 8 is preceded by a space instead of a minus sign.

Repeating characters Suppose you love the letter b (because it stands for big, bold, and beautiful) and want to print "bbbbbbbbbbbbbbbbbbb". Here's a short-cut:

```
PRINT STRING$(20, "b")
```

That tells the computer to print a string of 20 b's.

Here's a different way to accomplish the same goal:

```
PRINT STRING$(20, 98)
```

That tells the computer to print, 20 times, the character whose Ascii code number is 98.

STRING$ can make the computer repeat a single character, but not a whole word. So if you say STRING$(20, "blow"), the computer will *not* repeat the word "blow"; instead, the computer will repeat just the first character of "blow" (which is "b").

Let's make the computer draw a dashed line containing 50 dashes, like this:

```
--------------------------------------------------
```

Here's how: just say PRINT STRING$(50, "-").

Let's make the computer print this triangle:

```
*
**
***
****
*****
******
*******
********
*********
**********
***********
************
*************
**************
***************
****************
*****************
******************
*******************
********************
```

To do that, we want the computer to print 1 asterisk on the first line, then 2 asterisks on the next line, then 3 asterisks on the next line, and so on, until it finally prints 20 asterisks on the bottom line. Here's the program:

```
FOR i = 1 TO 20
    PRINT STRING$(i, "*")
NEXT
```

The FOR line makes i be 1, then 2, then 3, and so on, up to 20. When i is 1, the PRINT line makes the computer print one asterisk, like this:

```
*
```

When i is 2, the PRINT line makes the computer print a line of 2 asterisks, like this:

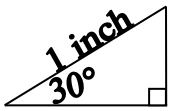
```
**
```

The FOR line makes i be every number from 1 up to 20, so computer will print 1 asterisk, then underneath print a line of 2 asterisks, then underneath print a line of 3 asterisks, and so on, until the entire triangle is printed.

Trigonometry

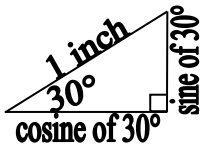
The study of triangles is called **trigonometry** — and the computer can do it for you!

For example, look at this triangle:



In that triangle, the left angle is 30°, the bottom-right angle is 90°, and the longest side (the hypotenuse) is 1 inch long.

The side opposite the 30° angle is called the **sine** of 30°; the remaining side is called the **cosine** of 30°:



How long is the sine of 30°? How long is the cosine of 30°?

Since the longest side (the hypotenuse) is 1 inch long, and since the sine and the cosine are shorter sides, the sine and the cosine must each be shorter than 1 inch. So the lengths of the sine and cosine are each less than 1. But which decimals are they?

To find out, you can use a ruler. You'll discover that the sine is half an inch long, and the cosine is nearly seven-eighths of an inch long. But a faster and more accurate way to measure the sine and cosine is to let the computer do it! Yes, the computer can calculate triangles in its mind!

This program makes the computer measure the sine and cosine of 30°:

```
degrees = ATN(1) / 45
PRINT SIN(30 * degrees)
PRINT COS(30 * degrees)
```

The top line is a special formula that defines the word *degrees*. The first PRINT line prints the sine of 30 degrees:

```
 .5
```

The bottom line prints the cosine of 30°, which is a decimal that's slightly less than .87.

The computer can measure the sine and cosine of *any* size angle. Try it! For example, to make the computer print the sine and cosine of a 33° angle, say:

```
degrees = ATN(1) / 45
PRINT SIN(33 * degrees)
PRINT COS(33 * degrees)
```

If you choose an angle of -33° instead of 33°, the triangle will dip down instead of rising up, and so the sine will be a negative number instead of positive.

In those PRINT lines, the "* degrees" is important: it tells the computer that you want the sine of 33 **degrees**. If you accidentally omit the "* degrees", the computer will print the sine of 33 **radians** instead. (A radian is larger than a degree. A radian is about 57.3 degrees. More precisely, a radian is 180/π degrees.)

Tangent The sine divided by the cosine is called the **tangent**. For example, to find the tangent of 33°, divide the sine of 33° by the cosine of 33°.

To make the computer print the tangent of 33°, you could tell the computer to PRINT SIN(33 * degrees) / COS(33 * degrees). But to find the tangent more quickly and easily, say just PRINT TAN(33 * degrees).

Arc functions The opposite of the tangent is called the **arctangent**:

```
the tangent      of 30°is about .58
the arctangent of .58 is about 30°
```

Similarly, the opposite of the sine is called the **arcsine**, and the opposite of the cosine is called the **arccosine**.

This program prints the arctangent of .58, the arcsine of .5, and the arccosine of .87:

```
degrees = ATN(1) / 45
PRINT ATN(.58) / degrees
x = .5: PRINT ATN(x / SQR(1 - x * x)) / degrees
x = .87: PRINT 90 - ATN(x / SQR(1 - x * x)) / degrees
```

Line 2 prints the arctangent of .58, in degrees. (If you omit the "/ degrees", the computer will print the answer in radians instead of degrees.) Line 4 sets x equal to .5 and then prints its arcsine (by using a formula that combines ATN with SQR). The bottom line sets x equal to .87 and then prints its arccosine (by using a formula that combines 90 with ATN and SQR). The answer to each of the three problems is about 30 degrees.

Subscripts

Instead of being a single string, x$ can be a whole *list* of strings, like this:

```
x$=("love"
   "hate"
   "kiss"
   "kill"
   "peace"
   "war"
   "why")
```

Here's how to make x$ be that list of strings.…

Begin your program by saying:

```
DIM x$(7)
```

That line says x$ will be a list of 7 strings. DIM means **dimension**; the line says the dimension of x$ is 7.

Next, tell the computer what strings are in x$. Type these lines:

```
x$(1) = "love"
x$(2) = "hate"
x$(3) = "kiss"
x$(4) = "kill"
x$(5) = "peace"
x$(6) = "war"
x$(7) = "why"
```

That says x$'s first string is "love", x$'s second string is "hate", etc.

If you want the computer to print all those strings, type this:

```
FOR i = 1 TO 7
    PRINT x$(i)
NEXT
```

That means: print all the strings in x$. The computer will print:

```
love
hate
kiss
kill
peace
war
why
```

That program includes a line saying x$(1) = "love". Instead of saying x$(1), math books say:

x_1

The "1" is called a **subscript**.

Similarly, in the line saying x$(2) = "hate", the number 2 is a subscript. Some programmers pronounce that line as follows: "x string, subscripted by 2, is hate". Hurried programmers just say: "x string 2 is hate".

In that program, x$ is called an **array** (or **matrix**). Definition: an **array** (or **matrix**) is a variable that has subscripts.

Subscripted DATA

That program said x$(1) is "love", and x$(2) is "hate", and so on. This program does the same thing, more briefly:

```
DIM x$(7)
DATA
love,hate,kiss,kill,peace,war,why
FOR i = 1 TO 7
    READ x$(i)
NEXT
FOR i = 1 TO 7
    PRINT x$(i)
NEXT
```

The DIM line says x$ will be a list of 7 strings. The DATA line contains a list of 7 strings. The first FOR..NEXT loop makes the computer READ those strings and call them x$. The bottom FOR...NEXT loop makes the computer print those 7 strings.

In that program, the first 3 lines say:

```
DIM
DATA
FOR i
```

Most practical programs begin with those 3 lines.

Let's lengthen the program, so the computer prints all this:

```
love
hate
kiss
kill
peace
war
why

why love
why hate
why kiss
why kill
why peace
why war
why why
```

That consists of two verses. The second verse resembles the first, except each line of the second verse begins with "why".

To make the computer print all that, just add the shaded lines to the program:

```
DIM x$(7)
DATA
love,hate,kiss,kill,peace,war,wh
y
FOR i = 1 TO 7
  READ x$(i)
NEXT
FOR i = 1 TO 7
  PRINT x$(i)
NEXT
PRINT
FOR i = 1 TO 7
    PRINT "why "; x$(i)
NEXT
```

The shaded PRINT line leaves a blank line between the first verse and the second. The shaded FOR..NEXT loop, which prints the second verse, resembles the FOR...NEXT loop that printed the first verse but prints "why" before each x$(i).

Let's add a third verse, which prints the words in reverse order:

```
why
war
peace
kill
kiss
hate
love
```

Before printing that third verse, print a blank line:

```
PRINT
```

Then print the verse itself. To print the verse, you must print x$(7), then print x$(6), then print x$(5), etc. To do that, you could say:

```
PRINT x$(7)
PRINT x$(6)
PRINT x$(5)
etc.
```

But this way is shorter:

```
FOR i = 7 TO 1 STEP -1
    PRINT x$(i)
NEXT
```

Numeric arrays

Let's make y be this list of five numbers: 100, 94, 201, 8.3, and -7. To begin, tell the computer that y will consist of five numbers:

```
DIM y(5)
```

Next, tell the computer what the six numbers are:

```
DATA 100,94,201,8.3,-7
```

Make the computer READ all that data:

```
FOR i = 1 TO 5
    READ y(i)
NEXT
```

To make the computer PRINT all that data, type this:

```
FOR i = 1 TO 5
    PRINT y(i)
NEXT
```

If you want the computer to add those 5 numbers together and print their sum, say:

```
PRINT y(1) + y(2) + y(3) + y(4) + y(5)
```

Strange example

Getting tired of x and y? Then pick another letter! For example, you can play with z:

Silly, useless program	What the program means
`DIM z(5)`	z will be a list of 5 numbers
`FOR i = 2 TO 5`	
`    z(i) = i * 100`	z(2)=200; z(3)=300; z(4)=400; z(5)=500
`NEXT`	
`z(1) = z(2) - 3`	z(1) is 200 - 3, so z(1) is 197
`z(3) = z(1) - 2`	z(3) changes to 197 - 2, which is 195
`FOR i = 1 TO 5`	
`    PRINT z(i)`	print z(1), z(2), z(3), z(4), and z(5)
`NEXT`	

The computer will print:

```
 197
 200
 195
 400
 500
```

Problems and solutions

Suppose you want to analyze 20 numbers. Begin your program by saying:

```
DIM x(20)
```

Then type the 20 numbers as data:

```
DATA etc.
```

Tell the computer to READ the data:

```
FOR i = 1 TO 20
    READ x(i)
NEXT
```

Afterwards, do one of the following, depending on which problem you want to solve….

Print all x values Solution:

```
FOR i = 1 TO 20
    PRINT x(i)
NEXT
```

Print all x values, in reverse order Solution:

```
FOR i = 20 TO 1 STEP -1
    PRINT x(i)
NEXT
```

Print the sum of all x values In other words, print x(1) + x(2) + x(3)+… + x(20). Solution: start the sum at 0 —

```
sum = 0
```

and then increase the sum, by adding each x(i) to it:

```
FOR i = 1 TO 20
    sum = sum + x(i)
NEXT
```

Finally, print the sum:

```
PRINT "The sum of all the numbers is"; sum
```

Find the average of x In other words, find the average of the 20 numbers. Solution: begin by finding the sum —

```
sum = 0
FOR i = 1 TO 20
    sum = sum + x(i)
NEXT
```

then divide the sum by 20:

```
PRINT "The average is"; sum / 20
```

Find whether any x value is 79.4 In other words, find out whether 79.4 is a number in the list. Solution: if x(i) is 79.4, print "Yes" —

```
FOR i = 1 TO 20
    IF x(i)=79.4 THEN PRINT "Yes, 79.4 is in the list": END
NEXT
```

otherwise, print "No":

```
PRINT "No, 79.4 is not in the list"
```

In x's list, count how often 79.4 appears Solution: start the counter at zero —

```
counter = 0
```

and increase the counter each time you see the number 79.4:

```
FOR i = 1 TO 20
    IF x(i) = 79.4 THEN counter = counter + 1
NEXT
```

Finally, print the counter:

```
PRINT "The number 79.4 appears"; counter; "times"
```

Print all x values that are negative In other words, print all the numbers that have minus signs. Solution: begin by announcing your purpose —

```
PRINT "Here are the values that are negative:"
```

then print the values that are negative; in other words, print each x(i) that's less than 0:

```
FOR i = 1 TO 20
    IF x(i) < 0 THEN PRINT x(i)
NEXT
```

Print all x values that are above average Solution: find the average —

```
sum = 0
FOR i = 1 TO 20
    sum = sum + x(i)
NEXT
average = sum / 20
```

then announce your purpose:

```
PRINT "The following values are above average:"
```

Finally, print the values that are above average; in other words, print each x(i) that's greater than average:

```
FOR i = 1 TO 20
    IF x(i) > average THEN PRINT x(i)
NEXT
```

Find x's biggest value In other words, find which of the 20 numbers is the biggest. Solution: begin by assuming that the biggest is the first number —

```
biggest = x(1)
```

but if you find another number that's even bigger, change your idea of what the biggest is:

```
FOR i = 2 TO 20
    IF x(i) > biggest THEN biggest = x(i)
140 NEXT
```

Afterwards, print the biggest:

```
PRINT "The biggest number in the list is"; biggest
```

Find x's smallest value In other words, find which of the 20 numbers is the smallest. Solution: begin by assuming that the smallest is the first number —

```
smallest = x(1)
```

but if you find another number that's even smaller, change your idea of what the smallest is:

```
FOR i = 2 TO 20
    IF x(i) < smallest THEN smallest = x(i)
NEXT
```

Afterwards, print the smallest:

```
PRINT "The smallest number in the list is"; smallest
```

Check whether x's list is in strictly increasing order In other words, find out whether the following statement is true: x(1) is a smaller number than x(2), which is a smaller number than x(3), which is a smaller number than x(4), etc. Solution: if x(i) is *not* smaller than x(i + 1), print "No" —

```
FOR I = 1 TO 19
    IF x(i) >= x(i + 1) THEN
        PRINT "No, the list is not in strictly increasing order"
        END
    END IF
NEXT
```

otherwise, print "Yes":

```
PRINT "Yes, the list is in strictly increasing order"
```

Test yourself: look at those problems again, and see whether you can figure out the solutions *without peeking at the answers*.

Multiple arrays

Suppose your program involves three lists. Suppose the first list is called a$ and consists of 18 strings; the second list is called b and consists of 57 numbers; and the third list is called c$ and consists of just 3 strings. To say all that, begin your program with this statement:

```
DIM a$(18), b(57), c$(3)
```

Double subscripts

You can make x$ be a **table** of strings, like this:

```
x$= ⎛"dog"     "cat"     "mouse"     ⎞
    ⎝"hotdog"  "catsup"  "mousetard"⎠
```

Here's how to make x$ be that table.…

Begin by saying:

```
DIM x$(2, 3)
```

That says x$ will be a table having 2 rows and 3 columns.

Then tell the computer what strings are in x$. Type these lines:

```
x$(1, 1) = "dog"
x$(1, 2) = "cat"
x$(1, 3) = "mouse"
x$(2, 1) = "hotdog"
x$(2, 2) = "catsup"
x$(2, 3) = "moustard"
```

That says the string in x$'s first row and first column is "dog", the string in x$'s first row and second column is "cat", etc.

If you'd like the computer to print all those strings, type this:

```
FOR i = 1 TO 2
    FOR j = 1 TO 3
        PRINT x$(i, j),
    NEXT
    PRINT
NEXT
```

That means: print all the strings in x$. The computer will print:

```
dog             cat             mouse
hotdog          catsup          mousetard
```

Most programmers follow this tradition: **the row's number is called i, and the column's number is called j**. That program obeys that tradition. The "FOR i = 1 TO 2" means "for both rows"; the "FOR j = 1 TO 3" means "for all 3 columns".

Notice i comes before j in the alphabet; i comes before j in x(i, j); and "FOR i" comes before "FOR j". If you follow the i-before-j tradition, you'll make fewer errors.

At the end of the first PRINT line, the comma makes the computer print each column in a separate zone. The other PRINT line makes the computer press the Enter key at the end of each row. The x$ is called a **table** or **2-dimensional array** or **doubly subscripted array**.

Multiplication table

This program prints a multiplication table:

```
DIM x(10, 4)
FOR i = 1 TO 10
    FOR j = 1 TO 4
        x(i, j) = i * j
    NEXT
NEXT
FOR i = 1 TO 10
    FOR j = 1 TO 4
        PRINT x(i, j),
    NEXT
    PRINT
NEXT
```

The top line says x will be a table having 10 rows and 4 columns.

The line saying "x(i, j) = i * j" means the number in row i and column j is i*j. For example, the number in row 3 and column 4 is 12. Above that line, the program says "FOR i = 1 TO 10" and "FOR j = 1 TO 4", so that x(i,j)=i*j for *every* i and j, so *every* entry in the table is defined by multiplication.

The computer prints the whole table:

```
1             2             3             4
2             4             6             8
3             6             9             12
4             8             12            16
5             10            15            20
6             12            18            24
7             14            21            28
8             16            24            32
9             18            27            36
10            20            30            40
```

Instead of multiplication, you can have addition, subtraction, or division: just change the line saying "x(i, j) = i * j".

Summing a table

Suppose you want to analyze this table:

```
  32.7       19.4       31.6       85.1
  -8        402        -61          0
5106          -.2        0         -1.1
  36.9         .04       1         11
 777        666         55.44       2
   1.99       2.99       3.99       4.99
  50         40         30         20
  12         21         12         21
   0       1000          2        500
```

Since the table has 9 rows and 4 columns, begin your program by saying:

```
DIM x(9, 4)
```

Each row of the table becomes a row of the DATA:

```
DATA 32.7, 19.4, 31.6, 85.1
DATA -8, 402, -61, 0
DATA 5106, -.2, 0, -1.1
DATA 36.9, .04, 1, 11
DATA 777, 666, 55.44, 2
DATA 1.99, 2.99, 3.99, 4.99
DATA 50, 40, 30, 20
DATA 12, 21, 12, 21
DATA 0, 1000, 2, 500
```

Make the computer READ the data:

```
FOR i = 1 TO 9
    FOR j = 1 TO 4
        READ x(i, j)
    NEXT
NEXT
```

To make the computer print the table, say this:

```
FOR i = 1 TO 9
    FOR j = 1 TO 4:
        PRINT x(i,j),
    NEXT
    PRINT
NEXT
```

Here are some problems, with solutions.…

Find the sum of all the numbers in the table

Solution: start the sum at 0 —

```
sum = 0
```

and then increase the sum, by adding each x(i, j) to it:

```
FOR i = 1 TO 9
    FOR j = 1 TO 4
        sum = sum + x(i, j)
    NEXT
NEXT
```

Finally, print the sum:

```
PRINT "The sum of all the numbers is"; sum
```

The computer will print:

```
The sum of all the numbers is 8877.84
```

Find the sum of each row In other words, make the computer print the sum of the numbers in the first row, then the sum of the numbers in the second row, then the sum of the numbers in the third row, etc. Solution: the general idea is —

```
FOR i = 1 TO 9
    print the sum of row i
NEXT
```

Here are the details:

```
FOR i = 1 TO 9
    sum = 0
    FOR j = 1 TO 4
        sum = sum + x(i, j)
    NEXT
    PRINT "The sum of row"; i; "is"; sum
NEXT
```

The computer will print:

```
The sum of row 1 is 168.8
The sum of row 2 is 333
The sum of row 3 is 5104.7
etc.
```

Find the sum of each column In other words, make the computer print the sum of the numbers in the first column, then the sum of the numbers in the second column, then the sum of the numbers in the third column, etc. Solution: the general idea is —

```
FOR j = 1 TO 4
    print the sum of column j
NEXT
```

Here are the details:

```
FOR j = 1 TO 4
    sum = 0
    FOR i = 1 TO 9
        sum = sum + x(i, j)
    NEXT
    PRINT "The sum of column"; j; "is"; sum
NEXT
```

The computer will print:

```
The sum of column 1 is 6008.59
The sum of column 2 is 2151.23
The sum of column 3 is 75.03
The sum of column 4 is 642.99
```

In all the other examples, "FOR i" came before "FOR j"; but in this unusual example, "FOR i" comes *after* "FOR j".

SUB procedures

Here's a sick program:

```
PRINT "We all know..."
PRINT "You are stupid!"
PRINT "You are ugly!"
PRINT "...and yet we love you."
```

It makes the computer print this message:

```
We all know...
You are stupid!
You are ugly!
...and yet we love you.
```

So the computer prints "We all know...", then insults the human ("You are stupid! You are ugly!"), then prints "...and yet we love you."

Here's a more sophisticated way to write that program:

```
PRINT "We all know..."
insult
PRINT "...and yet we love you."

SUB insult
PRINT "You are stupid!"
PRINT "You are ugly!"
END SUB
```

I'm going to explain that sophisticated version. Just *read* my explanation: don't type the sophisticated version into your computer yet. (Wait until you read the next section, called "Manipulate the program".)

In the sophisticated version, the top 3 lines tell the computer to print "We all know...", then insult the human, then print "...and yet we love you." But the computer doesn't know how to insult yet.

The bottom 4 lines teach the computer how to insult: they say "insult" means to print "You are stupid!" and "You are ugly!" Those bottom 4 lines define the word insult; they're the **definition** of insult.

That program is divided into two **procedures**. The top 3 lines are called the **main procedure** (or **main routine** or **main module**). The bottom 4 lines (which just define the word "insult") are called the **SUB procedure** (or **subroutine** or **submodule**).

The SUB procedure's first line (**SUB insult**) means: here's the SUB procedure that defines the word "insult". The SUB procedure's bottom line (**END SUB**) means: this is the END of the SUB procedure.

When you run the program (by pressing the F5 key), the computer will say:

```
We all know...
You are stupid!
You are ugly!
...and yet we love you.
```

Refrains

This is chanted by boys playing tag — and protesters fearing dictators:

```
The lion is a-coming near.
         He'll growl and sneer
         And drink our beer.
The lion never brings us cheer.
         He'll growl and sneer
         And drink our beer.
The lion is the one we fear.
         He'll growl and sneer
         And drink our beer.
Gotta stop the lion!
```

In that chant, this refrain is repeated:

```
         He'll growl and sneer
         And drink our beer.
```

This program prints the entire chant:

```
PRINT "The lion is a-coming near."
refrain
PRINT "The lion never brings us cheer."
refrain
PRINT "The lion is the one we fear."
refrain
PRINT "Gotta stop the lion!"

SUB refrain
PRINT "         He'll growl and sneer"
PRINT "         And drink our beer."
END SUB
```

Big love

This program prints a love poem:

```
PRINT "The most beautiful thing in the world is"
PRINT "LOVE"
PRINT "The opposite of war is"
PRINT "LOVE"
PRINT "And when I look at you, I feel lots of"
PRINT "LOVE"
```

In that program, many of the lines make the computer print the word LOVE. Let's make those lines print the word LOVE bigger, like this:

```
*                 *         *         *      * * * * *
*               *   *       *       *       *
*             *       *     *   *           * * *
*               *   *         * *           *
* * * * *         *             *           * * * * *
```

To make LOVE be that big, run this version of the program:

```
CLS
PRINT "The most beautiful thing in the world is"
big.love
PRINT "The opposite of war is"
big.love
PRINT "And when I look at you, I feel lots of"
big.love

SUB big.love
PRINT "*                 *         *         *      * * * * *"
PRINT "*               *   *       *       *       *"
PRINT "*             *       *     *   *           * * *"
PRINT "*               *   *         * *           *"
PRINT "* * * * *         *             *           * * * * *"
END SUB
```

In that version, the lines say "big.love" instead of PRINT "LOVE". The SUB procedure teaches the computer how to make big.love.

Variables

Each procedure uses its own part of the RAM. For example, the main procedure uses a different part of the RAM than a SUB procedure.

Suppose the main procedure says "x = 4", and a SUB procedure named "joe" says "x = 100". The computer puts 4 into the main procedure's x box and puts 100 into joe's x box, like this:

main procedure's x box	4
joe's x box	100

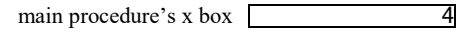
Those two boxes are stored in different parts of the RAM from each other, and they don't interfere with each other.

For example, suppose you run this program:

```
x = 4
joe
PRINT x

SUB joe
PRINT x
x = 100
END SUB
```

The computer begins by doing the main procedure, which says "x = 4", so the computer puts 4 into the main procedure's x box:



The main procedure's next line says "joe", which makes the computer do the joe procedure. The joe procedure begins by saying "PRINT x"; but since joe's x box is still empty, the computer will print 0. Joe's next line says "x = 100", which puts 100 into joe's x box. Then the computer comes to the end of joe, returns to the main procedure, and does the "PRINT x" line at the bottom of the main procedure; but since the main procedure's x box still contains 4, the computer will print 4. The computer will not print 100.

If a committee of programmers wants to write a big, fancy program, the committee divides the programming task into a main procedure and several SUB procedures, then assigns each procedure to a different programmer. If you're one of the programmers, you can use any variable names you wish, without worrying about what names the other programmers chose: if you accidentally pick the same variable name as another programmer, it's no problem, since each procedure stores its variables in a different part of the RAM.

If you *want* a variable to affect and be affected by what's in another procedure, use one of these methods…

Method 1: SHARED At the top of the main procedure, you can say:

```
COMMON SHARED x
```

That means x is a variable whose box will be shared among all procedures, so that if a procedure says "x = 4" the x will be 4 in *all* procedures.

For example, suppose you say:

```
COMMON SHARED x
x = 4
joe
PRINT x

SUB joe
PRINT x
x = 100
END SUB
```

Then when the computer comes to joe's first line, which says "PRINT x", the computer will print 4 (because the main procedure had made x become 4); and when the computer comes to the main procedure's bottom line, which says "PRINT x", the computer will print 100 (because the joe procedure had made x become 100).

Put the COMMON SHARED line at the main procedure's *top*.

You can write a program containing other shared variables besides x. For example, if you want x and sammy$ to both be common shared variables, say:

```
COMMON SHARED x, sammy$
```

If you want y$ to be a list of 20 strings, you normally say DIM y$(20); but if you want to share that list among all the procedures, say this instead:

```
DIM SHARED y$(20)
```

Put that line just at the top of the main procedure; you do *not* need to say DIM y$(20) in the SUB procedures.

The program is your world! A SHARED variable is called a **global variable**, since its value is shared throughout the entire program. An ordinary, unshared variable is called a **local variable**, since its value is used just in one procedure.

Method 2: arguments Here's a simple program:

```
INPUT "How many times do you want to kiss"; n
FOR i = 1 TO n
    PRINT "kiss"
NEXT
```

It asks "How many times do you want to kiss", then waits for your answer, then prints the word "kiss" as many times as you requested. For example, if you type 3, the computer will print:

```
kiss
kiss
kiss
```

If you input 5 instead, the computer will print this instead:

```
kiss
kiss
kiss
kiss
kiss
```

Let's turn that program into a SUB procedure that gets its input from the main procedure instead of from a human. Here's the SUB procedure:

```
SUB kiss (n)
FOR i = 1 TO n
    PRINT "kiss"
NEXT
END SUB
```

In that SUB procedure's top line, the "(n)" means "input the number n from the main procedure, instead of from a human". If the main procedure says —

```
kiss 3
```

then the n will be 3, so the SUB procedure will print "kiss" 3 times, like this:

```
kiss
kiss
kiss
```

If the main procedure says —

```
kiss 5
```

then the n will be 5, so the SUB procedure will print "kiss" 5 times.

Please type this complete program, which contains that SUB procedure:

```
PRINT "The boy said:"
kiss 3
PRINT "His girlfriend said okay!"
PRINT "Then the boy said:"
kiss 5
PRINT "His girlfiend said okay!"
PRINT "Finally, the boy said:"
kiss 8
PRINT "His girlfriend said:"
PRINT "I'm not prepared to go that far."

SUB kiss (n)
FOR i = 1 TO n
    PRINT "kiss"
NEXT
END SUB
```

When you run that program, the computer will print:

```
The boy said:
kiss
kiss
kiss
His girlfriend said okay!
Then the boy said:
kiss
kiss
kiss
kiss
kiss
His girlfriend said okay!
Finally, the boy said:
kiss
kiss
kiss
kiss
kiss
kiss
kiss
kiss
His girlfriend said:
I'm not prepared to go that far.
```

In that SUB procedure's top line, the n is called the **parameter**; put it in parentheses. In the line that says "kiss 3", the 3 is called the **argument**.

In that program, instead of saying —

```
kiss 3
```

you can say:

```
y = 3
kiss y
```

Then y's value (3) will become n, so the SUB procedure will print "kiss" 3 times. The n (which is the parameter) will use the same box as y (which is the argument). For example, if you insert into the SUB procedure a line saying "n = 9", the y will become 9 also.

You can write fancier programs. Here's how to begin a SUB procedure called joe having 3 parameters (n, m, and k$):

```
SUB joe (n, m, k$)
```

To use that subroutine, give a command such as:

```
joe 7, 9, "love"
```

Suppose your main procedure says:

```
DIM x$(3)
x$(1) = "love"
x$(2) = "death"
x$(3) = "war"
```

That means x$ is a list of these 3 strings: "love", "death", and "war". To make joan be a SUB procedure manipulating that list, make joan's top line say —

```
SUB joan (x$())
```

In that line, the () warns the computer that x$ is a list. You do *not* need to say DIM x$(3) in the SUB procedure. When you want to make the main procedure use joan, put this line into the main procedure:

```
joan x$()
```

Those lines, "SUB joan (x$())" and "joan x$()", work even if x$ is a table defined by a line such as DIM x$(30, 40).

Style

To become a *good* programmer, write your programs using a good style. Here's how.…

Design a program

First, decide on your ultimate goal. Be optimistic. Maybe you'd like the computer to play the perfect game of chess? or translate every English sentence into French?

Research the past Whatever you want the computer to do, someone else probably thought of the same idea already and wrote a program for it.

Find out. Ask your friends. Ask folks in nearby schools, computer stores, computer centers, companies, libraries, and bookstores. Look through books and magazines. There are even books that list what programs have been written. Ask the company you bought your computer from.

Even if you don't find exactly the program you're looking for, you may find one that's close enough to be okay, or that will work with just a little fixing or serve as *part* of your program or at least give you a *clue* as to where to begin. In a textbooks or magazines, you'll probably find a discussion of the problem you're trying to solve and the pros and cons of various solutions to it — some methods are faster than others.

If you keep your head in the sand and don't look at what other programmers have done already, your programming effort may turn out to be a mere exercise, useless to the rest of the world.

Simplify Too often, programmers embark on huge projects and never get them done. Once you have an idea of what's been done before and how hard your project is, simplify it.

Instead of making the computer play a perfect game of chess, how about settling for a game in which the computer plays unremarkably but at least doesn't cheat? Instead of translating every English sentence into French, how about translating just English colors? (We wrote that program already.)

In other words, **pick a less ambitious, more realistic goal**, which if achieved will please you and be a steppingstone to your ultimate goal.

Finding a bug in a program is like finding a needle in a haystack: removing the needle is easier if the haystack is small than if you wait until more hay's been piled on.

Specify the I/O Make your new, simple goal more precise. That's called **specification**. One way to be specific is to **draw a picture, showing what your screen will look like if your program's running successfully**.

In that picture, find the lines typed by the computer. They become your program's PRINT statements. Find the lines typed by the human: they become the INPUT statements. Now you can start writing your program: **write the PRINT and INPUT statements** on paper, with a pencil, and leave blank lines between them. You'll fill in the blanks later.

Suppose you want the computer to find the average of two numbers. Your picture will look like this:

```
What's the first number? 7
What's the second number? 9
The average is 8
```

Your program at this stage will be:

```
INPUT "What's the first number"; a
INPUT "What's the second number"; b
etc.
PRINT "The average is"; c
```

All you have left to do is figure out what the "etc." is. Here's the general method.…

Choose your statements Suppose you didn't have a computer. Then how would you get the answer?

Would you have to use a mathematical formula? If so, put the formula into your program, but remember that the equation's left side must have just one variable. For example, if you're trying to solve a problem about right triangles, you might have to use the Pythagorean formula $a^2+b^2=c^2$; but the left side of the equation must have just one variable, so your program must say a=SQR(c^2-b^2), or b=SQR(c^2-a^2), or c=SQR(a^2+b^2), depending on whether you're trying to compute a, b, or c.

Would you have to use a memorized list, such as an English-French dictionary or the population of each state or the weight of each chemical element? If so, that list becomes your DATA, and you need to READ it. If it would be helpful to have the data numbered — so the first piece of data is called x(1), the next piece of data is called x(2), etc. — use the DIM statement.

Subscripts are particularly useful if one long list of information will be referred to *several* times in the program.

Does your reasoning repeat? That means your program should have a loop. If you know how many times to repeat, say FOR...NEXT. If you're not sure how often, say DO...LOOP. If the thing to be repeated isn't repeated immediately, but just after several other things have happened, make the repeated part be a SUB procedure.

At some point in your reasoning, do you have to make a *decision*? Do you have to choose among several alternatives? To choose between two alternatives, say IF...THEN. To choose among three or more alternatives, say SELECT CASE. If you want the computer to make the choice arbitrarily, "by chance" instead of for a reason, say IF RND<.5.

Do you have to compare two things? The way to say "compare x with y" is: IF x = y THEN.

Write pseudocode Some English teachers say that before you write a paper, you should make an outline. Some computer teachers give similar advice about writing programs.

The "outline" can look like a program in which some of the lines are written in plain English instead of computerese. For example, one statement in your outline might be:

```
a = the average of the 12 values of x
```

Such a statement, written in English instead of in computerese, is called **pseudocode**. Later, when you fill in the details, expand that pseudocode to this:

```
sum = 0
FOR i = 1 TO 12
    sum = sum + x(i)
NEXT
average = sum / 12
```

Organize yourself Keep the program's over-all organization simple. That will make it easier for you to expand the program and find bugs. Here's some

folklore, handed down from generation to generation of programmers, that will simplify your organization.…

Use top-down programming. That means write a one-sentence description of your program; then expand that sentence to several sentences; then expand each of those sentences to several more sentences; and so on, until you can't expand any more. Then turn each of those new sentences into lines of program. Then your program will be in the same order as the English sentences, therefore organized the same way as an English-speaking mind.

A variation is to **use SUB procedures**. That means writing the essence of the program as a very short main procedure; instead of filling in the grubby details immediately, replace each piece of grubbiness by a SUB procedure. Your program will be like a good book: your main procedure will move swiftly, and the annoying details will be relegated to the appendices at the back; the appendices are the SUB procedures. Make each procedure brief — no more than 20 lines — so the entire procedure can fit on the screen; if it starts getting longer and grubbier, replace each piece of grubbiness by *another* SUB procedure.

Avoid GOTO. It's hard for a human to understand a program that's a morass of GOTO statements. It's like trying to read a book where each paragraph says to turn to a different page! When you *must* say GOTO, try to go forward instead of backwards and not go too far.

Use variables After you've written some lines of your program, you may notice that your reasoning "almost repeats": several lines bear a strong resemblance to each other. You can't use DO...LOOP or FOR...NEXT unless the lines repeat exactly. To make the repetition complete, use a variable to represent the parts that are different.

For example, suppose your program contains these lines:

```
PRINT 29.34281 + 9.876237 * SQR(5)
PRINT 29.34281 + 9.876237 * SQR(7)
PRINT 29.34281 + 9.876237 * SQR(9)
PRINT 29.34281 + 9.876237 * SQR(11)
PRINT 29.34281 + 9.876237 * SQR(13)
PRINT 29.34281 + 9.876237 * SQR(15)
PRINT 29.34281 + 9.876237 * SQR(17)
PRINT 29.34281 + 9.876237 * SQR(19)
PRINT 29.34281 + 9.876237 * SQR(21)
```

Each of those lines says PRINT 29.3428 + 9.87627 * SQR(a number). The number keeps changing, so call it x. All those PRINT lines can be replaced by this loop:

```
FOR x = 5 TO 21 STEP 2
  PRINT 29.34281 + 9.876237 * SQR(x)
NEXT
```

Here's a harder example to fix:

```
PRINT 29.34281 + 9.876237 * SQR(5)
PRINT 29.34281 + 9.876237 * SQR(97.3)
PRINT 29.34281 + 9.876237 * SQR(8.62)
PRINT 29.34281 + 9.876237 * SQR(.4)
PRINT 29.34281 + 9.876237 * SQR(200)
PRINT 29.34281 + 9.876237 * SQR(12)
PRINT 29.34281 + 9.876237 * SQR(591)
PRINT 29.34281 + 9.876237 * SQR(.2)
PRINT 29.24281 + 9.876237 * SQR(100076)
```

Again, let's use x. All those PRINT lines can be combined like this:

```
DATA 5,97.3,8.62,.4,200,12,591,.2,100076
FOR i = 1 TO 9
  READ x
  PRINT 29.34281 + 9.876237 * SQR(x)
NEXT
```

This one's even tougher:

```
PRINT 29.34281 + 9.876237 * SQR(a)
PRINT 29.34281 + 9.876237 * SQR(b)
PRINT 29.34281 + 9.876237 * SQR(c)
PRINT 29.34281 + 9.876237 * SQR(d)
PRINT 29.34281 + 9.876237 * SQR(e)
PRINT 29.34281 + 9.876237 * SQR(f)
PRINT 29.34281 + 9.876237 * SQR(g)
PRINT 29.34281 + 9.876237 * SQR(h)
PRINT 29.34281 + 9.876237 * SQR(i)
```

Let's assume a, b, c, d, e, f, g, h, and i have been computed earlier in the program. The trick to shortening those lines is to change the names of the variables. Throughout the program, say x(1) instead of a, say x(2) instead of b, say x(3) instead of c, etc. Say DIM x(9) at the beginning of your program. Then replace all those PRINT lines by this loop:

```
FOR i = 1 TO 9
    PRINT 29.34281 + 9.876237 * SQR(x(i))
NEXT
```

Make it efficient

Your program should be **efficient**. That means it should use as little of the computer's time and memory as possible.

To use less of the computer's memory, make your DIMensions as small as possible. Try writing the program without any arrays at all; if that turns out to be terribly inconvenient, use the smallest and fewest arrays possible.

To use less of the computer's time, avoid having the computer do the same thing more than once.

These lines force the computer to compute SQR(8.2 * n + 7) three times:

```
PRINT SQR(8.3 * n + 7) + 2
PRINT SQR(8.3 * n + 7) / 9.1
PRINT 5 - SQR(8.3 * n + 7)
```

You should change them to:

```
k = SQR(8.3 * n + 7)
PRINT k + 2
PRINT k / 9.1
PRINT 5 - k
```

These lines force the computer to compute x ^ 9 + 2 a hundred times:

```
FOR i = 1 TO 100
    PRINT (x ^ 9 + 2) / i
NEXT
```

You should change them to:

```
k = x ^ 9 + 2
FOR i = 1 TO 100
    PRINT k / i
NEXT
```

These lines force the computer to count to 100 twice:

```
sum = 0
FOR i = 1 TO 100
    sum = sum + x(i)
NEXT
PRINT "The sum of the x's is"; sum
product = 1
FOR i = 1 TO 100
    product = product * x(i)
NEXT
PRINT "The product of the x's is"; product
```

You should combine the two FOR...NEXT loops into a single FOR...NEXT loop, so the computer counts to 100 just once. Here's how:

```
sum = 0
product = 1
FOR i = 1 TO 100
    sum = sum + x(i)
    product = product * x(i)
NEXT
PRINT "The sum of the x's is"; sum
PRINT "The product of the x's is"; product
```

Here are more tricks to make your program run faster.…

Instead of exponents, use multiplication.

```
slow:   y = x ^ 2
faster: y = x * x
```

Test it

When you've written a program, **test** it: run it and see whether it works.

If the computer does *not* gripe, your tendency will be to say "Whoopee!" Don't cheer too loudly. **The answers the computer prints might be wrong.** Even if its answers look reasonable, don't assume they're right: the computer's errors can be subtle. Check some of its answers by computing them with a pencil.

Even if the answers the computer prints are correct, don't cheer. Maybe you were just lucky. Type different input, and see whether your program still works. Probably you can input something that will make your program go crazy or print a wrong answer. Your mission: to find input that will reveal the existence of a bug.

Try 6 kinds of input.…

Try simple input Type in simple integers, like 2 and 10, so the computation is simple, and you can check the computer's answers easily.

Try input that increases See how the computer's answer changes when the input changes from 2 to 1000.

Does the change in the computer's answer look reasonable? Does the computer's answer go up when it should go up, and down when it should go down?… and by a reasonable amount?

Try input testing each IF For a program that says —

```
IF x < 7 THEN GOTO 10
```

input an x less than 7 (to see whether line 10 works), then an x greater than 7 (to see whether the line underneath the IF line works), then an x equal to 7 (to see whether you really want "<" instead of "<="), then an x very close to 7, to check round-off error.

For a program that says —

```
IF x ^ 2 + y < z THEN GOTO 10
```

input an x, y, and z that make x ^ 2 + y less than z. Then try inputs that make x ^ 2 + y very close to z.

Try extreme input What happens if you input:

a huge number, like 45392000000 or 1E35?
a tiny number, like .00000003954 or 1E-35?
a trivial number, like 0 or 1?
a typical number, like 45.13?
a negative number, like -52?

Find out.

If the input is supposed to be a string, what happens if you input aaaaa or zzzzz? What happens if you capitalize the input? If there are supposed to be two inputs, what happens if you input the same thing for each?

Try input making a line act strange If your program contains division, try input that will make the divisor be zero or a tiny decimal close to zero. If your program contains the square root of a quantity, try input that will make the quantity be negative. If your program says "FOR i = x TO y", try input that will make y be less than x, then equal to x. If your program mentions x(i), try input that will make i be zero or negative or greater than the DIM.

Try input that causes round-off error: for a program that says "x - y" or says "IF x = y", try input that will make x almost equal y.

Try garbage Computers often print wrong answers. A computer can print a wrong answer because its circuitry is broken or because a program has a bug. But **the main reason why computers print wrong answers is incorrect input**. Incorrect input is called **garbage** and has several causes.…

The user's finger slips. Instead of 400, he inputs 4000. Instead of 27, he inputs 72. Trying to type .753, he leaves out the decimal point.

The user got wrong info. He tries to input the temperature, but his thermometer is leaking. He tries to input the results of a questionnaire, but everybody who filled out his questionnaire lied.

The instructions aren't clear, so the user isn't sure what to input.

If the program asks "How far did the ball fall?" should the user type the distance in feet or in meters? Is time to be given in seconds or minutes? Are angles to be measured in degrees or radians?

Can the user input "y" instead of "yes"?

Maybe the user isn't clear about whether to insert commas, quotation marks, and periods. If several items are to be typed, should they be typed on the same line or on separate lines? If your program asks "How many brothers and sisters do you have?" and the user has 2 brothers & 3 sisters, should he type "5" or "2,3" or "2 brothers and 3 sisters"?

If the program asks "What is your name?" should the user type "Joe Smith" or "Smith,Joe" or just "Joe"? For a quiz that asks "Who was the first U.S. President?" what if the user answers "George Washington" or simply "Washington" or "washington" or "G. Washington" or "General George Washington" or "President Washington" or "Martha's husband"? Make the instructions clearer:

```
Who was the first U.S. President (give just his last name)?
```

The user tries to joke or sabotage. Instead of inputting his name, he types an obscene comment. When asked how many brothers and sisters he has, he says 275.

Responsibility! As a programmer, it's your duty to include clear directions for using your program, and you must make the program reject ridiculous input.

For example, if your program is supposed to print weekly paychecks, it should refuse to print checks for more than $10000. Your program should contain these lines:

```
10 INPUT "How much money did the employee earn"; e
IF e > 10000 THEN
    PRINT e; "is quite a big paycheck!  I don't believe you."
    PRINT "Please retype your request."
    GO TO 10
END IF
```

That IF line is called an **error trap** (or **error-handling routine**). Your program should contain several, to prevent printing checks that are too small (2¢?) or negative or otherwise ridiculous ($200.73145?)

To see how your program reacts to input that's either garbage or unusual, **ask a friend to run your program**. That person might input something you never thought of.

Document it

Write an explanation that helps other people understand your program.

An explanation is called **documentation**. When you write an explanation, you're **documenting** the program.

You can write the documentation on a separate sheet of paper, or you can make the computer print the documentation when the user runs or lists the program.

A popular device is to begin the program by making the computer ask the user:

```
Do you need instructions?
```

You need two kinds of documentation: how to use the program, and how the program was written.

How to use the program Your explanation of using the program should include:

the program's name
how to get the program from the disk
the program's purpose
a list of other programs that must be combined with this program, to make a workable combination
the correct way to type the input and data (show an example)
the correct way to interpret the output
the program's limitations (input it can't handle, a list of error messages that might be printed, round-off error)
a list of bugs you haven't fixed yet

How the program was written An explanation of how you wrote the program will help other programmers borrow your ideas, and help them expand your program to meet new situations. It should include:

your name
the date you finished it
the computer you wrote it for
the language you wrote it in (probably QBasic)
the name of the method you used ("solves quadratic equations by using the quadratic formula")
the name of the book or magazine where you found the method
the name of any program you borrowed ideas from
an informal explanation of how program works ("It loops until x>y, then computes the weather forecast.")
the purpose of each SUB procedure
the meaning of each variable
the significance of reaching a line (for a program saying "IF x < 60 THEN GOTO 1000", say "Reaching line 1000 means the student flunked.")

Visual Basic

The most popular computer language is **Visual Basic for Windows (VB)**. More programs are written in VB than in any other computer language.

Using VB, you can easily create Windows programs that let the human use a mouse to click on icons, choose from menus, use dialog boxes, etc.

After inventing the first VB, Microsoft invented improved versions:

VB 2, **VB 3**, **VB 4**, **VB 5**, **VB 6**
VB 7 (also called **VB.Net**)
VB 7.1 (also called **VB.Net 2003**)
VB 8 (also called **VB 2005**)
VB 9 (also called **VB 2008**)
VB 10 (also called **VB 2010**)
VB 11 (also called **VB 2012**)
VB 14 (also called **VB 2015**)

The most traumatic change was the switch from VB 6 to VB 7: programs written for VB 6 must be rewritten to work with VB 7.

This chapter explains the newest version: VB 2015.

Visual Basic is part of **Visual Studio**, which is Microsoft's suite of programming languages. Visual Studio includes **Visual Basic**, **Visual C++**, **Visual C#**, and other programming tools.

Microsoft lets you get Visual Studio **free**! The main free version is called **Visual Studio Community**. You can copy it from Microsoft's Website. It's free just if you promise to use it either *individually* (not in a big company's team) or *non-commercially* (just to study). Visual Studio Community improves on an older stripped-down version, called **Visual Studio Express**.

Before you read this chapter and study VB, prepare yourself! Do 2 prerequisite activities:

Learn QBasic or QB64, which are much easier than VB. I explained them on pages 507-561. Read and practice that material.

Practice using good Windows programs (such as a Windows word-processing program), so you see how Windows programs should act. I explained good programs for modern Windows on pages 65-131, 137-158, and 231-249. Read and practice whichever of those Windows programs you have access to.

VB uses these **commands** (which resemble QBasic's):

VB command	Page
`Beep()`	566
`Case "fine"`	573
`ColorDialog1.ShowDialog()`	584
`Console.ReadKey()`	586
`Console.WriteLine(5 + 2)`	586
`Console.Write(5 + 2)`	586
`Debug.Print(5 + 2)`	586
`Dim x`	567
`Dim x As Integer`	595
`Dim x As Integer = 7`	599
`Dim x = 7`	599
`Dim x() = {81, 52, 207, 19}`	600
`Dim x(2) As Double`	599
`Do`	586, 590
`document.Clear()`	589
`document.Copy()`	590
`document.Cut()`	589
`document.LoadFile…`	588
`document.Paste()`	590
`document.SaveFile…`	588
`Else`	571
`ElseIf age < 100 Then`	571
`End`	568, 573
`End Class`	563
`End If`	571
`End Module`	586
`End Select`	573
`End Sub`	563, 573
`Exit Do`	591
`Exit Sub`	573
`For Each i In x`	600
`For x = 1 To 5`	592
`For x = 15 To 17 Step .1`	593
`GoTo joe`	590
`If age < 18 Then`	570, 571
`Imports System.Math`	599
`Loop`	586, 590
`Loop Until guess = "pink"`	591
`Module Module1`	586
`MsgBox("Hair looks messy")`	568
`My.Computer…WriteAllText…`	587
`Next`	592
`OpenFileDialog1.ShowDialog()`	588
`Option Explicit Off`	585
`PrintForm1.Print()`	563, 586
`Private Sub Form1_Load…`	563, 576
`Public Class Form1`	563
`Randomize()`	601
`RichTextBox1.SaveFile…`	587
`Select Case feeling`	573
`SaveFileDialog1.ShowDialog()`	588
`Sub Main()`	586
`Text = 4 + 2`	563
`x = 47`	567
`? 5+2`	586
`'Yeah, this is an example`	585

VB uses these **functions** (which resemble QBasic's):

VB function	Value	Page
`Chr(13)`	Enter key	579
`CInt(3.9)`	4	600
`ColorDialog1.Color`	varies	584
`Fix(3.89)`	3.0	594
`GetSelected(0)`	varies	580
`IIf(age < 18…`	varies	572
`InputBox("Name?")`	varies	569
`Int(3.89)`	3.0	594
`Math.Abs(-3.89)`	3.89	594
`Math.Ceiling(3.89)`	4.0	594
`Math.PI`	about 3.14	594
`Math.Round(3.89)`	4.0	594
`Math.Sign(3.89)`	1	594
`Math.Sqrt(9)`	3.0	594
`My…LocalTime`	varies	584
`My…MyDocuments`	Docu. folder	587
`My…ReadAllText`	varies	587
`MsgBox("Love me?"…`	varies	572
`Now`	varies	597
`Rnd`	varies	601
`TypeName(4.95D)`	"Decimal"	599
`Val("7")`	7	569
`VarType(4.95D)`	14	598

In VB, you never write "a long program". Instead, you begin by drawing **objects** on the screen (as if you were using a graphics program). Then for each object, you write a little program (called a **subroutine**) that tells the computer how to manipulate the object. VB handles these objects:

VB object	Page
`Button`	576
`CheckBox`	577
`ColorDialog`	584
`ComboBox`	582
`Form1`	563
`Form2`	583
`Label`	579
`ListBox`	580
`MenuStrip`	588
`NumericUpDown`	581
`OpenFileDialog`	589
`PictureBox`	582
`PrintForm`	586
`RadioButton`	578
`RichTextBox`	581
`SaveFileDialog`	587
`TextBox`	581
`Timer`	583
`ToolStrip`	589
`WebBrowser`	583

Each object has **properties**, which you can manipulate:

VB property	Object	Page
`BackColor`	`Form1`	566, 574
`Checked`	`CheckBox`	577
`DecimalPlaces`	`NumericUpDown`	582
`Dock`	`RichTextBox`	581
`DropDownStyle`	`ComboBox`	582
`EnableAutoDrag…`	`RichTextBox`	581
`Enabled`	`Timer`	583
`FormBorderStyle`	`Form1`	575
`Image`	`PictureBox`	582
`Interval`	`Timer`	583
`MaximizeBox`	`Form1`	575
`Maximum`	`NumericUpDown`	582
`Minimum`	`NumericUpDown`	582
`MultiLine`	`TextBox`	581
`(Name)`	`RichTextBox1`	588
`Opacity`	`Form1`	575
`PasswordChar`	`TextBox`	581
`ScrollBars`	`TextBox`	581
`SelectedIndex`	`ListBox`	580
`SelectedItem`	`ListBox`	580
`SelectionMode`	`ListBox`	580
`Size`	`Form1`	575
`SizeMode`	`PictureBox`	582
`StartPosition`	`Form1`	575
`Text`	`Form1`	563, 574
`Url`	`WebBrowser`	583
`Value`	`NumericUpDown`	581
`Visible`	`Form2`	583
`WindowState`	`Form1`	566, 574

Fun

Let's have fun programming!

Copy the Community

Here's how to copy Visual Studio Community 2015 (including Visual Basic 2015) to your hard disk, using Windows 10. (Windows 7, 8, and 8.1 are also acceptable and act similarly.)

Using Microsoft Edge (or Internet Explorer), go to VisualStudio.com. Tap (or click) "Download Community 2015" then "No thanks" then "Save" then "Run".

The computer will say "Initializing setup" then "Choose". Tap the "Install" button then "Yes".

The computer will say "Acquiring" and "Applying". About 33 minutes later (depending on the speed of your computer and Internet connection), the computer will say "Setup Completed!"

Tap "Restart Now". The computer will say "Restarting". The screen will go black. Then computer will say "Please wait". The computer will ask you to log in again (by typing your password).

If the computer asks "How do you want to open this?" tap "OK".

The computer will say "Welcome to Visual Studio".Close the Microsoft Edge (or Internet Explorer) window (by clicking the X at the screen's top-right corner).

Start Visual Studio

To start using Visual Studio, type "vi" in the Windows 10 Search box (which is next to the Windows Start button) then click "Visual Studio 2015: Desktop app".

If you haven't used Visual Studio before, the computer says "Sign in". To reply, do this:

Click the "Sign in" button. Type your email address and press Enter. Type your Microsoft account's password and press Enter. The computer says "We're preparing for first use".

The computer says "Visual Studio." After a delay, you see the "**Start Page**" window.

Create simple programs

Click "**New Project**" (which is near the screen's left edge) then "**Visual Basic**" then "**Windows Forms Application**".

Double-click in the Name box (which is near the screen's bottom). Type a name for your project (such as Funmaker). At the end of your typing, press the Enter key.

You see an **object**, called the **Form1** window. Double-click in that window (below "Form1"). That tells the computer you want to write a program (subroutine) about that window.

The computer starts writing the **subroutine** for you. The computer writes:

```
Public Class Form1
    Private Sub Form1_Load…

    End Sub
End Class
```

The line saying "Private Sub Form1_Load" is the subroutine's **header**. The line saying "End Sub" is the subroutine's **footer**; it marks the end of the subroutine. Between those lines, insert lines that tell the computer what to do to the object (which is the Form1 window). The lines you insert are called the subroutine's **body**.

Simplest example Let's make the Form1 window show the answer to this math problem: 4 + 2. To do that, type this line —

```
        Text = 4 + 2
```

The computer automatically indents that line for you, so the subroutine becomes:

```
    Private Sub Form1_Load…
        Text = 4 + 2
    End Sub
```

To run your program, click "Start" (which is at the screen's top center) **or press the F5 key**. (If the "F5" is blue or tiny or on a new computer by Microsoft, HP, Lenovo, or Toshiba, that key works just *while you hold down the Fn key*, which is left of the Space bar.) Then you see the Form1 window again; but instead of saying "Form1", it says the text's answer:

```
6
```

When you've finished admiring that answer, stop the program by clicking the Form1 window's X button. Then you see the subroutine again:

```
    Private Sub Form1_Load…
        Text = 4 + 2
    End Sub
```

Edited example Let's edit that subroutine, so instead of saying the answer to 4 + 2, it will say the answer to 79 + 2.

To do that, change the 4 to 79. Here's how: click the 4's left edge, then press the Delete key (to delete the 4), then type 79, so the subroutine looks like this:

```
    Private Sub Form1_Load…
        Text = 79 + 2
    End Sub
```

Run that program by clicking "Start". Then the Form1 window shows the new answer:

```
81
```

When you finish admiring that, click Form1's X button.

To make the computer subtract 3 from 7, change the text line to this:

```
        Text = 7 - 3
```

When you run the program (by clicking "Start"), the Form1 window will show the answer:

```
4
```

To make the computer do -26.3+1, change the text line to this:

```
        Text = -26.3 + 1
```

The Form1 window will show the answer:

```
-25.3
```

Your own examples Go ahead! Try changing the subroutine, to do different math problems instead!

Multiply To multiply, use an asterisk. So to multiply 2 by 6, type this:

```
        Text = 2 * 6
```

The Form1 window will show:

```
12
```

Divide To divide, use a slash. So to divide 8 by 4, type this:

```
        Text = 8 / 4
```

The Form1 window will show:

```
2
```

To divide 2 by 3, type this:

```
        Text = 2 / 3
```

The Form1 window will show:

```
0.6666…
```

Maximize the Form1 window (by clicking its maximize button, which is next to its X). That makes the Form1 window consume the whole screen temporarily and show:

```
0.666666666666667
```

When you finish admiring that, return the Form1 window to its normal size (by clicking its Restore Down button, which is next to its X).

Congratulations You've written VB subroutines and created VB programs, so you've become a VB programmer! You can put on your résumé, "VB programmer!"

Type faster

Here are tricks that let you type faster.

You don't need to capitalize computer words such as "Text". The computer will capitalize them automatically, eventually. For example, if you type "text" instead of "Text", the computer will change "text" to "Text" when you type the equal sign afterwards.

You don't need to finish typing computer words such as "Text". The computer will finish typing them for you, automatically, eventually, if the computer can deduce what you meant. For example, you can type "te" instead of "Text"; the computer will change "te" to "Text" when you type the equal sign afterwards.

Instead of typing computer words, you can choose them from lists. For example, instead of typing "Text", you can do this:

> Type the letter "t". You'll see a list of computer words that begin with "t". (To see that whole list, click the list's up-arrow & down-arrow or press the keyboard's up-arrow & down-arrow keys.) If you type "te", you'll see a list of computer words that begin with "te". In a list, when you see the word you want, either double-click the word or do this: highlight the word (by clicking it) then press the keyboard's Tab key.

You don't need to put spaces around symbols, such as "=" and "+". The computer will insert those spaces automatically, when you end the line (by clicking "Start" or pressing the Enter key or down-arrow key or clicking a different line).

Huge and tiny numbers

When dealing with huge and tiny number, be careful!

Avoid commas Do *not* put commas in big numbers. To write four million, do *not* write 4,000,000; instead, write 4000000.

Use decimals for big answers The computer sometimes has difficulty handling answers bigger than 2,000,000,000, which in modern English is called "2 billion." To avoid difficulty, **put a decimal point in any problem whose answer might be bigger than 2 billion**.

For example, suppose you want the computer to multiply 3000 by 1000000. Since the answer to that problem is 3 billion, which is bigger than 2 billion, you should put a decimal point in that problem, like this:

```
Text = 3000 * 1000000.0
```

After typing a decimal point, you must type a digit (such as 0).

Suppose you forget to insert a decimal point and say just this:

```
Text = 3000 * 1000000
```

When you try to run the program (by clicking "Start"), the computer will complain in 3 ways:

> It will put a squiggly red line under the "3000 * 1000000".
>
> The screen's bottom will say "Constant expression not representable in type 'Integer'."
>
> The screen's middle will say, "There were build errors. Would you like to continue and run the last successful build?" To reply, click "No" then fix your error (by inserting .0) and click "Start" again.

E notation If the computer's answer is huge (at least a quadrillion, which is 1000000000000000) or tiny (less than .0001), the computer will put an E in the answer. The E means "move the decimal point".

For example, suppose the computer says the answer to a problem is:

```
1.586743E+15
```

The E means, "move the decimal point". The plus sign means, "towards the right". Altogether, **the E+15 means, "move the decimal point towards the right, 15 places."** So look at 1.586743 and move the decimal point towards the right, 15 places; you get 1586743000000000.

So when the computer says the answer is 1.586743E+15, the computer really means the answer is 1586743000000000, approximately. The exact answer might be 1586743000000000.2 or 1586743000000000.79 or some similar number, but the computer prints just an approximation.

Suppose your computer says the answer to a problem is:

```
9.23E-06
```

After the E, the minus sign means, "towards the *left*". So look at 9.23 and move the decimal point towards the left, 6 places. You get: .00000923

So when the computer says the answer is 9.23E-06, the computer really means the answer is: .00000923

You'll see E notation rarely: the computer uses it just if an answer is huge (at least a quadrillion) or tiny (tinier than .0001). But when the computer *does* use E notation, remember to move the decimal point!

The highest number The highest number the computer can handle well is about 1E308, which is 1 followed by 308 zeros. If you try to go much higher, the computer will gripe, by saying "Overflow" or "∞" (which is the symbol for infinity) or "NaN" (which means "Not a Number").

For example, if you say —

```
Text = 1E309
```

the computer will put a squiggly red line under "1.0E+309", screen's bottom will say "Overflow", and the screen's middle will say "There were build errors" and wait for you to click "No".

Dividing by 0 If you ask the computer to divide by 0, the computer will have difficulty.

For example, if you say —

```
Text = 5 / 0
```

the computer will try to divide 5 by 0, give up (because you can't divide by 0), and say the answer is "∞".

If you say —

```
Text = -5 / 0
```

the computer will try to divide -5 by 0, give up (because you can't divide by 0), and say the answer is "-∞".

If you say —

```
Text = 0 / 0
```

the computer will try to divide 0 by 0, give up (because you can't divide by 0), get confused, and say the answer is "NaN" (which means "Not a Number").

The tiniest decimal The tiniest decimal the computer can handle accurately is 1E-308 (which is a decimal point followed by 308 digits, 307 of which are zeros). If you try to go tinier, the computer will either say 0 or give you a rough approximation.

Order of operations

What does "2 plus 3 times 4" mean? The answer depends on whom you ask.

To a clerk, it means "start with 2 plus 3, then multiply by 4"; that makes 5 times 4, which is 20. But to a scientist, "2 plus 3 times 4" means something different: it means "2 plus three fours", which is 2 + 4 + 4 + 4, which is 14.

Since computers were invented by scientists, computers think like scientists. If you type —

```
Text = 2 + 3 * 4
```

the computer will think you mean "2 plus three fours", so it will do 2 + 4 + 4 + 4 and display this answer:

```
14
```

The computer will *not* display the clerk's answer, which is 20. So if you're a clerk, tough luck!

Scientists and computers follow this rule: **do multiplication and division before addition and subtraction**. So if you type —

```
Text = 2 + 3 * 4
```

the computer begins by hunting for multiplication and division. When it finds the multiplication sign between the 3 and the 4, it multiplies 3 by 4 and gets 12, like this:

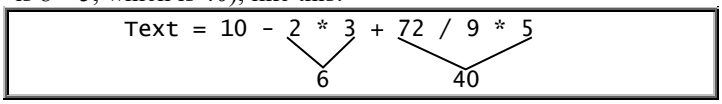
```
Text = 2 + 3 * 4
           \ /
            12
```

So the problem becomes 2 + 12, which is 14, which the computer will display.

For another example, suppose you type:

```
Text = 10 - 2 * 3 + 72 / 9 * 5
```

The computer begins by doing all the multiplications and divisions. So it does 2 * 3 (which is 6) and does 72 / 9 * 5 (which is 8 * 5, which is 40), like this:



So the problem becomes 10 - 6 + 40, which is 44, which is the answer the computer will display.

Parentheses You can use parentheses the same way as in algebra. For example, if you type —

```
Text = 5 - (1 + 1)
```

the computer will compute 5 - 2 and print:

```
3
```

You can put parentheses inside parentheses. If you type —

```
Text = 10 - (5 - (1 + 1))
```

the computer will compute 10 - (5 - 2), which is 10 - 3, and will display:

```
7
```

Strings

Let's make the computer fall in love. Let's make it say, "I love you". To do so, type this in your subroutine:

```
Text = "I love you"
```

Type that carefully:

> Type the word Text, then a blank space, then an equal sign, then another blank space. Then type a quotation mark, but be careful: **to type the quotation mark, you must hold down the Shift key.** Then type these words: *I love you*. Then type another quotation mark.

When you run the program (by clicking "Start"), it will make the text (at the top of Form1's window) display:

```
I love you
```

You can change the computer's personality. For example, if you edit the subroutine to make it become —

```
Text = "I hate you"
```

the computer will reply:

```
I hate you
```

Notice that **to make a subroutine print a message, you must put the message between quotation marks**. The quotation marks make the computer copy the message without worrying about what the message means. For example, if you misspell "I love you", and type —

```
Text = "aieee luf ya"
```

the computer will still copy the message (without worrying about what it means); the computer will make Form1 say:

```
aieee luf ya
```

Type faster Instead of typing —

```
Text = "I love you"
```

you can type just this:

```
text="I love you
```

The computer automatically capitalizes the first letter (T) and types the second quotation mark. Before the computer runs the program, the computer will also put spaces around the equal sign.

Red strings While you're typing the subroutine, **the computer makes each string look red** (and each computer word look blue).

Those colors appear just while you're looking at the subroutine you've been typing. When you run the program, the program's answers (and other results) appear black.

Jargon The word "joy" consists of 3 characters: j and o and y. Programmers say that the word "joy" is a **string** of 3 characters.

> A **string** is any collection of characters, such as "joy" or "I love you" or "aieee luf ya" or "76 trombones" or "GO AWAY!!!" or "xypw exr///746". The computer will print whatever string you wish, but in your subroutine **put the string in quotation marks**.

Strings versus numbers The computer can handle two types of expressions: **strings** and **numbers**. In your subroutine, put strings (such as "joy" and "I love you") in quotation marks. Numbers (such as 4 + 2) do *not* go in quotation marks.

Combine strings You can combine strings:

```
Text = "fat" & "her"
```

The computer will combine "fat" with "her", so the computer will display:

```
father
```

You can combine a string with a number:

```
Text = "The lucky number is " & 4 + 2
```

The computer will display "The lucky number is " then the answer to this math problem: 4 + 2. The computer will display:

```
The lucky number is 6
```

When combining a string with a number, make the computer leave a space between the string and the number, by putting a space before the last quotation mark.

Combining strings or numbers (by using the symbol "&") is called **concatenating**.

When typing the symbol "&" to concatenate, **press the keyboard's Space bar before and after the "&"**. If you rely on the computer to put those spaces in automatically, you'll be sorry, because the symbol "&" without spaces can have a different meaning, and the computer will occasionally guess wrong about which "&" you meant.

Accidents Suppose you accidentally put the number 2 + 2 in quotation marks, like this:

```
Text = "2 + 2"
```

The quotation marks make the computer think "2 + 2" is a string instead of a number. Since the computer thinks "2 + 2" is a string, it copies the string without analyzing what it means; Form1 will say:

```
2 + 2
```

It will *not* say 4.

Suppose you want the computer to show the word "love" but you accidentally forget to put the string "love" in quotation marks, and type this instead:

```
Text = love
```

Since you forgot the quotation marks, the computer is confused. Whenever the computer is confused, it either gripes at you or says zero. In this particular example, here's how the computer gripes at you: it puts a red squiggly line under "love," and, when you run the program, it makes the screen's middle say "There were build errors" and makes screen's bottom say:

```
'love' is not declared.
```

Display a quotation mark The symbol for *inches* is ". Let's make Form1 say:

```
The nail is 2" long.
```

This Text command does *not* work:

```
        Text = "The nail is 2" long."
```

When the computer sees the quotation mark after 2, it mistakenly thinks that quotation mark is paired with the quotation mark before "The", then gets totally confused.

Here's the correct way to write that line:

```
        Text = "The nail is 2"" long."
```

The symbol "" means: display a quotation mark. That Text line makes Form1 display:

```
The nail is 2" long.
```

Here's the rule: to display a quotation mark ("), put the symbol "" in your Text statement.

Let's make the computer display this sentence:

```
I saw "Hamlet" last night.
```

To display the quotation mark before "Hamlet", you must type "". To display the quotation mark after "Hamlet", you must type "". So type this:

```
        Text = "I saw ""Hamlet"" last night."
```

Color

Normally, the Form1 window's middle is a big blank area that's nearly white (very light gray). To make it red instead, put this line in your subroutine:

```
        BackColor = Color.Red
```

For example, to make the window's title say "I love you" and make the window's background color be red, put both of these lines in your subroutine —

```
        Text = "I love you"
        BackColor = Color.Red
```

so the whole subroutine looks like this:

```
Public Class Form1
    Private Sub Form1_Load…
        Text = "I love you"
        BackColor = Color.Red
    End Sub
End Class
```

The computer understands these color names:

```
Yellow, Gold, Goldenrod, LemonChiffon
Orange, Brown, Chocolate, Tan
Red, Pink, DeepPink, Crimson
Purple, Violet, Magenta, Orchid
Blue, Cyan, Navy, DeepSkyBlue
Green, Lime, Chartreuse, Khaki
White, Gray, Black, Silver
```

It understands many others, too: altogether, it knows the names of 147 colors. You'll see the complete list when you've typed:

```
        BackColor = Color.
```

(Use the list's up-arrow & down-arrow.)

Don't put spaces in the middle of a color name: type "DeepSkyBlue", not "Deep Sky Blue".

Beep

To make the computer **beep** (play 3 musical notes through the computer's speakers), put this line in your subroutine:

```
        Beep()
```

Multi-statement line

In your subroutine, **a line can include many statements separated by colons**, like this:

```
        Text = "I love you" : BackColor = Color.Red
```

That line means the same thing as:

```
        Text = "I love you"
        BackColor = Color.Red
```

Maximize

To maximize the Form1 window (so it consumes the whole screen), put this line in your subroutine:

```
        WindowState = 2
```

For example, let's make the computer say "You turned me on, and I love you!" and maximize the Form1 window (so the human can see all that). Just put both of these lines in your subroutine:

```
        WindowState = 2
        Text = "You turned me on, and I love you!"
```

Final steps

When you finish playing with your program, here's what to do.

Make sure you see the subroutine you typed. (If you see Form1's window instead, close that window by clicking its X button.)

Save If you like the program you created and want to save it on disk, click the **Save All** button. (It looks like 2 floppy disks that are *tiny*. It's near the screen's top, below the "t" in "Project".) That makes sure your program is saved. (It's saved in its own folder, which is in the **Projects folder**, which is in the **Visual Studio 2015 folder**, which is in the **Documents folder**, which is on drive C.)

Afterwards, if you make further changes to the program, click the Save All button again to save them.

New If you're tired of working on a program and want to start inventing a different program instead, click the **New Project** button (which is near the screen's top-left corner, below the word "View", and shows a yellow sunburst before 2 sheets of paper). Then click "Windows Forms Application", double-click in the Name box, type a name for the new program, and press the Enter key.

If the previous program wasn't saved, the computer says "Save changes". If you want to save the previous program, click "Yes"; otherwise, click "No".)

Exit When you finish using Visual Studio, click the X button that's in the screen's top right corner.

Open When you start using Visual Studio, look at the the word "Recent" (near the screen's left edge). Below "Recent", you see a list of programs you used recently. If you want to use or edit one of those programs, click that program's name. Either run the program again (by clicking "Start") or edit the program's commands.

Run the .exe file When the computer ran your program, it made an .exe file (called Funmaker.exe), which you can run again without going into Visual Studio. Here's how:

```
Exit from Visual Studio. In the Windows 10 search box (which is next to the
Windows Start button), type "Funmaker". Tap "Funmaker: File Folder in
Projects". Double-click the "Funmaker" folder then "bin" then "Debug" then
the first "Funmaker" (which says its type is "Application").
```

Variables

A letter can stand for a number, a string, or other things.

For example, x can stand for the number 47, as in this subroutine:

```
Dim x
x = 47
Text = x + 2
```

The top line (Dim x) warns the computer that x will stand for something. (The "Dim" comes from the word "Dimension".)

The second line (x = 47) says x stands for the number 47. In other words, x is a name for the number 47. Warning: if you forgot to type the top line (Dim x), the computer refuses to let you type the second line (x = 47).

The bottom line (Text = x + 2) makes the computer display x + 2. Since x is 47, the x + 2 is 49; so the computer will display 49. That's the only number the computer will display; it will not display 47.

Jargon

A letter standing for something is called a **variable** (or **name** or **identifier**). A letter standing for a number is called a **numeric variable**. In that subroutine, x is a numeric variable; it stands for the number 47. The **value** of x is 47.

In that subroutine, the statement "x = 47" is called an **assignment statement**, because it **assigns** 47 to x.

A variable is a box

When you run that subroutine, here's what happens inside the computer.

The computer's random-access memory (RAM) consists of electronic boxes. When the computer encounters the line "x = 47", the computer puts 47 into box x, like this:

box x | 47 |

Then when the computer encounters the line "Text = x + 2", the computer will display what's in box x, plus 2; so the computer will display 49.

Faster typing

Instead of typing —

```
x = 47
```

you can type just this:

```
x=47
```

At the end of that line, when you press the Enter key, the computer automatically puts spaces around the equal sign.

More examples

Here's another subroutine:

```
Dim y
y = 38
Text = y - 2
```

The top line says y is a variable. The next line says y is 38. The bottom line says to display y - 2. Since y is 38, the y - 2 is 36; so the computer will display 36.

Another example:

```
Dim b
b = 8
Text = b * 3
```

The top line says b is a variable. The next line says b is 8. The bottom line says to display b * 3, which is 8 * 3, which is 24; so the computer will display 24.

One variable can define another:

```
Dim n, d
n = 6
d = n + 1
Text = n * d
```

The top line says n and d are variables. The next line says n is 6. The next line says d is n + 1, which is 6 + 1, which is 7; so d is 7. The bottom line says to display n * d, which is 6 * 7, which is 42; so the computer will display 42.

Changing a value

A value can change:

```
Dim k
k = 4
k = 9
Text = k * 2
```

The second line says k is 4, but the next line changes k's value to 9, so the bottom line displays 18.

When you run that subroutine, here's what happens inside the computer's RAM. The second line (k = 4) makes the computer put 4 into box k:

box k | 4 |

The next line (k = 9) puts 9 into box k. The 9 replaces the 4:

box k | 9 |

That's why the bottom line (Text = k * 2) displays 18.

String variables

A string is any collection of characters, such as "I love you". Each string must be in quotation marks.

A letter can stand for a string:

```
Dim x
x = "I love you"
Text = x
```

The top line warns the computer that x will stand for something. The next line says x stands for the string "I love you". The bottom line makes the computer display:

```
I love you
```

In that subroutine, x is a variable. Since it stands for a string, it's called a **string variable**.

You can combine strings:

```
Dim x
x = "so"
Text = x & "up"
```

(When typing that example, you must leave a space before the ampersand, to avoid confusion.) Since the second line says x is "so", the bottom line will make Text be "so" & "up" and display this:

```
soup
```

If you insert a space by typing " up" instead of "up", like this —

```
Dim x
x = "so"
Text = x & " up"
```

the computer will display:

```
so up
```

Long variable names

A variable's name can be a letter (such as x) or a longer combination of characters, such as:

```
CityPopulationIn2001
```

For example, you can type:

```
Dim CityPopulationIn2001
CityPopulationIn2001 = 30716
Text = CityPopulationIn2001 + 42
```

The computer will print:

```
30758
```

The variable's name can be as long as you wish: up to 255 characters! The name's first character must be a letter; the remaining characters can be letters or digits. The computer ignores capitalization: it assumes that CityPopulationIn2001 is the same as citypopulationin2001.

Beginners are usually too lazy to type long variable names, so beginners use variable names that are short. But when you become a pro and write a long, fancy program containing hundreds of lines and hundreds of variables, you should use long variable names to help you remember each variable's purpose.

In this book, I'll use short variable names in short programs (so you can type those programs quickly) but long variable names in long programs (so you can keep track of which variable is which).

Pop-up boxes

Here's how to make a box appear suddenly on your screen.

Message box

Into any subroutine, you can insert this line:

```
MsgBox("Warning: your hair looks messy today")
```

When the computer runs the program and encounters that line, the computer suddenly creates a **message box** (a window containing a short message), which appears in front of all other windows (so they're covered up) and contains this message: "Warning: your hair looks messy today". The computer automatically makes the window be wide enough to include the whole message and be centered on the screen.

The window includes an OK button. When the human finishes reading the message, the human must click that OK button (or press Enter) to make the window go away.

After the window goes away, Form1 reappears and the computer continues running the rest of the program (including any lines below the MsgBox line). Form1 remains on the screen until the human clicks Form1's X button, which closes the form and ends the program.

End program automatically To please the human, make the *computer* click Form1's X button and end the program, by putting this command under the MsgBox line —

```
End
```

so your subroutine looks like this:

```
MsgBox("Warning: your hair looks messy today")
End
```

The top line makes the message box say "Warning: your hair looks messy today" then wait for the human to click OK. The bottom line ends the program (without requiring the human to click an X button).

Putting End under MsgBox makes the screen look like this:

```
Public Class Form1
    Private Sub Form1_Load…
        MsgBox("Warning: your hair looks messy today")
        End
    End Sub
End Class
```

Try it!

That End line is helpful. If you omit it and say just —

```
MsgBox("Warning: your hair looks messy today")
```

here's what happens when the human runs the program:

> The computer creates a message box saying "Warning: your hair looks messy today". Then the computer waits for the human to click the message box's OK button.
>
> When the human clicks the OK button, the message box disappears. Then the computer is supposed to do any remaining lines in the subroutine. But there are no lines remaining to be done. So the computer just waits for the human to close the program by clicking its X button.
>
> What if the human is too stupid to know to click the X button? Instead of clicking the X button, what if the human just keeps waiting to see whether the computer will do something? The situation is stupid: the computer waits for the human to click the X button, while the human waits for the computer to say what to do next.
>
> To end such confusion, say End below the MsgBox line. The End line makes the computer stop running the program and automatically click the X button.

Faster typing If you type just —

```
ms(
```

the computer will automatically change it to:

```
MsgBox(
```

Add an icon To make the message box fancier, say **vbExclamation**, like this:

```
MsgBox("Warning: your hair looks messy today", vbExclamation)
End
```

That makes the message box window include an **exclamation icon** (an exclamation point in a yellow triangle).

You can choose from 4 icons:

Icon	Command
! (in a yellow triangle)	vbExclamation
X (in a red circle)	vbCritical
i (in a blue circle)	vbInformation
? (in a blue circle)	vbQuestion

Math A message box can do math. For example, if you write a subroutine that says —

```
MsgBox(4 + 2)
```

and then run the program (by clicking "Start"), the computer will create a message box that displays the answer, 6.

Input box

For a wild experience, type this subroutine:

```
Dim x
x = InputBox("What is your name?")
Text = "I love " & x
```

Run the program (by clicking "Start"). Here's what happens…

The InputBox line makes the computer suddenly creates an **input box**, which is a window letting the human type info into the computer. That window appears in front of all other windows (so they're covered up) and is centered on the screen. It contains this **prompt**: "What is your name?" It also contains a white box (into which the human can type a response) and an OK button.

The computer waits for the human to type a response. When the human finishes typing a response, the human must click the OK button (or press Enter) to make the window go away.

Then Form1 reappears, and the computer makes x be whatever the human typed. For example, if the human typed —

```
Sue
```

x will be Joan. Then the Text line will make Form1 try to say:

```
I love Joan
```

To let the subroutine handle names that are long, **maximize the Form1 window**, by inserting this line —

```
WindowState = 2
```

so the subroutine becomes:

```
Dim x
x = InputBox("What is your name?")
WindowState = 2
Text = "I love " & x
```

Numeric input To input a string, you've learned to say InputBox. **To input a number, say InputBox but also say Val**, to emphasize that you want the computer to produce a numeric value.

For example, this subroutine asks for your two favorite numbers and says their sum:

```
Dim x, y
x = Val(InputBox("What is the first number?"))
y = Val(InputBox("What is the second number?"))
Text = x + y
```

When you run the program (by clicking "Start"), the computer asks "What is the first number?", waits for you to type it, and calls it x. Then the computer asks "What is the second number?", waits for you to type it, and calls it y. Then the computer says the sum of the numbers. For example, if the first number was 7 and the second number was 2, the computer will display the sum:

```
9
```

In that program, if you accidentally omit each Val, the computer will think x and y are strings instead of numbers, so the computer will add the string "7" to the string "2" and display this longer string:

```
72
```

Predict your future This subroutine makes the computer predict your future:

```
Dim y
y = Val(InputBox("In what year were you born?"))
WindowState = 2
Text = "In the year 2030, you'll turn " & 2030 - y & " years old."
```

When you run the program, the computer asks, "In what year were you born?" If you answer —

```
1962
```

y will be the numeric value 1962, and the computer will correctly print:

```
In the year 2030, you'll turn 68 years old.
```

Prices Suppose you're selling tickets to a play. Each ticket costs $2.79. (You decided $2.79 would be a nifty price, because the cast has 279 people.) These lines find the price of multiple tickets:

```
Dim t
t = Val(InputBox("How many tickets?"))
WindowState = 2
Text = "The total price is $" & t * 2.79
```

Conversion These lines convert feet to inches:

```
Dim f
f = Val(InputBox("How many feet?"))
WindowState = 2
Text = f & " feet = " & f * 12 & " inches"
```

When you run the program, the computer asks "How many feet?" If you answer —

```
3
```

the computer will say:

```
3 feet = 36 inches
```

Trying to convert to the metric system? These lines convert inches to centimeters:

```
Dim i
i = Val(InputBox("How many inches?"))
WindowState = 2
Text = i & " inches = " & i * 2.54 & " centimeters"
```

Nice day today, isn't it? These lines convert the temperature from Celsius to Fahrenheit:

```
Dim c
c = Val(InputBox("How many degrees Celsius?"))
WindowState = 2
Text = c & " degrees Celsius = " & c * 1.8 + 32 & " degrees Fahrenheit"
```

When you run the program, the computer asks "How many degrees Celsius?" If you answer —

```
20
```

the computer will say:

```
20 degrees Celsius = 68 degrees Fahrenheit
```

See, you can write the *Guide* yourself! Just hunt through any old math or science book, find any old formula (such as f = c * 1.8 + 32), and turn it into a program.

Control commands

A subroutine is a list of commands you want the computer to obey. Here's how to control which commands the computer obeys, and when, and in what order.

If

This subroutine makes the computer discuss the human's age:

```
Dim age
age = Val(InputBox("How old are you?"))
MsgBox("I hope you enjoy being " & age)
End
```

When that program is run (by clicking "Start"), the computer asks "How old are you?" and waits for the human's reply. For example, if the human says —

```
15
```

the age will be 15. Then the computer will say:

```
I hope you enjoy being 15
```

After the human reads that message in the message box, the human should get out of the message box (by clicking the message box's "OK" or pressing the Enter key). Then the computer will automatically close Form1.

Let's make that subroutine fancier, so if the human is under 18 the computer will also say "You are still a minor". To do that, just add a line saying —

```
If age < 18 Then MsgBox("You are still a minor")
```

so the subroutine looks like this:

```
Dim age
age = Val(InputBox("How old are you?"))
MsgBox("I hope you enjoy being " & age)
If age < 18 Then MsgBox("You are still a minor")
End
```

For example, if the human runs the program and says —

```
15
```

the computer will say —

```
I hope you enjoy being 15
```

and then say:

```
You are still a minor
```

(At the end of each sentence, the computer waits for the human to click the message box's OK.)

If instead the human says —

```
25
```

the computer will say just:

```
I hope you enjoy being 25
```

In that program, the most important line is:

```
If age < 18 Then MsgBox("You are still a minor")
```

That line contains the words If and Then. **Whenever you say "If", you must also say "Then".** Don't put a comma before "Then". What comes between "If" and "Then" is called the **condition**; in that example, the condition is "age < 18". If the condition is true (if the age is really less than 18), the computer does the **action**, which comes after the word "Then" and is:

```
MsgBox("You are still a minor")
```

Else Let's teach the computer how to respond to adults.

Here's how to program the computer so that if the age is less than 18, the computer will say "You are still a minor", but if the age is *not* less than 18 the computer will say "You are an adult" instead:

```
Dim age
age = Val(InputBox("How old are you?"))
MsgBox("I hope you enjoy being " & age)
If age < 18 Then MsgBox("You are still a minor") Else MsgBox("You are an adult")
End
```

In programs, **the word "Else" means "otherwise"**. That program's If line means: if the age is less than 18, then print "You are still a minor"; otherwise (if the age is *not* less than 18), print "You are an adult". So the computer will print "You are still a minor" or else print "You are an adult", depending on whether the age is less than 18.

Try running that program! If you say you're 50 years old, the computer will reply by saying —

```
I hope you enjoy being 50
```

and then (after you click "OK"):

```
You are an adult
```

Multi-line If If the age is less than 18, here's how to make the computer say "You are still a minor" and also say "Ah, the joys of youth":

```
If age < 18 Then MsgBox("You are still a minor") : MsgBox("Ah, the joys of youth")
```

Here's a more sophisticated way to say the same thing:

```
If age < 18 Then
    MsgBox("You are still a minor")
    MsgBox("Ah, the joys of youth")
End If
```

That sophisticated way (in which you type 4 short lines instead of a single long line) is called a **multi-line If** (or a **block If**).

In a multi-line If:

The top line says If and Then (with nothing after Then). The computer will type the word "Then" for you, if you forget to type it yourself.

The computer indents the middle lines for you. They're called the **block** and typically say MsgBox.

The bottom line says End If. The computer automatically types it for you.

In the middle of a multi-line If, you can say Else:

```
If age < 18 Then
    MsgBox("You are still a minor")
    MsgBox("Ah, the joys of youth")
Else
    MsgBox("You are an adult")
    MsgBox("We can have adult fun")
End If
```

That means: if the age is less than 18, then say "You are still a minor" and "Ah, the joys of youth"; otherwise (if age *not* under 18) say "You are an adult" and "We can have adult fun". The computer automatically unindents the word "Else".

ElseIf Let's make the computer do this:

If age is under 18, say "You're a minor".
If age is *not* under 18 but is under 100, say "You're a typical adult".
If age is *not* under 100 but is under 125, say "You're a centenarian".
If age is *not* under 125, say "You're a liar".

Here's how:

```
If age < 18 Then
    MsgBox("You're a minor")
ElseIf age < 100 Then
    MsgBox("You're a typical adult")
ElseIf age < 125 Then
    MsgBox("You're a centenarian")
Else
    MsgBox("You're a liar")
End If
```

Different relations You can make the If clause very fancy:

IF clause	Meaning
`If age = 18`	If age is 18
`If age < 18`	If age is less than 18
`If age > 18`	If age is greater than 18
`If age <= 18`	If age is less than or equal to 18
`If age >= 18`	If age is at least 18 (greater than or equal to 18)
`If age <> 18`	If age is not 18
`If sex = "male"`	If sex is "male"
`If sex < "male"`	If sex is a word (such as "female") that comes before "male" in the dictionary
`If sex > "male"`	If sex is a word (such as "neuter") that comes after "male" in the dictionary

In the If statement, the symbols =, <, >, <=, >=, and <> are called **relations**.

When writing a relation, mathematicians and computerists habitually **put the equal sign last**:

Right	Wrong
<=	=<
>=	=>

When you press the Enter key at the end of the line, the computer will automatically put your equal signs last: the computer will turn any "=<" into "<="; it will turn any "=>" into "<=".

To say "not equal to", say "less than or greater than", like this: <>.

Or The computer understands the word Or. For example, here's how to type, "If age is either 7 or 8, say the word *wonderful*":

```
If age = 7 Or age = 8 Then MsgBox("wonderful")
```

That example is composed of two conditions: the first condition is "x = 7"; the second condition is "x = 8". Those two conditions combine, to form "x = 7 Or x = 8", which is called a **compound condition**.

If you use the word Or, put it between two conditions.

Right: `If age = 7 Or age = 8 Then MsgBox("wonderful")`
(because "age = 7" and "age = 8" are conditions)

Wrong: `If age = 7 Or 8 Then MsgBox("wonderful")`
(because "8" is not a condition)

And The computer understands the word And. Here's how to type, "If age is more than 5 and less than 10, say *you get hamburgers for lunch*":

```
If age > 5 And age < 10 Then MsgBox("you get hamburgers for lunch")
```

Here's how to type, "If score is at least 60 and less than 65, say *you almost failed*":

```
If score >= 60 And score < 65 Then MsgBox("you almost failed")
```

Here's how to type, "If n is a number from 1 to 10, say *that's good*":

```
If n >= 1 And n <= 10 Then MsgBox("that's good")
```

Immediate If Here's a shortcut. Instead of saying —

```
If age < 18 then Text = "Minor" else Text = "Adult"
```

you can say:

```
Text = IIf(age < 18, "Minor", "Adult")
```

That line means:

Text is this: if age < 18 then "Minor" else "Adult"

That line is used in this subroutine:

```
Dim age
age = InputBox("How old are you?")
Text = IIf(age < 18, "Minor", "Adult")
```

The abbreviation **IIf** means "Immediate If". It lets you do an If immediately, without have to type the words "Then" and "Else".

Yes/no message box

Let's make the computer ask, "Do you love me?" If the human says "Yes", let's make the computer say "I love you too!" If the human says "No", let's make the computer say "I don't love you either!"

This subroutine accomplishes that goal:

```
Dim response
response = InputBox("Do you love me?")
If response = "yes" Then
    MsgBox("I love you too!")
Else
    MsgBox("I don't love you either!")
End If
End
```

But that subroutine has a flaw: what if the human types neither "yes" nor "no"? Instead of typing "yes", what if the human types "YES" or "Yes" or "yeah" or "yep" or "yessiree" or just "y" or "certainly" or "I love you tremendously" or "not sure"? In those situations, since the human didn't type simply "yes", the computer will say "I don't love you either!", which is inappropriate.

The problem with that subroutine is it gives the human too many choices: it lets the human type *anything* in the input box.

To make sure the computer reacts appropriately to the human, give the human fewer choices. Restrict the human to choosing just Yes or No. Here's how: show the human a Yes button and a No button, then force the human to click one of them. This subroutine accomplishes that:

```
If MsgBox("Do you love me?", vbYesNo) = vbYes Then
    MsgBox("I love you too!")
Else
    MsgBox("I don't love you either!")
End If
End
```

The MsgBox line makes the computer create a message box saying "Do you love me?" A normal message box contains an OK button, but vbYesNo makes this be a **yes/no message box** instead (which contains Yes and No buttons instead of an OK button).

If the human clicks the Yes button, the subroutine makes the computer say "I love you too!" If the human does otherwise (by clicking the No button), the computer says "I don't love you either!"

Long programs While running a long program, the computer should occasionally ask whether the human wants to continue. To make the computer ask that, insert this line:

```
If MsgBox("Do you want to continue?", vbYesNo) = vbNo Then End
```

That line creates a yes/no message box asking "Do you want to continue?" If the human clicks the No button, the program will end (and the computer will automatically click the program's X button).

Select

Let's turn your computer into a therapist!

To do that, make the computer ask the patient "How are you?" and let the patient type whatever words the patient wishes. Just begin the subroutine like this:

```
Dim feeling
feeling = InputBox("How are you?")
```

That makes the computer ask "How are you?" and makes the patient's response be called the feeling.

Make the computer continue the conversation as follows:

If the patient said "fine", print "That's good!"
If the patient said "lousy" instead, print "Too bad!"
If the patient said anything else instead, print "I feel the same way!"

To accomplish all that, you can use a multi-line If:

```
If feeling = "fine" Then
    MsgBox("That's good!")
ElseIf feeling = "lousy" Then
    MsgBox("Too bad!")
Else
    MsgBox("I feel the same way!")
End If
```

Then end the whole program:

```
End
```

Instead of typing that multi-line If, you can type this **Select statement** instead, which is briefer and simpler:

```
Select Case feeling
    Case "fine"
        MsgBox("That's good!")
    Case "lousy"
        MsgBox("Too bad!")
    Case Else
        MsgBox("I feel the same way!")
End Select
```

Like a multi-line If, a Select statement consumes several lines. The top line of that Select statement tells the computer to analyze the feeling and Select one of the cases from the list underneath. That list is indented and says:

In the case where the feeling is "fine",
    say "That's good!"

In the case where the feeling is "lousy",
    say "Too bad!"

In the case where the feeling is anything else,
    say "I feel the same way!"

While you're typing the Select statement, the computer automatically indents the lines for you and automatically types "End Select" underneath.

Complete subroutine Here's a complete subroutine:

```
Dim feeling
feeling = InputBox("How are you?")
Select Case feeling
    Case "fine"
        MsgBox("That's good!")
    Case "lousy"
        MsgBox("Too bad!")
    Case Else
        MsgBox("I feel the same way!")
End Select
MsgBox("I hope you enjoyed your therapy. Now you owe $50.")
End
```

The InputBox line makes the computer ask the patient, "How are you?" The next several lines are the Select statement, which makes the computer analyze the patient's answer and print "That's good!" or "Too bad!" or else "I feel the same way!"

Regardless of what the patient and computer said, that subroutine's bottom MsgBox line always makes the computer end the conversation by saying:

I hope you enjoyed your therapy. Now you owe $50.

In that program, try changing the strings to make the computer say smarter remarks, become a better therapist, and charge even more money.

Fancy cases You can create fancy cases:

Statement	Meaning
`Case "fine"`	If it's "fine"
`Case "fine", "lousy"`	If it's "fine" or "lousy"
`Case 6`	If it's 6
`Case 6, 7, 18`	If it's 6 or 7 or 18
`Case Is < 18`	If it's less than 18
`Case Is > 18`	If it's greater than 18
`Case Is <= 18`	If it's less than or equal to 18
`Case Is >= 18`	If it's at least 18 (greater than or equal to 18)
`Case 6, 7, Is >=18`	If it's 6 or 7 or at least 18
`Case 10 To 100`	If it's between 10&100 (at least 10 but no more than 100)
`Case 6, 10 To 100`	If it's 6 or between 10&100

When typing a Case statement, don't bother typing the word "Is". The computer will type it for you automatically.

Exit Sub

To make the computer skip the bottom part of your subroutine, say **Exit Sub**, like this:

```
MsgBox("I love the company president")
Exit Sub
MsgBox("I love him as much as stale bread")
```

When you run that program (by clicking "Start"), the computer will say "I love the company president" but then exit from the subroutine, without saying "I love him as much as stale bread". The computer will say just:

I love the company president

Suppose you write a subroutine that displays many messages, and you want to run the program several times (so several of your friends see the messages). If one of your friends would be offended by the last few messages, send that friend an *abridged* subroutine! Here's how: put Exit Sub above program part that you want the computer to ignore.

"Exit Sub" versus "End". Instead of saying "Exit Sub", you can say "End". Here's the difference:

When the computer encounters "Exit Sub" in a subroutine, the computer stops running that subroutine but continues running the rest of the program: for example, it displays Form1, until the human clicks Form1's X button.

When the computer encounters "End" in a subroutine, the computer stops running the whole program and automatically clicks Form1's X button.

Property list

While you're creating or editing a Visual Basic program, you see **tabs** near the screen's top-left corner. Try clicking those tabs now:

If you click the **"Form1.vb [Design]" tab**, you see the Form1 window itself, so you can admire the Form1 window's size, color, and any writing in it.

If you typed a subroutine for Form1, you also see a **"Form1.vb" tab**. If you click that tab, you see the subroutine you typed.

Try this experiment….

Click the "Form1.vb [Design]" tab, so you see the Form1 window itself. **Then click (just once) in the middle of the Form1 window.**

Then the screen's bottom-right corner should show a list, whose title is:

Properties
Form1 System.Windows.Forms.Form

If you don't see that list yet, press the F4 key (or click View then then Properties Window) then try again to click in the middle of the Form1 window.

That list is called **Form1's main property list** (or **properties window**). It's divided into these 9 **categories**:

Accessibility
Appearance
Behavior
Data
Design
Focus
Layout
Misc
Window Style

Here's the full list:

Property	Value
Accessibility	
AccessibleDescription	
AccessibleName	
AccessibleRole	Default
Appearance	
BackColor	Control
BackgroundImage	(none)
BackgroundImageLayout	Tile
Cursor	Default
Font	Microsoft Sans Serif, 7.8pt
ForeColor	ControlText
FormBorderStyle	Sizable
RightToLeft	No
RightToLeftLayout	False
Text	Form1
UseWaitCursor	False
Behavior	
AllowDrop	False
AutoValidate	EnablePreventFocusChange
ContextMenuStrip	(none)
DoubleBuffered	False
Enabled	True
ImeMode	NoControl
Data	
(ApplicationSettings)	
(DataBindings)	
Tag	
Design	
(Name)	Form1
Language	(Default)
Localizable	False
Locked	False
Focus	
CausesValidation	True
Layout	
AutoScaleMode	Font
AutoScroll	False
AutoScrollMargin	0, 0
AutoScrollMinSize	0, 0
AutoSize	False
AutoSizeMode	GrowOnly
Location	0, 0
MaximumSize	0, 0
MinimumSize	0, 0
Padding	0, 0, 0, 0
Size	300, 300
StartPosition	WindowsDefaultLocation
WindowState	Normal
Misc	
AcceptButton	(none)
CancelButton	(none)
KeyPreview	False
Window Style	
ControlBox	True
HelpButton	False
Icon	(Icon)
IsMdiContainer	False
MainMenuStrip	(none)
MaximizeBox	True
MinimizeBox	True
Opacity	100%
ShowIcon	True
ShowInTaskbar	True
SizeGripStyle	Auto
TopMost	False
TransparencyKey	

(The screen shows part of the list. To see the whole list, use the list's scroll arrows.)

Text

The top of Form1's window normally says "Form1". That's called the window's **title** (or **caption** or **text**). Instead of making the title say "Form1", you can make it say "Results" or "Payroll results" or "Mary's window" or "Fun stuff" or "Hey, I'm a funny window" or anything else you wish!

To make Form1's title say "Fun stuff", you can put this line in Form1's subroutine —

```
Text = "Fun stuff"
```

but here's an easier way:

In Form1's main property list, click the word "Text" (which is in the Appearance category, after you scroll up or down to see it), then type what you want the title to be, so the property list's Text line becomes this:

Text Fun stuff

When you finish typing, press the Enter key.

Try that now! It makes the top of Form1 say "Fun stuff" immediately (or when you press Enter or click "Start" or the Form1 window or the "Form1.vb [Design]" tab).

Color

Normally, the Form1 window's middle is a big blank area that's nearly white (a color called **Control**, which is very light gray). To make it red instead, you can put this line in Form1's subroutine —

```
BackColor = Color.Red
```

but here's an easier way:

In Form1's main property list, click **BackColor** (which is in the Appearance category) then BackColor's down-arrow then a color category ("Custom" or "Web" or "System") then the color you want (such as Red, which you'll see in the Web category, after you scroll down).

Try that now! It makes Form1's background color become Red instantly.

Maximize

The Form1 window is normally medium-sized. To maximize it, you can use 3 methods.

Manual method While the program is running (because you clicked "Start"), you can manually click the Form1 window's maximize button. That maximizes the window but just temporarily: when you finish running the program (by clicking the Form1 window's X button), the computer forgets about maximization. The next time you run the program, it will *not* be maximized, unless you click the maximize button again.

Equation method Insert this equation in Form1's subroutine:

```
WindowState = 2
```

Property-list method In Form1's main property list, click WindowState (which is in the Layout category) then WindowState's down-arrow then Maximized. That makes the property list's WindowState line become:

WindowState	Maximized

When you run the program (by clicking "Start"), Form1's window will be maximized.

Refuse to maximize

Instead of maximizing the Form1 window, you can do just the opposite: you can *prevent* the user from maximizing. Here's how.…

In Form1's main property list, click **MaximizeBox** (in the Windows Style category) then press the F key (which means "False"). That makes the property list's MaximizeBox line become:

MaximizeBox	False

That make Form1's maximize button (which is also called the maximize box) be **grayed out** while the program runs; the maximize button will become gray instead of black-and-white. That grayed-out button will ignore all attempts to be clicked, so the window will refuse to maximize.

Resize

Normally, Form1 is 300 pixels wide and 300 pixels tall. Here's how to adjust that size.…

Property-list method In Form1's main property list, click **Size** (in the Layout category), then change "300, 300" to the size you wish, by editing those numbers. For example, if you want Form1 to be 500 pixels wide and 400 pixels tall, change the size to "500, 400". The first number is the form's width; the second number is the form's height.

The biggest permissible size is the size of your whole screen, plus a few pixels more. For example, if your screen is Full HD (which is 1080p and has a resolution of 1920-by-1080), the biggest permissible size for you is "1924, 1084". If you want Form1 to be half as wide and half as tall as the full screen, choose "960, 540".

For a Full HD screen, the smallest permissible size is "166, 47". That's barely enough to show Form1's fundamental buttons (close, maximize, and minimize), not much else!

If you request a size that's very big (almost as big as the screen), Form1 won't look that big until you run the program (by clicking "Start").

Drag method While the program is running (because you clicked "Start"), you can change Form1's size by dragging its bottom right corner. That changes the size just temporarily: when you finish running the program (by clicking Form1's X button), the computer forgets how you dragged Form1's corner, and Form1 reverts to its previous size.

Here's how to change Form1's size so the computer remembers the new size:

Make sure the program is *not* running. (If it's running, stop it by clicking its X button.)

Click the "Form1.vb [Design]" tab (so you see what Form1 looks like, not subroutines you typed).

At Form1's bottom right corner, you see a tiny white square (called a **handle**). Drag that handle until Form1 becomes the size you wish.

That changes Form1's size permanently (or until you change the size again). You'll see that size in the property list's Size line (in the Layout category).

Refuse to resize

In Form1's main property list, the Appearance category's **FormBorderStyle** line normally says:

FormBorderStyle	Sizable

Try this experiment: click FormBorderStyle then FormBorderStyle's down-arrow then "FixedToolWindow", so the line becomes:

FormBorderStyle	FixedToolWindow

That prevents stupid humans from changing Form1's size. When a human runs the program (by clicking "Start"), Form1's window will have no maximize button, no restore-down button, no minimize button, and no resizable edges. Form1 stays the size you specified in the property list (such as the property list's Size line), so stupid humans can't mess up your beautiful design (unless they edit your subroutine or property list).

Form position

Here's how to adjust Form1's position.…

Property-list method In Form1's main property list, click the Layout category's **StartPosition** then StartPosition's down-arrow. You see this list of choices:

Manual
Center Screen
WindowsDefaultLocation
WindowsDefaultBounds
CenterParent

Click a choice now. You'll see the effect later (when you click "Start" to run the program).

The computer assumes you want "WindowsDefaultLocation" unless you click a different choice instead.

"WindowsDefaultLocation" puts Form1 near the screen's top-left corner (leaving a 1¾-inch margin gap) and makes Form1's size be what you chose in the Size line.

"CenterScreen" puts Form1 at the screen's center and makes Form1's size be what you chose in the Size line.

"CenterParent" puts Form1 at the center of what Windows thinks is appropriate (which is typically left of the screen's center) and makes Form1's size be what you chose in the Size line.

"WindowsDefaultBounds" puts Form1 very near the screen's top-left corner (leaving just a ½-inch margin gap) and makes Form1 be big (9¼ inches wide, 6½ inches tall). The Size line is ignored.

"Manual" puts Form1 at the screen's top-left corner (leaving no gap, unless you change the Location line to something different from "0, 0") and makes Form1's size be what you chose in the Size line.

All those inch measurements are approximate and depend on your screen's size.

Drag method While the program is running, you can move Form1 by dragging its **title bar** (the blue horizontal bar that's at Form1's top and typically says "Form1"). That moves Form1 just temporarily; when you finish running the program (by clicking Form1's X button), the computer forgets how you dragged Form1, and Form1 reverts to its previous position.

Opacity

Normally, Form1 is completely opaque: while the program is running, Form1 completely blocks the view of anything behind it.

To have fun, reduce Form1's opacity: in Form1's main property list, click the Windows Style category's **Opacity**, then change "100%" to "75%". When you run the program (by clicking "Start"), Form1 will be just partly opaque; it will be partly transparent, so you can see, faintly, what's behind the form.

If you make the opacity even lower — 50% or 25% — Form1 will be hardly opaque at all — it will be very transparent — so you can easily see what's behind it, as if Form1 were just a ghost.

Don't make the opacity be 0%. That would make Form1 completely invisible, so you couldn't see it at all, couldn't click its close box, and couldn't stop the program!

Don't make the opacity be less than 25%. That would make Form1 difficult to see.

Try making the opacity be 90%.

Opacity doesn't work well if your Windows version is old (Windows XP) or stripped-down (Windows Vista Basic or Windows 7 Starter), since those Windows versions lack **Windows Aero** (which makes windows partly transparent).

Toolbox

You've learned how to create and manipulate an object called "Form1". You can create other objects also, by using the **toolbox**.

See the toolbox

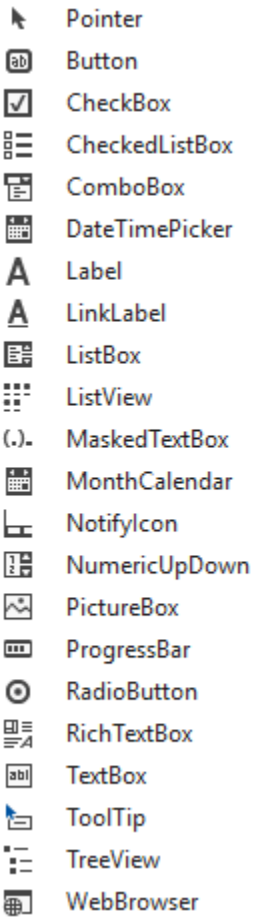
Click the "**Form1.vb [Design]**" tab then "**View**" (which is near the screen's top-left corner) then "**Toolbox**". Then you see 10 **toolbox categories**:

All Windows Forms
Common Controls
Containers
Menus & Toolbars
Data
Components
Printing
Dialogs
WPF Interoperability
General

(If you don't see that whole list yet, scroll down.)

See common controls

Click "Common Controls" once or twice, until you see this list indented under "Common Controls":



To the right of the word "Toolbox", you see an X. Left of the X you see a **pushpin**. If the pushpin is still horizontal, **make it vertical** by clicking it. That makes the toolbox stay on the screen *nicely* (perminantly and left of your other work).

Each object in the toolbox is called a **tool**.

Button

Try this experiment. Double-click the **Button** tool. That makes a button appear in Form1's middle, near Form1's top-left corner (or near a previous button). The button is a rectangle and says "Button1" on it.

(If you wish, drag that button to a different place in Form1. You can also change the button's size by dragging its 9 square handles. But for your first experiment, just leave the button where the computer put it.)

The button says "Button1" on it. Just for fun, let's make it say "Click me" instead. To do that, click Text (in the property list) and type "Click me", so the property list's Text line becomes:

```
Text                Click me
```

That makes the button's text become "Click me" (instead of "Button1").

Notice that the property list concerns the button and its text (instead of Form1's text), because the button is highlighted.

Let's write a program so if a human clicks the button (which says "Click me"), Form1 will say "Thanks for the click". To do that, double-click the button. The double-clicking tells the computer you want to write a subroutine about that object (the button).

The computer starts writing the subroutine for you. The computer writes:

```
Public Class Form1
    Private Sub Button1_Click…

    End Sub
End Class
```

Insert this line in the middle of the subroutine —

```
        Text = "Thanks for the click"
```

so the subroutine looks like this:

```
Public Class Form1
    Private Sub Button1_Click…
        Text = "Thanks for the click"
    End Sub
End Class
```

That subroutine tells the computer that when Button1 is clicked, the computer should say "Thanks for the click" on Form1.

Try it: run that program (by clicking "Start"). You'll see Form1 with a button on it that says "Click me". If you click the button, the subroutine makes Form1 say "Thanks for the click" (after you maximize Form1 so you can see all that).

In that subroutine, the computer assumes you want the text "Thanks for the click" to be on Form1, not on the button. If you want that text to be on the *button* instead, say **Button 1's Text** instead of just Text. To say **Button 1's Text**, type **Button1.Text**, so the subroutine looks like this:

```
Public Class Form1
    Private Sub Button1_Click…
        Button1.Text = "Thanks for the click"
    End Sub
End Class
```

But to fit "Thanks for the click" onto the button, you must widen the button, by doing this:

If the program is still running, finish running it (by clicking Form1's X button). Then click the "Form1.vb [Design]" tab, so you see Form1 and can modify the appearance of Form1 (and of its button). Then widen the button (by dragging the button's handles).

Two buttons Let's write a program that has *two* buttons! Let's make the first button be called "Red" and the second button be called "Blue". If the human clicks the "Red" button, let's make Form1 turn red; if the human clicks the "Blue" button, let's make Form1 turn blue.

To do all that, start a new program as follows:

If a previous program is still running, finish running it (by clicking Form1's X button). If you're not in Visual Basic, go into it.

Click "New Project" or the New Project button (which is near the screen's top-left corner, below the word "File"). Click "Windows Forms Application", type a name in the Name box, and press Enter, so you see the Form1 window.

You should also see the Toolbox. (If you don't see it yet, continue following the "See the toolbox" instructions on the previous page.)

In the Toolbox, double-click the Button tool. A command button appears in Form1 and is called Button1. In the property list, click Text then type "Click here for red" (and press Enter), so the property list's Text line becomes:

Text	Click here for red

That tries to make the button's text become "Click here for red". To fit all that text onto the button, widen the button (by dragging one of its handles).

In the Toolbox, double-click the Button tool again. That makes another command button appear in Form1 and be called Button2. Unfortunately, the Button2 button covers up the Button1 button, so you can't see the Button1 button. Drag the Button2 button out of the way (toward the right), so you can see both buttons side-by-side.

The Button2 button should be highlighted. (If it's not highlighted, click it to make it highlighted.) In its property list, change its Text from "Button2" to "Click here for blue" (by clicking Text then typing "Click here for blue" and pressing Enter). Widen the Button2 button (by dragging one of its handles) so it shows all of "Click here for blue".

Now your screen shows Form1 with two buttons on it. The first button says "Click here for red". The second button says "Click here for blue".

Double-click the "Click here for red" button, and write this subroutine for it:

```
    Private Sub Button1_Click…
        BackColor = Color.Red
    End Sub
```

That subroutine says: clicking that button will make Form1's background color be red.

Move that subroutine out of the way (by clicking the "Form1.vb [Design]" tab), so you can see Form1.

Double-click the "Click here for blue" button, and write this subroutine for it:

```
    Private Sub Button 2_Click…
        BackColor = Color.Blue
    End Sub
```

While you're writing that subroutine, you'll see the other subroutine above it. Altogether, you see:

```
Public Class Form1
    Private Sub Button1_Click…
        BackColor = Color.Red
    End Sub

    Private Sub Button 2_Click…
        BackColor = Color.Blue
    End Sub
End Class
```

Then run the program by clicking "Start". Here's what happens.…

You see Form1 with two buttons on it. The first button says "Click here for red"; if you click it, Form1 turns red. The other button says "Click here for blue"; if you click it, Form1 turns blue.

Try clicking one button, then the other. Click as often as you like. When you get tired of clicking, end the program (by clicking Form1's X button).

Where to put buttons A good habit is to put buttons side-by-side, in Form1's bottom right corner. That way, the buttons won't interfere with any other objects on Form1.

Exit button To stop running a typical program, you have to click its X button. Some humans don't know to do that. To help them, create a button called "Exit", so that clicking it will make the computer exit from the program.

To do that, create an ordinary button; but make the button's text say "Exit" (or anything else you prefer, such as "Quit" or "End" or "Abort" or "Close" or "Click here to end the program"), and make the button's subroutine say End, like this:

```
    Private Sub Button3_Click…
        End
    End Sub
```

Put that Exit button in Form1's bottom-right corner.

Check box

A **check box** is a small gray square, with text to the right of the square. At first, the gray square has nothing inside it: it's empty. While the program runs, clicking the square makes a green check mark (✔) appear in the square. If you click the square again, the check mark disappears.

To create a check box, double-click the **CheckBox** tool. That makes a check box appears in Form1. Drag the check box wherever you wish.

The first check box's text is temporarily "CheckBox1"; to change that text, click Text (in the property list) and type whatever text you wish. At the end of your typing, press Enter. Suggestion: if you want to type a *lot* of text, do this instead:

> Click Text's down-arrow. You'll see a *big* box to type in. Press Enter at the end of each line you type. When you've finished typing all text you want, do this: while holding down the Ctrl key, tap the Enter key.

If you want the computer to react immediately to whether the check box is checked, give the check box this subroutine:

```
    Private Sub CheckBox1_CheckedChanged…
        If CheckBox1.Checked Then
            type here what to do if CheckBox1 just became checked
        Else
            type here what to do if CheckBox1 just became unchecked
        End If
    End Sub
```

Dressed example For example, this subroutine makes the computer say "I am dressed" if the check box just became checked but say "I am naked" if the check box just became empty:

```
    Private Sub CheckBox1_CheckedChanged…
        If CheckBox1.Checked Then
            Text = "I am dressed"
        Else
            Text = "I am naked"
        End If
    End Sub
```

When that program runs, the check box starts by being empty. Clicking the check box makes you see ✔ and makes the computer say "I am dressed". The next time you click the check box, the ✔ disappears from the box, so the box becomes empty and the computer say "I am naked". Clicking the check box again makes the ✔ reappear and makes the computer say "I am dressed".

Here's how to type that subroutine fast:

> Type the word "if", then a space, then the letters "che". You see a list of computer words that begin with the letter "Che". In that list, double-click "CheckBox1". That makes the computer type "CheckBox1" for you.
>
> Type a period. You see a list of computer words; from that list, choose "Checked" by double-clicking it (or if "Checked" was highlighted already, you can choose it by pressing the Tab key).

Multiple check boxes Form1 can contain many check boxes. The human can check several at the same time, so that several of the boxes contain check marks simultaneously.

Although you can put buttons and check boxes wherever you wish, it's customary to arrange buttons horizontally (so the second button is to the right of the first) but arrange check boxes vertically (so the second check box is below the first). The check boxes (and their texts) form a vertical list of choices.

OK button If Form1 contains several check boxes, you should typically delay the computer's reaction until the human has decided which boxes to check, has checked all the ones desired, and has clicked an OK button to confirm that the correct boxes are checked.

To do that, make the check boxes have no subroutines. Instead, create an OK button in Form1's bottom-right corner (by creating a button there and making its text be "OK"), then make the OK button's subroutine look like this:

```
    Private Sub Button1_Click…
        If CheckBox1.Checked Then
            type here what to do if CheckBox1 is checked
        Else
            type here what to do if CheckBox1 is unchecked
        End If
        If CheckBox2.Checked Then
            type here what to do if CheckBox2 is checked
        Else
            type here what to do if CheckBox2 is unchecked
        End If
End Sub
```

That subroutine says: when the OK button is clicked, notice which check boxes are checked and react appropriately.

For example, let's make a program that alters Form1's appearance, to make it red or maximized or red maximized or return to normal. Here's how to do all that:

Create a check box (called CheckBox1) with title "Red".

Create a check box (called CheckBox2) with title "maximized".

Create a command button (called Button1) with title "OK" and this subroutine:

```
    Private Sub Button1_Click…
        If CheckBox1.Checked Then
            BackColor = Color.Red
        Else
            BackColor = Color.WhiteSmoke
        End If
        If CheckBox2.Checked Then
            WindowState = 2
        Else
            WindowState = 0
        End If
End Sub
```

Radio button

A **radio button** resembles a check box but looks and acts like the button on an old-fashioned radio, because of these differences:

To create a check box, double-click the **CheckBox** tool.
To create a radio button, double-click the **RadioButton** tool.

A check box is a tiny gray **square**.
A radio button is a tiny gray **circle**.

While the program is running,
clicking a checkbox makes a **green checkmark** appear in the square.
Clicking a radio button makes a **blue dot** appear in the circle.

Green checkmarks can appear in many checkboxes, simultaneously.
You see just one blue dot. When you click a radio button, the blue dot hops to that radio button and leaves the previous button.

Like checkboxes, radio buttons are arranged vertically (so the second radio button is below the first). The radio buttons (and their titles) form a vertical list of choices.

When the human starts running your program, the first radio button (which is RadioButton1) has a blue dot inside the gray circle, and the computer automatically does RadioButton1's subroutine (even if the human hasn't clicked RadioButton1's button yet).

Afterwards, if the human clicks a different radio button, here's what happens:

The blue dot hops to that radio button. The computer does that button's subroutine; but before doing so, the computer does the previous button's subroutine one more time so it can display a message such as "Sorry to hear you don't like this choice anymore".

If you want the computer to react immediately to whether the radio button has the blue dot, give the radio button this subroutine:

```
    Private Sub RadioButton1_CheckedChanged…
        If RadioButton1.Checked Then
            type here what to do if RadioButton1 just got the blue dot
        Else
            type here what to do if RadioButton1 just lost the blue dot
        End If
    End Sub
```

3-color example For example, let's write a program that has 3 radio buttons, labeled "Red", "Blue", and "Green". While the program is running, if the human switches from "Red" to "Blue" (by clicking "Blue" after having clicked "Red"), let's make the program say "Sorry you don't like red anymore" and make Form1 become blue. Let's make the program act similarly for switching between other pairs of colors.

To do that, maximize Form 1 (by making its WindowState property be Maximized) and create the 3 radio buttons (labeled "Red", "Blue", and "Green"). Then give the "Red" button (which is RadioButton1) this subroutine:

```
    Private Sub RadioButton1_CheckedChanged…
        If RadioButton1.Checked Then
            BackColor = Color.Red
        Else
            Text = "Sorry you don't like red anymore"
        End If
    End Sub
```

That subroutine runs just when the human changes the Red radio button's appearance (by clicking it or unclicking it):

When that radio button's appearance changes to "checked" (contains a blue dot), that subroutine makes Form1 be red.

When that radio button's appearance changes to "unchecked" (no blue dot), that subroutine makes Form1 say "Sorry you don't like red anymore".

Here's how to type that subroutine fast:

Type the word "if", then a space, then the letter "r". You see a list of computer words that begin with the letter R. In that list, double-click "RadioButton1". That makes the computer type "RadioButton1" for you.

Type a period. You see a list of computer words; from that list, choose "Checked" by double-clicking it (or if "Checked" was highlighted already, you can choose it by pressing the Tab key).

To type the rest of the subroutine fast, keep choosing from lists.

To finish the program, type this subroutine for the "Blue" button (which is RadioButton2) —

```
    Private Sub RadioButton2_CheckedChanged…
        If RadioButton2.Checked Then
            BackColor = Color.Blue
        Else
            Text = "Sorry you don't like blue anymore"
        End If
    End Sub
```

and this subroutine for the "Green" button (which is RadioButton3):

```
    Private Sub RadioButton3_CheckedChanged…
        If RadioButton3.Checked Then
            Text = "Welcome to New York"
        Else
            MsgBox("You've left New York")
        End If
    End Sub
```

3-city example For a similar example, let's write an airplane program that has 3 radio buttons, labeled "Los Angeles", "Dallas", and "New York". While the program is running, if the human switches from "Los Angeles" to "Dallas" (by clicking "Dallas" after having clicked "Los Angeles"), let's make the program say "You've left Los Angeles" and "Welcome to Dallas". Let's make the program act similarly for traveling between the other cities.

To do that, create the 3 radio buttons (labeled "Los Angeles", "Dallas", and "New York"). Then give the "Los Angeles" button (which is RadioButton1) this subroutine:

```
Private Sub RadioButton1_CheckedChanged…
    If RadioButton1.Checked Then
        Text = "Welcome to Los Angeles"
    Else
        MsgBox("You've left Los Angeles")
    End If
End Sub
```

That subroutine runs just when the human changes the Los Angeles radio button's appearance (by clicking it or unclicking it):

When that radio button's appearance changes to "checked" (contains a blue dot), that subroutine makes the computer say "Welcome to Los Angeles".

When that radio button's appearance changes to "unchecked" (no blue dot), that subroutine makes the computer say "You've left Los Angeles".

To finish the program, type this subroutine for the "Dallas" button (which is RadioButton2) —

```
Private Sub RadioButton2_CheckedChanged…
    If RadioButton2.Checked Then
        Text = "Welcome to Dallas"
    Else
        MsgBox("You've left Dallas")
    End If
End Sub
```

and this subroutine for the "New York" button (which is RadioButton3):

```
Private Sub RadioButton3_CheckedChanged…
    If RadioButton3.Checked Then
        Text = "Welcome to New York"
    Else
        MsgBox("You've left New York")
    End If
End Sub
```

OK button When the human clicks a radio button, the computer can react to the click immediately, but that might startle and upset the human. If you want to be gentler, delay the computer's reaction until the human also clicks a general OK button, which confirms the human's desires.

To do that, make the radio buttons have no subroutines, so nothing will happen when those buttons are clicked. In Form1's bottom-right corner, create an ordinary button whose text says "OK" and whose subroutine looks like this:

```
Private Sub Button1_Click…
    If RadioButton1.Checked Then
        type here what to do if RadioButton1 just got the blue dot
    ElseIf RadioButton2.Checked Then
        type here what to do if RadioButton2 just got the blue dot
    ElseIf RadioButton3.Checked Then
        type here what to do if RadioButton3 just got the blue dot
    ElseIf RadioButton4.Checked Then
        type here what to do if RadioButton4 just got the blue dot
    Else
        type here what to do if bottom radio button got blue dot
    End If
End Sub
```

That subroutine says: when the OK button is clicked, notice which radio button was clicked and react appropriately.

Label

Form1 has two main parts. One part is a blue bar across Form1's top: it includes Form1's minimize button, maximize button, close button, and text. The other part (Form1's middle) is a big light-gray box: it includes objects you created, such as ordinary buttons, check boxes, and radio buttons.

In Form1's middle, let's type this text:

```
I love you
```

To do that, double-click the **Label** tool. That makes the word "Label1" appear in Form1's middle. Drag "Label1" to the spot in Form1 where you wish to begin typing. To change "Label1" to "I love you", click Text (in Label1's property list) then type "I love you", so the property list says:

```
Text                    I love you
```

At the end of that typing, press Enter. Then "Label1" becomes "I love you", so "I love you" is in Form1's middle.

Multi-line text Instead of making Form1's middle say just "I love you", let's make it say:

```
I love you
You turned me on
Let's get married
```

Here's how:

After you've created a label (by double-clicking the Label tool) and clicked Text, click Text's down-arrow. You'll see a big box to type in. Press Enter at the end of each line you type. When you've finished typing all text you want, do this: while holding down the Ctrl key, tap the Enter key.

Text equation Here's a different way to make Form1's middle say "I love you".

Create a label (by double-clicking the Label tool). Tell the computer you want to write a subroutine for Form1 (by double-clicking in Form1 but *not* in the label). Put this line in Form1's subroutine:

```
Label1.Text = "I love you"
```

That means: the label's text is "I love you." That line makes Form1's subroutine become this:

```
Private Sub Form1_Load…
    Label1.Text = "I love you"
End Sub
```

When you run the program (by clicking "Start"), the computer will run that subroutine and make Form1's middle say:

```
I love you
```

If instead you want the Form1's middle to say —

```
I love you
You turned me on
```

change the Text line to this:

```
Label1.Text = "I love you" & Chr(13) & "You turned me on"
```

That makes the computer type "I love you" then press key #13 (which is the Enter key) then type "You turned me on". Instead of that long Text line, you can give this pair of shorter Text lines:

```
Label1.Text = "I love you"
Label1.Text &= Chr(13) & "You turned me on"
```

In that pair of lines, the first line makes the Text be "I love you"; the next line changes the Text to become all that, combined with Chr(13) and "You turned me on".

Math Let's make Form1's middle say the answer to 4 + 2.

To do that, create a label (by double-clicking the Label tool). Tell the computer you want to write a subroutine for Form1 (by double-clicking in Form1 but *not* in the label). Put this line in Form1's subroutine:

```
Label1.Text = 4 + 2
```

That line means: Label1's text is the answer to 4 + 2. That line makes Form1's subroutine become this:

```
Private Sub Form1_Load…
    Label1.Text = 4 + 2
End Sub
```

When you run the program (by clicking "Start"), the computer will run that subroutine and write the answer (6) in Form1's middle.

To make Form1's middle say the answer to 4 + 2 and, on the next line, say the answer to 48 + 3, you can put this line in Form1's subroutine —

```
Label1.Text = 4 + 2 & Chr(13) & 48 + 3
```

or give this pair of lines instead:

```
Label1.Text = 4 + 2
Label1.Text &= Chr(13) & 48 + 3
```

In that pair of lines, the first line makes the Text be the answer to 4 + 2; the next line changes the Text to become all that, combined with Chr(13) and the answer to 48 + 3.

List box

A **list box** is a big white box that contains a list of choices, such as these color choices —

```
Red
Blue
Green
```

or these country choices —

```
United States
Canada
Mexico
```

The list can be short (2 or 3 choices) or tall (hundreds of choices). If the list is too tall fit in the box, the computer will automatically add scroll arrows so humans can scroll through the list.

To create a list box, double-click the **ListBox** tool. A list box (big white box) appears in the middle of Form1. Drag the list box wherever you wish.

The first list box is called ListBox1. Inside that list box, you temporarily see the word "ListBox1", but you should put your own list of choices there instead, by using this method —

In the list box's property list, click "Items" then "…" Type the list of choices, such as:
United States
Canada
Mexico
To do that, press Enter at the end of each line. When you've finished typing the whole list, click "OK".

or this alternate method:

Click the list box's right-arrow (which is near the box's top-right corner) then "Edit Items". Type the list of choices, such as:
United States
Canada
Mexico
To do that, press Enter at the end of each line. When you've finished typing the whole list, click "OK" then click in the list box.

Then on Form1, you see the list box containing your choices.

By dragging the box's handles, try to make the box just tall enough to hold *all* the choices. (If it isn't tall enough, the computer automatically adds scroll arrows so humans can scroll through the list while the program runs.)

By dragging the box's handles, make the box just wide enough to hold the widest choice.

Select one You can give List1 this kind of subroutine:

```
Private Sub ListBox1_SelectedIndexChanged…
    Select Case ListBox1.SelectedItem
        Case "United States"
            type here what to do if "United States" is clicked
        Case "Canada"
            type here what to do if "Canada" is clicked
        Case "Mexico"
            type here what to do if "Mexico" is clicked
    End Select
End Sub
```

Here's a shorter way to type the subroutine:

```
Private Sub ListBox1_SelectedIndexChanged…
    Select Case ListBox1.SelectedIndex
        Case 0
            type here what to do if the list's top item ("United States") is clicked
        Case 1
            type here what to do if the list's next item ("Canada") is clicked
        Case 2
            type here what to do if the list's next item ("Mexico") is clicked
    End Select
End Sub
```

If you want the action to be delayed until the human clicks an OK button, do this:

Create the OK button (a command button whose caption is "OK").

Give ListBox1 no subroutine, but give the OK button this kind of subroutine —

```
Private Sub Button1_Click…
    Select Case ListBox1.SelectedItem
        Case "United States"
            type here what to do if "United States" is clicked
        Case "Canada"
            type here what to do if "Canada" is clicked
        Case "Mexico"
            type here what to do if "Mexico" is clicked
    End Select
End Sub
```

or this subroutine:

```
Private Sub Button1_Click…
    Select Case ListBox1.SelectedIndex
        Case 0
            type here what to do if the list's top item ("United States") is clicked
        Case 1
            type here what to do if the list's next item ("Canada") is clicked
        Case 2
            type here what to do if the list's next item ("Mexico") is clicked
    End Select
End Sub
```

Select multi If you want to let the human select *several* items from the list (instead of just one item), do this:

In ListBox1's property list, click **SelectionMode** then SelectionMode's down-arrow.

Click either "MultiSimple" or "MultiExtended". (If you choose "MultiSimple", the human can select several items by clicking them, and deselect an item by clicking that item again. If you choose "MulitExtended", the human can select one item by clicking it, select or deselect extra items by holding down the Ctrl key while clicking them, and select a contiguous bunch of items easily by clicking the bunch's first item and Shift-clicking the last.)

Create an OK button (an ordinary button whose caption is "OK").
Give ListBox1 no subroutine, but give the OK button this kind of subroutine:

```
If ListBox1.GetSelected(0) Then type here what to do if the list's top item ("United States") clicked
If ListBox1.GetSelected(1) Then type here what to do if the list's next item ("Canada") clicked
If ListBox1.GetSelected(2) Then type here what to do if the list's next item ("Mexico") clicked
```

Label Next to your list box, you should put some text, explaining the list box's purpose to the human. To put the text there, create a label with that text (by double-clicking the Label tool), and drag the label until it's next to your list box.

Text box

You already learned that Form1's subroutine can contain this line:

```
x = InputBox("What is your name?")
```

When you run the program, that line makes the computer create an **input box**. The input box is a pop-up window containing a message ("What is your name?"), a wide white box (in which the human types a response), and an OK button (which the human clicks when finished typing).

That technique works adequately but gives you no control over the size or position of its objects (the window, message, white response box, and OK button).

To be more professional, get control by creating a **text box** instead. Here's how.

Double-click the **TextBox** tool. That creates a text box (a white box in which the human can type a response). Drag it wherever you wish. Adjust its size by dragging its handles.

Above the box (or left of it), put a label (by double-clicking the Label tool). Make the label contain a message (such as "What is your name?").

Below the box (or right of the box), create an OK button (a button whose text says "OK"). Make the OK button's subroutine include these lines —

```
Dim x
x = TextBox1.Text
```

and anything else you want the computer to do, such as:

```
MsgBox("I love " & x)
```

Form1 can contain *several* text boxes. For example, you can include:

a text box for the human's first name
a text box for the human's last name
a text box for the human's address
text boxes for the human's city, state, and ZIP code

That makes Form1 be truly a form to fill in! Create just one OK button to handle all those text boxes, so the human clicks the OK button after filling in the entire form.

Password character If you want the human to type a password into a text box, do this: in the text box's property list, click **PasswordChar** then type an asterisk (the symbol *). That makes the box show asterisks instead of the characters the human is typing. That prevents enemies from discovering the password by peeking over the human's shoulder.

MultiLine The typical text box holds just one line of text. To let your text box handle *several* lines of text well, make 3 adjustments:

In the text box's property list, click MultiLine then press the T key (which stands for True). That lets the text box handle *several* lines of text, lets the human press the Enter key at the end of each line, and lets the computer press the Enter key automatically if there are too many words to fit on a line.

Make the text box taller and wider (by dragging its handles), so it can show more lines of text and more words per line. That reduces the human's frustration.

In the text box's property list, click ScrollBars then press the V key (which stands for Vertical). That creates a vertical scroll bar, which helps the human move through the text, in case you didn't make the text box tall enough to handle all the words.

Rich-text box

Instead of double-clicking the TextBox tool, try double-clicking the **RichTextBox** tool. It creates a text box that's already tall, MultiLine (so the human can type many lines of text in the box), with a vertical scroll bar (which appears when the human types more lines than can fit in the box) and the ability to handle **formatted text** (which is called **rich text**). That box is called **RichTextBox1**.

For best results, make the box even taller and wider (by dragging its bottom-right corner).

In that box, the human can type a number, or a word, or a sentence, or a paragraph, or *several* paragraphs (by pressing the Enter key at the end of each paragraph), or a whole essay! What the human types in that box is called a **document**.

For example, if you want to invent your own word-processing program, the first step is to create a rich-text box for the human to type the words into.

Improve the rich-text box Here are 2 popular ways to improve how a rich-text box works:

In RichTextBox1's property list (at the screen's bottom-right corner), click "**EnableAutoDragDrop**" then press the T key. That makes EnableAutoDragDrop be True. Then whenever the human is typing the document, the human can highlight a phrase and drag it to a different spot in the document.

Click RichTextBox1's right-arrow (which is near the box's top-right corner) then "**Dock in parent container**". That makes RichTextBox1 expand and consume all of Form1. Then while the program is running, if the human changes Form1's size (by maximizing Form1 or by dragging Form1's bottom-right corner), RichTextBox1 will change size automatically, to still fill Form1.

Number box

To make the computer wait for the human's response, you learned you can create a text box (by double-clicking the TextBox tool) and an OK button whose subroutine includes these lines:

```
Dim x
x = TextBox1.Text
```

If you want to force the human to type a number instead of words, create a **number box** instead of a text box. Here are the details.…

Double-click the **NumericUpDown** tool. That creates a number box (a white box in which the human can type a number). Drag it wherever you wish. Adjust its width by dragging its handles.

Above the box (or left of it), put a label (by double-clicking the Label tool). Make the label contain a message (such as "How many children do you have?").

Below the box (or right of the box), create an OK button (a button whose text says "OK"). Make the OK button's subroutine include these lines —

```
Dim x
x = NumericUpDown1.Value
```

and anything else you want the computer to do, such as:

```
MsgBox("I'm glad you have " & x)
```

When the human runs the program, the human sees the number box. That box temporarily has 0 in it, but the human can change that number by retyping it or by clicking the box's up-arrow (which increases the number) or down-arrow (which decreases the number). When the human has changed the number to what the human wishes, the human clicks the OK button, whose subroutine makes x become the human's number.

Alter the box's properties Normally, the number box refuses to let the human say any number over 100. If you want it to permit numbers up to 500, make its property list's **Maximum** line say 500. If you want it to permit just numbers up to 20, make its Maximum line say just 20. If you want to encourage the human to type a number that's small, make the box be narrow (by adjusting its handles).

Normally, the number box refuses to let the human say any number below 0. If you want it to permit numbers down to minus 500, make the property list's **Minimum** line say -500. If you want it to require the number to be at least 3, make its Minimum line say 3.

Normally, the number box refuses to accept decimals. If you want it to permit 2 digits after the decimal point (so the human can type dollars-and-cents), make the property list's **DecimalPlaces** line say 2.

The number box normally begins displaying the number 0. If you want it to begin by displaying the number 5 instead, make the property list's **Value** line say 5.

By adjusting those properties (Maximum, Minimum, DecimalPlaces, Value, and the box's width), you can encourage the human to be reasonable.

Combo box

A **combo box** is a fancy text box that includes a list of suggested responses.

To create a combo box, double-click the **ComboBox** tool. That creates a combo box. Like a text box, it's a white box in which the human can type a response; but the combo box's right edge shows a down-arrow, which the human can click to see a list of suggested responses.

Drag the combo box wherever you wish.

Click the box's right-arrow (which is near the box's top-right corner) then "Edit Items". Type your list of suggested responses, such as:

```
United States
Canada
Mexico
```

(Press Enter at the end of each line.) When you've finished typing the whole list, click "OK" then click in the combo box.

Above (or left of) the box, put a label (by double-clicking the Label tool). Make the label contain a prompt (an instruction to the human about what to put into the box).

Below (or right of) the box, create an OK button (a command button whose caption is "OK"). Make the OK button's subroutine include these lines —

```
        Dim x
        x = ComboBox1.Text
```

and anything else you want the computer to do, such as:

```
        MsgBox("I'm glad you said " & x)
```

Drop-down style In combo box's property list, click **DropDownStyle** then DropDownStyle's down-arrow. You see 3 styles:

```
Simple
DropDown
DropDown List
```

Click whichever style you wish. If you don't choose otherwise, the computer assumes you want "DropDown". That works as I described: the human can type anything into the box, and the suggestion list appears just if the human clicks the box's down-arrow.

If you choose "Simple" instead, the human can still type anything into the box, and the suggestion list *always* appears (without requiring a down-arrow click) if you make the combo box tall enough to hold the list.

If you choose "DropDown List" instead, the human can*not* type into the box; the human is required to choose from the suggestion list, which appears when the human clicks the box.

Picture box

Here's how to make Form1 show a picture.

First, **enlarge Form1** (by dragging its bottom-right corner), to let it hold a big picture better.

Then double-click the **PictureBox** tool. That puts a box in Form1's middle, near Form1's top-left corner.

Enlarge that box (by dragging its bottom-right corner), to let it hold a big picture better. If you want the box to be smaller than Form1 (so Form1 can hold other objects also), drag the box where you wish (by pointing at the box's middle, the dragging).

Click the box's right-arrow (which is near the box's top-right corner) **then "Choose Image" then the bottom "Import" button then "Pictures"** (which is on the left). That shows what's in your hard disk's Pictures folder.

Double-click the picture you want (after clicking or double-clicking any folders it's buried in). For example, you can try double-clicking the "Sample Pictures" icon (which Windows has put in your Pictures folder) then "Penguins" (Windows 7's photo of a penguin trio) or "Annie in the Sink" (Windows Vista's photo of Annie the cat, sitting in a sink).

You see a bigger view of the picture (or its top-left corner). **Click "OK".**

Click the Size Mode box's down-arrow. You see this menu:

```
Normal
StretchImage
AutoSize
CenterImage
Zoom
```

If the picture is bigger than the box, here's what those choices mean.

Zoom is the safest choice: it shrinks the picture nicely, so it fits in the box's center.

StretchImage fills the whole box by shrinking (or stretching) the picture, which gets distorted.

CenterImage puts just the picture's center into the box.

Normal puts just the picture's top-left corner into the box.

AutoSize stretches the box, to hold as much of the picture as possible.

The computer assumes you want "Normal". If you prefer a different choice (such as "Zoom"), click it.

Should you dock? If you click "Dock in parent container", the box will expand to fill Form1. (If you regret that expansion, undo it by clicking "Undock in parent container".)

Add a form

Besides Form1, you can create extra forms, called Form2, Form3, Form4, etc. To create an extra form, click the **Add New Item** button (which is near the screen's top, under the words "Edit" and "View") then double-click the Windows Form icon.

For example, let's make a button (on Form1) so that when you click that button, Form2 suddenly appears and says "I love you". Here's how.…

Start a new program (so you have a blank Form1).

Create Form2, by doing this:

Click the Add New Item button (which is near the screen's top, under the word "Edit"). Double click the Windows Form icon.

You see Form2. (It covers Form1). Make it say "I love you" (by typing "I love you" in the property list's Text box and pressing Enter).

Make Form1 reappear (by clicking the "Form1.vb [Design]" tab). On Form1, create a button (by double-clicking the Button tool). Make it say "Click me" (by typing "Click me" in the property list's Text box and pressing Enter). Double-click that button and type this subroutine line:

```
Form2.Visible = True
```

That means: when the button is clicked, make Form2 suddenly become visible.

When you run the program (by clicking "Start"), you see Form1, which contains a button saying "Click me". If you click that button, the computer displays Form2, which covers Form1 and says "I love you".

To stop running the program, close the Form2 window (by clicking its X button) then close the Form1 window (by clicking its X button).

Web browser

Here's how to make a form's middle show a Web page.

Create a blank form. (For a quick, fun experiment, you can use Form1, though in a practical program you'd use another form instead, such as Form2.) Make that blank form be maximized (by making its property list's WindowState line say "Maximized") or at least rather big (by making its property list's Size line have rather big numbers).

Double-click the **WebBrowser** tool. That makes the form's entire middle be devoted to the Web and be called WebBrowser1. In WebBrowser1's property list, click "**Url**" then type the Web address you want the form to show (such as "www.yahoo.com").

When you run the program (by clicking "Start"), the form's middle will show that Web page (or as much of it as will fit in the form's middle, accompanies by scroll arrows).

Timer

To make the computer pause, use the **Timer** tool. Here are examples.

I love you!!!!!!!!!! Here's how to make the computer say "I love you", then pause, then add an exclamation point (so you see "I love you!"), then pause, then add another exclamation point (so you see "I love you!!"), then keep repeating that process, so you eventually see "I love you!!!!!!!!!!" and beyond!

Make Form1's Text begin as "I love you" by doing this:

Click in Form1, so the screen's bottom right corner shows Form1's main property list. In that list, click "Text" then type "I love you", so the property list's Text line becomes this:

Text	I love you

When you finish typing, press the Enter key. That makes Form1's title (top) say "I love you".

The next step is to say "add an exclamation point after pausing". To deal with pausing, you must use the Timer tool. Here's how.…

Look at the toolbox (which is at the screen's left side and shows the tools). Using the toolbox's scroll-down arrow, scroll down until you see a heading called "Components".

Left of that heading, you see a triangle. That triangle should be solid black. (If the triangle has a white middle instead, click the triangle to make it solid black.)

Under the heading "Components", you should see the **Timer** tool. Double-click it. That puts a Timer1 icon below Form1.

At the screen's bottom-right corner, you see Timer1's property list, which looks like this:

Property	**Value**
(ApplicationSettings)	
(Name)	Timer1
Enabled	False
GenerateMember	True
Interval	100
Modifiers	Friend
Tag	

In that property list, click "**Interval**" then type 2000, so the Interval line becomes this:

Interval	2000

That makes each pause be **2000 milliseconds** (which is 2000 "thousands of a second", which is 2 seconds).

In that property list, click "**Enabled**" then press the T key, so the Enabled line becomes this:

Enabled	True

That turns the timer on, so it works.

Double-click the Timer1 icon, so you can write Timer1's subroutine. Type this line in Timer1's subroutine:

```
        Text &= "!"
```

That makes the Text (of Form1) lengthen, by having an extra "!" added. Typing that line makes Timer1's subroutine become this:

```
    Private Sub Timer1_Tick…
        Text &= "!"
    End Sub
```

When you run the program (by clicking "Start"), the computer will show Form1 saying "I love you", then pause for the next clock tick (the interval between ticks being 2000 milliseconds), then do Timer1's subroutine (which turns "I love you" into I love you!"), then pause for the next clock tick, then do again Timer1's subroutine (which turns "I love you!" into "I love you!!"), then pause for the next clock tick, then do again Timer1's subroutine (which turns "I love you!!" into "I love you!!!"), then keep repeating that process, so you eventually see "I love you!!!!!!!!!!" and beyond. When the exclamation points become too numerous to fit in Form1's title area, the computer changes the extra exclamation points to "…". The program keeps running until you stop it (by clicking Form1's X button).

If you want the exclamation points to come faster, make the interval shorter, by making Timer1's Interval be *less* than 2000 milliseconds. For example, try making the Interval be 1000 milliseconds (which is 1 second), or 500 milliseconds (which is half a second), or 1 millisecond (which is almost instantaneous).

If you want the computer to add just one exclamation point and then relax (without adding further exclamation points), make Timer1's subroutine become this:

```
    Private Sub Timer1_Tick…
        Text &= "!"
        Timer1.Enabled = False
    End Sub
```

That subroutine says: when the clock ticks, add an exclamation point to the text but then **disable the timer**, so no further exclamation points will be added.

To play a joke on a human, make Timer1's Interval be 3000 (so the computer will pause 3 seconds before giving the joke's punch line) and make Timer1's subroutine become this:

```
Private Sub Timer1_Tick…
    Text &= "r mother!"
    Timer1.Enabled = False
End Sub
```

That subroutine says: when the clock ticks (after 3 seconds), make the Text change from "I love you" to "I love your mother!" then disable the timer (because the joke's timing is done).

Try making Timer1's subroutine become this instead:

```
Private Sub Timer1_Tick…
    Text &= "I'm happy when you're gone"
End Sub
```

That subroutine says: when the clock ticks (after 3 seconds), make the Text change from "I love you" to "I'm happy when you're gone".

Count the seconds Here's how to make Form1 count how many seconds have elapsed, so Form1 begins by saying 0, then a second later says 1, then a second later says 2, etc.

Make Form1's Text begin at 0 by doing this:

Click in Form1, so the screen's bottom right corner shows Form1's main property list. In that list, click "Text", then type number 0 and press Enter.

In the toolbox (which at the screen's left side and shows the tools), find the Timer tool (by scrolling down to "Components", clicking any + sign left of "Components", then scrolling down further). Double-click that Timer tool. That puts a Timer1 icon below Form1.

In Timer1's property list (which is at the screen's bottom-right corner), click "Interval" then type 1000, so you see this line:

```
Interval                1000
```

Click "Enabled" then press the T key, so the Enabled line becomes this:

```
Enabled                 True
```

Double-click the Timer1 icon. Type this subroutine for Timer1:

```
        Text += 1
```

That increases the text's number, by adding 1 to it.

When you run the program (by clicking "Start"), Form1's Text begins as 0 but increases to 1, then 2, then 3, etc.

Tell the date and time Here's how to make Form1 act as a clock, so it tells you the date and time and updates itself every second!

Create a Timer1 icon (by double-clicking the Timer tool, which is in the toolbox under "Components"). In Timer1's property list (which is at the screen's bottom-right corner), make the "Interval" be 1000 and make "Enabled" be True.

Double-click the Timer1 icon. Type this subroutine for Timer1:

```
        Text = My.Computer.Clock.LocalTime
```

That makes the text become a message such as this:

```
12/31/2009 11:59:30 PM
```

You'll see such a message when you run the program (by clicking "Start"). Since you set the Interval to 1000 milliseconds (which is 1 second), that text will correct itself every second.

Switch to blue Here's how to make Form1 begin as red but then, after a pause, become blue.

Make Form1 begin as red by doing this:

Click in Form1, so the screen's bottom right corner shows Form1's main property list. In that list, click "BackColor" (which you'll see after you scroll up) then BackColor's down-arrow then "Web" then "Red" (which you'll see after you scroll down).

Create a Timer1 icon (by double-clicking the Timer tool, which is in the toolbox under "Components"). In Timer1's property list (which is at the screen's bottom-right corner), make the "Interval" be 2000 and make "Enabled" be True.

Double-click the Timer1 icon. Type this subroutine for Timer1:

```
        BackColor = Color.Blue
```

When you run the program (by clicking "Start"), Form1 begins as red but switches to blue (after a delay of 2000 milliseconds, which is 2 seconds).

Let's make the subroutine fancier, so Form1 keeps alternating between red and blue. We'll make Form1 start as red, then switch to blue, then switch back to red, then switch back to blue, then switch back to red, etc., forever. To do that, change the subroutine line to this:

```
        BackColor = IIf(BackColor = Color.Red, Color.Blue, Color.Red)
```

It says the BackColor becomes this: if the BackColor was Red, then it becomes Blue, else it becomes Red.

Color dialog

Here's how to let the human pick a color for Form1.

Look at the toolbox (which is at the screen's left side and shows the tools). Using the toolbox's scroll-down arrow, scroll down until you see a heading called "Dialogs".

Left of that heading, you see a square. That square should contain a minus sign. (If it contains a plus sign instead, change the plus sign to a minus sign by clicking it.)

Under the heading "Dialogs", you should see the **ColorDialog** tool. Double-click it. That puts a **ColorDialog1** icon below Form1 and lets Form1's subroutine mention "ColorDialog1".

Double-click Form1. Write this Form1 subroutine:

```
        ColorDialog1.ShowDialog()
        BackColor = ColorDialog1.Color
```

When you run the program (by clicking "Start"), the subroutine's top line makes the computer **show** the human the **color dialog box**, which contains 48 colors (plus a feature to let the human invent custom colors). When the human clicks one of the 48 colors (or a custom color) and then clicks "OK", the subroutine's bottom line makes Form1's background color become the color the human chose.

While viewing the color dialog box, here's how the human can create a custom color:

Click "Define Custom Colors".

At the color dialog box's right edge, you see a triangle pointing toward the left. Drag that triangle up, until it's halfway up the bar it points to.

You see a big, colorful square. Click your favorite color in that square.

Below that square, you see a box marked "Color/Solid"; that shows the color you've chosen. Adjust that color, by dragging the triangle up (which makes the color lighter) or dragging the triangle down (which makes the color darker) or clicking a different spot in the big, colorful square.

When you're satisfied, click "Add to Custom Colors". That creates a small square for the color. Click that square then "OK".

Helpful hints

Here are some hints to help you master programming.

Stop debugging

While your program is running, you can interrupt it by clicking the **Stop Debugging** button (which is a red square at the screen's top center).

The computer refuses to let you edit a program that's in the middle of running. If you try to edit a program that's running, the computer gripes by saying —

```
Changes are not allowed while code is running.
```

then waits for you to click "OK" (which means you've read the gripe).

To edit a program that's running, stop it first (by clicking Form1's X or the Stop Debugging button) then try to edit your program.

Avoiding Dim

If x is a variable, you're supposed to warn the computer by saying:

```
        Dim x
```

If you're too lazy to say "Dim" for each variable, say **Option Explicit Off** at your program's top, so your program looks like this:

```
Option Explicit Off
Public Class Form1
    Private Sub Form1_Load…

    End Sub
End Class
```

To type "Option Explicit Off" up there, do this:

```
While holding down the Ctrl key, tap the Home key.
Press the Enter key.
Press the up-arrow key.
Type "Option Explicit Off".
```

The "Option Explicit Off" prevents the computer from griping about missing Dim lines. It makes your program's variables work even if you don't say "Dim". But it also prevents the computer from warning you about using variables in ridiculous ways. Say "Option Explicit Off" just if you're too lazy to say "Dim" — and you're sure you're not making ridiculous mistakes about variables.

Apostrophe

In your subroutine, you can **type comments to help programmers understand your program**. The comments can mention your name, the date you wrote the program, the program's purpose, the purpose of each variable, special tricks you used, cynical comments, and any other comments you'd like to share with your programming buddies and to remind yourself of how you've been thinking.

To type such a comment in your subroutine, **begin the comment with an apostrophe**, like this:

```
        'This subroutine is another dumb example by Russ.
        'It was written on Halloween, under a full moon.
        c = 40 'because Russ has 40 computers
        h = 23 'because 23 of his computers are haunted
        Text = c - h 'That many computers are unhaunted.
```

When you run the program, **the computer ignores everything that's to the right of an apostrophe**. So the computer ignores lines 1 and 2; in lines 3 & 4, the computer ignores the "because…"; in the bottom line, the computer ignores the comment about being unhaunted. Since c is 40, and h is 23, the bottom line makes the computer say:

```
17
```

Everything to the right of an apostrophe is called a **comment** (or **remark**).

Turning green When you type the subroutine, **the computer makes each apostrophe and comment turn green**. Then the computer ignores what's green.

Temporarily ignore Suppose you've written a subroutine but wonder what would happen if one of the lines were deleted. To find out, you could delete the line (by pressing the Delete key repeatedly or using other techniques), then run the shortened program, then put the line back in (by retyping it). But here's a faster way to do that experiment:

```
To temporarily make the computer ignore the line, type an apostrophe in front of that line. The apostrophe turns that line into a comment, so the computer ignores the line. Later, when you want to reactivate that line, just delete the apostrophe.
```

Temporarily deactivating a line (by putting an apostrophe before it so it becomes a comment) is called **commenting out** the line.

Multiple lines To make *several* lines become comments, you can type an apostrophe in front of each of those lines; but here's a faster way: drag across those lines (by using your mouse), then click the **Comment-out button** (which is near the screen's top, under "Tools", and shows two green lines between black lines).

That makes the computer type an apostrophe in front of each of those lines and makes the lines turn green.

Later, when you want to reactivate those lines, drag across them again then click the **Uncomment button** (which is to the right of the Comment-out button): that removes the apostrophes and makes the lines turn black again.

Places for output

You can make the computer show answers in many places. Let's review the places you saw previously, then explore places that are more exotic.

Top of Form1

You learned that if Form1's subroutine says —

```
        Text = 5 + 2
```

the computer writes the answer, 7, at the **top of Form1**, where Form1's **title** belongs.

Unfortunately, the top of Form1 doesn't have much space: the answer must be narrow (unless you widened Form1) and the answer must not consume 2 lines.

Pop-up window

If the subroutine says —

```
MsgBox(5 + 2)
```

the computer writes the answer in a **pop-up window** that appears suddenly.

If the answer is long, the pop-up window expands automatically, vertically and horizontally, to hold the answer. (To create a 2-line answer, say this where you want the computer to press the Enter key: & Chr(13) &.)

Afterwards, the computer waits for the human to click "OK".

Middle of Form1

If you've created a label (by double-clicking the Label tool) and your subroutine says —

```
Label1.Text = 5 + 2
```

the computer writes the answer in the middle of Form1, where Label1 is.

If the answer is long, the Label1 area expands automatically, vertically and horizontally, to hold the answer, up to the size of Form1. (To create a 2-line answer, say this where you want the computer to press the Enter key: & Chr(13) &.)

Output window

If the subroutine says —

```
Console.WriteLine(5 + 2)
```

or —

```
Debug.Print(5 + 2)
```

the computer writes the answer at the screen's bottom, at the bottom of the **output window**.

After you admire that answer, stop the program (by clicking Form1's X button or the Stop Debugging button (which is a red square at the screen's top center).

Immediate window

To create an **immediate window**, click "Debug" (which is at the screen's top) then "Windows" then "Immediate". Then you see an **immediate window** at the screen's bottom.

In that window, type a command such as:

```
>? 5+2
```

Type it correctly: begin with the symbol >, then a question mark, then a space, then the computation. When you finish typing that, press the Enter key. The computer immediately types the answer underneath:

```
7
```

Console screen

To create a new program normally, you click "Windows Forms Application".

Instead of clicking "Windows Forms Application", try clicking "**Console Application**". That tells the computer you want a stripped-down version of Visual Basic, where the computer writes answers on a **console screen** (which looks like DOS instead of Windows and has no forms or buttons or icons).

When you've double-clicked the Console Application icon, you immediately see this stripped-down subroutine:

```
Module Module1

    Sub Main()

    End Sub

End Module
```

Click in the middle of that subroutine and say "Console.WriteLine(5 + 2)", so the subroutine becomes this:

```
Module Module1

    Sub Main()
        Console.WriteLine(5 + 2)
    End Sub

End Module
```

Just above the "End Sub", say "Do" and "Loop", like this:

```
Module Module1

    Sub Main()
        Console.WriteLine(5 + 2)
        Do

        Loop
    End Sub

End Module
```

When you type the "Do" (and press Enter), the computer automatically types the "Loop" for you.

When you run the program (by clicking "Start"), the computer writes the answer on a **console screen**, which is a window whose middle looks like DOS. (To create a 2-line answer, give 2 Console.WriteLine commands. At the end of each answer, the computer presses the Enter key, unless you say **Write** instead of **WriteLine**.) Your subroutine's "Do" and "Loop" make the computer pause, so you have time to read the answer.

After you've read the answer, close the console screen (by clicking its X button).

Avoiding Do In the subroutine, instead of typing "Do" (and waiting for the computer to type "Loop"), you can type "Console.ReadKey()", so the subroutine looks like this:

```
Module Module1

    Sub Main()
        Console.WriteLine(5 + 2)
        Console.ReadKey()
    End Sub

End Module
```

The "Console.ReadKey()" makes the computer wait for the human to press a key. When the human presses any key (such as Enter), the computer ends the program and closes the console screen.

Avoiding Console Here's a shortcut. Instead of typing "Console." so often (before each WriteLine and Write and ReadKey), just type this line at the subroutine's top —

```
Imports System.Console
```

so the subroutine looks like this:

```
Imports System.Console
Module Module1

    Sub Main()
        WriteLine(5 + 2)
        ReadKey()
    End Sub

End Module
```

Print form

Here's how to let the human print Form1 onto paper.

Double-click the **PrintForm** tool, which is in the Visual Basic PowerPacks category (whose tools you can see by clicking the triangle left of "Visual Basic PowerPacks" once or twice). That puts a PrintForm1 icon below Form1 and lets subroutines mention "PrintForm1".

On Form1, create a button (by double-clicking the Button tool). Make the button's text say "Print" (by clicking "Text" then typing "Print"). Double-click the button, so you can write the button's subroutine. Make the button's subroutine say:

```
PrintForm1.Print()
```

When the human runs the program and clicks the Print button, the computer will print most of Form1 onto paper.

The computer doesn't bother printing Form1's border or Text (title). It prints just Form1's middle, including the objects in it.

Hard disk

If Form1's subroutine says —

```
My.Computer.FileSystem.WriteAllText("Joan.txt", 5 + 2, False)
```

the computer writes the number 7 (the answer to 5+2) onto your hard disk, in a file called Joan.txt. Unfortunately, that file is hard to access, since it's buried in folders. (Specifically, it's in the Debug folder, which is in the bin folder, which is in your program's inner folder, which in your program's outer folder, which is in the Projects folder, which is in the Visual Studio 2015 folder, which is in the Documents folder.)

If you don't like the name Joan, invent a different name instead.

ProgramData folder This line is more practical:

```
My.Computer.FileSystem.WriteAllText("\ProgramData\Joan.txt", 5 + 2, False)
```

It makes the computer write the number 7 (the answer to 5 + 2) onto your hard disk, in a file called Joan.txt, which is in the **ProgramData folder**.

After you've run the program (by clicking "Start"), you can see Joan.txt by doing this:

Click the File Explorer icon (which is at the screen's bottom, on the taskbar, and looks like a yellow manila folder) then "This PC" (which is at the left). Double-click "C:" then "ProgramData" then "Joan", whose hidden .txt ending makes the computer run the Notepad program, which shows you what's in Joan.txt. You see that Joan.txt contains the answer, 7. When you finish admiring the answer, close the front 2 windows (by clicking their X buttons).

Documents folder If you want Joan.txt to be in the **Documents folder** instead of the ProgramData folder, type these lines instead:

```
Dim doc
doc = My.Computer.FileSystem.SpecialDirectories.MyDocuments
My.Computer.FileSystem.WriteAllText(doc & "\Joan.txt", 5 + 2, False)
```

The top two lines makes the variable doc stand for the Documents folder. In the bottom line, the doc makes Joan.txt be in the Documents folder.

After you've run the program (by clicking "Start"), you can see Joan.txt by doing this:

Click the File Exploer icon (which is at the screen's bottom, on the taskbar, and looks like a yellow manily folder) then "Documents". Double-click "Joan", whose hidden .txt ending makes the computer run the Notepad program, which shows you what's in Joan.txt. You see that Joan.txt contains the answer, 7. When you finish admiring the answer, close the front 2 windows (by clicking their X buttons).

Append If Joan.txt exists before you run the subroutine, the subroutine erases that old Joan.txt to create a Joan.txt — unless you change the bottom line's "False" to "True", which makes the subroutine **append** the new answer to the end of the old Joan.txt, to make Joan.txt become longer and include *both* answers. In the bottom line, "True" means "append to the old file"; "False" means "*don't append* to the old file; *erase* the old file."

Reading Joan.txt After the computer has put an answer into Joan.txt, you can run a **reading program** that reads Joan.txt.

If Joan.txt is in the ProgramData folder, the reading program can have Form1's subroutine say:

```
Text = My.Computer.FileSystem.ReadAllText("\ProgramData\Joan.txt")
```

That line makes the computer read Joan.txt and tell you what answer Joan.txt contains.

If Joan.txt is in the Documents folder, the reading program can have Form1's subroutine say:

```
Dim doc
doc = My.Computer.FileSystem.SpecialDirectories.MyDocuments
Text = My.Computer.FileSystem.ReadAllText(doc & "\Joan.txt")
```

Those lines make doc be the Documents folder and make Text be the answer that the computer reads from doc's Joan.txt.

Rich-text box Try this experiment.…

Create a new program. On Form1, put a rich-text box (so the human can type a document into the box) and put a Save button (a button whose title is "Save").

To make the Save button work properly (so pressing it copies the human's typing from the box to the hard disk), make the button's subroutine be this:

```
Dim doc
doc = My.Computer.FileSystem.SpecialDirectories.My Documents
RichTextBox1.SaveFile(doc & "\Joan.doc")
```

The bottom line means: take what's in the rich-text box and save it as a file; put the file into the Documents folder and call it Joan.doc.

When the human runs that program, the computer will let the human type a document (essay) into the rich-text box. Then computer will wait for the human to click the Save button (which makes the computer copy the document to the hard disk's Documents folder, in a rich-text file called Joan.doc).

You can see Joan.doc by doing this:

Click the File Explorer icon (the yellow manila folder at the screen's bottom) then "Documents". Double-click "Joan", whose hidden .doc ending makes the computer run the Microsoft Word (or WordPad) program, which shows you what's in Joan.doc. You see that Joan.doc contains the essay. When you finish admiring the essay, close the front 2 windows (by clicking their X buttons).

"Save As" dialog box That subroutine forces the document to be in the Documents folder and be called "Joan.doc". Here's how to make the subroutine more flexible, (so the human can choose what folder to put the document in and what name to give the document.…

Double-click the **SaveFileDialog** tool (which is in the Dialogs category). That creates a **SaveFileDialog1** icon below Form1.

In the SaveFileDialog1's property list, click "DefaultExt" and type "doc". That will secretly put ".doc" at the end of every filename.

Make the Save button's subroutine be this:

```
SaveFileDialog1.ShowDialog()
RichTextBox1.SaveFile(SaveFileDialog1.FileName)
```

When the human clicks the Save button, the subroutine's top line makes the computer show the "Save As" dialog box, which lets the human invent a file name and choose a folder to put it in. For example, if the human types "Joe" (and then presses the Enter key), the file will be called "Joe.doc" (because the SaveFileDialog1's property list said the default extension is "doc").

The subroutine's bottom line means: look at the document that was typed in RichTextBox1, and save it as a file on the hard disk, using the file name (and folder) that the human specified in the "Save As" dialog box.

Say "document" Since RichTextBox1's main purpose is to handle a document, programmers prefer to say just "document" instead of "RichTextBox1" and write the Save button's program this way:

```
SaveFileDialog1.ShowDialog()
document.SaveFile(SaveFileDialog1.FileName)
```

To do that, you must change the box's name from "RichTextBox1" to "document". Here's how:

In RichTextBox1's property list (which is at the screen's bottom-right corner), click "(Name)" then type the word "document", so the line looks like this:

(Name) document

Reading Joan.doc After the computer has saved (copied) a document into your hard disk's Joan.doc, you can run a **reading program** that reads Joan.doc.

The reading program should have a rich text box named "document". It should also have an "Open" button whose subroutine says:

```
OpenFileDialog1.ShowDialog()
document.LoadFile(OpenFileDialog1.FileName)
```

But to make the computer understand what "OpenFileDialog1" means, you must double-click the **OpenFileDialog** tool before typing that subroutine.

Menu

You can create a menu.

Menu bar

At the top of Form1, let's create this **menu bar**:

Love Hate

Let's program the computer so clicking "Love" makes the computer say "I love you", and clicking "Hate" makes the computer say "I hate being a computer".

Here's how to accomplish all that.…

Double-click the **MenuStrip** tool (which is in the "Menus & Toolbars" category).

Click "Type Here" (which is near Form1's top). Then you see a blank box (plus two "Type Here" boxes). In the blank box, type your menu's first word ("Love").

Click the box that's to the right of "Love". Type your menu's second word ("Hate").

Congratulations! You created a menu!

Create menu subroutines Double-click "Love", then write this subroutine telling the computer what to do if "Love" is clicked:

```
Private Sub LoveToolStripMenuItem_Click…
    Text = "I love you"
End Sub
```

(The computer already typed the top and bottom lines for you, so type just the middle line.) When you finish typing that line, click the "Form1.vb [Design]" tab.

Double-click "Hate", then write this subroutine about clicking "Hate":

```
Private Sub HateToolStripMenuItem_Click…
    Text = "I hate being a computer"
End Sub
```

Run the program Go ahead: run the program (by clicking "Start"). You see the menu bar you created:

Love Hate

Clicking "Love" makes the computer say "I love you"; clicking "Hate" makes the computer say "I hate being a computer".

Pull-down menu

Let's expand the menu by adding "Color", so the menu becomes this:

Love Hate Color

Let's program the computer so clicking "Color" makes this **pull-down menu** appear under Color:

Yellow
Red

Let's program so clicking one of those colors makes Form1's background be that color.

Here's how to accomplish all that.…

Create a new menu item If your program is still running, stop it (by clicking its X button). Look at Form1's design (by clicking the "Form1.vb [Design]" tab). Click the "Type Here" that's to the right of "Hate". In the blank box that appears, type your menu's third word ("Color").

Create a pull-down menu To create Color's pull-down menu (saying "Yellow" and "Red"), click the "Type Here" that's under "Color". In the blank box that appears, type "Yellow". In the box under "Yellow", type "Red".

Congratulations! You created a pull-down menu!

Create menu subroutines Double-click "Yellow", then write this subroutine about Yellow:

```
Private Sub YellowToolStripMenuItem_Click…
    BackColor = Color.Yellow
End Sub
```

Click the "Form1.vb [Design]" tab, then double-click "Red", then write this subroutine about Red:

```
Private Sub RedToolStripMenuItem_Click…
    BackColor = Color.Red
End Sub
```

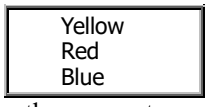
Run the program Go ahead: run the program (by clicking "Start"). You see the menu bar you created:

Love Hate Color

Clicking "Color" makes the computer show Color's pull-down menu; clicking the "Yellow" or "Red" makes Form1's background turn that color.

Submenu

Let's expand Color's pull-down menu by adding "Blue", so the menu becomes this:



Let's program the computer so clicking "Blue" makes this **submenu** appear to the right of Blue:

Let's program so clicking one of those kinds of blue makes Form1's background be that color.

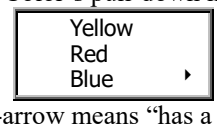
Here's how to accomplish all that.…

Create a new menu item If your program is still running, stop it (by clicking its X button). Look at Form1's design (by clicking the "Form1.vb [Design]" tab). Click "Color" then the "Type Here" that's under "Red". In the blank box that appears, type pull-down menu's third word ("Blue").

Create a submenu To create Blue's submenu (saying "Light Blue" and "Dark Blue"), click the "Type Here" that's to the right of "Blue". In the blank box that appears, type "Light Blue". In the box under "Light Blue", type "Dark Blue".

Congratulations! You created a submenu!

Creating a submenu for Blue made a right-arrow appear next to "Blue", so Color's pull-down menu looks like this:



That right-arrow means "has a submenu".

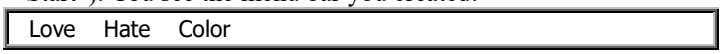
Create subroutines Double-click "Light Blue", then write this subroutine about Light Blue:

```
Private Sub LightBlueToolStripMenuItem_Click…
    BackColor = Color.LightBlue
End Sub
```

Click the "Form1.vb [Design]" tab, then double-click "Dark Blue", then write this subroutine about Dark Blue:

```
Private Sub DarkBlueToolStripMenuItem_Click…
    BackColor = Color.DarkBlue
End Sub
```

Run the program Go ahead: run the program (by clicking "Start"). You see the menu bar you created:



Clicking "Color" makes the computer show Color's pull-down menu; clicking "Blue" makes the computer show Blue's submenu; then clicking "Light Blue" or "Dark Blue" makes Form1's background turn that color.

Rearranging menu items

After you've created a menu, you can rearrange its items. Here's how.…

If your program is still running, stop it (by clicking its X button). Look at Form1's design (by clicking the "Form1.vb [Design]" tab).

To delete an item, click it then press the **Delete key**. If you change your mind, click the **Undo button** (which shows a blue arrow bending toward the left).

To move an item that's on the menu bar ("Love", "Hate", or "Color"), **drag** that item across to where you want it — and, to make sure the computer doesn't ignore you, drag slightly farther. To move an item that's on a pull-down menu ("Yellow", "Red", or "Blue") or submenu ("Light Blue" or "Dark Blue"), drag the item up or down to where you want it — and to make sure the computer doesn't ignore you, drag slightly farther.

Minimalist word processor

Here's how to invent a minimalist word-processing program.

Big Form1

Create a new program. Widen Form 1 (by dragging its bottom-right corner toward the right).

Tool strip

Onto Form 1, put a **tool strip (toolbar)** by doing this:

Double-click the **ToolStrip** tool (which is in the "Menus & Toolbars" category). That puts a ToolStrip1 icon below Form 1. Right-click that icon then click "Insert Standard Items". That makes these 7 icons appear across Form 1's top: New, Open, Save, Print, Cut, Copy, Paste, and Help. Each icon will act as a button.

Rich text box

Onto Form1, put a rich text box (by double-clicking the **RichTextBox** tool). Give that box the desired properties by doing this:

Click the box's right-arrow (which is near the box's top-right corner) then "Dock in parent container". That makes the box expand to fill the rest of Form1: the only things above the box are the tool strip and the title bar (which says Form1).

In the box's property list (which is at the screen's bottom-right corner), scroll up until you see "EnableAutoDragDrop", then click "EnableAutoDragDrop" and press the T key, so the line becomes this:

EnableAutoDragDrop True

Scroll up farther until you see "(Name)", then click "(Name)" and type "document", so the line becomes this:

(Name) document

More tools

Double-click these tools, which you'll need to finish the program:

OpenFileDialog (which is in the "Dialogs" category)
SaveFileDialog (which is in the "Dialogs" category)
PrintForm (which is in the "Visual Basic PowerPacks" category)

Then icons for those tools appear below Form1.

Subroutines

For each button on the tool strip, write a subroutine. Here's how.…

Double-click the tool strip's first button (the **New button**, which looks like a blank sheet of paper with a folded corner). Type this line (for the New button's subroutine):

```
document.Clear()
```

Make Form1 appear again (by clicking the "Form1.vb [Design]" tab). Double-click the tool strip's next button (the **Open button**, which looks like a yellow manila folder that's opening). Type these lines (for the Open button's subroutine):

```
OpenFileDialog1.ShowDialog()
document.LoadFile(OpenFileDialog1.FileName)
```

Make Form1 appear again (by clicking the "Form1vb [Design]" tab). In similar fashion, type these lines for the Save button:

```
SaveFileDialog1.ShowDialog()
document.SaveFile(SaveFileDialog1.FileName)
```

Type this line for the Print button:

```
PrintForm1.Print()
```

Type this line for the Cut button:

```
document.Cut()
```

Type this line for the Copy button:

```
document.Copy()
```

Type this line for the Paste button:

```
document.Paste()
```

Type this line for the Help button:

```
MsgBox("This is word processor version 1")
```

Run

When you run the program (by clicking "Start"), the program works correctly, if you did what I said!

Congratulations on creating a word-processing program.

The program's main limitations are:

It doesn't let you change margins (except by dragging Form1's bottom-right corner).

It doesn't let you change fonts.

Its Print button prints just *part* of the document. (It prints just the part that's visible on Form1 at the moment, and it can't print any part that's too far to the right to fit on the paper.)

Surpassing those limitations would require subroutines that are much longer!

Loops

Here's how to make the computer repeat.

Do...Loop

The computer can be religious. Just make Form1's subroutine say this:

```
MsgBox("I worship your feet")
MsgBox("But please wash them")
```

When you run the program, the computer shows a message box saying "I worship your feet" and waits for the human to click OK. Then the computer shows a message box saying "But please wash them" (and waits for the human to click OK again).

To make the computer do the lines many times, say "Do" above the lines and say "Loop" below them, so the subroutine looks like this:

```
Do
    MsgBox("I worship your feet")
    MsgBox("But please wash them")
Loop
```

The lines being repeated (the MsgBox lines) should be between the words Do and Loop and indented. (After you've typed the word "Do" and pressed Enter, the computer will automatically type the word "Loop" and created an indented blank space for you to type in.)

Run the program (by clicking "Start"). The computer says "I worship your feet" (and waits for the human to click OK), then says "But please wash them" (and waits for OK), then goes back and says "I worship your feet" again (and waits for OK), then says "But please wash them" again (and waits for OK), then goes back and says the same stuff again, and again, and again, and again, forever.

Since the computer's thinking keeps circling back to the same lines, the computer is said to be in a **loop**. In that subroutine, the **Do** means "do what's underneath and indented"; the **Loop** means "loop back and do it again". The lines that say Do and Loop — and the lines between them — form a loop, which is called a **Do loop**.

The computer does that loop repeatedly, forever — or until you **abort the program by doing this:**

Click the **Stop Debugging button** (a blue square near the screen's top center).

That works just if you're in the Visual Basic environment (so you see the Stop Debugging button). If you're *not* in the Visual Basic environment (because you're running the .exe file directly), the only way to abort a looping program is to shut down the computer (click the Start button then, in Windows 7, click Shutdown) or try this:

While holding down the Ctrl and Alt keys, tap the Delete key. Click "Start Task Manager" then the "Applications" tab (which is at the screen's top-left corner) then your program's name then "End Task". If you're lucky, that aborts the program. Close the Windows Task Manager window (by clicking its X button).

In that program, since the computer tries to go round and round the loop forever, the loop is called **infinite**. The only way to stop an infinite loop is to abort it.

Disappearing-message-box bug

When running a loop, the computer might accidentally **lose the program's focus** and forget to show the message box. To make the message box reappear, click the message box's button, which is on the **taskbar**. (The **taskbar** is at the screen's bottom and runs from the Start button to the clock.) Try double-clicking the message box's button. To run the program again, try clicking the green right-arrow (instead of pressing the F5 key).

GoTo

Instead of typing —

```
Do
    MsgBox("I worship your feet")
    MsgBox("But please wash them")
Loop
```

you can type:

```
joe:    MsgBox("I worship your feet")
        MsgBox("But please wash them")
        GoTo joe
```

(When you type that subroutine, the computer automatically spaces it correctly: when you press Enter at the top line's end, the computer automatically unindents "joe:".) The top line (named joe) makes the computer say "I worship your feet". The next line makes the computer say "But please wash them". The bottom line makes the computer Go back To the line named joe, so the computer forms a loop. The computer will loop forever — or until you abort the program (by clicking the Stop Debugging button, twice).

You can give a line a short name (such as joe) or a long name (such as BeginningOfMyFavoriteLoop). The name can even be a number (such as 10). Put the name at the line's beginning. After the name, put a colon (the symbol ":").

The line's name (such as joe or BeginningOfMyFavoriteLoop or 10) is called the line's **label**.

Skip ahead This subroutine is insulting:

```
MsgBox("Your face is outstanding.")
MsgBox("It belongs in a horror movie.")
MsgBox("It deserves an award!")
```

Let's turn that insult into a compliment. To do that, insert the shaded items:

```
        MsgBox("Your face is outstanding.")
        GoTo conclusion
        MsgBox("It belongs in a horror movie.")
conclusion: MsgBox("It deserves an award!")
```

The computer begins by saying "Your face is outstanding." Then the computer does GoTo conclusion, which makes the computer Go skip down To the conclusion line, which says "It deserves an award!" So the subroutine makes the computer say just —

```
Your face is outstanding.
```

and:

```
It deserves an award!
```

Is GoTo too powerful? Saying GoTo gives you great power: if you make the computer GoTo an earlier line, you'll create a loop; if you make the computer GoTo a later line, the computer will skip over several lines of your subroutine.

Since saying GoTo is so powerful, programmers are afraid to say it. Programmers know that the slightest error in saying GoTo will make a program act very bizarre! Programmers feel more comfortable using milder words instead (such as Do…Loop), which are safer and rarely get botched up. Since saying GoTo is scary, many computer teachers prohibit students from using it, and many companies fire programmers who say GoTo instead of Do…Loop.

But saying GoTo is fine when you've learned how to control the power! Though I usually say Do…Loop instead of GoTo, I say GoTo in certain situations where saying Do…Loop would be awkward.

Exiting a Do loop

Let's create a guessing game, where the human tries to guess the computer's favorite color, which is pink. To do that, say **GoTo** or **Exit Do** or **Loop Until**. Here's how.…

GoTo Just make Form1's subroutine say this:

```
        Dim guess
AskTheHuman: guess = InputBox("What's my favorite color?")
        If guess = "pink" Then
            MsgBox("Congratulations! You discovered my favorite color.")
        Else
            MsgBox("No, that's not my favorite color. Try again!")
            GoTo AskTheHuman
        End If
```

The top line (which is called AskTheHuman) asks the human to guess the computer's favorite color.

If the guess is "pink", the computer says:

```
Congratulations! You discovered my favorite color.
```

But if the guess is *not* pink, the computer will instead say "No, that's not my favorite color" and then Go back To AskTheHuman again to guess the computer's favorite color.

Exit Do Here's how to write that subroutine without saying GoTo:

```
        Dim guess
        Do
            guess = InputBox("What's my favorite color?")
            If guess = "pink" Then Exit Do
            MsgBox("No, that's not my favorite color. Try again!")
        Loop
        MsgBox("Congratulations! You discovered my favorite color.")
```

The Do loop makes the computer do this repeatedly: ask "What's my favorite color?" and then say "No, that's not my favorite color."

The only way to stop the loop nicely (without abortion) is to guess "pink", which makes the computer Exit from the Do loop; then the computer proceeds to the line underneath the Do loop. That line makes the computer say:

```
Congratulations! You discovered my favorite color.
```

Loop Until Here's another way to program the guessing game:

```
        Dim guess
        Do
            MsgBox("You haven't guessed my favorite color yet!")
            guess = InputBox("What's my favorite color?")
        Loop Until guess = "pink"
        MsgBox("Congratulations! You discovered my favorite color.")
```

The Do loop makes the computer do this repeatedly: say "You haven't guessed my favorite color yet!" and then ask "What's my favorite color?"

The Loop line makes the computer repeat the indented lines again and again, until the guess is "pink". When the guess is "pink", the computer proceeds to the line underneath the Loop and prints "Congratulations!"

The Loop Until's condition (guess = "pink") is called the **loop's goal**. The computer does the loop repeatedly, until the loop's goal is achieved. Here's how:

The computer does the indented lines, then checks whether the goal is achieved yet. If the goal is *not* achieved yet, the computer does the indented lines again, then checks again whether the goal is achieved. The computer does the loop again and again, until the goal is achieved. Then the computer, proud at achieving the goal, does the program's **finale**, which consists of any lines under the Loop Until line.

Saying —

```
        Loop Until guess = "pink"
```

is just a briefer way of saying this pair of lines:

```
            If guess = "pink" Then Exit Do
        Loop
```

For...Next

Let's make the computer say these sentences:

```
I like the number 1
I like the number 2
I like the number 3
I like the number 4
I like the number 5
```

To do that, put these lines into Form1's subroutine:

```
        For x = 1 To 5
            MsgBox("I like the number " & x)
        Next
```

The top line (For x = 1 To 5) says that x will be every number from 1 to 5; so x will be 1, then 2, then 3, then 4, then 5. The line underneath (which the computer indents) says what to do about each x: it says to create a message box saying "I like the number " and x.

Whenever a subroutine says the word For, it must also say Next; so the bottom line says Next. The computer types the word "Next" for you automatically.

The indented line, which is between the For line and the Next line, is the line that the computer will do repeatedly; so the computer will repeatedly say "I like the number " and an x. The first time, the x will be 1, so the computer will say:

```
I like the number 1
```

The next time, the x will be 2, so the computer will say:

```
I like the number 2
```

The computer will say similar sentences, for every number from 1 up to 5.

Monster song Let's make the computer say these lyrics:

```
I saw 2 monsters
Tra-la-la!
I saw 3 monsters
Tra-la-la!
I saw 4 monsters
Tra-la-la!
They all had a party: ha-ha-ha!
```

To do that, type these lines —

```
The first line of each verse:     MsgBox("I saw " & x & " monsters")
The second line of each verse:    MsgBox("Tra-la-la!")
```

and make x be every number from 2 up to 4:

```
        For x = 2 To 4
            MsgBox("I saw " & x & " monsters")
            MsgBox("Tra-la-la!")
        Next
```

At the end of the song, say the closing line:

```
        For x = 2 To 4
            MsgBox("I saw " & x & " monsters")
            MsgBox("Tra-la-la!")
        Next
        MsgBox("They all had a party: ha-ha-ha!")
```

That program makes the computer print the entire song.

Here's an analysis:

```
                                 For x = 2 To 4
The computer will do indented lines      MsgBox("I saw " & x & " monsters")
repeatedly, for x=2, x=3, and x=4.       MsgBox("Tra-la-la!")
                                 Next
Then the computer will do this once.  MsgBox("They all had a party: ha-ha-ha!")
```

Since the computer does the indented lines repeatedly, those lines form a loop. Here's the general rule: **the statements between For and Next form a loop**. The computer goes round and round the loop, for x=2, x=3, x=4, and x=5. Altogether, it goes around the loop 4 times, which is a finite number. Therefore, the loop is **finite**.

If you don't like the letter x, choose a different letter. For example, you can choose the letter i:

```
        For i = 2 To 4
            MsgBox("I saw " & i & " monsters")
            MsgBox("Tra-la-la!")
        Next
        MsgBox("They all had a party: ha-ha-ha!")
```

When using the word For, most programmers prefer the letter i; most programmers say "For i" instead of "For x". Saying "For i" is a tradition. Following that tradition, the rest of this book says "For i" (instead of "For x"), except in situations where some other letter feels more natural.

Say the squares To find the **square** of a number, multiply the number by itself. For example, the square of 3 is "3 times 3", which is 9. The square of 4 is "4 times 4", which is 16.

Let's make the computer say the square of 3, 4, 5, etc., up to 10, like this:

```
The square of 3 is 9
The square of 4 is 16
The square of 5 is 25
The square of 6 is 36
The square of 7 is 49
The square of 8 is 64
The square of 9 is 81
The square of 10 is 100
```

To do that, type this line —

```
        MsgBox("The square of " & i & " is " & i * i)
```

and make i be every number from 3 up to 10, like this:

```
        For i = 3 To 10
            MsgBox("The square of " & i & " is " & i * i)
        Next
```

Count how many copies This program makes the computer say "I love you" 4 times:

```
For i = 1 To 4
    MsgBox("I love you")
Next
```

Here's a smarter program, which asks how many times you want the computer to say "I love you":

```
Dim n
n = Val(InputBox("How many times do you want me to love you?"))
For i = 1 To n
    MsgBox("I love you")
Next
```

When you run that program, the computer asks:

```
How many times do you want me to love you?
```

If you answer 5 (and click the OK button), the n becomes 5 (so the computer says "I love you" 5 times). If you answer 7 instead, the computer says "I love you" 7 times. Get as much love as you like!

That program illustrates this rule:

```
To make the For...Next loop be flexible,
say "For i = 1 To n" and let the human input the n.
```

Step The For statement can be varied:

Statement	**Meaning**
`For i = 5 To 17 Step .1`	The i will go from 5 to 17, counting by tenths. So i will be 5, then 5.1, then 5.2, etc., up to 17.
`For i = 5 To 17 Step 3`	The i will be every 3rd number from 5 to 17. So i will be 5, then 8, then 11, then 14, then 17.
`For i = 17 To 5 Step -3`	The i will be every 3rd number from 17 down to 5. So i will be 17, then 14, then 11, then 8, then 5.

To count down, you *must* use the word Step. To count from 17 down to 5, give this instruction:

```
For i = 17 To 5 Step -1
```

This program prints a rocket countdown:

```
For i = 10 To 1 Step -1
    MsgBox(i)
Next
MsgBox("Blast off!")
```

The computer will say:

```
10
9
8
7
6
5
4
3
2
1
Blast off!
```

This statement is tricky:

```
For i = 5 To 16 Step 3
```

It says to start i at 5, and keep adding 3 until it gets past 16. So i will be 5, then 8, then 11, then 14. The i won't be 17, since 17 is past 16. The first value of i is 5; the last value is 14.

In the statement For i = 5 To 16 Step 3, the **first value** or **initial value** of i is 5, the **limit value** is 16, and the **step size** or **increment** is 3. The i is called the **counter** or **index** or **loop-control variable**. Although the limit value is 16, the **last value** or **terminal value** is 14.

Programmers usually say "For i", instead of "For x", because the letter i reminds them of the word **index**.

Fancy calculations

The computer can do fancy calculations.

Exponents

In Form1's subroutine, try giving this command:

```
Text = 4 ^ 3
```

To type the symbol ^, do this: while holding down the Shift key, tap this key:

^
6

That symbol (^) is called a **caret**.

In that line, **the "4 ^ 3" makes the computer use the number 4, three times**. The computer will multiply together those three 4's, like this: 4 times 4 times 4. Since "4 times 4 times 4" is 64, the computer will say:

```
64
```

In the expression "4 ^ 3", the 4 is called the **base**; the 3 is called the **exponent** or **power**.

Here's another example:

```
Text = 10 ^ 6
```

The "10 ^ 6" makes the computer use the number 10, six times. The computer will multiply together those six 10's (like this: 10 times 10 times 10 times 10 times 10 times 10) and say the answer, 1000000.

Here's another example:

```
Text = 3 ^ 2
```

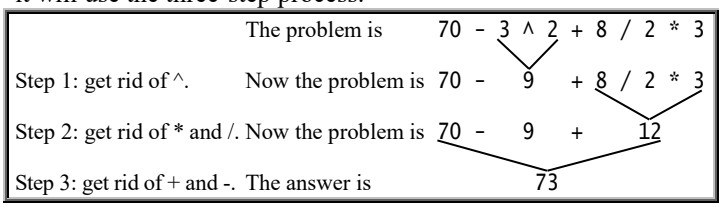
The "3 ^ 2" makes the computer use the number 3, two times. The computer will multiply together those two 3's (like this: 3 times 3) and say the answer, 9.

Order of operations The symbols +, -, *, /, and ^ are all called **operations**.

To solve a problem, the computer uses the three-step process taught in algebra (and pre-algebra). For example, suppose you say:

```
Text = 70 - 3 ^ 2 + 8 / 2 * 3
```

The computer will *not* begin by subtracting 3 from 70; instead, it will use the three-step process:



In each step, it looks from left to right. For example, in step 2, it sees / and gets rid of it before it sees *.

Speed Though exponents are fun, the computer handles them slowly. For example, the computer handles 3 ^ 2 slower than 3 * 3. So for fast calculations, say 3 * 3 instead of 3 ^ 2.

Square roots What positive number, when multiplied by itself, gives 9? The answer is 3, because 3 times itself is 9.

3 **squared** is 9. 3 is called the **square root** of 9.

To make the computer deduce the square root of 9, type this:

```
Text = Math.Sqrt(9)
```

The computer will print 3.

The symbol Math.Sqrt is called a **function**. The number in parentheses (9) is called the function's **input** (or **argument** or **parameter**). The answer, which is 3, is called the function's **output** (or **value**).

Math.Sqrt(9) gives the same answer as 9 ^ .5. The computer handles Math.Sqrt(9) faster than 9 ^ .5.

Cube roots What number, when multiplied by itself and then multiplied by itself *again*, gives 64? The answer is 4, because 4 times 4 times 4 is 64. The answer (4) is called the **cube root** of 64.

Here's how to make the computer find the cube root of 64:

```
Text = 64 ^ (1 / 3)
```

The computer will say 4.

Stripping

Sometimes the computer prints *too* much info: you wish the computer would print less, to save yourself the agony of reading excess info irrelevant to your needs. Whenever the computer prints too much info about a numerical answer, use Math.Abs, Fix, Int, Math.Ceiling, Math.Round, or Math.Sign.

Math.Abs removes any minus sign. ("Abs" is short for "Absolute value".) For example, the Math.Abs of -3.89 is 3.89. So if you say Text = Math.Abs(-3.89), the computer will say just 3.89.

Fix removes any digits after the decimal point. For example, the Fix of 3.89 is 3. So if you say Text = Fix(3.89), the computer will say just 3. The Fix of -3.89 is -3.

Int rounds the number DOWN to an integer that's LOWER. For example, the Int of 3.89 is 3 (because 3 is an integer that's lower than 3.89); the Int of -3.89 is -4 (because -4 is lower than -3.89).

Math.Ceiling rounds the number UP to an integer that's HIGHER. For example, the Math.Ceiling of 3.89 is 4 (because 4 is an integer that's higher than 3.89); the Math.Ceiling of -3.89 is -3 (because -3 is higher than -3.89).

Math.Round can round to the NEAREST integer. For example, the Math.Round of 3.89 is 4. The Math.Round of -3.89 is -4. The Math.Round of a number ending in .5 is an integer that's even (not odd); for example, the Math.Round of 26.5 is 26 (because 26 is even), but the Math.Round of 27.5 is 28 (because 28 is even); this rounding method is called **unbiased rounding** and explained in the next section ("Types of data"). If you want traditional rounding instead of unbiased rounding, ask for Math.Round(26.5,System.MidpointRounding.AwayFromZero), which produces 27. If you say Text = Math.Round(865.739, 2), the computer will round 865.739 to 2 decimal places and say 865.74.

Math.Sign removes ALL the digits and replaces them with a 1, unless the number is 0. For example, the Math.Sign of 3.89 is 1. The Math.Sign of -3.89 is -1. The Math.Sign of 0 is just 0.

Math.Abs, Fix, Int, Math.Ceiling, Math.Round, and Math.Sign are all called **stripping functions** or **strippers** or **diet functions** or **diet pills**, because they strip away the number's excess fat and reveal just the fundamentals that interest you.

Pi

A circle's **circumference** (the distance around a circle) is about 3 times as long as the circle's **diameter** (the distance across the circle). So the circumference divided by the diameter is about 3. More precisely, it's **pi**, which is about 3.1415926535897931, a number that Visual Basic calls **Math.PI**. If you type —

```
Text = Math.PI
```

the computer will display this approximation:

```
3.14159265358979
```

Avoid "Math."

Many of those functions expect you to type "Math." To avoid having to type "Math.", put this line at your program's top (above "Public Class Form1"):

```
Imports System.Math
```

Then you can omit "Math." For example, instead of typing —

```
Text = Math.Sqrt(9)
```

you can type just:

```
Text = Sqrt(9)
```

Instead of typing —

```
Text = Math.PI
```

you can type just:

```
Text = PI
```

Types of data

If you want x to be a variable in your subroutine, you must warn the computer by giving your subroutine a command such as:

```
Dim x
```

Here's how to make your program run faster, consume less RAM, and correct more errors: instead of saying just "Dim x", warn the computer what **type of data** the x will stand for, by giving one of these 8 popular commands:

Command	Meaning	RAM	Speed
`Dim x As Integer`	x will be a number from 0 to 2147483647, with no decimal point, but maybe a negative sign	4 bytes	fastest
`Dim x As Long`	x will be a number from 0 to 9223372036854775807, with no decimal point, but maybe a negative sign	8 bytes	fast
`Dim x As Double`	x will be a number from 0 to 1E308, with maybe a decimal point and negative sign, 15-digit accuracy	8 bytes	fast
`Dim x As Decimal`	x will be a number having up to 28 digits, with maybe a decimal point and negative sign, 28-digit accuracy	16 bytes	slowest
`Dim x As Date`	x will be a date and time (such as #12/31/2009 11:59:30 PM#), with a year between 1 and 9999	8 bytes	slow
`Dim x As Boolean`	x will be either the word True or the word False	2 bytes	fast
`Dim x As String`	x will be a string (such as "I love you") up to 2 billion characters long 2 bytes per character, plus	10 bytes	slow
`Dim x As Char`	x will be a single character (such as "j")	2 bytes	fast

Here's how to choose among them:

If x stands for a reasonably small number (2147483647 or less) without a decimal point, choose **Integer**.
If x stands for a longer number (up to 922337203854775807) without a decimal point, choose **Long**.
If x stands for a number that's even bigger or has a decimal point, choose **Double** unless you need more than 15-digit accuracy, which demands **Decimal**.

If x stands for a date or time, choose **Date**.
If x stands for the word True or the word False, choose **Boolean**.
If x stands for a single character (such as "c"), choose **Char**. If x stands for a longer string, choose **String**.

For example, if you want x to be 3000000, say:

```
Dim x As Integer
x = 3000000
```

According to the chart's top line, saying "Dim x As Integer" makes x consume 4 bytes of RAM. The computer can store 3000000 (or any integer up to 2147483647) in just 4 bytes of RAM, because the computer stores the number by using a special trick called **binary representation**.

These 7 variations are less popular:

Instead of **Integer**, you can choose **UInteger** (which means unsigned integer).
It can handle numbers that are twice as big (up to 4294967295) but can't handle a negative sign.

Instead of **Long**, you can choose **ULong** (which means unsigned long).
It can handle numbers that are twice as big (up to 18446744073709551615) but can't handle a negative sign.

Instead of **Integer** (which consumes 4 bytes), you can choose **Short** (which consumes just 2 bytes and is limited to numbers up to 32767) or **SByte** (which consumes just 1 byte and is limited to numbers up to 127). But those alternatives run slow, because the Pentium chip was designed to handle 4-byte integers, not shorter integers. Use those alternatives just if you're worried about the number of bytes. Here are other alternatives, which also run slow: **UShort** (which consumes 2 bytes, handles numbers up to 65535, no decimals or negatives) and **Byte** (which consumes 1 byte, handles numbers up to 255, no decimals or negatives).

Instead of **Double**, you can choose **Single** (which means single-length numbers). It consumes fewer bytes (4 instead of 8) but runs slow (because the Pentium chip was designed to handle decimal points in 8-byte numbers, not shorter ones). It has less accuracy (7-digit instead of 15-digit) and is restricted to smaller numbers (up to 3E38, not 1E308). Use it just if you're worried about the number of bytes.

Details

Here are more details about the 8 popular Dim commands.

Integer An **Integer** is a number from 0 to 2147483647, with maybe a negative sign in front, but without a decimal point. For example, these numbers can all be Integer:

```
0   1   2   3   10   52   53   1000   2147483647
   -1  -2  -3  -10  -52  -53   1000  -2147483647
```

Technical note: although 2147483648 is slightly too big to be an Integer, -2147483648 is a special number that *can* be an Integer, though it's rarely used and must be written as:

```
-2147483647 - 1
```

If you say "Dim x As Integer" and then try to say "x = 52.9", the computer will round 52.9 to 53, so x will be 53.

To round, Visual Basic 2015 makes the computer use this strange method, called **unbiased rounding**:

> If the number's decimal part is less than .5 (for example, if it's .4), the computer rounds down. For example, 26.4 rounds down to 26.
>
> If the number's decimal part is more than .5 (for example, if it's .51 or .6), the computer rounds up. For example, 26.51 rounds up to 27.
>
> If the number's decimal part is exactly .5 (not less, not more, not .51), the computer uses this strange method: it round to the nearest integer that's even (not odd). For example, 26.5 rounds down to 26 (since 26 is even), but 27.5 rounds up to 28 (since 28 is even).

That makes .5 sometimes round down and sometimes rounds up, so there's no bias toward rounding in a particular direction. That unbiased rounding method appeals to statisticians (and a few economists and very few bankers) who want to eliminate bias from rounded results. It's called **unbiased rounding** (or **round-to-even** or **statisticians rounding** or **bankers rounding** or **Dutch rounding** or **Gaussian rounding)**.

Long A **Long** is a number from 0 to 9223372036854775807, with maybe a negative sign in front, but without a decimal point. For example, these numbers can all be Longs:

```
0  1  2  3  10  52  53  1000  9223372036854775807
0 -1 -2 -3 -10 -52 -53 -1000 -9223372036854775807
```

Technical note: although 9223372036854775808 is slightly too big to be a Long, -9223372036854775808 is a special number that *can* be a Long, though it's rarely used and must be written as:

```
-9223372036854775807 - 1
```

If you say "Dim x As Long" and then try to say "x = 52.9", the computer will round 52.9 to 53, so x will be 53. (To round, the computer uses unbiased rounding.)

If you write a number that has no decimal point and is small (no more than 2147483647), the computer assumes you want it to be an Integer. If you want it to be a Long instead, **put L after it**, like this: 57L. For example, if you tell the computer to multiply 3000 by 1000000, like this —

```
        Text = 3000 * 1000000
```

the computer assumes you want to multiply the Integer 3000 by the Integer 1000000; but the answer is too long to be an Integer, so the computer gripes (by saying "not representable in type 'Integer'"). Multiplying 3000 by 1000000 is okay if you say the numbers are Longs, not Integers, like this:

```
        Text = 3000L & 1000000L
```

Then the computer will show the correct answer:

```
3000000000
```

Double A **Double** is a number from 0 to 1E308 (which is a "1 followed by 308 zeros"), with maybe a negative sign and a decimal point. After the decimal point, you can have as many digits as you wish. For example, these numbers can all be Double:

```
0  1  2  3  4.99  4.9995  4.999527  1000.236  26127.85  1E308
0 -1 -2 -3 -4.99 -4.9995 -4.999527 -1000.236 -26127.85 -1E308
```

The computer manages to store a Double rather briefly (just 8 bytes) by "cheating": **the computer stores the number just approximately, to an accuracy of about 15 significant digits**.

For example, if you say —

```
        Dim x As Double
        x = 100 / 3
        Text = 100 / 3
```

the computer will show 15 digits:

```
33.3333333333333
```

If you say —

```
        Dim x As Double
        x = 1000000.000000269
        Text = x
```

the computer will round to 15 digits and show:

```
1000000.00000027
```

When handling Double variables, the computer can give inaccurate results. The inaccuracy is especially noticeable if you do a subtraction where the two numbers nearly equal each other. For example, if you say —

```
        Dim x, y As Double
        x = 8000.1
        y = x - 8000
        Text = y
```

the computer will make x be *approximately* 8000.1, so y will be *approximately* .1. The Print line will print:

```
0.100000000000364
```

Notice that the last few digits are wrong! That's the drawback of Double: you can't trust the last few digits of the answer! Double is accurate enough for most scientists, engineers, and statisticians, since they realize all measurements of the real world are just approximations; but Double is *not* good enough for accountants who fret over every penny. Double's errors drive accountants bananas. **For accounting problems that involve decimals, consider using Decimal instead of Double**, since Decimal is always accurate, though slower.

Technical notes:

> A Double can be slightly bigger than 1E308. The biggest permissible Double is actually 1.7976931348623157E308.
>
> If a Double is at least a quadrillion (which is 1000000000000000) or tiny (less than .0001), the computer will display it by using E notation.
>
> When you type a Double in your subroutine, the computer stores the first 16 significant digits accurately, stores an approximation of the 17th significant digit, and ignores the rest.
>
> If you type a number that has no decimal point and no E, the computer will think you're trying to type an Integer or a Long; and if it has many digits, the computer will complain that a Long is not allowed to have so many digits. To correct the problem, indicate you're trying to type a Double, by putting .0 at the end of the number or using E notation.
>
> When the computer displays an answer, it displays the first 15 significant digits and hides the rest, since it knows the rest are unreliable. For example, if you set Text equal to the biggest number (1.7976931348623157E308), the computer will display it rounded to 15 digits, so it will display 1.79769313486232E308.
>
> The tiniest decimal the computer can handle accurately is 1E-308 (which is a decimal point followed by 308 digits, 307 of which are zeros). If you try to go tinier, the computer will give you a rough approximation. The tiniest permissible Double is 4.9406564584126544E-324; if you try to go tinier than that, the computer will say 0.

Decimal If you say "Dim x as **Decimal**" (instead of "Dim x as Double", the computer will store x very accurately (28 digits, and sometimes a 29th). **The computer handles Decimals slower than any other kind of number**, so say "Dim x as Decimal" just if you need extra accuracy and don't care about speed.

If you say "Dim x as Decimal", the computer actually stores all x's digits as an extra-long integer and also stores a note about where the decimal point belongs.

To write a Decimal number, put D after the number, to emphasize that the number is a Decimal, not a Double, like this:

```
Dim x As Decimal
x = 1000000.000000269D
```

The biggest permissible Decimal is 79228162514264337593543950335D (which has 29 digits and no decimal point). The tiniest permissible Decimal is 0.00000000000000000000000000001D (which has 27 zeros after the decimal point).

A Decimal number cannot contain E. It's limited to 28 (or 29) digits. When counting how many digits are in the number, you must count the zeros: the limit is indeed 28 (or 29) digits (not 28 "significant digits").

Date A **Date** is a date with time. For example, these lines make x be December 31, 2009, at 30 seconds after 11:59 PM:

```
Dim x As Date
x = #12/31/2009 11:59:30 PM#
Text = x
```

Notice you must put the symbol # before and after the date-with-time. The computer will print:

```
12/31/2009 11:59:30 PM
```

For the year, you can pick 2009 or 1999 or 1776 or 1492 or even earlier. You can pick any year from 1 (which was shortly after Christ) to 9999 (which is many centuries from now). If you type a 2-digit year, the computer will put "20" before your typing, to make a 4-digit year (unless your 2-digit year is at least 30, in which case the computer will put "19" before your typing instead).

You can omit any part of the date-and-time that doesn't interest you. For example, if you don't care about the seconds, leave them out. If you don't care about the time-of-day, leave it out and type just the date; if you don't care about the date, leave it out and type just the time of day.

The computer makes assumptions:

If you leave out the time of day, the computer assumes you mean the day's beginning (which is midnight, 12:00:00 AM).

If you leave out the date, the computer assumes you mean the beginning of modern times (which is January 1 in the year 1).

To avoid pissing off people who don't like those assumptions, the computer avoids displaying 12:00:00 AM and avoids displaying 1/1/1. For example, if you leave out the time of day and type this —

```
Dim x As Date
x = #12/31/2009#
Text = x
```

x will be #12/31/2009 12:00:00 AM# but the computer will display just:

```
12/31/2009
```

If you leave out the date and type this —

```
Dim x As Date
x = #11:59:30 PM#
Text = x
```

x will be #1/1/1 11:59:30 PM# but the computer will display just:

```
11:59:30 PM
```

If you say —

```
x = Now
```

the computer will make x be the current date-with-time. For example, if the computer encounters that line while running the program on December 31, 2009 (at 30.16 seconds after 11:59 PM), x will become #12/31/2009 11:59:30 PM#.

Boolean A **Boolean** is either the word True or the word False. Here's an example:

```
Dim x As Boolean
x = True
Text = x
```

The computer will display:

```
True
```

Here's another example:

```
Dim x As Boolean
x = False
Text = x
```

The computer will display:

```
False
```

Technical notes:

If you say "Dim x As Boolean" and then try to say "x = 0", the computer will make x be False.

If you say "Dim x As Boolean" and then try to say "x = 1" (or say that x is any other non-zero number), the computer will make x be True.

It's called "Boolean" to honor George Boole (the 19th-century mathematician who discovered that the word False acts like the number 0, and True acts like the number 1).

String A **String** is a collection of characters, such as "joy" or "I love you" or "aieee luf ya" or "76 trombones" or "GO AWAY!!!" or "xypw exr///746". Here's an example:

```
Dim x As String
x = "joy"
Text = x
```

The computer will display:

```
joy
```

Versions of Visual Basic before 2005 used a code called the **American Standard Code for Information Interchange (Ascii)**, which consumed just 1 byte per character; but Visual Basic 2005, 2008, 2010, 2012, 2013, and 2015 use a different code instead, called **Unicode**, which uses 2 bytes per character, to permit fancier characters for foreign languages.

Since the string "joy" contains 3 characters, and each character consumes 2 bytes, x consumes 6 bytes of RAM — plus 10 bytes to remember how long the string is. So altogether, x consumes 16 bytes of RAM.

If you say "Dim x As String" and try to say "x = 9 + 3.5", the computer will look at the equation's right side, realize it's 12.5, and try to make x be 12.5; but because of the "Dim x as String", the computer must turn x into a string, so x will become the string "12.5" (which is four characters long).

Character A **Char** is a single character, such as "j". It consumes just 2 bytes. To emphasize that "j" is just a single character, not "a string whose length is 1", write c after the "j", like this:

```
Dim x As Char
x = "j"c
Text = x
```

The computer will display:

```
j
```

So if x is a Char, the computer requires just 2 bytes to store it. (To store a String, the computer needs 2 bytes per character, plus 10 bytes to store the string's length; but to store a Char, the computer needs just 2 bytes, since the computer doesn't have to store a length.)

If you say —

```
Dim x As Char
x = "hat"
```

the x will be just the first character of the string "hat", so x will be just "h". Then if you say —

```
Text = x
```

the computer will display just:

```
h
```

Object You've learned that x can stand for a number, date, Boolean, string, or character.

Here's another possibility: x can stand for an **object**, such as Form1 or Button1 or any other VB thing, such as Color.Red.

For example, suppose you created a button called Button1. If you put this line in Form1's subroutine, Button1's title will become "Click me":

```
Button1.Title = "Click me"
```

These lines do the same thing:

```
Dim x As Object
x = Button1
x.Text = "Click me"
```

Saying "Dim x As Object" is vague. It has exactly the same meaning as "Dim x", which is vague. If you say "Dim x As Object" (or just "Dim x"), you're saying that x stands for a Windows object (such as Form1 or Button1) or some other kind of object (such as a number, date, Boolean, string, or character). The computer handles such an x slowly: it consumes 4 bytes to remember what part of the RAM holds x's details, plus several bytes to store the details.

Multiple variables

If you want x and y to be Integers, z to be a String, and temperature to be a Double, say this —

```
Dim x, y As Integer
Dim z As String
Dim temperature as Double
```

or say it all in one line:

```
Dim x, y As Integer, z As String, temperature As Double
```

Suffix

Here's the normal way to make x be a String:

```
Dim x As String
```

This way is shorter:

```
Dim x$
```

That dollar sign means "As String". The dollar sign is called a **suffix** (or **type-declaration character**).

You can use these suffixes:

Suffix	Meaning
$	As String
%	As Integer
&	As Long
#	As Double
@	As Decimal
!	As Single

Repeating the suffix Below the Dim line, you can type the suffix again if you wish. For example, after you've made x be a string by saying —

```
Dim x$
```

you can say either —

```
x = "I love you"
```

or this, which means the same thing:

```
x$ = "I love you"
```

The computer doesn't care whether you type the $ again. Type it just if you want to emphasize it to other programmers who look at your subroutine.

Constants

Your subroutine can mention variables (such as x and y) and constants (such as 3.7 and "I love you"). Here's how the computer tells a constant's type:

If the constant is the word True or the word False, it's a **Boolean**.

If the constant begins and ends with the symbol #, it's a **Date**.

If the constant is enclosed in quotation marks (such as "I love you"), it's a **String**, unless it has a c afterwards (such as "j"c), which makes it a **Char** (and is limited to just one character).

If the constant is a number, here's what happens.…

If the number has no decimal point and no E and is short (between -2147483648 and 2147483647), it's an **Integer**. If the number has no decimal point and no E and is between -9223372036854775808 and 9223372036854775807 but is not an Integer, it's a **Long**. Any other number is a **Double**.

To force a number to be a **Decimal** instead, put D (or @) after the number, like this: 4.95D

To force a number to be a **Long** (even though it's small enough to be an Integer), put L (or &) after the number, like this: 52L

To force a number to be a **Double** (even though it's simple enough to be an Integer or Long), put .0 after the number, like this: 52.0.

VarType

Each type of constant has a code number:

Type of constant	Code number
Integer	3
Long	20
Double	5
Decimal	14
Date	7
Boolean	11
String	8
Char	18
Object	9

If you say **VarType**, the computer will examine a constant and tell you its code number. For example, if you say —

```
Text = VarType(4.95D)
```

the computer will examine 4.95D, realize it's a Decimal, and say Decimal's code number, which is:

```
14
```

Here are more examples:

If you say Text = VarType ("I love you"), the computer will examine "I love you", realize it's a String, and print String's code number, which is 8.

If you say Text = VarType(2000000000), the computer will examine 2000000000, realize it's an Integer, and print Integer's code number, which is 3.

If you say Text = VarType(300000000), the computer will examine 300000000, realize it's a Long, and print Long's code number, which is 20.

VarType of a variable If you say VarType(x), the computer will notice what type of variable x is and print its code number. For example, if you say —

```
Dim x As Decimal
Text = VarType(x)
```

the computer will say Decimal's code number, which is 14.

If you say just "Dim x" (or "Dim x As Object") without specifying further details of x's type, VarType(x) will be whatever type the x acquires. For example, if you say —

```
Dim x
x = 4.95D
Type = VarType(x)
```

the computer will print Decimal's code number, which is 14.

TypeName

If you say **TypeName** instead of **VarType**, the computer will say the type's name instead of its code number.

For example, if you say —

```
Text = TypeName(4.95D)
```

the computer will say:

```
Decimal
```

Instead of saying "Object" (or "Nothing"), the computer will try to be more specific. For example, if you created a command button called Button1 and say —

```
Text = TypeName(Button1)
```

the computer will say:

```
Button
```

If x is an Object but doesn't have a more specific value or type yet, "Text = TypeName(x)" will make the computer say:

```
Nothing
```

Initial value

Instead of saying —

```
Dim x As Integer
x = 7
```

you can combine those two lines into this single line:

```
Dim x As Integer = 7
```

In that line, 7 is called x's **initial value** (or **initializer**), because it's what x is initially (in the beginning).

You can shorten that line further, by saying just this:

```
Dim x = 7
```

Since 7 is an Integer (according to the rules about which constants are Integers), the computer will assume you also mean "x As Integer". If you say this instead —

```
Dim x = 7.0
```

the computer will assume you mean "x As Double".

Saying "Dim x = 5" has a slightly different effect than saying "Dim x" then "x = 5".Compare these subroutines:

```
Dim x
x = 5
x = 8.4
Text = x
```

```
Dim x = 5
x = 8.4
Text = x
```

In the left subroutine, the Dim line says x is a vague variable (an object). The next line says x is 5. The next line changes x to 8.4, so Text will be 8.4. In the right-hand subroutine, the first line says x is 5 but also makes x be an integer variable (since that line implies "x As Integer"); since x is an integer variable, the next line makes x be 8 (not 8.4), so Text will be just 8.

Operations

When you do operations (add, subtract, multiply, divide, exponents, or beyond), here's what kind of answer you get.

Exponents When you do **exponents** (using the symbol "^"), the answer is a **Double**.

Division When you **divide** one number by another (using the symbol "/"), here's what happens:

If both numbers are Decimal, the answer is **Decimal**.

If one of the numbers is Single and the other is Single or Decimal, the answer is **Single**.

In all other situations, the answer is **Double**.

Add, subtract, multiply When you **add, subtract, or multiply** numbers (using the symbol + or - or *), here's what happens:

If both numbers are the same type, the computer makes the answer be **the same type**. (Exception: if both "numbers" are actually Boolean, the computer makes the answer be Short.)

If the numbers have different types from each other, and both types are **signed** (permit minus signs), the computer notices which type is **wider** (can handle more numbers) and makes the answer be that type. Here are the signed types, from narrowest to widest: SByte, Short, Integer, Long, Decimal, Single, Double. (Single is wider than Decimal because Single can handle higher powers of 10.) For example, if one number is an Integer and the other number is a Long, the answer is a Long (because Long is wider than Integer).

If the numbers have different types from each other, and at least one of those types is **unsigned** (Boolean, Byte, UShort, UInteger, or ULong), the computer makes the answer be the wider type — or a signed type that's even wider.

Advanced math Here's how the computer handles advanced math:

Math.PI and **Math.Sqrt**(x) are Double.

Math.Sign(x) is an Integer.

Math.Abs(x) and **Fix**(x) and **Int**(x) are the same type as x, if x's type is signed. If x's type is unsigned, the computer turns x into a wider signed number first.

Math.Ceiling(x) and **Math.Round**(x) are Double, if x is a Double or Single. They're Decimal if x is otherwise.

Combine When you combine strings or numbers (by using the symbol "&"), the answer is a string.

Form1 declarations

Normally, each subroutine has its own variables. For example, if Form1's subroutine uses a variable called x, and Button1's subroutine uses a variable that's also called x, Form1's x has nothing to do with Button1's x. Form1's x is stored in a different part of RAM from Button1's x. If Form1 says x = 5, Button1's x remains unaffected by that statement.

If you *want* Form1's x to be the same as Button1's x and use the same RAM, say "Dim x" *above* the "Private Sub Form1" line instead of below.

Example For example, try this experiment.…

Create a new program. Double-click Form1, so you can type Form1's subroutine. Your screen looks like this:

```
Public Class Form1
    Private Sub Form1_Load…

    End Sub
End Class
```

Click *above* the "Private Sub Form1" line and type "Dim x" there, so your screen looks like this:

```
Public Class Form1
    Dim x
    Private Sub Form1_Load…

    End Sub
End Class
```

Type Form1's subroutine under the "Private Sub Form1" line, like this:

```
Public Class Form1
    Dim x
    Private Sub Form1_Load…
        x = 5
    End Sub
End Class
```

Create Button1 (by clicking the "Form1.vb [Design]" tab then double-clicking the Button tool). Double-click Button1, then type "Text = x" for Button1's subroutine. Altogether, your screen looks like this:

```
Public Class Form1
    Dim x
    Private Sub Form1_Load…
        x = 5
    End Sub

    Private Sub Button1_Click…
        Text = x
    End Sub
End Class
```

Since the "Dim x" is *above* both subroutines (instead of being buried inside one subroutine), the x's value affects *both* subroutines (not just one of them).

When you run that program (by clicking "Start"), Form1's subroutine makes x be 5. Then when you click Button1, Button1's subroutine makes Text be x, which is 5, so the computer says:

```
5
```

Conversion functions

In the middle of a calculation, you can convert to a different type of data by using these conversion functions:

Function	Meaning
CInt	convert to Integer
CLng	convert to Long
CDbl	convert to Double
CDec	convert to Decimal
CDate	convert to Date
CBool	convert to Boolean
CStr	convert to String
CChar	convert to Char
CUInt	convert to UInteger
CULng	convert to ULong
CShort	convert to Short
CSByte	convert to SByte
CUShort	convert to UShort
CByte	convert to Byte
CSng	convert to Single
CObj	convert to Object

For example, CInt(3.9) is "3.9 converted to the nearest Integer", which is 4. If you say —

```
Text = CInt(3.9)
```

the computer will say:

```
4
```

If you say —

```
Text = CInt(3.9) + 2
```

the computer will say:

```
6
```

Arrays

Instead of being just a number, x can be a *list* of numbers.

Example For example, if you want x to be this list of numbers —

```
{81, 52, 207, 19}
```

type this in Form1's subroutine:

```
Dim x() = {81, 52, 207, 19}
```

In that line, the symbol "x()" means "x's list". Notice that when you type the list of numbers, you must **put commas between the numbers** and put the entire list of numbers in **braces**, {}. On your keyboard, the "{" symbol is to the right of the P key and requires you to hold down the Shift key.

Since all numbers in that list are Integers, you can improve that line by saying "As Integer", like this:

```
Dim x() As Integer = {81, 52, 207, 19}
```

If you don't say "As Integer", the computer will treat those numbers as just vague objects, and the program will run slower.

In x's list, **the starting number** (81) **is called x_0** (pronounced "x subscripted by zero" or "x sub 0" or just "x 0"). The next number (52) is called x_1 (pronounced "x subscripted by one" or "x sub 1" or just "x 1"). The next number is called x_2. Then comes x_3. So **the four numbers in the list are called x_0, x_1, x_2, and x_3**.

To make the computer say what x_2 is, type this line:

```
Text = x(2)
```

That line makes Text be x_2, which is 207, so the computer will say:

```
207
```

Altogether, the subroutine says:

```
Dim x() As Integer = {81, 52, 207, 19}
Text = x(2)
```

The first line says x's list is these Integers: 81, 52, 207, and 19. The bottom line makes the computer say x_2's number, which is 207.

This subroutine makes the computer say x_2's number (which is 207) in a message box:

```
Dim x() As Integer = {81, 52, 207, 19}
MsgBox(x(2))
```

This subroutine makes the computer say all 4 numbers:

```
Dim x() As Integer = {81, 52, 207, 19}
For i = 1 To 4
    MsgBox(x(i))
Next
```

That makes the computer say the numbers for x(1), x(2), x(3), and x(4), so the computer will say 81, 52, 207, and 19.

Here's a shorter way to make the computer say all 4 numbers:

```
Dim x() As Integer = {81, 52, 207, 19}
For Each i In x
    MsgBox(i)
Next
```

That makes x's list be {81, 52, 207, 19}, makes i be **Each number In x** (so i is 81, then 52, then 207, then 19), and makes the computer say each i.

Longer lists Instead of having just 4 numbers in the list, you can have 5 numbers, or 6 numbers, or a thousand numbers, or many billions of numbers. The list can be quite long! Your only limit is how much RAM your computer has.

Jargon Notice this jargon:

In a symbol such as x_2, the lowered number (the 2) is called the **subscript**.

To create a subscript in your subroutine, use parentheses. For example, to create x_2, type x(2).

A variable having subscripts is called an **array**. For example, x is an array if there's an x_0, x_1, x_2, etc.

Different types Instead of having Integers, you can have different types. For example, you can say:

```
Dim x() As Double = {81.2, 51.7, 207.9, 19.5}
```

You can even say:

```
Dim x() As String = {"love", "hate", "peace", "war"}
```

You can even have mixed types:

```
Dim x() = {5, 91.3, "turkey", #11:59:30 PM#}
```

Uninitialized Instead of making the Dim line include a list of numbers, you can type the numbers underneath, if you warn the computer how many numbers will be in the list, like this:

```
Dim x(2) As Double
x(0) = 200.1
x(1) = 700.4
x(2) = 53.2
Text = x(0) + x(1) + x(2)
```

The top line says x_0, x_1, and x_2 will be Doubles. The next lines say x_0 is 200.1, x_1 is 700.4, and x_2 is 53.2. The bottom line makes the computer say their sum:

```
953.7
```

In that top line, if you omit the "As Double", the program will give the same answer but slower. But in that top line, the 2 is required, to warn the computer how many subscripts to reserve RAM for; if you omit the 2 (or type a lower number instead), the computer will gripe.

Random numbers

Usually, the computer is predictable: it does exactly what you say. But sometimes, you want the computer to be *un*predictable.

For example, if you're going to play a game of cards with the computer and tell the computer to deal, you want the cards dealt to be unpredictable. If the cards were predictable — if you could figure out exactly which cards you and the computer would be dealt — the game would be boring.

In many other games too, you want the computer to be unpredictable, to "surprise" you. Without an element of surprise, the game would be boring.

Being unpredictable increases the pleasure you derive from games — and from art. To make the computer act artistic, and create a new *original* masterpiece that's a "work of art", you need a way to make the computer get a "flash of inspiration". Flashes of inspiration aren't predictable: they're surprises.

Here's how to make the computer act unpredictably.…

Rnd is a RaNDom decimal (bigger than 0 and less than 1) whose data type is Single. For example, it might be .6273649 or .9241587 or .2632801. Every time your program mentions Rnd, the computer concocts another decimal. For example, if Form1's subroutine says —

```
MsgBox(Rnd)
MsgBox(Rnd)
MsgBox(Rnd)
```

the computer says these decimals:

```
.7055475
.533424
.5795186
```

The first time your program mentions Rnd, the computer chooses its favorite decimal, which is .7055475. Each succeeding time your program mentions Rnd, the computer uses the previous decimal to concoct a new one. It uses .7055475 to concoct .533424, which it uses to concoct .5795186. The process by which the computer concocts each new decimal from the previous one is weird enough so we humans cannot detect any pattern.

These lines make the computer say 16 decimals:

```
For i = 1 To 16
    MsgBox(Rnd)
Next
```

You can say either Rnd or Rnd(); the computer doesn't care. If you say just Rnd, the computer might change it to Rnd().

Percentages

When the computer says random decimals, about half the decimals will be less than .5, and about half will be more than .5.

Most of the decimals will be less than .9. In fact, about 90% will be.

About 36% of the decimals will be less than .36; 59% will be less than .59; 99% will be less than .99; 2% will be less than .02; a quarter of them will be less than .25; etc.

You might see some decimal twice, though most of the decimals will be different from each other.

Randomize

If you run a program about Rnd again, you'll see exactly the same decimals again, in the same order.

If you'd rather see a different list of decimals, say **Randomize()** at the subroutine's top:

```
Randomize()
For i = 1 To 16
    MsgBox(Rnd)
Next
```

When the computer sees Randomize(), the computer looks at the clock and manipulates the time's digits to produce the first value of Rnd.

So the first value of Rnd will be a number that depends on the time of day, instead of the usual .7055475. Since the first value of Rnd will be different than usual, so will the second, and so will the rest of the list.

Every time you run the program, the clock will be different, so the first value of Rnd will be different, so the whole list will be different — unless you run the program at exactly the same time the next day, when the clock is the same. But since the clock is accurate to a tiny fraction of a second, the chance of hitting the same time is extremely unlikely.

Coin flipping

Here's how to make the computer flip a coin:

```
Randomize()
If Rnd < 0.5 Then MsgBox("heads") Else MsgBox( "tails")
```

The Randomize line makes the value of Rnd depend on the click. The If line says there's a 50% chance that the computer will print "heads"; if the computer does *not* print "heads", it will print "tails".

When you've typed that subroutine, the computer changes Rnd to Rnd(), so it looks like this:

```
Randomize()
If Rnd() < 0.5 Then MsgBox("heads") Else MsgBox( "tails")
```

Until you run the program, you won't know which way the coin will flip; the choice is random. Each time you run the program, the computer will flip the coin again; each time, the outcome is unpredictable. Try running it several times!

To write that subroutine shorter, say IIf:

```
Randomize()
MsgBox(IIf(Rnd() < 0.5, "heads", "tails"))
```

The bottom line creates a message box saying this: if the random number is less than .5, then "heads", else "tails".

This subroutine flips the coin 10 times:

```
Randomize()
For i = 1 To 10
    MsgBox(IIf(Rnd() < 0.5, "heads", "tails"))
Next
```

Love or hate?

Who loves ya, baby? These lines try to answer that question:

```
Randomize()
Dim x As String
x = InputBox("Type the name of someone you love")
If Rnd < 0.67 Then
    MsgBox(x & " loves you, too")
Else
    MsgBox(x & " hates your guts")
End If
```

The Randomize() line makes the value of Rnd depend on the clock. The Dim line says x will be a variable that stands for a String. The InputBox line makes the computer wait for the human to type a name. Suppose he types Suzy. Then x is "Suzy". The If line says there's a 67% chance the computer will say "Suzy loves you, too", but there's a 33% chance the computer will instead say "Suzy hates your guts".

Try running the program several times. Each time, input a different person's name. Find out which people love you and which people hate your guts — according to the computer!

Here's a shorter way to write that subroutine:

```
Randomize()
Dim x = InputBox("Type the name of someone you love")
MsgBox(x & IIf(Rnd < .67, " loves you, too", " hates your guts"))
```

The Randomize() line makes the value of Rnd depend on the clock. The Dim line makes the variable x be the response to "Type the name of someone you love". The MsgBox line creates a message box that says x then this: if the random number is less than .67 then " loves you, too" else " hates your guts".

Random integers

If you want a random integer from 1 to 10, ask for 1 + Int(Rnd * 10). Here's why:

```
Rnd is a decimal, bigger than 0 and less than 1.
So Rnd * 10 is a decimal, bigger than 0 and less than 10.
So Int(Rnd * 10) is an integer, at least 0 and no more than 9.
So 1 + Int(Rnd * 10) is an integer, at least 1 and no more than 10.
```

Guessing game These lines play a guessing game:

```
       Randomize()
       MsgBox("I'm thinking of a number from 1 to 10.")
       Dim ComputerNumber = 1 + Int(Rnd * 10)
AskHuman: Dim guess = Val(InputBox("What do you think my number is?"))
       If guess < ComputerNumber Then MsgBox("Your guess is too low."): GoTo AskHuman
       If guess > ComputerNumber Then MsgBox("Your guess is too high."): GoTo AskHuman
       MsgBox("Congratulations! You found my number!")
```

The second line makes the computer say "I'm thinking of a number from 1 to 10." The next line makes the computer think of a random number from 1 to 10. The InputBox line asks the human to guess the number.

If the guess is less than the computer's number, the first If line makes the computer say "Your guess is too low" and then GoTo AskHuman, which lets the human guess again. If the guess is *greater* than the computer's number, the second If line makes the computer say "Your guess is too high" and then GoTo AskHuman.

When the human guesses correctly, the computer arrives at the bottom line, which makes the computer say:

```
Congratulations! You found my number!
```

Dice These lines make the computer roll a pair of dice:

```
       Randomize()
       MsgBox("I'm rolling a pair of dice")
       Dim a = 1 + Int(Rnd * 6)
       MsgBox("One of the dice says " & a)
       Dim b = 1 + Int(Rnd * 6)
       MsgBox("The other says " & b)
       MsgBox("The total is " & a + b)
```

The second line makes the computer say:

```
I'm rolling a pair of dice
```

Each of the dice has 6 sides. The next line, Dim a = 1 + Int(Rnd * 6), rolls one of the dice, by picking a number from 1 to 6. The line saying "b = 1 + Int(Rnd * 6)" rolls the other. The bottom line says the total.

For example, a run might say these sentences:

```
I'm rolling a pair of dice
One of the dice says 3
The other says 5
The total is 8
```

Here's another run:

```
I'm rolling a pair of dice
One of the dice says 6
The other says 4
The total is 10
```

Daily horoscope These lines predict what will happen to you today:

```
Randomize()
Dim x() = {"wonderful", "fairly good", "so-so", "fairly bad", "terrible"}
MsgBox("You will have a " & x(Int(Rnd * 5)) & " day today!")
```

The Dim line makes x be a list of 5 fortunes, so x_0 is "wonderful", x_1 is "fairly good", x_2 is "so-so", x_3 is "fairly bad", and x_4 is "terrible". Since Int(Rnd * 5) is a random integer from 0 to 4, the x(Int(Rnd * 5)) is a randomly chosen fortune. The computer will say —

```
You will have a wonderful day today!
```

or —

```
You will have a terrible day today!
```

or some in-between comment.

For inspiration, run that program when you get up in the morning. Then notice whether your day turns out the way the computer predicts!

Python

Python is a computer language that resembles Basic. It tries to be even easier to learn than Basic, though in some ways it's harder.

Python is considered to be modern; Basic is considered to be old-fashioned. Many colleges teach students to program in Python instead of Basic.

Python was invented by a Dutchman, Guido van Rossum, in December 1989, as a hobby, to keep himself busy while his office was closed for Christmas vacation. He called it "Python" to honor the British comedy group **Monty Python's Flying Circus**. In October 2000 he invented an improved version, **Python 2**. In December 2008, he invented a further improvement, **Python 3**.

This chapter explains the current version, Python 3.4.3, which is a slight improvement on Python 3.

In your Python program, you can put these **commands** —

Command	What the computer will do	Page
`break`	break out of the "while" loop, stop repeating that loop	616
`elif age<100:`	do the indented lines when earlier conditions false and age<100	612
`else:`	do the indented lines when "if" conditions are false	611
`for x in range(20):`	repeat the indented lines, for x being 0 through 19 (less than 20)	614
`if age<18:`	do the indented lines if age<18	611
`if age==18:`	do the indented lines if age is 18	612
`if age!=18:`	do the indented lines if age is not 18	612
`while True:`	do the indented lines repeatedly	613
`x=2`	make x be 2	607
`x+=2`	make x increase by 2	608
`x-=2`	make x decrease by 2	608
`#Zoo is fishy`	ignore this comment	607

and these **functions** (which have parentheses):

Function	Value	Page
`eval(input('What number? '))`	whatever number the human will input	610
`input('What is your name? ')`	whatever name the human will input	609
`int(input('What number? ')`	whatever integer the human will input	610
`float(input('What number? ')`	the number the human will input, with decimal	610
`print('I love you')`	'I love you' will print onto the computer's screen	605
`print(2+2)`	4 will print onto the computer's screen	605
`range(20)`	the numbers less than 20 (0 through 19)	614

Fun

Let's have fun programming in Python! If you have any difficulty, phone me at 603-666-6644 (day or night) for free help.

Get Python

Here's how to copy Python (version 3.5.1) from the Internet to a Windows 10 computer, free (using Microsoft Edge).

Go to:

```
Python.org/ftp/python/3.5.1/python-3.5.1-qme64-webinstall.exe
```

Tap the "Run" button then "Install Now" then "Yes". The computer will say "Installing" then "Setup was successful." Tap "Close". Close the Internet Explorer window (by clicking its X button).

Start Python

To start Python (version 3.5.1), your first step is to tap "IDLE" by choosing one of these methods:

Search-box method In the search box (which is next to the Windows Start button), type "idle" then tap "IDLE (Python 3.5 64-bit): Desktop app".

Start-button method Tap the Windows Start button then "All apps". If you see "IDLE" (under "Recently added"), tap it; otherwise, tap "Python 3.5" (which you'll see at the screen's left edge when you scroll down or when you tap "0-9" then "P") then tap "IDLE".

You see the **Python Shell window**, which is also called Python's **Integrated DeveLopment Environment (IDLE)**.

Math

In the Python Shell window, you see this Python prompt:

```
>>>
```

To the right of that prompt, you can type any Python command. For example, you can type 4+2, so the screen looks like this:

```
>>> 4+2
```

Try doing that: type 4+2.

After typing 4+2, press the Enter key. The Enter key makes the computer read what you typed and reply to it. The computer will reply by typing the answer, 6, like this:

```
6
```

So your screen looks like this:

```
>>> 4+2
6
```

Below that, the computer shows the Python prompt again, so your screen looks like this –

```
>>> 4+2
6
>>>
```

and you can give another command.

If you want to subtract 3 from 7, type 7-3, so your screen looks like this:

```
>>> 7-3
```

When you press the Enter key at the end of that line, the computer will reply:

```
4
```

You can use decimal points and negative numbers. For example, if you type -26.3+1, the computer will say:

```
-25.3
```

Multiplication To multiply, use an asterisk. So to multiply 2 by 6, type this:

```
>>> 2*6
```

The computer will say:

```
12
```

Division To divide, use a slash. So to divide 8 by 4, type this:

```
>>> 8/4
```

Instead of saying the answer is 2, the computer will say —

```
2.0
```

because **whenever the computer divides, its answer includes a decimal point**.

If you try to divide by 0 (by giving a command such as 3/0 or 0/0), the computer will refuse: it will say "ZeroDivisionError".

Last digit might be wrong To divide 5 by 3, type this:

```
>>> 5/3
```

The computer will say:

```
1.6666666666666667
```

In that example, the computer gave the right answer, rounded to 17 digits. But in other calculations that have a decimal answer, the computer might accidentally say the last digit wrong. For example, suppose you say to divide 7 by 3, like this:

```
>>> 7/3
```

The computer will accidentally say:

```
2.3333333333333335
```

In that answer, the 5 should be 3 instead. Moral: **when Python makes the computer give a long decimal answer, don't trust its last digit!** (I hope Python's future versions hide that error, by showing just the 16 reliable digits and hiding the 17th digit.)

To see an even scarier example, type this:

```
>>> .1+.2
```

The answer should be simply .3, but Python makes the computer say this:

```
.30000000000000004
```

The last digit, the 17th, should be 0, not 4.

Avoid commas Do *not* put commas in big numbers. To write four million, do *not* write 4,000,000; instead, write 4000000.

E notation If the computer's answer is tiny (less than .0001) or "a huge number containing a decimal point" (at least 10000000000000000.0), the computer will put an e in the answer. The e means "move the decimal point".

For example, suppose the computer says the answer to a problem is:

```
1.3586281902638497e+18
```

The e means "move the decimal point". The plus sign means, "toward the right". Altogether, the **e+18 means "move the decimal point toward the right, 18 places."** So look at 1.3586281902638497 and move the decimal point toward the right, 18 places; you get —

```
1358628190263849700.
```

which has the same meaning as:

```
1358628190263849700.0
```

So when the computer says the answer is 1.3586281902638497e+18, the computer really means the answer is 1358628190263849700.0, approximately. Since you can't trust the computer's last digit (the 7) and the zeros that belong after it, the exact answer might be 1358628190263849700.2 or 1358628190263849700.29 or 1358628190263849800.0 or some similar number, but the computer says just an approximation.

Suppose your computer says the answer to a problem is:

```
9.23e-06
```

After the e, the minus sign means, "towards the *left*". So look at 9.23 and move the decimal point towards the left, 6 places. You get:

.00000923

So when the computer says the answer is 9.23e-06, the computer really means the answer is:

.00000923

You'll see e notation rarely: the computer uses it just if an answer involves decimals and tinier than .0001 or huge (at least 10 quadrillion). But when the computer *does* use e notation, remember to move the decimal point!

The highest number The highest number the computer can handle well is about 1e308, which is 1 followed by 308 zeros then a decimal point. If you try to go much higher, the computer will gripe by saying —

```
inf
```

which means "infinity".

The tiniest decimal The tiniest decimal the computer can handle well is about 1e-323, which is a decimal point followed by 323 digits (322 zeros then 1). If you try to go much tinier, the computer will give up and say just:

```
0.0
```

Order of operations What does "2 plus 3 times 4" mean? The answer depends on whom you ask.

To a clerk, it means "start with 2 plus 3, then multiply by 4"; that makes 5 times 4, which is 20. But to a scientist, "2 plus 3 times 4" means something different: it means "2 plus three fours", which is 2+4+4+4, which is 14.

Since computers were invented by scientists, computers think like scientists. If you type —

```
>>> 2+3*4
```

the computer will think you mean "2 plus three fours", so it will do 2+4+4+4 and say this answer:

```
14
```

The computer will *not* print the clerk's answer, which is 20. So if you're a clerk, tough luck!

Scientists and computers follow this rule: **do multiplication and division before addition and subtraction**. So if you type —

```
>>> 2+3*4
```

the computer begins by hunting for multiplication and division. When it finds the multiplication sign between the 3 and the 4, it multiplies 3 by 4 and gets 12, like this:

```
>>> 2+3*4
        \/
        12
```

So the problem becomes 2+12, which is 14, which the computer prints.

For another example, suppose you type:

```
>>> 10-2*3+72/9*5
```

The computer begins by doing all the multiplications and divisions. So it does 2*3 (which is 6) and does 72/9*5 (which is 8.0*5, which is 40.0), like this:

```
>>> 10-2*3+72/9*5
          \/  \/
          6   40.0
```

So the problem becomes 10-6+40.0, which is 44.0, which is the answer the computer says:

```
44.0
```

You can use parentheses the same way as in algebra. For example, if you type —

```
>>> 5-(1+1)
```

the computer will compute 5-2 and say:

```
3
```

You can put parentheses inside parentheses. If you type —

```
>>> 10-(5-(1+1))
```

the computer will compute 10-(5-2), which is 10-3, and will say:

```
7
```

Strings

Let's make the computer fall in love. Let's make it say, 'I love you'.

To do that, type 'I love you', beginning and ending with a **single-quote mark** (which is the same mark as an apostrophe), so your screen looks like this:

```
>>> 'I love you'
```

At the end of that typing, when you press the Enter key, the computer will obey your command: it will say:

```
'I love you'
```

You can change the computer's personality. For example, if you give this command —

```
>>> 'I hate you'
```

the computer will reply:

```
'I hate you'
```

Notice that **to make the computer say a message, you must put the message between single-quote marks**. The single-quote marks make the computer copy the message without worrying about what the message means. For example, if you misspell 'I love you' and type —

```
>>> 'aieee luf ya'
```
the computer will still copy the message (without worrying about what it means); the computer will say:
```
'aieee luf ya'
```

Jargon The word 'joy' consists of 3 characters: j and o and y. Programmers say that the word 'joy' is a **string** of 3 characters.

A **string** is any collection of characters, such as 'joy' or 'I love you' or 'aieee luf ya' or '76 trombones' or 'GO AWAY!!!' or 'xypw exr///746'. The computer will say whatever string you wish, but remember to **put the string in single-quote marks**.

Strings versus numbers The computer can handle two types of expressions: **strings** and **numbers**. Put strings (such as 'joy' and 'I love you') in single-quote marks. Numbers (such as 4+2) do *not* go in single-quote marks.

Accidents Suppose you accidentally put the number 2+2 in single-quote marks, like this:
```
>>> '2+2'
```
The single-quote marks make the computer think '2+2' is a string instead of a number. Since the computer thinks '2+2' is a string, it copies the string without analyzing what it means; the computer will say:
```
'2+2'
```
It will *not* say 4.

Suppose you want the computer to say the word 'love' but you accidentally forget to put the string 'love' in single-quote marks. You accidentally type this instead:
```
>>> love
```
Since you forget to type the single-quote marks, the computer will try to figure out what you mean but will get confused, since it doesn't know the meaning of love. Whenever the computer gets confused, it gripes by saying you have a "NameError" or "SyntaxError".

String arithmetic You can add strings. For example, 'fat'+'her' is 'father'. So if you type —
```
>>> 'fat'+'her'
```
the computer will say:
```
'father'
```
You can multiply a string by a number. For example, 'fat' multiplied by 3 is 'fatfatfat'. So if you type —
```
>>> 'fat'*3
```
the computer will say:
```
'fatfatfat'
```
If you prefer, write the number *before* the string, like this:
```
>>> 3*'fat'
```
The computer will still say:
```
'fatfatfat'
```

Print

If you say **print**, the computer will print onto your screen more briefly.

For example, if you say —
```
>>> print('I love you')
```
The computer will print this onto your screen:
```
I love you
```
The computer will *not* print single-quote marks around that reply.

After the word **print**, you must type a **parenthesis**. If you forget to type the parenthesis and put a blank space instead, the computer will say "SyntaxError: Missing parentheses".

If you say —
```
>>> print('love',2+2,'you')
```
the computer prints the results of 'love' and 2+2 and 'you', all on the same line of your screen but separated by spaces, like this:
```
love 4 you
```
Yes, the computer produces love 4 you.

This command makes the computer do 6+2, 6-2, 6*2, and 6/2, all at once:
```
>>> print(6+2,6-2,6*2,6/2)
```
That makes the computer print the four answers, all on the same line:
```
8 4 12 3.0
```
The computer puts spaces between the answers.

Create a program

Here's how to create a Python program.

At the top of the Python Shell window, you see this menu:
```
File Edit Shell Debug Options Window Help
```
Click "File" then "New File".

You see the **program window**, called "Untitled". The program window is empty: it doesn't contain any >>> prompt.

The program window partly covers up the Python Shell window. To make programming easier, **drag the word "Untitled" toward the right**; as you do so, the entire program window moves toward the right. Keep dragging toward the right until the program window no longer overlaps the Python Shell window. (If your screen isn't wide enough to accomplish that, just drag as far as possible.)

In the program window, type your program. For example, let's type a program that makes the computer say:
```
make your nose
touch your toes
```
To do that, type this program:
```
print('make your nose')
print('touch your toes')
```
At the end of each line, press the Enter key.

When you've done all that, click "File" then "Save". Invent a name for your program, such as Joe; type the name then press the Enter key. That makes the computer copy the program to your hard disk. (If you're using Python 3.5.1, the program will be in your hard disk's Python35 folder. If you named the program Joe, the program's name will actually be Joe.py, because the computer automatically puts ".py" at the end of the program's name. The ".py" means "written in Python".)

To run the program, tap the F5 key. (Exception: if the "F5" is blue or tiny or on a new computer by Microsoft, HP, Lenovo, or Toshiba, tap that key *while holding down the blue Fn key*, which is left of the Space bar.) Then, in the Python Shell window, you see the result of the program running, so you see:
```
make your nose
touch you toes
```
That writing is called the program's **output**, since it's what the program puts out.

Above the output, you see "RESTART". Above and below the output, you see the >>> prompt, so you can give another Python command.

If you want to edit the program you wrote, **click in the program window** (which is to the right of the Python Shell window or at least peeks out behind the the Python Shell window) or do this in the Program Shell window:

Click "Window" then your program's name (such as "Joe.py".

You see your program again. Make whatever changes you wish, then save the program again (by clicking "File" then "Save"), then run the program (by tapping the F5 key).

To see an old program you created, go to the Python Shell window then click "File" then "Open" then double-click the program's name. You see the program's lines. To run the program, tap the F5 key.

Warning: **in a normal program, you must say print**. For example, to make a program say the answer to 2+2, you can't type just 2+2; instead the program must say:
```
print(2+2)
```
Saying just 2+2 is okay next to the >>> prompt, which means you're in **interactive mode**, not in a program.

Polite versus fast To run a Python program, you must save it first. I showed you the **polite** way to do Python: save the program (by clicking "File" then "Save") then run the program (by tapping the F5 key).

Here's the **faster** way to run a Python program: tap the F5 key (which means you want to run the program), then watch the computer yell at you (for not saving the program first), then press the Enter key (which means you agree to save it). That's impolite (so you get yelled at), but it's faster than clicking "File" then "Save".

Finish

When you finish using Python, close all windows (by clicking their X buttons).

Tricky printing

Printing can be tricky! Here are the tricks.

Indenting Suppose you want the computer to print this letter onto your screen:

```
Dear Joan,
  Thank you for the beautiful
necktie.  Just one problem--
I do not wear neckties!
              Love,
              Fred-the-Hippie
```

This program prints it:

```
print('Dear Joan,')
print('  Thank you for the beautiful')
print('necktie.  Just one problem—')
print('I do not wear neckties!')
print('              Love,')
print('              Fred-the-Hippie')
```

In the program, each line contains 2 single-quote marks. **To make the computer indent a line, put blank spaces AFTER the first single-quote mark.**

Blank lines Life consists sometimes of joy, sometimes of sorrow, and sometimes of a numb emptiness. To express those feelings, run this program:

Program	**What the computer will do**
`print('joy')`	print 'joy'
`print()`	print a blank empty line, under 'joy'
`print('sorrow')`	print "sorrow"

Altogether, the computer will print:

```
joy

sorrow
```

Apostrophe An apostrophe is this symbol:

```
'
```

Many words contain apostrophes:

```
can't  don't  won't  ain't  I'll  I'd  I've  I'm
Jack's  O'Doole  gov't  '60s  it's  let's  Qur'an
```

To put an apostrophe in a string's middle, use one of these tricks:

Backslash trick Type a backslash before the apostrophe.

Double-quote trick Enclose the string in double-quote marks instead of single-quote marks.

For example, suppose you want the computer to say:

```
We've gone to Jack's house
```

This does *not* work:

```
>>> print('We've gone to Jack's house')
```

Instead, you must use the backslash trick (putting a backslash before each apostrophe) —

```
>>> print('We\'ve gone to Jack\'s house')
```

or the double-quote trick (putting the string in double-quote marks instead of single-quote marks):

```
>>> print("We've gone to Jack's house")
```

If you use the backslash trick, make sure you type a backslash (\), not a forward slash (/). The backslash key is *above* the Enter key.

New line In a string, **\n** means "create a **new line**". For example, if you type —

```
>>> print('Love\nDeath')
```

the computer will print the word Love, then create a new line (by pressing the Enter key), then print the word Death, so you see this:

```
Love
Death
```

That's how to make one print statement print 2 lines.

Separator If you say —

```
>>> print('he','art','be','at')
```

the computer will print the 4 words and put blank spaces between them, like this:

```
he art be at
```

If instead you say —

```
>>> print('he','art','be','at',sep='!')
```

the computer will print the 4 words and **sep**arate them with exclamation points instead of spaces, so you see this:

```
he!art!be!at
```

That's because sep='!' means "the **sep**arator is an exclamation point".

If instead you say —

```
>>> print('he','art','be','at',sep='')
```

The computer will print those 4 words and separate them with nothing, so you see this:

```
heartbeat
```

If instead you say —

```
>>> print('the boy','the dog','the car',sep=' who chased ')
```

the computer will print:

```
the boy who chased the dog who chased the car
```

End In your program, if you say —

```
print('fat')
print('her')
```

the computer will print 'fat' and 'her' on separate lines, like this:

```
fat
her
```

That's because, at the end of printing 'fat', the computer presses the Enter key.

Suppose you say this instead:

```
print('fat',end='!')
print('her')
```

The end='!' means:

At the **end** of printing the line, print an exclamation point instead of pressing the Enter key.

So after printing 'fat', the computer will print an exclamation point instead of pressing the Enter key. The computer will print:

```
fat!her
```

Suppose you say this instead:

```
print('fat',end=' ')
print('her')
```

The end=' ' means:

At the **end** of printing the line, press the space bar instead of the Enter key.

So after printing 'fat', the computer will press the space bar instead of the Enter key. The computer will print:

```
fat her
```

Suppose you say this instead:

```
print('fat',end='')
print('her')
```

The end='' means:

> At the **end** of printing the line, do *nothing* — *don't* press the Enter key.

So after printing 'fat', the computer *won't* press the Enter key; instead, the computer will just obey the next command, which makes the computer print 'her', so 'her' appears next to 'fat', like this:

```
father
```

Lines that aren't commands

Usually, each line you type is a command. Here's how to change that.

Semicolon To type two commands on one line, **put a semicolon between the commands**:

```
>>> 2+3; 7+1
```

The computer will say:

```
5
8
```

Backslash To type just *part* of a command on one line, put a backslash at the end of that part. Type the rest of the command on the line below.

For example, instead of typing —

```
>>> 3+6+200
```

you can type:

```
>>> 3+6+\
      200
```

(The computer automatically indents the second line for you.) The computer will say the answer:

```
209
```

Instead of typing —

```
>>> print('I love you')
```

you can type:

```
>>> print('I lo\
ve you')
```

(Since you put the backslash in the middle of a string, the computer does *not* indent the second line.) The computer will say:

```
I love you
```

If you want to type a command that's too long to fit on your screen, put a backslash at the end of the command's first part; underneath, type the rest of the command.

Don't put a backslash in the middle of a computer word (such as "print"). Don't put a backslash in the middle of a number (such as 57).

Comment Occasionally, jot a note to remind yourself what your program does. Slip the note into your program by putting a **hashtag** (the symbol "#") before it:

```
#This program is another dumb example, written by Russ.
#It was written on Halloween, under a full moon.
print('I love you') #because I want to date someone
```

When you run the program, **the computer ignores everything that's to the right of a hashtag**. So the computer ignores the top two lines; in the bottom line, the computer ignores the "because…". The program makes the computer print just this:

```
I love you
```

Everything to the right of a hashtag is called a **comment**. While the computer runs the program, it ignores the comments. But the comments remain part of the program; they appear in the right-hand window with the rest of the program. Though the comments appear in the program, they don't affect the run.

Variables

You can name a number. For example, you can make Joan be the name for the number 7, by typing this:

```
>>> Joan=7
```

Then Joan+2 is 9, so if you type —

```
>>> Joan+2
```

the computer will reply:

```
9
```

The name can be short (like Joan) or long (like PopeFrancisTheGreat) or *very* short (like x) or technical (like TemperatureOfBasementFloor) or include digits (like LeaderOfThe3Musketeers) or disgusting (like number_of_times_we_vomited).

When you invent a name, you face these restrictions:

> The name must consist of just **letters, digits, and underscores**. (So no periods, apostrophes, special characters, or blank spaces.)
>
> The name must not begin with a digit.
>
> The name must not be one of these **keywords** (which are also called **reserved words**): and, as, assert, break, class, continue, def, del, elif, else, except, False, finally, for, from, global, if, import, in, is, lambda, None, nonlocal, not, or, pass, raise, return, True, try, while, with, yield.
>
> To avoid confusion, the name shouldn't be a **Python function** such as "print".

Capitalization makes a difference.

> If you say x=5, the computer will know x is the name for 5 but won't know what X is yet. If you say Y=8, the computer will know Y is the name for 8 but won't know what y is yet.

Some companies (such as Google) **prohibit employees from using capital letters** in names, except in special circumstances. If you work at one of those companies, make a name be:

> x (not X)
> joan (not Joan)
> pope_francis_the_great (not PopeFrancisTheGreat)
> leader_of_the_3_musketeers (not LeaderOfThe3Musketeers)

You can name *any* number. For example, you can say:

```
>>> x=-34.1
```

Then x is -34.1, so if you type —

```
>>> x*2
```

the computer will multiply -34.1 by 2 and say:

```
-68.2
```

You can name any string. For example, you can say:

```
>>> y='go'
>>> y*3
```

Then the computer will multiply 'go' by 3 and say:

```
'gogogo'
```

Beginners are usually too lazy to type long names, so beginners use names that are short (such as x). But when you become a pro and write a long, fancy program containing hundreds of lines and hundreds of names, you should use long names to help you remember each name's purpose. A name can be as long as you wish. In this book, I'll use short names in short programs (so you can type those programs quickly) but long names in long programs (so you can keep track of which name is which).

Jargon

A **name** (for a number or a string) is also called an **identifier**. It's also called a **variable**.

For example, suppose you say:

```
>>> Joan=7
```

That line makes Joan be a **name**, an **identifier**, a **variable**, whose **value** is 7. Since that line **assigns 7 to Joan**, that line is called an **assignment statement**. That line **defines Joan** to be 7.

If a variable (such as Joan) stands for a number, it's called a **numeric variable**. If a variable stands for a string instead, it's called a **string variable**.

Restart

When you run a program, the computer begins by doing a **restart**, which makes it forget any names you invented previously, so the program can start fresh.

After the program has run, the computer still remembers the names in the program. For example, if your program said Joan=7, the computer knows Joan is 7 even after the program

has finished running, so if you say —

```
>>> Joan
```

The computer will say:

```
7
```

A variable is a box

When you say Joan=7, here's what happens inside the computer.

The computer's random-access memory (RAM) consists of electronic boxes. The line Joan=7 makes the computer create a box named Joan and put 7 into it, like this:

box Joan | 7

Then when the computer encounters print(x+2), the computer prints what's in box Joan, plus 2; so the computer prints 9.

Variable from variables

One variable can define another. For example, suppose you type:

```
>>> n=6
>>> d=n+1
>>> n*d
```

The top line says n is 6. The next line says d is n+1, which is 6+1, which is 7; so d is 7. The bottom line says to print n*d, which is 6*7, which is 42; so the computer will print:

```
42
```

Change a value

A value can change:

```
>>> k=4
>>> k=9
>>> k*2
```

The top line says k's value is 4. The next line changes k's value to 9, so the bottom line prints 18.

When you run that program, here's what happens inside the computer's RAM. The top line (k=4) makes the computer put 4 into box k:

box k | 4

The next line (k = 9) puts 9 into box k. The 9 replaces the 4:

box k | 9

That's why k*2 prints 18.

Self-changing variable A variable can change itself. Look at this program:

```
x=7
x=x+2
print(x)
```

The top line (x=7) says x starts by being 7. The next line (x=x+2) means: the new x is "what x was before, plus 2". So the new x is 7+2, which is 9. The bottom line prints:

```
9
```

Let's examine that program more closely. The top line (x=7) puts 7 into box x:

box x | 7

When the computer sees the next line (x=x+2), it examines the equation's right side and sees the x+2. Since x is 7, the x+2 is 7+2, which is 9. So the line "x=x+2" means x=9. The computer puts 9 into box x:

box x | 9

The program's bottom line prints 9.

Instead of typing —

```
x=x+2
```

you can type this shortcut:

```
x+=2
```

You can pronounce "x+=2" this way:

```
x gets added this amount: 2
```

Here's another weirdo:

```
b=6
b+=1
print(b*2)
```

The second line (b+=1) says the new b gets added this amount: 1. So the new b is 6+1, which is 7. The bottom line prints:

```
14
```

In that program, the top line says b is 6; but the next line increases b, by adding 1; so b becomes 7. Programmers say that b has been **increased** or **incremented**. In the second line, the "1" is called the **increase** or the **increment**.

The opposite of "increment" is **decrement**:

```
j=500
j-=1
print(j)
```

The top line says j starts at 500; but the next line decreases j by subtracting 1, so the new j is 500-1, which is 499. The bottom line prints:

```
499
```

In that program, j was **decreased** (or **decremented**). In the second line, the "1" is called the **decrease** (or **decrement**).

Hassles

Variables can cause hassles.

Undefined variable If you type —

```
>>> Joan
```

the computer tries to say Joan's value (a number or string). If the computer fails (because you forgot to write a line such as Joan=7), the computer says "NameError".

What's before the equal sign? When writing an equation (such as x=47), put this before the equal sign: the name of just one box (such as x). So **before the equal sign, put one variable**:

```
Allowed:      d=n+1  (d is one variable)
Not allowed:  d-n=1  (d-n is two variables)
Not allowed:  1=d-n  (1 is not a variable)
```

The variable on the equation's *left* side is the only one that changes. For example, the statement d=n+1 changes the value of d but not n. The statement b=c changes the value of b but not c:

```
>>> b=1
>>> c=7
>>> b=c
>>> b+c
```

The third line changes b, to make it equal c; so b becomes 7. Since both b and c are now 7, the bottom line prints 14.

"b=c" versus "c=b" Saying "b=c" has a different effect from "c=b". That's because "b=c" changes the value of b (but not c); saying "c=b" changes the value of c (but not b).

Compare these programs:

```
b=1          b=1
c=7          c=7
b=c          c=b
print(b+c)   print(b+c)
```

In the left program, the third line changes b to 7, so both b and c are 7. The bottom line prints 14.

In the right program, the third line changes c to 1, so both b and c are 1. The bottom line prints 2.

While you run those programs, here's what happens inside the computer's RAM. For both programs, the second and third lines do this:

box b | 1

box c | 7

In the left program, the third line makes the number in box b become 7 (so both boxes contain 7, and the bottom line prints 14). In the right program, the third line makes the number in box c become 1 (so both boxes contain 1, and the bottom line prints 2).

When to use variables

Here's a practical example of when to use variables.

Suppose you're selling something that costs $1297.43, and you want to do these calculations:

```
multiply   $1297.43 by 2
multiply   $1297.43 by .05
add        $1297.43 to $483.19
divide     $1297.43 by 37
```

To do those four calculations, you could run this program:

```
print(1297.43*2,1297.43*.05,1297.43+483.19,1297.43/37)
```

But that program's silly, since it contains the number 1297.43 four times. This program's briefer, because it uses a variable:

```
c=1297.43
print(c*2,c*.05,c+483.19,c/37)
```

So **whenever you need to use a number several times, turn the number into a variable**, which will make your program briefer.

Paranoid If you're paranoid, you'll love this program:

```
t='They're laughing at you!'
print(t)
print(t)
print(t)
```

The top line says t stands for the string 'They're laughing at you!' The later lines make the computer print:

```
They're laughing at you!
They're laughing at you!
They're laughing at you!
```

Nursery rhymes The computer can recite nursery rhymes:

```
p='Peas porridge'
print(p,'hot!')
print(p,'cold!')
print(p,'in the pot,')
print('Nine days old!')
```

The top line says p stands for 'Peas porridge'. The later lines make the computer print:

```
Peas porridge hot!
Peas porridge cold!
Peas porridge in the pot,
Nine days old!
```

This program prints a fancier rhyme:

```
h='Hickory, dickory, dock!'
m='THE MOUSE (squeak! squeak!)'
c='THE CLOCK (tick! tock!)'
print(h)
print(m,'ran up',c)
print(c,'struck one')
print(m,'ran down')
print(h)
```

Lines 1-3 define h, m, and c. The later lines make the computer print:

```
Hickory, dickory, dock!
THE MOUSE (squeak! squeak!) ran up THE CLOCK (tick! tock!)
THE CLOCK (tick! tock!) struck one
THE MOUSE (squeak! squeak!) ran down
Hickory, dickory, dock!
```

Input

Humans ask questions; so to turn the computer into a human, you must make it ask questions too. **To make the computer ask a question, use the word "input".**

This program makes the computer ask for your name:

```
n=input('What is your name? ')
print('I adore anyone whose name is',n)
```

The top line says n is the answer to the question 'What is your name?' When you run the program and the computer sees that line, the computer asks 'What is your name?' then waits for you to answer the question; your answer will be called n. For example, if you answer Maria, then n is 'Maria'. The bottom line makes the computer print:

```
I adore anyone whose name is Maria
```

When you run that program, here's the whole conversation that occurs between the computer and you; I've underlined the part typed by you.…

```
Computer asks for your name: What is your name? Maria
Computer praises your name: I adore anyone whose name is Maria
```

Go ahead, type that program and run it, but be careful: **when you type the input line, leave a space after the question mark.**

Just for fun, run that program again and pretend you're somebody else.…

```
Computer asks for your name: What is your name? Bud
Computer praises your name: I adore anyone whose name is Bud
```

When the computer asks for your name, if you say something weird, the computer gives you a weird reply.…

```
Computer asks:   What is your name? none of your business!
Computer replies: I adore anyone whose name is none of your business!
```

That program begins by making the computer ask:

```
What is your name?
```

You can make the computer say this instead:

```
Enter your name:
```

To do so, change the program's top line to this:

```
n=input('Enter your name: ')
```

The program's bottom line makes the computer reply like this:

```
I adore anyone whose name is Maria
```

You can make the computer add an exclamation point, like this:

```
I adore anyone whose name is Maria!
```

To do that, change the program's bottom line to this:

```
print('I adore anyone whose name is',n+'!')
```

The +'!' means:

```
add an exclamation point, with no space before the exclamation point
```

College admissions

This program prints a letter, admitting you to the college of your choice:

```
c=input('What college would you like to enter? ')
print('Congratulations!')
print('You have just been admitted to',c)
print('because it fits your personality.')
print('I hope you go to',c+'.')
print('            Respectfully yours,')
print('            The Dean of Admissions')
```

When the computer sees the input line, the computer asks 'What college would you like to enter?' and waits for you to answer. Your answer will be called c. If you'd like to be admitted to Harvard, you'll be pleased.…

```
Computer asks you:   What college would you like to enter? Harvard
Computer admits you: Congratulations!
                     You have just been admitted to Harvard
                     because it fits your personality.
                     I hope you go to Harvard.
                               Respectfully yours,
                               The Dean of Admissions
```

The program's 5th line includes these symbols:

```
+'.'
```

Those symbols mean:

```
add a period, with no space before the period
```

You can choose any college you wish:

```
Computer asks you:   What college would you like to enter? Hell
Computer admits you: Congratulations!
                     You have just been admitted to Hell
                     because it fits your personality.
                     I hope you go to Hell.
                               Respectfully yours,
                                The Dean of Admissions
```

That program consists of three parts:

1. The computer begins by asking you a question ('What college would you like to enter?'). The computer's question is called the **prompt**, because it prompts you to answer.

2. Your answer (the college's name) is called **your input**, because it's information that you're *putting into* the computer.

3. The computer's reply (the admission letter) is called the **computer's output**, because it's the final answer that the computer puts out.

Input versus print

The word **input** is the opposite of the word **print**.

The word **print** makes the computer print information out. The word **input** makes the computer take information in.

What the computer prints out is called the **output**. What the computer takes in is called **your input**.

Input and Output are collectively called **I/O**, so the input and print statements are called **I/O statements**.

Once upon a time

Let's make the computer write a story, by filling in the blanks:

Once upon a time, there was a youngster named _____
(your name)

who had a friend named _____.
(friend's name)

_____ wanted to _____ _____,
(your name) (verb (such as "pat")) (friend's name)

but _____ didn't want to _____ _____!
(friend's name) (verb (such as "pat")) (your name)

Will _____ _____ _____?
(your name) (verb (such as "pat")) (friend's name)

Will _____ _____ _____?
(friend's name) (verb (such as "pat")) (your name)

To find out, come back and see the next exciting episode

of _____ and _____!
(your name) (friend's name)

To write the story, the computer must ask for your name, your friend's name, and a verb. To make the computer ask, your program must say **input**:

```
y=input('What is your name? ')
f=input('What is the name of your friend? ')
v=input('In 1 word, say something you can do to your friend? ')
```

Then make the computer print the story:

```
print('Here is my story....')
print('Once upon a time, there was a youngster named',y)
print('who had a friend named',f+'.')
print(y,'wanted to',v,f+',')
print('but',f,'did not want to',v,y+'!')
print('Will',y,v,f+'?')
print('Will',f,v,y+'?')
print('To find out, come back and see the next exciting episode')
print('of',y,'and',f+'!')
```

Here's a sample run:

```
What is your name? Dracula
What is the name of your friend? Madonna
In 1 word, say something you can do to your friend? bite
Here is my story....
Once upon a time, there was a youngster named Dracula
who had a friend named Madonna.
Dracula wanted to bite Madonna,
but Madonna did not want to bite Dracula!
Will Dracula bite Madonna?
Will Madonna bite Dracula?
To find out, come back and see the next exciting episode
of Dracula and Madonna!
```

Here's another run:

```
What is your name? Superman
What is the name of your friend? King Kong
In 1 word, say something you can do to your friend? tickle
Here is my story....
Once upon a time, there was a youngster named Superman
Who had a friend named King Kong.
Superman wanted to tickle King Kong,
but King Kong did not want to tickle Superman!
Will Superman tickle King Kong?
Will King Kong tickle Superman?
To find out, come back and see the next exciting episode
of Superman and King Kong!
```

Try it: put in your own name, the name of your friend, and something you'd like to do to your friend.

Numeric input

To let you input a **number** (instead of a string), your program should say "**eval(input**" instead of just "input".

For example, this program lets you input a number and makes the computer double it:

```
n=eval(input('What number will you give me? '))
print('That number doubled is',n*2)
```

The top line says f is the answer, **eval**uated as a number, to the question 'What number will you give me?' When you run the program and the computer sees that line, the computer asks 'What number will you give me?' then waits for you to answer the question; your number will be called n. For example, if you say 3, then n is 3. The bottom line makes the computer print:

```
That number doubled is 6
```

When you run that program, here's the whole conversation that occurs between the computer and you; I've underlined the part typed by you.…

```
Computer asks for a number:  What number will you give me? 3
Computer doubles it:         That number doubled is 6
```

Go ahead, type that program and run it, but be careful: **at the end of the eval line, type TWO parentheses**.

In that program, the **eval** tells the computer you'll input a **number**.

If you leave out the eval, the computer will assume you'll input a string instead of a number. Then if you input 3, the computer will assume you mean the string '3', so the computer will double it (by repeating it) and say 33.

If you say **int** instead of eval, the computer will assume you'll input an **integer** (a number that has no decimal point). Then if you input a number containing a decimal point, the computer will say "ValueError".

If you say **float** instead of eval, the computer will assume you'll input a **floating-point number** (a number that has a decimal point). Then if you input 3, the computer will assume you mean 3.0, so the computer will double it and say 6.0 (instead of just 6).

This program makes the computer predict your future:

```
print('I predict what will happen to you in the year 2030!')
y=eval(input('In what year were you born? '))
print('In the year 2030, you will turn',2030-y,'years old.')
```

Here's a sample run:

```
I predict what will happen to you in the year 2030!
In what year were you born? 1972
In the year 2030, you will turn 58 years old.
```

Suppose you're selling tickets to a play. Each ticket costs $2.79. (You decided $2.79 would be a nifty price, because the cast has 279 people.) This program finds the price of multiple tickets:

```
t=eval(input('How many tickets? '))
print('The total price is $',t*2.79)
```

This program tells you how much the "oil crisis" costs you, when you drive your car:

```
m=eval(input('How many miles do you want to drive? '))
p=eval(input('How many pennies does a gallon of gas cost? '))
r=eval(input('How many miles-per-gallon does your car get? '))
print('The gas for your trip will cost $',m*p/(r*100))
```

Here's a sample run:

```
How many miles do you want to drive? 400
How many pennies does a gallon of gas cost? 257.9
How many miles-per-gallon does your car get? 31
The gas for your trip will cost $ 33.277419354838706
```

So the gas will cost a hair less than $33.28.

Conversion

This program converts feet to inches:

```
f=eval(input('How many feet? '))
print(f,'feet =',f*12,'inches')
```

Here's a sample run:

```
How many feet? 2
2 feet = 24 inches
```

Trying to convert to the metric system? This program converts inches to centimeters:

```
i=eval(input('How many inches? '))
print(i,'inches =',i*2.54,'centimeters')
```

Nice day today, isn't it? This program converts the temperature from Celsius to Fahrenheit:

```
c=eval(input('How many degrees Celsius? '))
print(c,'degrees Celsius =',c*1.8+32,'degrees Fahrenheit')
```

Here's a sample run:

```
How many degrees Celsius? 20
20 degrees Celsius = 68.0 degrees Fahrenheit
```

See, you can write the *Guide* yourself! Just hunt through any old math or science book, find any old formula (such as f=c*1.8+32), and turn it into a program.

If

Let's write a program so if the human is less than 18 years old, the computer will say:

```
You are still a minor.
```

Here's the program:

```
age=eval(input('How old are you? '))
if age<18: print('You are still a minor')
```

The top line makes the computer ask 'How old are you?' and wait for the human to type an age. Since **the symbol for "less than" is "<"**, the bottom line says: if the age is less than 18, print 'You are still a minor'.

Go ahead! Run that program! The computer begins the conversation by asking:

```
How old are you?
```

Try saying you're 12 years old, by typing a 12, so the screen looks like this:

```
How old are you? 12
```

When you finish typing the 12 and press the Enter key at the end of it, the computer will reply:

```
You are still a minor
```

Try running that program again, but this time try saying you're 50 years old instead of 12, so the screen looks like this:

```
How old are you? 50
```

When you finish typing the 50 and press the Enter key at the end of it, the computer will *not* say "You are still a minor". Instead, the computer will say nothing — since we didn't teach the computer how to respond to adults yet!

In that program, the bottom line says:

```
if age<18: print('You are still a minor')
```

That line begins with the word "if". **Whenever you say "if", you must also write a colon** (the symbol ":").

What comes between "if" and the colon is called the **condition**. In that example, the condition is "age<18". If the condition is true (if age is really less than 18), the computer does the **action**, which comes after the colon and is:

```
print('You are still a minor')
```

Else

Let's teach the computer how to respond to adults.

Here's how to program the computer so if the age is less than 18, the computer will say "You are still a minor", but if the age is *not* less than 18 the computer will say "You are an adult" instead:

```
age=eval(input('How old are you? '))
if age<18: print('You are still a minor')
else: print('You are an adult')
```

In programs, **the word "else" means "otherwise"**. That program's 2nd and 3rd lines mean: if the age is less than 18, then print 'You are still a minor'; otherwise (if the age is *not* less than 18), print 'You are an adult'. So the computer will print 'You are still a minor' or else print 'You are an adult', depending on whether the age is less than 18.

Try running that program! If you say you're 50 years old, so the screen looks like this —

```
How old are you? 50
```

the computer will reply by saying:

```
You are an adult
```

Multi-line

If the age is less than 18, here's how to make the computer print "You are still a minor" and also print "Ah, the joys of youth":

```
if age<18: print('You are still a minor'); print('Ah, the joys of youth')
```

Type that correctly: put a **colon** after "if age<18" but a **semicolon** between the two print statements.

Here's a more sophisticated way to say the same thing:

```
if age<18:
    print('You are still a minor')
    print('Ah, the joys of youth')
```

That sophisticated way (in which you type 3 short lines instead of a single long line) is called a **multi-line "if"** (or a **block "if"**).

Here's how to type that **multi-line "if"**:

Type the top line (which begins with "if" and ends with a colon). After you type the colon, press the Enter key.

When the computer sees you typed a colon and then pressed the Enter key, the computer knows you're trying to create a multi-line, so the computer automatically indents the next line for you. When you finish typing that line (which says to print 'You are still a minor'), press the Enter key again. The computer automatically indents the next line for you.

The computer will indent every line you type, until you begin a line by pressing the Backspace key, which tells the computer to stop indenting. Pressing the Backspace key makes the computer unindent that line.

The indented lines are called the **block**. The line above them, which ends in a colon, is called the block's **header**.

You can also create a **multi-line "else"**, so your program looks like this:

```
age=eval(input('How old are you? '))
if age<18:
    print('You are still a minor')
    print('Ah, the joys of youth')
else:
    print('You are an adult')
    print('We can have adult fun')
```

That means: if the age is less than 18, print 'You are still a minor' and 'Ah, the joys of youth'; otherwise (if age *not* under 18) print 'You are an adult' and 'We can have adult fun'.

Elif

Let's say this:

If age is under 18, print "You are a minor".
If age is *not* under 18 but is under 100, print "You are a typical adult".
If age is *not* under 100 but is under 120, print "You are a centenarian".
If age is *not* under 120, print "You are a liar".

Here's another way to say the same thing, in English:

If age is under 18, print "You are a minor".
Otherwise, if age is under 100, print "You are a typical adult".
Otherwise, if age is under 120, print "You are a centenarian".
Otherwise, print "You are a liar".

The Python word for "otherwise" is "else", and the Python word for "otherwise if" is **"elif" (which is short for "else if")**, so the Python program is:

```
if age<18: print('You are a minor')
elif age<100: print('You are a typical adult')
elif age<120: print('You are a centenarian')
else: print('You are a liar')
```

Double equal sign

Suppose you want to say:

If age is 25

Here's how to say that:

```
if age==25:
```

Python doesn't let the "if" condition have a simple equal sign (=); instead you must type a **double equal sign** (==). If you accidentally type a single equal sign there, the computer will say "SyntaxError".

Therapist Let's turn your computer into a therapist!

To make the computer ask the patient, "How are you?", begin the program like this:

```
feeling=input('How are you? ')
```

Make the computer continue the conversation by responding this way:

If the patient says "fine", print "That's good!"
If the patient says "lousy" instead, print "Too bad!"
If the patient says anything else instead, print "I feel the same way!"

Here's how:

```
if feeling=='fine': print('That\'s good!')
elif feeling=='lousy': print('Too bad!')
else: print('I feel the same way!')
```

Here's a complete program:

```
feeling=input('How are you? ')
if feeling=='fine': print('That\'s good!')
elif feeling=='lousy': print('Too bad!')
else: print('I feel the same way!')
print('I hope you enjoyed your therapy.  Now you owe $50.')
```

The top line makes the computer ask the patient, "How are you?" The next several lines makes the computer analyze the patient's answer and print 'That's good!' or 'Too bad!' or else 'I feel the same way!' Regardless of what the patient and computer said, that program's bottom line always makes the computer end the conversation by printing:

```
I hope you enjoyed your therapy.  Now you owe $50.
```

In that program, try changing the strings to make the computer print smarter remarks, become a better therapist, and charge even more money.

Fancy "if" conditions

Different relations You can make the "if" clause very fancy:

"if" clause	Meaning
`if b<4`	If b is less than 4
`if b>4`	If b is greater than 4
`if b<=4`	If b is less than or equal to 4
`if b>=4`	If b is greater than or equal to 4
`if b==4`	If b is 4
`if b=='fine'`	If b is the word 'fine'
`if b!=4`	If b does not equal 4
`if b!='fine'`	If b does not equal the word 'fine'
`if b<'fine'`	If b is a word that comes before 'fine' in dictionary
`if b>'fine'`	If b is a word that comes after 'fine' in dictionary

In the "if" clause, the symbols <, >, <=, >=, ==, and != are called **relations**.

Or The computer understands the word "or". For example, here's how to say, "If x is either 7 or 8, print the word *wonderful*":

```
if x==7 or x==8: print('wonderful')
```

That example is composed of two conditions: the first condition is "x==7"; the second condition is "x==8". Those two conditions combine, to form "x==7 or x==8", which is called a **compound condition**.

If you use the word "or", put it between two conditions.

Right: `if x==7 or x==8: print('wonderful')`
Right because "x==7" and "x==8" are conditions.

Wrong: `if x==7 or 8: print('wonderful')`
Wrong because "8" is not a condition.

And The computer understands the word "and". Here's how to say, "If p is more than 5 and less than 10, print *tuna fish*":

```
if p>5 and p<10: print('tuna fish')
```

Here's how to say, "If s is at least 60 and less than 65, print *you almost failed*":

```
if s>=60 and s<65: print('you almost failed')
```

Here's how to say, "If n is a number from 1 to 10, print *that's good*":

```
if n>=1 AND n<=10: print('that's good')
```

Loops

You can make the computer repeat, again and again. Something repeated is called a **loop**. Here's how to create a loop.

While True

This program makes the computer print the word "love" once:

```
print('love')
```

This fancier program makes the computer print the word "love" *three* times:

```
print('love')
print('love')
print('love')
```

When you run that program, the computer will print:

```
love
love
love
```

Let's make the computer print the word "love" *many* times. To do that, we must make the computer do this line many times:

```
print('love')
```

To make the computer do the line many times, say "while True" above the line, so the program looks like this:

```
while True:
    print('love')
```

Here's how to type that program:

Delete any lines you typed previously, so you can start fresh.

Type the top line (which begins with "while" and ends with a colon). After you type the colon, press the Enter key.

When the computer sees you typed a colon and then pressed the Enter key, the computer knows you're trying to create a multi-line, so the computer automatically indents the next line for you. When you finish typing that line (which says to print 'love'), press the Enter key again. (The computer will automatically indent any extra lines you type, until you begin a line by pressing the Backspace key, which tells the computer to stop indenting.)

When you run that program, the computer will print "love" many times, so it will print:

```
love
love
love
love
love
love
etc.
```

The computer will print "love" on every line of the Python Shell window.

But even when that window is full of "love", the computer won't stop: the computer will try to print even more loves onto your window! The computer will lose control of itself and try to devote its entire life to making love! The computer's mind will spin round and round, always circling back to the thought of making love again!

Since the computer's thinking keeps circling back to the same thought, the computer is said to be in a **loop**. In that program, the "while True" means "do repeatedly what's indented". The "while True" and the indented lines underneath form a loop, called a "**while loop**".

To stop the computer's lovemaking madness, you must give the computer a "jolt" that will put it out of its misery and get it out of the loop. To jolt the computer out of the program, **abort** the program. To abort the program, do this: while holding down the Control key (which says "Ctrl" on it), tap the C key. That makes the computer stop running your program; it will **break out of your program**; it will **abort your program** and say "KeyboardInterrupt".

In that program, since the computer tries to go round and round the loop forever, the loop is called **infinite**. The only way to stop an infinite loop is to abort it.

Cats and dogs Run this program:

```
while True:
    print('cat')
    print('dog')
```

The computer will repeatedly print 'cat' and 'dog', so the screen will look like this:

```
cat
dog
cat
dog
cat
dog
cat
dog
etc.
```

Yes, on the screen it will be raining cats and dogs! The computer will keep printing "cat" and "dog" until you abort the program.

Interactive mode Instead of creating that program (which requires you to press the F5 key to run), you can create the cats and dogs by typing in **interactive mode**, at the >>> prompt, like this:

```
>>> while True:
        print('cat')
        print('dog')
```

When you create the blank line under 'dog' (by pressing the Enter key again), the computer performs the while loop and prints lots of cats and dogs, until you abort. Here's why:

In interactive mode, a blank line means "perform the loop *now*".

Conversions This program, which you saw before, converts feet to inches:

```
f=eval(input('How many feet? '))
print(f,'feet =',f*12,'inches')
```

Here's a sample run:

```
How many feet? 2
2 feet = 24 inches
```

Suppose you want to:

convert 2 feet to inches
and also convert 7 feet to inches
and also convert 1000 feet to inches
and also convert 59.2 feet to inches
and also convert 3 feet to inches
and also convert 5280 feet to inches
and also convert other quantities of feet to inches

To do all that, you can run that conversion program many times: each time you want to run that conversion program, say "run" (by pressing the F5 key). But instead of pressing the F5 key so many times, you can make the computer rerun the program for you automatically! To do that, begin your program by by typing:

```
While True:
```

That means: automatically do, repeatedly, the indented lines underneath. Type those indented lines, so the program becomes like this:

```
While True:
    f=eval(input('How many feet? '))
    print(f,'feet =',f*12,'inches')
```

When you run that program (by pressing the F5 key once), the computer will repeatedly convert feet to inches, each time asking you 'How many feet?' The computer will keep converting feet to inches until you abort the program.

Counting Suppose you want the computer to count, starting at 3, like this:

```
3
4
5
6
7
8
etc.
```

This program does it, by a special technique:

```
c=3
while True:
    print(c)
    c+=1
```

In that program, c is called the **counter**, because it helps the computer count.

The top line says c starts at 3. The "while" loop says to repeatedly do this:

print c, then increase c by adding 1 to it

So the computer prints c (which is 3), then increases c (so c becomes 4), then repeats the indented lines again, so the computer prints the new c (which is 4), then increases c again (so c becomes 5), then repeats the indented lines again, so the computer prints the new c (which is 5), then increases c again (so c becomes 6), etc. The computer repeatedly prints c and increases it. Altogether, the computer prints:

```
3
4
5
6
7
8
9
10
11
etc.
```

The program's an infinite loop: the computer will print 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, and so on, forever, unless you abort it.

Here's the general procedure to make the computer count:

Start c at some value (such as 3).

Then write a "while" loop.

In the "while" loop, make the computer use c (such as by saying to print c), and increase c (by saying c+=1).

To read the printing more easily, say end=' ':

```
c=3
while True:
    print(c,end=' ')
    c+=1
```

That makes the computer print horizontally:

```
3 4 5 6 7 8 etc.
```

This program makes the computer count, starting at 1:

```
c=1
while True:
    print(c,end=' ')
    c+=1
```

The computer will print 1, 2, 3, 4, etc.

This program makes the computer count, starting at 0:

```
c=0
while True:
    print(c,end=' ')
    c+=1
```

The computer will print 0, 1, 2, 3, 4, etc.

For

Let's make the computer print every number from 0 to 19, like this:

```
0
1
2
3
4
5
6
7
etc.
19
```

Here's the program:

```
for x in range(20):
    print(x)
```

The top line says x will be every number under 20; so x will be 0, then 1, then 2, etc. The line underneath, which is indented, says what to do about each x; it says to print each x.

The computer will do the indented line repeatedly, so the computer will repeatedly print(x). To begin, x will be 0, so the computer will print:

```
0
```

The next time the computer prints x, the x will be 1, so the computer will print:

```
1
```

The computer will print every number from 0 up to 19. It will not print 20.

How to start at 1 If you want to print every number from 1 to 20, say this instead:

```
for x in range(1,21):
    print(x)
```

That makes the computer start at 1 (instead of 0) and print the numbers under 21, like this:

```
1
2
3
4
5
etc.
20
```

Interactive mode Instead of creating that program (which requires you to press the F5 key to run), you can type in **interactive mode**, at the >>> prompt, like this:

```
>>> for x in range(1,21):
        print(x)

```

When you create the blank line under print(x) (by pressing the Enter key again), the computer performs the loop and prints the numbers under 21, starting at 1.

When men meet women Let's make the computer print these lyrics:

```
I saw 2 men
meet 2 women.
Tra-la-la!

I saw 3 men
meet 3 women.
Tra-la-la!

I saw 4 men
meet 4 women.
Tra-la-la!

I saw 5 men
meet 5 women.
Tra-la-la!

They all had a party!
Ha-ha-ha!
```

To do that, type these lines —

```
The first line of each verse:    print('I saw',x,'men')
The second line of each verse:   print('meet',x,'women.')
The third line of each verse:    print('Tra-la-la!')
Blank line under each verse:     print()
```

after making x be every number from 2 up to 5 (so x starts at 2 but stays less than 6):

```
for x in range(2,6):
    print('I saw',x,'men')
    print('meet',x,'women.')
    print('Tra-la-la!')
    print()
```

At the end of the song, print the closing couplet:

```
for x in range(2,6):
    print('I saw',x,'men')
    print('meet',x,'women.')
    print('Tra-la-la!')
    print()
print('They all had a party!')
print('Ha-ha-ha!')
```

(The computer automatically indents every line under "for", until you begin a line by pressing the Backspace key, which tells the computer to stop indenting.) That program makes the computer print the entire song.

Here's an analysis:

```
                        for x in range(2,6):
The computer will do the    print('I saw',x,'men')
indented lines repeatedly,  print('meet',x,'women.')
for x=2, x=3, x=4, and x=5. print('Tra-la-la!')
                            print()
Then the computer will  print('They all had a party!')
print this couplet once.    print('Ha-ha-ha!')
```

Since the computer does the indented lines repeatedly, those lines form a loop. Here's the general rule: **the statements indented under "for" form a loop**. The computer goes round and round the loop, for x=2, x=3, x=4, and x=5. Altogether, it goes around the loop 4 times, which is a finite number. Therefore, the loop is **finite**.

If you don't like the letter x, choose a different letter. For example, you can choose the letter i:

```
for i in range(2,6):
    print('I saw',i,'men')
    print('meet',i,'women.')
    print('Tra-la-la!')
    print()
print('They all had a party!')
print('Ha-ha-ha!')
```

When using the word "for", most programmers prefer the letter i; most programmers say "for i" instead of "for x". Saying "for i" is an "old tradition". Following that tradition, the rest of this book says "for i" (instead of "for x"), except in situations where some other letter feels more natural.

Print the squares To find the **square** of a number, multiply the number by itself. The square of 3 is "3 times 3", which is 9. The square of 4 is "4 times 4", which is 16.

Let's make the computer print the square of 3, 4, 5, etc., up to 20, like this:

```
The square of 3 is 9
The square of 4 is 16
The square of 5 is 25
The square of 6 is 36
The square of 7 is 49
etc.
The square of 20 is 400
```

To do that, type this line —

```
    print('The square of',i,'is',i*i)
```

and make i be every number from 3 up to 20 (so below 21), like this:

```
for i in range(3,21):
    print('The square of',i,'is',i*i)
```

Count how many copies This program, which you saw before, prints "love" on every line of your screen:

```
while True:
    print('love')
```

That program prints "love" again and again, until you abort the program by pressing Ctrl with C.

But what if you want to print "love" just 20 times? This program prints "love" 20 times —

```
for i in range(20):
    print('love')
```

because it makes i be 0 then 1 then 2 then 3, etc., up to 19.

As you can see, "for" resembles "while" but is more powerful: "for" makes the computer count!

Count to midnight This program makes the computer count to midnight:

```
for i in range(1,12):
    print(i)
print('midnight')
```

The computer will print:

```
1
2
3
4
5
6
7
8
9
10
11
midnight
```

At the end of the indented line, let's say end=' ', like this:

```
for i in range(1,12):
    print(i,end=' ')
print('midnight')
```

That makes the computer print each item on the same line and separated by spaces, like this:

```
1 2 3 4 5 6 7 8 9 10 11 midnight
```

If you want the computer to press the Enter key before "midnight", say \n:

```
for i in range(1,12):
    print(i,end=' ')
print('\nmidnight')
```

That extra print line makes the computer press the Enter key just before "midnight", so the computer will print "midnight" on a separate line, like this:

```
1 2 3 4 5 6 7 8 9 10 11
midnight
```

Let's make the computer count to midnight 3 times, like this:

```
1 2 3 4 5 6 7 8 9 10 11
midnight
1 2 3 4 5 6 7 8 9 10 11
midnight
1 2 3 4 5 6 7 8 9 10 11
midnight
```

To do that, indent the entire program under the word "for":

```
for j in range(3):
    for i in range(1,12):
        print(i,end=' ')
    print('\nmidnight')
```

That version contains a loop inside a loop: the loop that says "for i" is inside the loop that says "for j". The j loop is called the **outer loop**; the i loop is called the **inner loop**. The inner loop's variable must differ from the outer loop's. Since we called the inner loop's variable "i", the outer loop's variable must *not* be called "i"; so I picked the letter j instead.

Programmers often think of the outer loop as a bird's nest, and the inner loop as an egg *inside the nest*. So programmers say the inner loop is **nested in** the outer loop; the inner loop is a **nested loop**.

Step size The "for" statement can be varied.

If you say —

```
for i in range(5,18,3):
```

the i will start at 5, stay under 18, and keep increasing by 3.

So i will be 5,
then 8 (because i increased by 3),
then 11 (because i increased by 3 again),
then 14 (because i increased by 3 again),
then 17 (because i increased by 3 again),
then stop (because i must stay under 18).

In that example:

The 5 is called the **start value**.

The 18 is called the **stop value**.

The 3 is called the **increase** (or **increment** or **step size**).

The i is called the **counter** (or **index** or **loop-control variable**).

Although 18 is the stop value, 17 is the **last value** (or **terminal value**).

Programmers usually say "for i", instead of "for x", because the letter i reminds them of the word **index**.

If you say —

```
for i in range(17,4,-3):
```

the i will start at 17, not get to 4, and keep decreasing by 3.

So i will be 17,
then 14 (because i decreased by 3),
then 11 (because i decreased by 3 again),
then 8 (because i decreased by 3 again),
then 5 (because i decreased by 3 again),
then stop (because i must not get to 4 or beyond).

In that example, 3 is called the **decrease** (or **decrement**); -3 is the **step size**.

To count *down*, you must say a *negative* step size, such as -3 or -1. So to count every number from 17 down to 5, give this instruction:

```
for i in range(17,4,-1):
```

This program prints a rocket countdown:

```
for i in range(10,0,-1):
    print(i)
print('Blast off!')
```

The computer will start at 10, count *down* (because the step size is -1), and stop the loop before saying 0; so the computer will print:

```
10
9
8
7
6
5
4
3
2
1
Blast off!
```

Suppose you want i to be 6.0, then 6.1, then 6.2, etc., up to 8.0. **Python doesn't let the range contain decimal points**, so use this trick: make j be 60, then 61, then 62, etc., up to 80, then make i be a tenth of j, like this:

```
for j in range(60,81)
    i=j/10
    print(i)
```

Break

If you're stuck in jail, you hope to break out. Similarly, if a computer is stuck in a loop (doing the same thing again and again), the computer hopes to break out.

To let the computer break out of a loop, say "break". Saying "break" lets the computer stop looping; it lets the computer break free from the loop and skip ahead to the rest of your program.

For example, suppose you say:

```
while True:
    print('eat')
    break
    print('sandwiches under')
print('the trees')
```

The "while" tells the computer to obey the indented lines repeatedly, to form a loop. The first indented line makes the computer print:

```
eat
```

But the next line says "break", which makes the computer break out of the loop, stop looping, do no more indented lines, and so not print 'sandwiches under'; the computer will skip ahead to the next *un*indented line, which prints:

```
the trees
```

So the program makes the computer print just this:

```
eat
the trees
```

Guessing game This program plays a guessing game, where the human tries to guess the computer's favorite color, which is pink:

```
while True:
    if 'pink'==input('What is my favorite color? '): break
    print('No, that is not my favorite color. Try again!')
print('Congratulations! You discovered my favorite color.')
```

Here's what the 2nd line means. If 'pink' matches the human's reply to the question 'What is my favorite color?', break out of the loop, so the computer skips ahead to unindented line, which prints:

```
Congratulations! You discovered my favorite color.
```

But if 'pink' does *not* match the human's reply, the computer will continue looping, by saying:

```
No, that is not my favorite color. Try again!
```

Here's another way to program the guessing game:

```
while True:
    print('You have not guessed my favorite color yet!')
    if 'pink'==input('What is my favorite color? '): break
print('Congratulations! You discovered my favorite color.')
```

That program's loop makes the computer do this repeatedly: say 'You have not guessed my favorite color yet!' and then ask 'What is my favorite color?' The computer will repeat the indented lines again and again, until the guess is 'pink'. When the guess is "pink", the computer breaks out of the loop and proceeds to the bottom line, which prints 'Congratulations!'.

Sex This program makes the computer discuss human sexuality:

```
while True:
    sex=input('Are you male or female? ')
    if sex=='male':
        print('So is Frankenstein!')
        break
    if sex=='female':
        print('So is Mary Poppins!')
        break
    print('Please say male or female!')
```

The 2nd line makes the computer ask, 'Are you male or female?' If the human claims to be "male", the computer prints 'So is Frankenstein!' and stops looping. If the human says "female" instead, the computer prints 'So is Mary Poppins!' and stops looping. If the human says anything else (such as "not sure" or "super-male" or "macho" or "none of your business"), the computer prints 'Please say male or female!' and then does the loop again, so the computer asks again, 'Are you male or female?'

That program's bottom line is called an **error handler** (or **error-handling routine** or **error trap**), since its only purpose is to handle human error (a human who says neither "male" nor "female"). The error handler prints a gripe message ('Please say male or female!') and then lets the human try again (by having the human do the loop again).

Here's how to accomplish the same goal without indenting so much:

```
while True:
    sex=input('Are you male or female? ')
    if sex=='male' or sex=='female': break
    print('Please say male or female!')
if sex=='male': print('So is Frankenstein!')
else: print('So is Mary Poppins!')
```

That "while" loop says:

> Ask the human 'Are you male or female?' and call the answer "sex".
>
> If the sex is male or female, that's fine, so break out of the loop; otherwise, print 'Please say male o female!' and do the loop again.

Let's extend that program's conversation. If the human says "female", let's make the computer say "So is Mary Poppins!", then ask "Do you like her?", then continue the conversation this way:

> If human says "yes", make computer say "I like her too. She is my mother."
> If human says "no", make computer say "I hate her too. She owes me a dime."
> If human says neither "yes" nor "no", make computer handle that error.

To accomplish all that, put the shaded lines into the program:

```
while True:
    sex=input('Are you male or female? ')
    if sex=='male' or sex=='female': break
    print('Please say male or female!')
if sex=='male': print('So is Frankenstein!')
else:
    print('So is Mary Poppins!')
    while True:
        opinion=input('Do you like her? ')
        if opinion=='yes' or opinion=='no': break
        print('Please say yes or no!')
    if opinion='yes': print('I like her too. She is my mother.')
    else: print('Neither do I. She still owes me a dime.')
```

Rules Here are the rules about saying "break":

> The "break" command is legal just if the computer's in a loop.
>
> You can say "break" if the computer's in a "while" loop or a "for" loop.
>
> If the computer's in nested loops (a loop inside a loop), the "break" command makes the computer break out of the inner loop but not the outer loop.

Data structures

You can combine numbers and strings, to build a **data structure**. Here's how.

Lists

Here's a **list**:

```
['love','death',666,'giggle',3.14]
```

That list contains 5 **items**: 'love' and 'death' and 666 and 'giggle' and 3.14.

In a list, put commas between the items.

Begin the list with an **open bracket** (the symbol "[").
End the list with a **closed bracket** (the symbol "]").
So the entire list is enclosed in **brackets** (the symbols "[]").

If you say —

```
>>> ['love','death',666,'giggle',3.14]
```

or say —

```
>>> print(['love','death',666,'giggle',3.14])
```

the computer will say the list:

```
['love', 'death', 666, 'giggle', 3.14]
```

If you say —

```
>>> [5+3,70+20]
```

The computer will do the math and say:

```
[8, 90]
```

A **list** is also called an **array**.

Variable A variable can be a list. For example, you can say:

```
>>> x=['love','death',666,'giggle',3.14]
```

Adding You can add lists together. If you say —

```
>>> ['dog','cat']+['mouse','cheese']
```

The computer will add the list ['dog','cat'] to the list ['mouse','cheese'] and say:

```
['dog', 'cat', 'mouse', 'cheese']
```

For The "for" statement can use a list. If you say —

```
for i in [18,21,100]:
```

the i will be 18 then 21 then 100. If you say —

```
for i in ['Joe','Fred','Mary']:
```

the i will be 'Joe' then 'Fred' then 'Mary'.

Let's make the computer print this message:

```
We love meat
We love potatoes
We love lettuce
We love tomatoes
```

This program does that:

```
for i in ['meat','potatoes','lettuce','tomatoes']:
    print('We love',i)
```

You can also write the program this way:

```
x=['meat','potatoes','lettuce','tomatoes']
for i in x:
    print('We love',i)
```

Subscripts Suppose you say:

```
>>> x=['Joe','Fred','Mary']
```

That list contains 3 items: 'Joe', 'Fred', and 'Mary'.

In x's list, **the starting item** (which is 'Joe') **is called x_0** (which is pronounced "x subscripted by zero" or "x sub 0" or just "x 0"). The next item (which is 'Fred') is called x_1 (which is pronounced "x subscripted by one" or "x sub 1" or just "x 1"). The next item is called x_2. So **the 3 numbers in the list are called x_0, x_1, and x_2**.

To make the computer say what x_2 is, type this:

```
>>> x[2]
```

The computer will say:

```
'Mary'
```

Notice this jargon:

In a symbol such as x_2, the lowered number (the 2) is called the **subscript**. To create a subscript, use brackets. For example, to create x_2, type x[2].

You can change what's in a list. For example, if you want to change x_2 to 'Alice', say:

```
>>> x[2]='Alice'
```

Suppose you say:

```
>>> x=['Joe','Fred','Mary']
>>> x[2]='Alice'
```

The x starts as ['Joe','Fred','Mary'], but 'Mary' changes to 'Alice'; so if you say —

```
>>> x
```

the computer will say:

```
['Joe', 'Fred', 'Alice']
```

Too long If you want to type a list that's too long to fit on one line, do this:

Type *part* of the list on one line. Type a backslash at the end of that part. Type the rest of the list below. Type a backslash at the end of each line (except the list's bottom line). The backslash means: the rest of the list continues below.

List in a list A list can contain another list. For example, look at this list:

```
>>> x=['Joe','Fred',['dog','cat']]
```

In that list, x[0] is 'Joe', x[1] is 'Fred', and x[2] is the list ['dog', 'cat']. Since 'dog' is the starting item of the list x[2], 'dog' is x[2][0]. Since 'cat' is the next item of the list x[2], 'cat' is x[2][1].

Blanks in a list You can create a list that's full of blanks, then fill the blanks later.

To create a list that has 100 blank items, say:

```
>>> x=[None]*100
```

The "None" means "blank". Those 100 blank items are called x_0, x_1, x_2, etc., up through x_{99}.

After creating that x, you can give a command such as:

```
>>> x[57]='fun'
```

That command is legal just *after* you've created x.

If you try giving that command without creating x previously, the computer will say "NameError".

If you try talking about x_{200} even though you created up through just x_{99}, the computer will say "IndexError".

Dictionaries

Suppose Jack is great, Jim is jolly, Sue is sweet, and Mary is smart.

To store that info, create a **dictionary** called d, like this:

```
>>> d={'Jack':'great', 'Jim':'jolly', 'Sue':'sweet', 'Mary':'smart'}
```

When you type that, put the dictionary in **braces**, which are the symbols "{}" and require you to press the Shift key.

Then if you want to use that dictionary to look up Sue, type:

```
>>> d['Sue']
```

The computer will use the dictionary, look up Sue, discover Sue is sweet, and say:

```
>>> 'sweet'
```

Instead of the letter d, you can use any variable name you wish.

Here's how to put a dictionary into a program:

```
d={'Jack':'great', 'Jim':'jolly', 'Sue':'sweet', 'Mary':'smart'}
name=input('What name should I look up? ')
if name in d: print(name,'is',d[name])
else: print('Sorry, I do not know about',name)
```

The top line creates the dictionary. The next line makes the computer ask "What name should I look up?" and wait for the human to type a name. If the human typed a name (such as "Sue") that's in the dictionary, the program's third line makes the computer print a message such as:

```
Sue is sweet
```

But if the human typed a name (such as "Alice") that's *not* in the dictionary, the program's bottom line makes the computer print a message such as:

```
Sorry, I do not know about Alice
```

Besides storing comments such as "sweet", you can make the dictionary store people's addresses, phone numberd, social-security numbers, birthdays, debts, sexual orientiations, and methods by which they'd like to kill you when they discover you've stored that private data.

A dictionary is also called a **lookup table**.

Let's make the computer translate English colors to French, by using this lookup table:

English	French
white	blanc
yellow	jaune
red	rouge
blue	bleu
black	noir

That lookup table becomes our multilingual dictionary. Here's the program:

```
d={'white':'blanc', 'yellow':'jaune', 'red':'rouge', 'blue':'bleu', 'black':'noir'}
EnglishColor=input('What color should I translate? ')
if EnglishColor in d: print('In French it is',d[EnglishColor])
else: print('Sorry, I do not know the French for',EnglishColor)
```

Too long If you want to type a dictionary (lookup table) that's too long to fit on one line, do this:

Type *part* of the dictionary on one line. Type a backslash at the end of that part. Type the rest of the dictionary below. Type a backslash at the end of each line (except the dictionary's bottom line). The backslash means: the rest of the dictionary continues below.

JavaScript & JScript

Pages 295-303 explained how to create Web pages by using HTML. Unfortunately, HTML is *not* a complete programming language.

For example, HTML lacks commands to do arithmetic. In HTML, there is no command to make the computer do 2+2 and get 4.

HTML lacks commands to create repetitions (which are called **loops**). In HTML, there is no command to make the computer repeat a task 10 times.

In 1996, a Netscape employee, Brendan Eich, invented an HTML supplement called **LiveScript**, which lets you create Web pages that do arithmetic, loops, counting, and many other fancy tricks. When folks noticed that LiveScript looks like a stripped-down version of Java, Netscape changed the name "LiveScript" to **JavaScript**.

JavaScript is included as part of Netscape Navigator (if you have Navigator version 2 or later). **JScript** (Microsoft's imitation of JavaScript) is included as part of Internet Explorer (if you have Internet Explorer version 3 or later).

Now every popular computer comes with JavaScript or JScript. That's because Netscape Navigator is free, Internet Explorer is free, Netscape Navigator & Internet Explorer are both available for IBM and Macs, and Internet Explorer is part of Windows.

Netscape, Microsoft, and the **European Computer Manufacturers Association (ECMA)** all decided to make JavaScript and JScript resemble each other more, by creating a standard called **ECMAScript**.

This chapter explains how to use JScript to create powerful Web pages. (JavaScript and ECMAScript are similar.)

Before learning JScript, make sure you've learned HTML (by reading pages 295-303).

JScript uses these commands:

JScript command	Page
`alert("Warning: bad hair")`	621
`document.write(2+2)`	619
`else`	623
`for (i=1; i<10; ++i)`	623
`if (age<18)`	623
`x=Array(3)`	621
`x=prompt("What name?","")`	621
`x=47`	621
`x[0]="love"`	621
`++x`	621
`--x`	621
`//I wrote this while drunk`	624

Simple program

You can create a Web page that says —

We *love* you

by typing this HTML program:

```
We <i>love</i> you
```

I explained how on page 296. (If you forget how, reread page 296 and practice it now.)

To create a Web page that makes the computer do 2+2 instead, type instead this HTML program (which includes a JScript program):

```
<script>
document.write(2+2)
</script>
```

The first line, which says <script>, warns the computer that you're going to start typing a JScript (or JavaScript) program. The next line, which is written in JScript, means: on the Web-page document, write the answer to 2+2. The bottom line, which says </script>, marks the bottom of your JScript program. When you run that program, the computer will do 2+2 and write this answer:

4

In that example, the first line, <script>, is an HTML tag. Like all HTML tags, it's enclosed in angle brackets: the symbols <>. That tag marks the beginning of your JScript program. The bottom line, </script>, is an HTML tag that marks the end of your JScript program. Between those two tags, write your JScript program.

Longer example

Let's make the computer write "We *love* you", then write the answer to 2+2, then write "ever *and ever*". This program does it:

```
We <i>love</i> you
<script>
document.write(2+2)
</script>
ever <i>and ever</i>
```

The first line makes the computer write "We *love* you". The next three lines hold the JScript program making the computer write the answer to 2+2, which is 4. The bottom line makes the computer write "ever *and ever*". So altogether, the computer will write:

We *love* you 4 ever *and ever*

Fancier arithmetic

This program makes the computer write the answer to 8-3:

```
<script>
document.write(8-3)
</script>
```

The computer will write:

5

This program makes the computer write the answer to -26.3+1:

```
<script>
document.write(-26.3+1)
</script>
```

The computer will write:

-25.3

Multiplication

To multiply, use an asterisk. So to multiply 2 by 6, type this:

```
<script>
document.write(2*6)
</script>
```

The computer will write:

12

Division

To divide, use a slash. So to divide 8 by 4, type this:

```
<script>
document.write(8/4)
</script>
```

The computer will write:

2

Avoid commas

Do *not* put commas in big numbers. To write four million, do *not* write 4,000,000; instead, write 4000000.

E notation

If the computer's answer is huge (at least 100000000000000000000) or tiny (less than .000001), the computer will typically print an e in the answer. The e means "move the decimal point".

For example, suppose the computer says the answer to a problem is:

```
1.5864321775908348e+21
```

The e means, "move the decimal point". The plus sign means, "towards the right". Altogether the e+21 means, "move the decimal point towards the right, 21 places." So look at 1.5864321775908348, and move the decimal point towards the right, 21 places; you get 1586432177590834800000.

So when the computer says the answer is 1.5864321775908348, the computer really means the answer is 1586432177590834800000, approximately. The exact answer might be 1586432177590834800000.2 or 1586432177590834800000.79 or some similar number, but the computer prints just an approximation.

Suppose your computer says the answer to a problem is:

```
9.23e-7
```

After the e, the minus sign means, "towards the *left*". So look at 9.23, and move the decimal point towards to left, 7 places. You get:

.000000923

You'll see e notation rarely: the computer uses it just if the answer is huge or tiny. But when the computer *does* use e notation, remember to move the decimal point!

The highest number

The highest number the computer can handle well is about 1E308, which is 1 followed by 308 zeros. If you try to go much higher, the computer will give up and say the answer is:

```
Infinity
```

The tiniest decimal

The tiniest decimal the computer can handle accurately is 1E-309 (which is a decimal point followed by 309 digits, 308 of which are zeros). If you try to go tinier, the computer will either write 0 or give you a rough approximation.

Long decimals

If an answer is a decimal that contains *many* digits, **the computer will typically write the first 16 significant digits accurately and the 17th digit approximately**. The computer won't bother writing later digits.

For example, suppose you ask the computer to write 100 divided by 3, like this:

```
<script>
document.write(100/3)
</script>
```

The computer will write:

```
33.333333333333336
```

Notice that the 17th digit, the 6, is wrong: it should be 3.

Division by 0

If you try to divide 1 by 0, the computer will say the answer is:

```
Infinity
```

If you try to divide 0 by 0, the computer will say the answer is —

```
NaN
```

which means "Not a Number".

Order of operations

JScript (and JavaScript) handle order of operations the same as QBasic, Visual Basic, and most other computer languages.

For example, if you type this program —

```
<script>
document.write(2+3*4)
</script>
```

the computer will "start with 2 then add three 4's", so it will write this answer:

```
14
```

You can use parentheses the same way as in algebra. For example, if you type —

```
<script>
document.write(5-(1+1))
</script>
```

the computer will compute 5-2 and write:

```
3
```

Strings

You learned how to put a JScript (or JavaScript) program in the middle of an HTML program. You can also do the opposite, you can put HTML in the middle of a JScript program.

For example, this JScript program makes the computer write "We *love* you":

```
<script>
document.write("We <i>love</i> you")
</script>
```

The computer will write:

```
We love you
```

In that program, the "We love you" is called a **string** of characters. Each string must begin and end with a quotation mark. Between the quotation marks, put any characters you want the computer to write. A string can include an HTML tag, such as .

Strings with numbers

If you bought 750 apples and buy 12 more, how many apples do you have altogether? This program makes the computer write the answer:

```
<script>
document.write(750+12," apples")
</script>
```

The computer will write the answer to 750+12 (which is 762) then the word " apples" (which includes a blank space), so altogether the computer will write:

```
762 apples
```

This program makes the computer put the answer into a complete sentence:

```
<script>
document.write("You have ",750+12," apples!")
</script>
```

The computer will write "You have " then 762 then "apples!", so altogether the computer will write:

```
You have 762 apples!
```

Writing several strings

Here's another example of strings:

```
<script>
document.write("fat")
document.write("her")
</script>
```

The computer will write "fat" then "her", so altogether the computer will write:

```
father
```

Let's make the computer write this instead:

```
fat
her
```

To do that, make the computer press the Enter key before her. Here's how: say
 (which is the HTML tag to break out a new line), like this —

```
<script>
document.write("fat")
document.write("<br>her")
</script>
```

or like this:

```
<script>
document.write("fat<br>her")
</script>
```

Addition

You can add strings together by using the + sign:

```
"fat"+"her" is the same as "father"
2+2+"ever" is the same as "4ever"
```

Variables

A letter can stand for a number. For example, x can stand for the number 47, as in this program:

```
<script>
x=47
document.write(x+2)
</script>
```

The second line says x stands for the number 47. In other words, x is a name for the number 47.

The next line says to write x+2. Since x is 47, the x+2 is 49; so the computer will write:

```
49
```

That's the only number the computer will write; it won't write 47.

A letter that stands for a number is called a **numeric variable**.

A letter can stand for a string. For example, y can stand for the string "We *love* you", as in this program:

```
<script>
y="We <i>love</i> you"
document.write(y)
</script>
```

The computer will write:

```
We love you
```

A letter that stands for a string is called a **string variable**.

A variable's name can be short (such as x) or long (such as town_population_in_2001). It can be as long as you wish! The name can contain letters, digits, and underscores, but not blank spaces. The name must begin with a letter or underscore, not a digit.

Increase

The symbol ++ means "increase". For example, ++n means "increase n".

This program increases n:

```
<script>
n=3
++n
document.write(n)
</script>
```

The n starts at 3 and increases to 4, so the computer prints 4.

Saying ++n gives the same answer as n=n+1, but the computer handles ++n faster.

The symbol ++ increases the number by 1, even if the number is a decimal. For example, if x is 17.4 and you say ++x, x will become 18.4.

Decrease

The opposite of ++ is --. The symbol -- means "decrease". For example, --n means "decrease n". Saying --n gives the same answer as n=n-1 but faster.

Arrays

A letter can stand for a list. For example, x can stand for a list, as in this program:

```
<script>
x=["love","death",48+9]
document.write(x)
document.write(x[2]/4)
</script>
```

That makes x be a list of three items: "love", "death", and the answer to 48+9 (which is 57). The next line makes the computer write all of x, like this:

```
love,death,57
```

In x (which is a list), there are 3 items:

```
The original item, which is called x[0], is "love".
The next item, which is called x[1], is "death".
The next item, which is called x[2], is 57.
```

The next line says to write x[2]/4, which is 57/4, which is 14.25; but since we didn't say
, the computer writes the 14.25 on the same line as the list, so altogether you see:

```
love,death,5714.25
```

A list is called an **array**.

Delayed definition If you want x to be a list of 3 items but don't want to list the 3 items yet, you can be vague by saying just —

```
x=Array(3)
```

Later, you can define x by lines such as:

```
x[0]="love"
x[1]="death"
x[2]=48+9
```

Pop-up boxes

Here's how to make a box appear suddenly on your screen.

Alert box

To create a surprise, make the computer create an **alert box**:

```
<script>
alert("Warning: your hair looks messy today")
document.write("You won't become Miss America")
</script>
```

When a human runs that program, the screen suddenly shows an **alert box**, which contains this message: "Warning: your hair looks messy today". (The computer automatically makes the box be in front of the Web page, be centered on the screen, and be wide enough to show the whole message.) The alert box also contains an OK button. The computer waits for the human to read that alert message and click "OK".

When the human clicks "OK", the alert box disappears and the computer obeys the program's next line, which makes the computer write onto the Web page:

```
You won't become Miss America
```

In an alert box, the computer uses its alert font, which you cannot change: you can*not* switch to italics or bold; you can*not* put HTML tags into that message.

Here's another example:

```
<script>
alert("You just won a million dollars")
document.write("Oops, I lost it, better luck next time")
</script>
```

When a human runs that program, an alert box tells the human "You just won a million dollars"; but when the human clicks "OK", the Web page says "Oops, I lost it, better luck next time".

Prompt box

To ask the human a question, make the computer create a **prompt box**:

```
<script>
x=prompt("What is your name?","")
document.write("I adore anyone whose name is ",x)
</script>
```

When a human runs that program, the computer creates a **prompt box**, which is a window letting the human type info into the computer. (The computer automatically makes the box be in front of the Web page and be slightly above the screen's center.) It contains this **prompt**: "What is your name?" It also contains a white box (into which the human can type a response) and an OK button.

The computer waits for the human to type a response. When the human finishes typing a response, the human must click the OK button (or press Enter) to make the window go away.

Then the Web page reappears and the computer makes x be whatever the human typed. For example, if the human typed —

```
Maria
```

x is Maria, so the computer writes this onto the Web page:

```
I adore anyone whose name is Maria
```

In that program, notice that the prompt line includes these symbols before the last parenthesis:

```
,""
```

If you type this instead —

```
,"Type your name here"
```

here's what happens: the white box (into which the human types a name) will temporarily say "Type your name here", until the human starts typing.

College admissions This program makes the computer write a letter admitting you to the college of your choice:

```
<script>
college=prompt("What college would you like to enter?","")
document.write("You're admitted to ",college,". I hope you go to ",college,".")
</script>
<p>Respectfully yours,
<br>The Dean of Admissions
```

When you run the program, a prompt box appears, asking "What college would you like to enter?" Type your answer (then click OK or press Enter).

For example, if you type —

```
Harvard
```

the college will be "Harvard", so the computer will write "You're admitted to" then "Harvard" then ". I hope you go to " then "Harvard", then "." then the remaining HTML code, like this:

```
You're admitted to Harvard. I hope you go to Harvard.

Respectfully yours,
The Dean of Admissions
```

If you type this instead —

```
Hell
```

the computer will write:

```
You're admitted to Hell. I hope you go to Hell.

Respectfully yours,
The Dean of Admissions
```

All the writing is onto your screen's Web page. Afterwards, if you want to copy that writing onto paper, click Internet Explorer's Print button. (If you don't see the Print button, make it appear by maximizing the Internet Explorer window.)

Numeric input This program makes the computer predict your future:

```
<script>
y=prompt("In what year were you born?","")
document.write("In the year 2020, you'll turn ",2020-y," years old")
</script>
```

When you run the program, the computer asks, "In what year were you born?" If you answer —

```
1962
```

y will be 1962, and the computer will write:

```
In the year 2020, you'll turn 58 years old.
```

Control statements

A program is a list of statements that you want the computer to perform. Here's how to control which statements the computer performs, and when, and in what order.

If

This program makes the computer discuss the human's age:

```
<script>
age=prompt("How old are you?","")
document.write("I hope you enjoy being ",age)
</script>
```

When that program is run, the computer asks "How old are you?" and waits for the human's reply. For example, if the human says —

```
15
```

the age will be 15. Then the computer will print:

```
I hope you enjoy being 15
```

Let's make that program fancier, so if the human is under 18 the computer will also say "You are still a minor". To do that, just add a line saying:

```
if (age<18) document.write("<br>You are still a minor")
```

Notice you must put parentheses after the word "if". Altogether, the program looks like this:

```
<script>
age=prompt("How old are you?","")
document.write("I hope you enjoy being ",age)
if (age<18) document.write("<br>You are still a minor")
</script>
```

For example, if the human runs the program and says —

```
15
```

the computer will print:

```
I hope you enjoy being 15
You are still a minor
```

If instead the human says —

```
25
```

the computer will print just:

```
I hope you enjoy being 25
```

Else

Let's teach the computer how to respond to adults.

Here's how to program the computer so that if the age is less than 18, the computer will say "You are still a minor", but if the age is *not* less than 18 the computer will say "You are an adult" instead:

```
<script>
age=prompt("How old are you?","")
document.write("I hope you enjoy being ",age)
if (age<18) document.write("<br>You are still a minor")
else document.write("<br>You are an adult")
</script>
```

In programs, **the word "else" means "otherwise"**. The program says: if the age is less than 18, write "You are still a minor"; otherwise (if the age is *not* less than 18), write "you are an adult". So the computer will write "You are still a minor" or else write "You are an adult", depending on whether the age is less than 18.

Try running that program! If you say you're 50 years old, the computer will reply by saying:

```
I hope you enjoy being 50
You are an adult
```

Fancy relations

Like JavaScript, Java's "if" statement uses this notation:

Notation	Meaning
`if (age<18)`	if age is less than 18
`if (age<=18)`	if age is less than or equal to 18
`if (age==18)`	if age is equal to 18
`if (age!=18)`	if age is not equal to 18
`if (age<18 && weight>200)`	if age<18 and weight>200
`if (age<18 || weight>200)`	if age<18 or weight>200
`if (sex=="male")`	if sex is "male"
`if (sex<"male")`	if sex is a word (such as "female") that comes before "male" in dictionary
`if (sex>"male")`	if sex is a word (such as "neuter") that comes after "male" in dictionary

Notice that in the "if" statement, you should use double symbols: you should say "==" instead of "=", say "&&" instead of "&", and say "||" instead of "|". If you accidentally say "=" instead of "==", the computer will gripe. If you accidentally say "&" instead of "&&" or say "|" instead of "||", the computer will still get the right answers but too slowly.

Braces

If a person's age is less than 18, let's make the computer write "You are still a minor" and make maturity=0. Here's how:

```
if (age<18)
{
    document.write("You are still a minor")
    maturity=0
}
```

Here's a fancier example:

```
if (age<18)
{
    document.write("You are still a minor")
    maturity=0
}
else
{
    document.write("You are an adult")
    maturity=1
}
```

For

Here's how to write the numbers from 1 to 10:

```
<script>
for (i=1; i<=10; ++i) document.write(i," ")
</script>
```

That means: do repeatedly, for i starting at 1, while i is no more than 10, and increasing i after each time: write i followed by a blank space (to separate i from the next number). The computer will write:

```
1 2 3 4 5 6 7 8 9 10
```

If instead you want to write each number on a separate line, say "
" (which means "break for new line") before each number:

```
<script>
for (i=1; i<=10; ++i) document.write("<br>",i)
</script>
```

The computer will write:

```
1
2
3
4
5
6
7
8
9
10
```

Let's get fancier! For each number, let's make the computer also write the number's **square** (what you get when you multiply the number by itself), like this:

```
1 squared is 1
2 squared is 4
3 squared is 9
4 squared is 16
5 squared is 25
6 squared is 36
7 squared is 49
8 squared is 64
9 squared is 81
10 squared is 100
```

Here's how:

```
<script>
for (i=1; i<=10; ++i) document.write("<br>",i," squared is ",i*i)
</script>
```

To get even fancier, let's make the computer write that info in a pretty table, like this:

NAME	SCORE
1	1
2	4
3	9
4	16
5	25
6	36
7	49
8	64
9	81
10	100

As I explained on page 299, you do that by saying <table border=1> above the table, <tr> at the beginning of each table row, <th> at the beginning of each column heading, <td> at the beginning of each data item, and </table> below the table:

```
<table border=1>
<tr><th>NAME<th>SCORE
<script>
for (i=1; i<=10; ++i) document.write("<tr><td>",i,"<td>",i*i)
</script>
</table>
```

Onclick

Let's create a Web page that asks, "What sex are you?" Below that question, let's put two buttons labeled "Male" and "Female". If the human clicks the "Male" button, let's make the computer say "So is Frankenstein". If the human clicks the "Female" button, let's make the computer say "So is Mary Poppins".

To accomplish all that, just type this HTML:

```
What sex are you?
<form>
<input type=button value="Male" onclick="alert('So is Frankenstein')">
<input type=button value="Female" onclick="alert('So is Mary Poppins')">
</form>
```

Here's what each line accomplishes:

Since we want the Web page to begin by asking "What sex are you?", the top line says "What sex are you?"

To create buttons, you must create a form to put them in, so the second line says <form>.

The next line says to create an input button labeled "Male", which when clicked will do this command: create an alert box saying "So is Frankenstein".

The next line says to create a similar input button labeled "Female", which when clicked will do this command: create an alert box saying "So is Mary Poppins".

The bottom line, </form>, marks the end of the form.

Notice these details:

After onclick, you put an equal sign, then a quotation mark, then any command written in JavaScript (or JScript), such as "alert". The computer knows the onclick command uses JavaScript, so you don't have to say <script>.

The JavaScript command must be in a pair of quotation marks. If you want to put a pair of quotation marks inside another pair of quotation marks, use a pair of single quotes (which look like apostrophes).

After onclick, instead of typing a JavaScript command, you can type *several* JavaScript commands, if you separate them by semicolons, like this:

```
onclick="x=4; y=2; alert(x+y)"
```

That would mean: if the button is clicked, make x=4, make y=2, and create an alert box showing their sum, 6.

When you create two buttons, the second button normally appears to the *right* of the first button. If you'd rather place the second button *below* the first button, say
 before the second button to put it on a new line, like this:

```
<br><input type=button value="Female" onclick="alert('So is Mary Poppins')">
```

Documentation

On page 302, I said you can write a comment in your HTML program by starting with the symbol "<!--" and ending with the symbol "-->", like this:

```
<!--I wrote this program while drunk-->
```

But while you're writing JavaScript (or JScript) program lines, which comes between <script> and </script>, you must write your comments differently, in JavaScript style: put each comment on a separate line that begins with //, like this:

```
//I wrote these JavaScript lines while even drunker
```

Emphasize JavaScript

To emphasize that your program is written in JavaScript (or a JavaScript clone such as JScript), you can say —

```
<script language="JavaScript">
```

or even say —

```
<script language="JavaScript" type="text/javascript">
```

instead of saying just <script>.

No JavaScript?

Most Web browsers understand JavaScript and JScript programs. But Web browsers that are very old or very primitive don't understand JavaScript at all.

If your Web-page program contains a JavaScript program, but somebody who lacks JavaScript tries to view your Web page, the page will look very messed up, and the person might even see your raw JavaScript code, including equal signs and words such as "document.write".

To make sure such a person doesn't see your raw code on the Web page, say this instead of just <script> —

```
<script>
<!--
```

and say this instead of just </script>:

```
//-->
</script>
```

Also, warn the JavaScript-deprived person that your page requires JavaScript, by putting this line below the </script> line:

```
<noscript>This page requires JavaScript</noscript>
```

Here's what that line accomplishes: if the person has no JavaScript, the Web page will say "This page requires JavaScript".

Java

Java is a programming language. It was invented in California in 1995 by James Gosling at **Sun Microsystems**, which later became part of **Oracle**.

Java resembles JavaScript (and JScript) but includes extra commands, so you can create a greater variety of programs. Those extra commands make Java a complete programming language (like QBasic and Visual Basic).

Java is easy to learn. It's almost as easy as QBasic, Visual Basic, JavaScript, and JScript. It's a simplified version of **C** (which is much harder and discussed in the next chapter).

Java uses these commands:

Java command	Page
`char grade;`	628
`char grade='A';`	628
`double x;`	627
`double[] x={81.2,51.7,207.9};`	628
`double[] x=new double[3];`	628
`double[][] x=new double[2][3];`	628
`else {`	630
`for (int i=20; i<=24; ++i) {`	631
`if (age<18) {`	630
`import java.util.Scanner;`	629
`import static java.lang.Math.*;`	627
`int x;`	627
`int x=3;`	627
`int[] x={81,52,207}`	628
`package joe;`	625
`public class Joe {`	625
`public static void main(…) {`	625
`Scanner in=new Scanner(…);`	629
`String x;`	629
`String x="he";`	629
`System.out.print("nose");`	626
`System.out.println("nose");`	626
`while (i<25) {`	631
`x=3;`	627
`++x;`	628
`--x;`	628
`// Zoo program is fishy`	626
`/* Zoo program is fishy */`	626

Java uses these functions:

Java function	Page
`in.nextDouble()`	630
`in.nextInt()`	629
`in.nextLine()`	629
`Math.abs`	627
`Math.acos(x)`	627
`Math.asin(x)`	627
`Math.atan(x)`	627
`Math.atan2(y,x)`	627
`Math.ceil(x)`	627
`Math.cos(x)`	627
`Math.exp(x)`	627
`Math.floor(x)`	627
`Math.log(x)`	627
`Math.pow(x,y)`	627
`Math.sin(x)`	627
`Math.sqrt(x)`	627
`Math.tan(x)`	627
`x.compareTo(y)`	630

Fun

Here's how to enjoy programming in Java.

To *run* programs that were written in Java, you must download (copy) the **Java Runtime Environment (JRE)** from Oracle's Website to your computer. To *develop* (create and edit) your own programs in Java, you must download the **Java Development Kit (JDK)**, which includes JRE. To develop your own program *easily* in Java, you must also download an **Integrated Development Environment (IDE)**, such as **NetBeans**.

You can download all those tools (**JRE**, **JDK**, and **NetBeans**) from Oracle's Website, free.

Compatibility

The newest, best Web browsers (Microsoft Edge and the newest version of Google Chrome) refuse to run some parts of Java, because those parts can be dangerous. So **while using Java, don't run Microsoft Edge or Chrome: instead run Internet Explorer** (or Firefox or Safari).

Reminder: if you're using Windows 10, run Internet Explorer by doing this: in the Windows search box, type "internet" then tap "Internet Explorer: Desktop app".

Copy Java tools to the hard disk

Here's how to copy the **Java Standard-Edition Development Kit (Java SE)** (version 8's update 111) and **NetBeans** (version 8.2) to your hard disk by using Windows 10 and Internet Explorer 11.

Start Internet Explorer (not Microsoft Edge, not Chrome). Go to: Oracle.com/technetwork/java/javase/downloads

Tap the "NetBeans" button then the circle before "Accept License Agreement". Tap the red down-arrow to the right of "Windows x64" then "Run" then "Yes".

Press the Enter key, 4 times.

The computer copies Java SE and NetBeans to your hard disk then says "Installation completed successfully". Press Enter.

Close the Internet Explorer window (by clicking its X).

Start Java

To start using **Java** (version 8, update 111) with **NetBeans** (version 8.2), double-tap the **"NetBeans IDE 8.2" icon**, which you should see on your Desktop screen.

If you *don't* see that icon, do this instead: tap the Windows Start button, then from the list of "All apps" (which old Windows 10 shows when you tap "All apps") choose "NetBeans IDE 8.2" (or choose "NetBeans" then "NetBeans IDE 8.2").

You see the NetBeans IDE 8.2 window. If it doesn't consume the whole screen yet, maximize it (by clicking the Maximize button, which is next to the X).

Start a new program

Tap the **New Project** button. (It's an orange square with a green plus sign on it. It's near the screen's top-left corner, below the word "Edit".)

In the Categories box, make sure the top choice ("Java") is highlighted (in blue or gray). If it's not highlighted yet, highlight it (by tapping it).

In the Projects box, make sure the top choice ("Java Application") is highlighted (in blue or gray). If it's not highlighted yet, highlight it (by tapping it).

Press Enter.

Invent a name for your project (such as "Joe"). Type the name and press Enter.

You see a big white box. In that box is a prototype Java program. That program does nothing useful, but you can edit it to do whatever you wish!

In that program, the important lines look like this:

```
package joe;
public class Joe {
    public static void main(String[] args) {
    }
}
```

In those lines, the characters are black or blue.

In other lines, the characters are gray. The computer ignores those gray lines — and you should too! — since they're just comments.

If you find the gray lines (and blank lines) too distracting, erase them. (To erase a line, tap it then do this: while holding down the Ctrl key, tap the E key.)

Let's program the computer to say:

```
make your nose
touch your toes
```

To do that, edit the prototype program by inserting these extra lines:

```
package joe;
public class Joe {
    public static void main (String[] args) {
        System.out.println("make your nose");
        System.out.println("touch your toes");
    }
}
```

Here's how to insert those extra lines. Click to the right of the second "{". Press Enter. Type the first extra line (making sure you capitalize the first "S" in "System"), but **be aware of these tricks:**

The computer indents the line automatically.

Whenever you type "(", the computer automatically types the matching ")" for you.

Whenever you type a quotation mark, the computer automatically types the matching quotation mark for you.

Make sure the line ends in a semicolon, but the computer probably typed it for you already.

At the end of typing the line, **move the cursor to the line's end** (to skip past what the computer typed), by pressing the right-arrow key twice (or the End key once).

If you ever want the computer to indent differently, do this before typing a line's first word or symbol….

To indent, press the Tab key.

To unindent, press the Backspace key repeatedly or do this: while holding down the Shift key, tap the Tab key.

Here's what those extra lines mean:

The first extra line makes the computer **system** send **out** a **print**ed **lin**e saying "make your nose" and makes the computer press Enter afterwards. (If you omit the "ln", the computer will *not* press Enter afterwards.)

The second extra line makes the computer print "touch your toes" and press Enter afterwards.

When you finish inserting those extra lines, congratulations! You've written a Java program!

Run the program

To run the program, **tap the big green triangle**, which is near the screen's top, below the word "Team").

In the **Output window** (at the screen's bottom), the computer will say —

```
make your nose
touch your toes
```

It will also say "BUILD SUCCESSFUL", which means you didn't make any obvious mistakes. Congratulations!

While the program you wrote is on the screen, you can edit it. After editing it, rerun it (by tapping the big green triangle).

When you finish playing with that program, you can start a new program by clicking the **New Project** button again.

Get old programs

Here's how to view old programs you created earlier:

While you're running NetBeans, tap "Projects" (which is at the screen's left edge). You see a list of projects (programs) that you created. Each project's name is at the screen's left edge. Indented under the project's name are files (and folders) containing details about the project.

If you want to delete one of the projects, tap its name (at the screen's left edge) then press the Delete key then click "Also delete sources" then "Yes".

If you want to use one of the projects now, double-tap the file that's indented underneath and ends in ".java". For example, if you want to use a project named "Joe", double-tap "Joe.java", which is indented under Joe's "Source Packages".

Comments

To put a comment in your program, begin the comment with the symbol //. The computer ignores everything that's to the right of //. Here's an example:

```
// This program is fishy
// It was written by a sick sailor swimming in the sun
package joe;
public class Joe {
    public static void main (String[] args) {
        System.out.println("Our funny God");  // religious
        System.out.println("invented cod");    // wet joke
    }
}
```

The computer ignores all the comments, which are to the right of //.

While you type the program, the computer makes each // and each comment turn gray. Then the computer ignores everything that's turned gray, so the computer prints just:

```
Our funny God
invented cod
```

Another way to write a comment is to begin it with the symbol /* and end it with the symbol */, like this:

```
/* This program is fishy
   It was written by a sick sailor swimming in the sun */
package joe;
public class Joe {
    public static void main (String[] args) {
        System.out.println("Our funny God");  /* religious */
        System.out.println("invented cod");    /* wet joke */
    }
}
```

Math

The computer can do math. For example, this line makes the computer do 4+2:

```
        System.out.println(4+2);
```

If you put that line into your program and run the program, the computer will print this answer on your screen, in the Output window:

```
6
```

If you bought 750 apples and buy 12 more, how many apples do you have altogether? This line prints the answer:

```
        System.out.println(750+12+" apples");
```

That line makes the computer do 750+12 (which is 762) and add the word " apples" (which includes a blank space), so the computer will print:

```
762 apples
```

This line makes the computer put the answer into a complete sentence:

```
        System.out.println("You have "+(750+12)+" apples!");
```

The computer will print "You have " and add 762 and add " apples!", so altogether the computer will print:

```
You have 762 apples!
```

Like most other languages (such as Basic and JavaScript), Java lets you use the symbols +, -, *, /, parentheses, decimal points, and e notation.

Integers versus double precision

Java handles two types of numbers well.

One type of number is called an **integer** (or **int**). An int contains no decimal point and no e. For example, -27 and 30000 are ints.

The other type of number that Java handles well is called a **double-precision number** (or a **double**). **A double contains a decimal point or an e.** For example, -27.0 and 3e4 are doubles. You can abbreviate: instead of writing "-27.0", you can write "-27.", and instead of writing "0.37" you can write ".37".

Largest and tiniest numbers

The largest permissible int is about 2 billion. More precisely:

```
the largest int is  2147483647
the lowest int is -2147483648
```

If you try to feed the computer an int that's too large or too low, the computer won't complain. Instead, the computer will typically print a wrong answer!

The largest permissible double is about 1.7e308. More precisely, it's 1.7976931348623158e308. If you feed the computer a math problem whose answer is bigger than that, the computer will give up and typically say the answer is:

```
Infinity
```

The tiniest double that the computer handles well is about 2.2e-308. More precisely, it's 2.2250738585072014e-308. If you feed the computer a math problem whose answer is tinier than that, the computer will either handle the rightmost digits inaccurately or omit the rightmost digits or give up, saying the answer is 0.0.

Tricky arithmetic

If you combine ints, the answer is an int. For example, 2+3 is this int: 5.

11/4 is this int: 2. (11/4 is *not* 2.75.)

If you combine doubles, the answer is a double. If you combine an int with a double, the answer is a double.

How much is 2000 times 2000000? Theoretically, the answer should be this int: 4000000000. But since 4000000000 is too large to be an int, the computer will print a wrong answer. To make the computer multiply 2000 by 2000000 correctly, ask for 2000.0*2000000.0, like this:

```
    System.out.println(2000.0*2000000.0);
```

That program makes the computer get the correct answer, 4000000000.0, which the computer will write in e notation, so you see this answer:

```
4.0E9
```

Long decimals

If an answer is a decimal that contains *many* digits, **the computer will typically print the first 16 significant digits accurately and the 17th digit approximately**. The computer won't bother printing later digits.

For example, suppose you ask the computer to print 10.0 divided by 9.0, like this:

```
    System.out.println(10.0/9.0);
```

The computer will print:

```
1.1111111111111112
```

Notice that the 17th digit, the 2, is slightly wrong: it should be 1.

Division by 0.0

If you try to divide 1.0 by 0.0, the computer will say the answer is:

```
Infinity
```

If you try to divide 0.0 by 0.0, the computer will say the answer is —

```
NaN
```

which means "Not a Number".

Advanced math

The computer can do advanced math. For example, it can compute square roots. This line makes the computer print the square root of 9:

```
        System.out.println(Math.sqrt(9.0));
```

The computer will print:

```
3.0
```

Say Math.sqrt(9.0) rather than Math.sqrt(9), because the number you find the square root of should be double-precision, not an integer. If you make the mistake of saying Math.sqrt(9), the computer will print the correct answer but slowly.

Besides sqrt, you can use these other advanced math functions:

To handle exponents, you can use sqrt (square root), exp (exponential power of e), and log (logarithm base e). You can also use pow: for example, pow(3.0,2.0) is 3.0 raised to the 2.0 power.

For trigonometry, you can use sin (sine), cos (cosine), tan (tangent), asin (arcsin), acos (arccosine), and atan (arctangent). You can also use atan2: for example, atan2(y,x) is the arctangent of y divided by x.

For absolute value, use abs. For example, abs(-2.3) is 2.3.

To round, use floor (which rounds down) or ceil (which stands for "ceiling" and rounds *up*). For example, floor(26.319) is 26.0, and ceil(26.319) is 27.0.

Before each advanced math function, you must say "Math." unless you insert this line above the "public class" line:

```
import static java.lang.Math.*;
```

Variables

Like Basic and JavaScript, Java lets you use variables. For example, you can say:

```
    n=3;
```

A variable's name can be short (such as n) or long (such as town_population_in_2001). It can be as long as you wish! The name can contain letters, digits, and underscores, but not blank spaces. The name must begin with a letter or underscore, not a digit.

Before using a variable, say what type of number the variable stands for. For example, if n and town_population_in_2001 will stand for numbers that are ints and mortgage_rate will stand for a double, begin your program by saying:

```
package joe;
public class Main {
    public static void main (String[] args) {
        int n, town_population_in_2001;
        double mortgage_rate;
```

If n is an integer that starts at 3, you can say —

```
    int n;
    n=3;
```

but you can combine those two lines into this single line:

```
    int n=3;
```

Here's how to say "n is an integer that starts at 3, and population_in_2001 is an integer that starts at 27000":

```
    int n=3, population_in_2001=27000;
```

Increase

Like JavaScript, Java uses the symbol ++ to mean "increase". For example, ++n means "increase n".

These lines create n, increase it, then print it:

```
int n=3;
++n;
System.out.println(n);
```

The n starts at 3 and increases to 4, so the computer prints 4.

Saying ++n gives the same answer as n=n+1, but the computer handles ++n faster.

The symbol ++ increases the number by 1, even if the number is a decimal. For example, if x is 17.4 and you say ++x, the x will become 18.4.

Decrease

The opposite of ++ is --. The symbol -- means "decrease". For example, --n means "decrease n". Saying --n gives the same answer as n=n-1 but faster.

Strange short cuts

If you use the following short cuts, your programs will be briefer and run faster.

Instead of saying n=n+2, say n+=2, which means "n's increase is 2". Similarly, instead of saying n=n*3, say n*=3, which means "n's multiplier is 3".

Instead of saying ++n and then giving another command, say ++n in the middle of the other command. For example, instead of saying —

```
++n;
j=7*n;
```

say:

```
j=7*++n;
```

That's pronounced: "j is 7 times an increased n". So if n was 2, saying j=7*++n makes n become 3 and j become 21.

Notice that when you say j=7*++n, the computer increases n *before* computing j. If you say j=7*n++ instead, the computer increases n *after* computing j; so j=7*n++ has the same effect as saying:

```
j=7*n;
++n;
```

Arrays

Instead of being just a number, x can be a *list* of numbers (as in Visual Basic and JavaScript).

Example For example, if you want x to be this list of ints —

```
{81, 52, 207, 19}
```

type this:

```
int[] x={81,52,207,19};
```

Notice that when you type the list of numbers, you must **put commas between the numbers** and put the entire list of numbers in **braces**, {}. On your keyboard, the "{" symbol is to the right of the P key and requires you to hold down the Shift key.

In x's list, **the starting number** (which is 81) **is called x_0** (which is pronounced "x subscripted by zero" or "x sub 0" or just "x 0"). The next number (which is 52) is called x_1 (which is pronounced "x subscripted by one" or "x sub 1" or just "x 1"). The next number is called x_2. Then comes x_3. So **the four numbers in the list are called x_0, x_1, x_2, and x_3**.

To make the computer say what x_2 is, type this line:

```
System.out.println(x[2]);
```

That line makes Text be x_2, which is 207, so the computer will print:

```
207
```

So the program says:

```
int[] x={81,52,207,19};
System.out.println(x[2]);
```

The first line says the integer list x is {81, 52, 207, 19}. The bottom line makes the computer say x_2's number, which is 207.

Jargon Notice this jargon:

In a symbol such as x_2, the lowered number (the 2) is called the **subscript**.

To create a subscript in your subroutine, use brackets. For example, to create x_2, type x[2].

A variable having subscripts is called an **array**. For example, x is an array if there's an x_0, x_1, x_2, etc.

Different types Instead of having ints, you can have different types. For example, you can say:

```
double[] x={81.2,51.7,207.9,19.5};
```

Uninitialized Instead of putting a list of numbers into the int line or double line, you can type the numbers underneath, if you warn the computer how many numbers will be in the list, like this:

```
double[] x=new double[3];
x[0]=200.1;
x[1]=700.4;
x[2]=53.2;
System.out.println(x[0]+x[1]+x[2]);
```

The top line says x_0, x_1, and x_2 will be doubles. The next lines say x_0 is 200.1, x_1 is 700.4, and x_2 is 53.2. The bottom line makes the computer print their sum:

```
953.7
```

Notice that if you say double[] x=new double[3], you can refer to x[0], x[1], and x[2], but not x[3]. If you accidentally refer to x[3], the computer will gripe about "ArrayIndexOutOfBoundsException".

If you want x to be a table having 2 rows and 3 columns of double-precision numbers, begin your program by saying:

```
double[][] x=new double[2][3];
```

Since Java always starts counting at 0 (not 1), the number in the table's top left corner is called x[0][0].

Character variables

A variable can stand for a character.

For example, suppose you're in school, take a test, and get an A on it. To proclaim your grade, write a program containing this line:

```
grade='A';
```

Here's the complete program:

```
package joe;
public class Joe {
    public static void main (String[] args) {
        char grade;                  The grade is a character.
        grade='A';                   The grade is 'A'.
        System.out.println(grade);   Print the grade.
    }
}
```

The computer will print:

```
A
```

In that program, you can combine these two lines —

```
char grade;                  The grade is a character.
grade='A';                   The grade is 'A'.
```

to form this single line:

```
char grade='A';              The grade is this character: 'A'.
```

String variables

A variable can stand for a whole String of characters:

```
String x;
x="he";
System.out.println("fat"+x+"red");
```

The first line says there's a String of characters, called x. The second line says x is this String of characters: "he". The third shaded line makes the computer print "fat" then x (which is "he") then "red", so the computer will print:

```
fathered
```

Java requires you to capitalize the first letter of String: say String, not string.

In that program, you can combine these two lines —

```
String x;
x="he";
```

to form this single line:

```
String x="he";
```

Input

Like Basic and JavaScript, Java lets you input; but Java makes it harder.

String input

This program lets you input a String and call it s:

```
package joe;
import java.util.Scanner;
public class Joe {
    public static void main (String[] args) {
        Scanner in=new Scanner(System.in);
        System.out.print("What is your name? ");
        String s=in.nextLine();
        System.out.println("I like the name "+s+" very much");
    }
}
```

How to type the program Carefully type your program, including the 3 commands that prepare the computer for input:

Say "**import java.util.Scanner**" at the program's top (below just the "package" line).
Say stuff about "**Scanner in**" immediately below the "public static void main" line.

Type that exactly! Beware of capitals and spaces!

After you've typed those 2 preparatory commands, the rest of the program is easy to type and understand:

The System.out.print line makes the computer ask "What is your name? ".
The next line makes String s be the next Line that the human types in.
The System.out.println makes the computer say "I like the name " then s then " very much".

How to run the program To run the program, press the F6 key.

The System.out.print line makes the computer ask, in the Output window (at the screen's bottom):

```
What is your name?
```

Then the computer waits for the human to type a name, such as "Joan" or "Dr. Hector von Snotblower, Jr., M.D."; but **before the human types, the human must make sure the word "Output" (at the Output window's top) has a blue background.** If Output's background isn't blue yet, the human must turn it blue by clicking it. (If Output's background is white instead of blue, the human will be accidentally typing in the Program Edit window instead of the Output window — and wreck your program!)

After the human gets a blue Output background and types a name (such as "Joan"), the screen's bottom looks like this:

```
What is your name? Joan
```

At the end of typing the name, the human should press the Enter key. Then the computer finishes running the program, so the Output window finally shows this:

```
What is your name? Joan
I like the name Joan very much
```

Integer input

That program lets you input a String. To input an integer instead, use the same technique, but instead of saying "nextLine" say "**nextInt**".

For example, this program asks the human's age then predicts how old the human will be 10 years from now:

```
package joe;
import java.util.Scanner;
public class Joe {
    public static void main (String[] args) {
        Scanner in=new Scanner(System.in);
        System.out.print("How old are you? ");
        int age=in.nextInt();
        System.out.println ("Ten years from now, you'll be "+(age+10));
    }
}
```

Here's how the program works:

The System.out.print line makes the computer ask "How old are you? ".
The next line makes the integer age be the next Integer that the human types in.
The System.out.println makes the computer say "Ten years from now, you'll be " then age+10.

Here's a sample run:

```
How old are you? 27
Ten years from now, you'll be 37
```

Double-precision input

In that program, age is an integer. If you want age to be double-precision instead, change the shaded line to this:

```
        double age=in.nextDouble();
```

Logic

Java lets you say "if", "while", "for", and create comments. Here are examples.…

If

If a person's age is less than 18, let's make the computer say "You are still a minor." Here's the fundamental line:

```
        if (age<18) System.out.println("You are still a minor.");
```

Notice you must put parentheses after the word "if".

If a person's age is less than 18, let's make the computer say "You are still a minor." and also say "Ah, the joys of youth!" and "I wish I were as young as you!" Here's how to say all that:

```
        if (age<18) {
            System.out.println("You are still a minor.");
            System.out.println("Ah, the joys of youth!");
            System.out.println("I wish I were as young as you!");
        }
```

Since that "if" line is above the "{", the "if" line is a structure line, similar to a "public class" line, and does *not* end in a semicolon.

Here's how to put that structure into a complete program, assuming age is an integer:

```
package joe;
import java.util.Scanner;
public class Joe {
    public static void main (String[] args) {
    {
        Scanner in=new Scanner(System.in);
        System.out.print("How old are you? ");
        int age=in.nextInt();
        if (age<18) {
            System.out.println("You are still a minor.");
            System.out.println("Ah, the joys of youth!");
            System.out.println("I wish I were as young as you!");
        }
        else {
            System.out.println("You are an adult.");
            System.out.println("Now we can have some adult fun!");
        }
        System.out.println("Glad to have met you.");
    }
}
```

If the person's age is less than 18, the computer will print "You are still a minor." and "Ah, the joys of youth!" and "I wish I were as young as you!" If the person's age is not less than 18, the computer will print "You are an adult." and "Now we can have some adult fun!" Regardless of the person's age, the computer will end the conversation by saying "Glad to have met you."

The "if" statement uses this notation:

Notation	Meaning
`if (age<18)`	if age is less than 18
`if (age<=18)`	if age is less than or equal to 18
`if (age==18)`	if age is equal to 18
`if (age!=18)`	if age is not equal to 18
`if (age<18 && weight>200)`	if age<18 and weight>200
`if (age<18 || weight>200)`	if age<18 or weight>200

Notice that in the "if" statement, you should use double symbols: you should say "==" instead of "=", say "&&" instead of "&", and say "||" instead of "|". If you accidentally say "=" instead of "==", the computer will gripe. If you accidentally say "&" instead of "&&" or say "|" instead of "||", the computer will still get the right answers but too slowly.

Strings The symbols <, <=, ==, and != let you compare numbers or characters but not Strings. If you try to use them to compare Strings, you'll get wrong answers.

For example, suppose x and y are strings, and you want to test whether they're equal. Do *not* say "if (x==y)". Instead, say:

```
        if (x.equals(y))
```

Make sure you put the period after x and put parentheses around y.

An alternative is to say:

```
        if (x.equalsIgnoreCase(y))
```

That makes the computer compare x with y and ignore capitalization. It makes the computer consider x to be "equal" to y if the only difference is "which letters in the string are capitalized".

To test whether x's string comes before y's in the dictionary, do not say "if (x<y)". Instead, say:

```
        if (x.compareTo(y)<0)
```

While

Let's make the computer print the word "love" repeatedly, like this:

```
love
love
love
love
love
love
love
etc.
```

This program does it:

```
package joe;
public class Joe {
    public static void main (String[] args) {
        while (true) System.out.println("love");
    }
}
```

The "while (true)" means: do repeatedly. The computer will do System.out.println("love") repeatedly, looping forever — or until you **abort** the program by clicking the red square (which is at the Output window's left edge). You'll see lots of love — as much love as fits in the Output window.

Let's make the computer start at 20 and keep counting, so the computer will print:

```
20
21
22
23
24
25
26
etc.
```

This program does it:

Program	**Meaning**
`package joe;`	
`public class Joe {`	
`  public static void main (String[] args) {`	
`    int i=20;`	Start the integer i at 20.
`    while (true) {`	Repeat indented lines forever:
`      System.out.println(i);`	print i then press Enter
`      ++i;`	increase i
`    }`	
`  }`	
`}`	

It prints faster than you can read. By the time your eye focuses, the computer is already printing numbers beyond 10000. The number will keep increasing until you abort the program (by clicking the red square at the screen's left edge).

In that program, if you say "while (i<25)" instead of "while (true)", the computer will do the loop only while i remains less than 25; the computer will print just:

```
20
21
22
23
24
```

Instead of saying "while (i<25)", you can say "while (i<=24)".

For

Here's a more natural way to get that output of numbers from 20 to 24:

```
package joe;
public class Joe {
    public static void main (String[] args) {
        for (int i=20; i<=24; ++i) System.out.println(i);
    }
}
```

In that program, the "for (int i=20; i<=24; ++i)" means "Do repeatedly. Start the integer i at 20, and keep repeating as long as i<=24. After each repetition, do ++i."

In that "for" statement, if you change the ++i to i+=2, the computer will increase i by 2 instead of by 1, so the computer will print:

```
20
22
24
```

The "for" statement is quite flexible. You can even say "for (int i=20; i<100; i*=2)", which makes i start at 20 and keep doubling, so the computer prints:

```
20
40
80
```

Like "if" and "while", the "for" statement can sit atop a group of indented lines that are in braces.

Visual C#

A Microsoft employee (**Anders Hejlsberg**) invented a nifty computer language. He called it **Cool** but changed the name to **C#** (pronounced "C sharp"), to emphasize it's higher than an earlier language, called **C**. (It's also higher than a C variant called **C++**.)

C# tries to combine the best features of Visual Basic, Java, C, and C++:

> Like Visual Basic, it lets you create windows easily.
>
> Like Java, it uses modern notation for typing lines in programs.
>
> Like C and C++, it runs fast.

C# is also influenced by an older programming language called **Pascal**. Before inventing C#, Anders Hejlsberg had already invented two famous Pascal versions (**Turbo Pascal** and **Delphi**) and a famous Java version (**J++**); he was an extremely experienced designer when he invented C#. He knew what was wrong with Pascal, Java, C++, and Visual Basic and how to improve them.

Microsoft recommends using Visual Basic to create simple programs but C# to create bigger projects. Microsoft considers Visual Basic and C# to be the most important computer languages to learn.

You already learned Visual Basic. Now let's tackle C#.

Modern C#, called **Visual C#**, is part of **Visual Studio**. Get Visual Studio's free version, called **Visual Studio Community**, by copying it from Microsoft's Website, using the method on page 563 ("Copy the Community"). This chapter assumes you've done that, so you have **Visual C# 2015**.

Visual C# 2015 understands these commands:

C# command	Page
`catch`	638
`char x;`	634
`class Program`	632
`Console.ReadKey();`	633
`Console.Write("Love");`	633
`Console.WriteLine("Love");`	633
`double x;`	634
`double x = -27.0;`	634
`double[] x = new double[3];`	636
`double[] x = { 81.2, 51.7, 7.9 };`	636
`double[,] x = new double[2, 3];`	636
`else`	637
`if (age < 18)`	636
`for (int i = 20; i <= 29; ++i)`	638
`goto yummy;`	638
`int x;`	634
`int x = 3;`	635
`int[] x = new int[3];`	636
`int[] x = { 81, 52, 207 };`	636
`int[,] x = new int[2, 3];`	636
`long x;`	634
`MessageBox.Show("Hair mess");`	641
`namespace Joymaker`	632
`private void Form1_Load(…)`	641
`public Form1()`	641
`public partial class Form1 : Form`	641
`return (a + b ) / 2;`	640
`static int average(int a, int b)`	640
`static void Main(string[] args)`	632
`static void x()`	639
`string x;`	634
`string[] x = { "love", "h" };`	636
`Text = "I love you";`	641
`try`	638
`uint x;`	634
`ulong x;`	634
`using System;`	632
`while (true)`	637
`x = 3;`	634
`x();`	639
`++x;`	635
`--x;`	635
`// Zoo program is fishy`	639

It also understands these functions:

C# function	Page
`Console.ReadLine()`	635
`Convert.ToDouble(x)`	635
`Convert.ToInt32(x)`	636
`Convert.ToInt64(x)`	636
`Convert.ToString(x)`	641
`Convert.ToUInt32(x)`	636
`Convert.ToUInt64(x)`	636
`Math.Abs(x)`	634
`Math.Acos(x)`	634
`Math.Asin(x)`	634
`Math.Atan(x)`	634
`Math.Atan2(y, x)`	634
`Math.Ceiling(x)`	634
`Math.Cos(x)`	634
`Math.Cosh(x)`	634
`Math.E`	634
`Math.Exp(y)`	634
`Math.Floor(x)`	634
`Math.Log(x)`	634
`Math.Log(x, b)`	634
`Math.Log10(x)`	634
`Math.PI`	634
`Math.Pow(x, y)`	634
`Math.Sin(x)`	634
`Math.Sinh(x)`	634
`Math.Sqrt(x)`	634
`Math.Tan(x)`	634
`Math.Tanh(x)`	634
`x.CompareTo("male")`	637

Fun

Here's how to enjoy programming in C#.

Start Visual Studio

To start using Visual Studio, type "vi" in the Windows 10 Search box (which is next to the Start button) then click "Visual Studio 2015: Desktop app".

If you haven't used Visual Studio before, the computer says "Sign in". To reply, do this:

> Click the "Sign in" button. Type your email address and press Enter. Type your Microsoft account's password and press Enter. The computer says "We're preparing for first use".

You see the Start Page window.

Start a new program

Click "**New Project**" (which is near the screen's left edge) then "**Visual C#**" then "**Console Application**".

Double-click in the Name box (which is near the screen's bottom). Type a name for your project (such as Joymaker). At the end of your typing, press the Enter key.

Type your program

The computer starts typing the program for you. The computer types:

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.Threading.Tasks;

namespace Joymaker
{
    class Program
    {
        static void Main(string[] args)
        {
        }
    }
}
```

Let's write a program that makes the computer say "I love you". To do that, insert 2 extra lines, so the program becomes this:

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.Threading.Tasks;

namespace Joymaker
{
    class Program
    {
        static void Main(string[] args)
        {
            Console.WriteLine("I love you");
            Console.ReadKey();
        }
    }
}
```

Here's how to insert those line:

Click under the word "void". Press Enter. Type the first inserted line, press Enter, and type the second inserted line.

The computer indents the lines for you, automatically.

You must type a semicolon at the end of each simple line. But there's no semicolon at the end of a **structure line** (a line that's blank or says just "{" or "}" or is immediately above "{").

Important line The most important line is the one that says:

```
Console.WriteLine("I love you");
```

It makes the computer write "I love you" onto the screen.

Helper line To make Console.WriteLine work properly, you must put this **helper line** near the program's bottom, just above the 3 final "}" lines:

```
Console.ReadKey();
```

That makes the computer pause until the human has read the computer's output and presses a key.

You must put that helper line in every normal program.

Run the program

To run your program, click "Start" (which is at the screen's top center) **or press the F5 key**. (If the "F5" is blue or tiny or the computer is new by Microsoft, HP, Lenovo, or Toshiba, that key works just while you hold down the Fn key, which is left of the Space bar.)

If you did everything correctly, you see the **console window** (which has white letters on a black background and resembles the DOS command-prompt screen). The console window shows the computer's output. It shows:

```
I love you
```

When you finish admiring that output, press the Enter key (or Space bar or any other normal key) or click the console window's X button.

If you want to run the program again, click "Start" again.

If you want to edit the program, retype the parts you wish then click "Start" again (which makes the computer debug and run the new version).

Final steps

Similar to Visual Basic, so read "Final steps" on page 566, but change "Funmaker" to "Joymaker" if you named your program "Joymaker".

Multiple lines

Your program can contain *several* lines. For example, to make the computer say —

```
I love you
Let's get married
```

type these lines:

```
Console.WriteLine("I love you");
Console.WriteLine("Let's get married");
```

Below them, type the helper line:

```
Console.ReadKey();
```

If you say **Write** instead of **WriteLine**, the computer won't press the Enter key at the end of its writing. For example, if you type:

```
Console.Write("I love you");
Console.WriteLine("Let's get married");
```

the computer will write "I love you" without pressing Enter, then write "Let's get married", so you see this:

```
I love youLet's get married
```

Math

The computer can do math. For example, this line makes the computer do 4+2:

```
Console.WriteLine(4 + 2);
```

It makes the computer write this answer on your screen:

```
6
```

If you have 750 apples and buy 12 more, how many apples will you have altogether? This line writes the answer:

```
Console.WriteLine("You will have " + (750 + 12) + " apples");
```

That line makes the computer write "You will have ", then write the answer to 750 + 12 (which is 762), then write "apples", so you see this:

```
You will have 762 apples
```

Like most other languages (such as Basic, JavaScript, Java, and C++), C# lets you use the symbols +, -, *, /, parentheses, decimal points, and e notation.

Types of numbers

C# handles 5 types of numbers well.

One type of number is called an **integer** (or **int**). An integer contains no decimal point and no e and is between -2147483648 and 2147483647. For example, -27 and 30000 are ints. Each int consumes 4 bytes (32 bits) of RAM.

An **unsigned integer** (or **uint**) resembles an integer but must not have a minus sign, and it can be between 0 and 4294967295. For example, 3000000000 is a uint, though it's too big to be an int.

A **long** resembles an integer but can be longer: it can be between -9223372036854775808 and 9223372036854775807. Each long consumes 8 bytes (64 bits) of RAM.

An **unsigned long** (or **ulong**) resembles a long but must not have a minus sign, and it can be between 0 and 18446744073709551615.

A **double-precision number** (or a **double**) contains a decimal point or an E. For example, -27.0 and 3E4 are doubles. A double can be up to 1.7976931348623158E308, and you can put a minus sign before it. Each double consumes 8 bytes of RAM. If you write a decimal point, put a digit (such as 0) after it.

Writing When Console.WriteLine makes the computer write an answer on your screen, the computer takes this shortcut: to write a double containing many digits after the decimal point, the computer writes just the first 15 significant digits; and if the only

digits after the decimal point are zeros, the computer doesn't bother writing those zeros or the decimal point.

Operations While you're writing a math problem, **if you include a double (such as 5.0), the computer makes the answer be a double**. For example, the answer to 5.0 + 3 is the double 8.0, though the computer doesn't bother writing the .0 on your screen.

If you feed the computer a problem that involves just ints, the computer tries to make the answer be an int. If the answer's too big to be an int, the computer gripes. For example, if you write —

```
Console.WriteLine(3000 * 1000000);
```

the computer will gripe (because 3000 and 1000000 are both ints but the answer is too big to be an int). You should rewrite the problem to include a double, like this —

```
Console.WriteLine(3000 * 1000000.0);
```

or —

```
Console.WriteLine(3000.0 * 1000000);
```

or:

```
Console.WriteLine(3000.0 * 1000000.0)
```

Then the answer will be a double (3000000000.0), which the computer will write on the screen in this shortcut form:

```
3000000000
```

If you feed the computer a math problem whose answer is too big to be a double, the computer will give up and typically say the answer is:

```
Infinity
```

The tiniest double that the computer handles well is 1e-308. If you feed the computer a math problem whose answer is tinier than that, the computer will either handle the rightmost digits inaccurately or give up, saying the answer is 0.0.

Dividing ints Since combining ints gives an answer that's an int, **11 / 4 is this int: 2**. So 11 / 4 is *not* 2.75. If you say —

```
Console.WriteLine(11 / 4);
```

the computer will write just:

```
2
```

If you want the computer to write 2.75 instead, say you want a double, by putting decimal points in the problem, like this:

```
Console.WriteLine(11.0 / 4.0);
```

That makes the computer write:

```
2.75
```

Dividing by 0 If you ask the computer to divide by 0, the computer will gripe.

Dividing by 0.0 If you ask the computer to divide by 0.0, the computer will get creative.
For example, if you say —

```
Console.WriteLine(5.0 / 0.0);
```

the computer will try to divide 5.0 by 0.0, give up (because you can't divide by 0), and say the answer is:

```
Infinity
```

If you say —

```
Console.WriteLine(-5.0 / 0.0);
```

the computer will try to divide -5 by 0, give up (because you can't divide by 0), and say the answer is:

```
-Infinity
```

If you say —

```
Console.WriteLine(0.0 / 0.0);
```

the computer will try to divide 0 by 0, give up (because you can't divide by 0), get confused, and say the answer is —

```
NaN
```

which means "Not a Number".

Advanced math

The computer can do advanced math. For example, it can compute square roots. This line makes the computer print the square root of 9:

```
Console.WriteLine(Math.Sqrt(9));
```

The computer will print 3.

Besides Sqrt, you can use other advanced-math functions:

Function	Traditional notation	What to type
square root of x	$\sqrt{x}$	`Math.Sqrt(x)`
x raised to the y power	x^y	`Math.Pow(x, y)`
e raised to the y power	e^y	`Math.Exp(y)`
pi	π	`Math.PI`
e	e	`Math.E`
absolute value of x	$\lvert x \rvert$	`Math.Abs(x)`
round x down, so ends in .0	$\lfloor x \rfloor$	`Math.Floor(x)`
round x up, so ends in .0	$\lceil x \rceil$	`Math.Ceiling(x)`
logarithm, base 10, of x	$\log_{10} x$	`Math.Log10(x)`
logarithm, base e, of x	ln x	`Math.Log(x)`
logarithm, base b, of x	$\log_b x$	`Math.Log(x, b)`
sine of x radians	sin x	`Math.Sin(x)`
cosine of x radians	cos x	`Math.Cos(x)`
tangent of x radians	tan x	`Math.Tan(x)`
arcsine of x, in radians	arcsin x	`Math.Asin(x)`
arccosine of x, in radians	arccos x	`Math.Acos(x)`
arctangent of x, in radians	arctan x	`Math.Atan(x)`
arctangent of y/x, in radians	arctan x/y	`Math.Atan2(y, x)`
hyperbolic sine of x	sinh x	`Math.Sinh(x)`
hyperbolic cosine of x	cosh x	`Math.Cosh(x)`
hyperbolic tangent of x	tanh x	`Math.Tanh(x)`

Variables

Like Basic and other languages, C# lets you use variables. For example, you can say:

```
n = 3;
```

A variable's name can be short (such as n) or long (such as town_population_in_2001). The name can contain letters, digits, and underscores, but not blank spaces. The name must begin with a letter or underscore, not a digit.

Before using a variable, say what type of thing the variable stands for. For example, if n and town_population_in_2001 will stand for numbers that are ints and mortgage_rate will stand for a double, your program should say:

```
int n, town_population_in_2001;
double mortgage_rate;
```

If x is a variable, your program should say one these lines:

Line	Meaning
`int x;`	x is an integer
`uint x;`	x is an unsigned integer
`long x;`	x is a long
`ulong x;`	x is an unsigned long
`double x;`	x is a double-precision number
`char x;`	x is a single character, such as 'A'
`string x;`	x is a string of characters, such as "love"

If n is an integer that starts at 3, you can say —

```
int n;
n = 3;
```

but you can combine those two lines into this single line:

```
int n = 3;
```

Here's how to say "n is an integer that starts at 3, and population_in_2001 is an integer that starts at 27000":

```
int n = 3, population_in_2001 = 27000;
```

If you want x to be the string "I love you", say —

```
string x;
x = "I love you";
```

or combine those lines, like this:

```
string x = "I love you";
```

Increase

The symbol ++ means "increase". For example, ++n means "increase n".

These lines increase n:

```
int n = 3;
++n;
Console.WriteLine(n);
```

The n starts at 3 and increases to 4, so the computer prints 4.

Saying ++n gives the same answer as n = n + 1, but the computer handles ++n faster.

The symbol ++ increases the number by 1, even if the number is a decimal. For example, if x is 17.4 and you say ++x, the x will become 18.4.

Decrease

The opposite of ++ is --. The symbol -- means "decrease". For example, --n means "decrease n". Saying --n gives the same answer as n = n - 1 but faster.

Strange short cuts

If you use the following short cuts, your programs will be briefer and run faster.

Instead of saying n = n + 2, say n += 2, which means "n's increase is 2". Similarly, instead of saying n = n * 3, say n *= 3, which means "n's multiplier is 3".

Instead of saying ++n and then giving another command, say ++n in the middle of the other command. For example, instead of saying —

```
++n;
j = 7 * n;
```

say:

```
j = 7 * ++n;
```

That's pronounced: "j is 7 times an increased n". So if n was 2, saying j = 7 * ++n makes n become 3 and j become 21.

Notice that when you say j = 7 * ++n, the computer increases n *before* computing j. If you say j = 7 * n++ instead, the computer increases n *after* computing j; so j = 7 * n++ has the same effect as saying:

```
j = 7 * n;
++n;
```

Input a string

These lines make the computer ask for your name:

```
Console.WriteLine("What is your name?");
string x = Console.ReadLine();
Console.WriteLine("I adore anyone whose name is " + x);
```

Below them, remember to put the helper line:

```
Console.ReadKey();
```

When you run that program (by pressing the F5 key), here's what happens.…

The top line makes the computer write this question:

```
What is your name?
```

The next line makes the string x be the answer you type. For example, if you answer "What is your name?" by typing "Maria" (and then pressing Enter), the computer will read your answer and make string x be what the computer reads; so x will be "Maria", and the next line will make the computer write:

```
I adore anyone whose name is Maria
```

So when you run that program, here's the whole conversation that occurs between the computer and you:

```
The computer asks for your name:  What is your name?
You type your name:               Maria
Computer praises your name:       I adore anyone whose name is Maria
```

Just for fun, run that program again and pretend you're somebody else.…

```
The computer asks for your name:  What is your name?
You type your name:               Bud
Computer praises your name:       I adore anyone whose name is Bud
```

When the computer asks for your name, if you say something weird, the computer will give you a weird reply.…

```
The computer asks for your name:  What is your name?
You type:                         none of your business!
The computer replies:             I adore anyone whose name is none of your business!
```

Input a double

To make x be a string that the human inputs, you've learned to say this:

```
string x = Console.ReadLine();
```

To make x be a double-precision number that the human inputs, say this instead:

```
double x = Convert.ToDouble(Console.ReadLine());
```

That's because Console.ReadLine() considers the human's input to be a string, and Convert.ToDouble converts that string to a double.

Examples These lines make the computer predict how old a human will be ten years from now:

```
Console.WriteLine("How old are you?");
double age = Convert.ToDouble(Console.ReadLine());
Console.WriteLine("Ten years from now, you'll be " + (age + 10));
```

The top line makes the computer ask, "How old are you?" The middle line makes age be the result of converting, to a double-precision number, the human's input. The bottom line makes the computer write the answer.

For example, if the human is 27 years old, the chat between the computer and the human looks like this:

```
How old are you?
27
Ten years from now, you'll be 37
```

If the human is 27.5 years old, the chat can look like this:

```
How old are you?
27.5
Ten years from now, you'll be 37.5
```

These lines make the computer convert feet to inches:

```
Console.WriteLine("How many feet?");
double feet = Convert.ToDouble(Console.ReadLine());
Console.WriteLine("That makes " + (feet * 12) " inches.");
```

Input an integer

To make x be an integer that the human inputs, say this instead:

```
int x = Convert.ToInt32(Console.ReadLine());
```

That's because Convert.ToInt32 converts a string to a 32-bit integer.

To make x be a special type of integer that the human inputs, say one of these:

```
uint x = Convert.ToUInt32(Console.ReadLine());
long x = Convert.ToInt64(Console.ReadLine());
ulong x = Convert.ToUInt64(Console.ReadLine());
```

Arrays

Instead of being just a number, x can be a *list* of numbers.

Example For example, if you want x to be this list of integers —

```
{ 81, 52, 207, 19 }
```

type this:

```
int[] x = { 81, 52, 207, 19 };
```

In that line, the symbol "int[]" means "int list". Notice that when you type the list of numbers, you must **put commas between the numbers** and put the entire list of numbers in **braces**, {}. On your keyboard, the "{" symbol is to the right of the P key and requires you to hold down the Shift key.

In x's list, **the starting number** (which is 81) **is called x_0** (which is pronounced "x subscripted by zero" or "x sub 0" or just "x 0"). The next number (which is 52) is called x_1 (which is pronounced "x subscripted by one" or "x sub 1" or just "x 1"). The next number is called x_2. Then comes x_3. So **the four numbers in the list are called x_0, x_1, x_2, and x_3**.

To make the computer say what x_2 is, type this line:

```
Console.WriteLine(x[2]);
```

That line makes the computer write x_2, which is 207, so the computer will write:

```
207
```

Altogether, the lines say:

```
int[] x = { 81, 52, 207, 19 };
Console.WriteLine(x[2]);
```

The first line says the integer-list x is { 81, 52, 207, 19 }. The second line makes the computer write x_2's number, which is 207.

Jargon Notice this jargon:

> In a symbol such as x_2, the lowered number (the 2) is called the **subscript**.
>
> To create a subscript in your subroutine, use brackets. For example, to create x_2, type x[2].
>
> A variable having subscripts is called an **array**. For example, x is an array if there's an x_0, x_1, x_2, etc.

Different types Instead of having integers, you can have different types. For example, you can say:

```
double[] x = { 81.2, 51.7, 207.9, 19.5 };
```

You can even say:

```
string[] x = { "love", "hate", "peace", "war" };
```

Uninitialized Instead of typing a line that includes x's list of numbers, you can type the numbers underneath, if you warn the computer how many numbers will be in the list, like this:

```
double[] x = new double[3];
x[0] = 200.1;
x[1] = 700.4;
x[2] = 53.2;
Console.WriteLine(x[0] + x[1] + x[2]);
```

The top line says x will be a new list of 3 doubles, called x_0, x_1, and x_2. The next lines say x_0 is 200.1, x_1 is 700.4, and x_2 is 53.2. The bottom line makes the computer say their sum:

```
953.7
```

Tables If you want x to be a table having 2 rows and 3 columns of double-precision numbers, say:

```
    double[,] x = new double[2, 3];
```

Since C# always starts counting at 0 (not 1), the number in the table's top left corner is called x[0, 0].

Logic

Like most computer languages, C# lets you say "if", "while", "for", and "goto" and create comments and subroutines. Here's how.…

If

If a person's age is less than 18, let's make the computer say "You are still a minor." Here's the fundamental line:

```
if (age < 18) Console.WriteLine("You are still a minor.");
```

Notice you must put parentheses after the word "if".

If a person's age is less than 18, let's make the computer say "You are still a minor." and also say "Ah, the joys of youth!" and "I wish I could be as young as you!" Here's how to say all that:

```
    if (age < 18)
    {
        cout <<"You are still a minor.\n";
        cout <<"Ah, the joys of youth!\n";
        cout <<"I wish I could be as young as you!";
    }
```

Since that "if" line is above the "{", the "if" line is a structure line and does *not* end in a semicolon.

How to type To type the symbol "{", do this: while holding down the Shift key, tap the "[" key (which is next to the P key). To type the symbol "}", do this: while holding down the Shift key, tap the "]" key.

When you type a line, don't worry about indenting it: when you finish typing the line (and press Enter), the computer will indent it the correct amount, automatically.

Complete program Here's how to put that structure into a complete program:

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.Threading.Tasks;

namespace Joan
{
    class Program
    {
        static void Main(string[] args)
        {
            Console.WriteLine("How old are you?");
            double age=Convert.ToDouble(Console.ReadLine());
            if (age < 18)
            {
                Console.WriteLine("You are still a minor.");
                Console.WriteLine("Ah, the joys of youth.");
                Console.WriteLine("I wish I could be as young as you!");
            }
            else
            {
                Console.WriteLine("You are an adult.");
                Console.WriteLine("Now we can have some adult fun!");
            }
            Console.WriteLine("Glad to have met you.");
            Console.ReadKey();
        }
    }
}
```

If the person's age is less than 18, the computer will write "You are still a minor." and "Ah, the joys of youth!" and "I wish I could be as young as you!" If the person's age is not less than 18, the computer will write "You are an adult." and "Now we can have some adult fun!" Regardless of the person's age, the computer will end the conversation by writing "Glad to have met you."

Since the computer types the top lines for you and also types the 3 braces at the program's bottom, you type just the lines in the middle, starting with:

```
Console.WriteLine("How old are you?");
```

Fancy "if" The "if" statement uses this notation:

Notation	Meaning
`if (age < 18)`	if age is less than 18
`if (age <= 18)`	if age is less than or equal to 18
`if (age == 18)`	if age is equal to 18
`if (age != 18)`	if age is not equal to 18
`if (age < 18 && weight > 200)`	if age < 18 and weight > 200
`if (age < 18 || weight > 200)`	if age < 18 or weight > 200
`if (sex == "male")`	if sex is "male"
`if (sex.CompareTo("male") < 0)`	if sex is a word (such as "female") that comes before "male" in the dictionary

Here's how to type the symbol "**|**": while holding down the Shift key, tap the "\" key.

Look at that table carefully! Notice that in the "if" statement, you should use double symbols: you should say "**==**" instead of "**=**", say "**&&**" instead of "**&**", and say "**||**" instead of "**|**".

If you accidentally say "**=**" instead of "**==**", the computer will gripe. If you accidentally say "**&**" instead of "**&&**" or say "**|**" instead of "**||**", the computer will say right answers but too slowly.

The symbol "<" compares just numbers, not strings. Instead of writing —

```
if (sex < "male")
```

you must write:

```
if (sex.CompareTo("male") < 0)
```

While

Let's make the computer write the word "love" repeatedly, like this:

```
love love love love love love love love love etc.
love love love love love love love love love etc.
love love love love love love love love love etc.
etc.
```

This line does it:

```
while (true) Console.Write("love ");
```

The "while (1)" means: do repeatedly. The computer will do cout <<"love " repeatedly, looping forever — or until you **abort** the program (by clicking the console window's X button).

Let's make the computer start at 20 and keep counting, so the computer will write:

```
20
21
22
23
24
25
26
27
28
29
30
31
32
etc.
```

These lines do it:

Program	Meaning
`int i = 20;`	Start the integer i at 20.
`while (true)`	Repeat these lines forever:
`{`	
`Console.WriteLine(i);`	print i then press Enter
`++i;`	increase i
`}`	

They write faster than you can read.

```
To pause the writing, press the Pause key.
To resume the writing, press the Enter key.
To abort the program, click the console window's X button.
```

In that program, if you say "while (i < 30)" instead of "while (true)", the computer will do the loop just while i remains less than 30; the computer will write just:

```
20
21
22
23
24
25
26
27
28
29
```

To let that program run properly, make sure its bottom includes the helper line saying "Console.ReadKey()", so altogether the program looks like this:

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.Threading.Tasks;

namespace Joan
{
    class Program
    {
        static void Main(string[] args)
        {
            int i=20;
            while (i < 30)
            {
                Console.WriteLine(i);
                ++i;
            }
            Console.ReadKey();
        }
    }
}
```

Instead of saying "while (i < 30)", you can say "while (i <= 29)".

For

Here's a more natural way to get that output of numbers from 20 to 29:

```
for (int i = 20; i <= 29; ++i) Console.WriteLine(i);
```

The "for (int i = 20; i <= 29; ++i)" means:

```
Do repeatedly. Start the integer i at 20, and keep repeating as long as i <= 29.
At the end of each repetition, do ++i.
```

In that "for" statement, if you change the "++i" to "i += 3", the computer will increase i by 3 instead of by 1, so the computer will write:

```
20
23
26
29
```

The "for" statement is quite flexible. You can even say "for (int i = 20; i < 100; i *= 2)", which makes i start at 20 and keep doubling, so the computer writes:

```
20
40
80
```

Like "if" and "while", the "for" statement can sit atop a group of indented lines that are in braces.

Goto

You can say "goto". For example, if you say "goto yummy", the computer will go to the line whose name is yummy:

```
    Console.WriteLine("my dog ");
    goto yummy;
    Console.WriteLine("never ");
yummy: Console.WriteLine("drinks whiskey");
```

The computer will write:

```
my dog
drinks whiskey
```

Exceptions

These lines try to make x be how many children the human has:

```
Console.WriteLine("How many children do you have?");
int x = Convert.ToInt32(Console.ReadLine());
```

Those lines ask the human "How many children do you have?" then wait for the human's response then try to convert that string to an integer (such as 2 or 0) and call it x. But what happens if the human does *not* input an integer? What if human inputs a number that includes a decimal point? What if the human types a word, such as "none" or "one" or "many"? What if the human types a phrase, such as "not sure" or "too many" or "none of your business" or "my girlfriend was pregnant but hasn't told me yet whether she got an abortion"? In those errant situations (which are called **exceptions**), the computer can't do Convert.ToInt32 and will instead abort the program, show the human all the program's lines, and highlight the problematic line. Then the human will be upset and confused!

To avoid upsetting people, change those lines to this group of lines instead:

```
AskAboutKids:
    Console.WriteLine("How many children do you have?");
try
{
    int x = Convert.ToInt32(Console.ReadLine());
}
catch
{
    Console.WriteLine("Please type an integer");
    go to AskAboutKids;
}
```

The group begins with a label (AskAboutKids) and makes the computer ask "How many children do you have?" Then the computer will **try** to do this line:

```
    int x = Convert.ToInt32(Console.ReadLine());
```

If the computer fails to do that line (because what the person typed can't be converted to an integer), the computer won't gripe; instead, it will **catch** the error and do the lines indented under "catch". Those lines are called the **catch block** (or **exception handler**). They make the computer say "Please type an integer" then go back to the beginning of AskAboutKids, to give the human another opportunity to answer the question correctly.

If the human doesn't know what an "integer" is, phrase the advice differently: make the computer write "Please type a simple number without a decimal point".

Comments

To put a comment in your program, begin the comment with the symbol //. The computer ignores everything that's to the right of //. Here's an example:

```
// This program is fishy
// It was written by a sick sailor swimming in the sun
Console.WriteLine("Our funny God");   // notice the religious motif
Console.WriteLine("invented cod");    // said by a nasty flounder
```

The computer ignores all the comments, which are to the right of //.

While you type the program, the computer makes each // and each comment turn green. Then the computer ignores everything that's turned green, so the computer writes just:

```
Our funny God
invented cod
```

Subroutines

Like most other languages, C# lets you invent subroutines and give them names. For example, here's how to invent a subroutine called "insult" and use it in the Main routine:

Program	**Meaning**
`using System;`	
`using System.Collections.Generic;`	
`using System.Linq;`	
`using System.Text;`	
`using System.Threading.Tasks;`	
`namespace Joan`	
`{`	
`  class Program`	
`  {`	
`    static void Main(string[] args)`	**Here's the main routine:**
`    {`	
`      Console.WriteLine("We all know...");`	write "We all know…"
`      insult();`	do the insult
`      Console.WriteLine("...and yet we love you.");`	write the ending
`      Console.ReadKey();`	
`    }`	
`    static void insult()`	**Here's how to insult:**
`    {`	
`      Console.WriteLine("You are stupid!");`	write "You are stupid!"
`      Console.WriteLine("You are ugly!");`	write "You are ugly!"
`    }`	
`  }`	
`}`	

The computer will write:

```
We all know...
You are stupid!
You are ugly!
...and yet we love you.
```

In that program, the lines beginning with "static void Main(string[] args)" define the Main routine. The bottom few lines, beginning with "static void insult()", define the subroutine called "insult".

Whenever you write a subroutine's name, you must put parentheses afterwards, like this: insult(). Those parentheses tell the computer: insult's a subroutine, not a variable.

To write a subroutine's definition simply, begin the definition by saying "static void".

Here's another example of a main routine and subroutine:

Routines	**Meaning**
`static void Main(string[] args)`	**Here's the main routine:**
`{`	
`  laugh();`	main routine says to laugh
`  Console.ReadKey();`	
`}`	
`static void laugh()`	**Here's how to laugh:**
`{`	
`  for (int i = 1; i <= 100; ++i) Console.Write("ha ");`	write "ha ", 100 times
`}`	

The Main routine says to laugh. The subroutine defines "laugh" to mean: write "ha " a hundred times.

Let's create a more flexible subroutine, so that whenever the Main routine says laugh(2), the computer will write "ha ha "and Enter; whenever the Main routine says laugh(5), the computer will write "ha ha ha ha ha " and Enter; and so on. Here's how:

Routines	**Meaning**
`static void Main(string[] args)`	**Here's the main routine:**
`{`	
`  Console.Write ("Here is a short laugh: ");`	
`  laugh(2);`	do laugh(2), so write "ha ha "
`  Console.Write ("Here is a longer laugh: ");`	
`  laugh(5);`	do laugh(5), so write "ha ha ha ha ha "
`  Console.ReadKey();`	
`}`	
`static void laugh(int n)`	**Here's how to laugh(n):**
`{`	
`  for (int i = 1; i <= n; ++i) Console.Write("ha ");`	write "ha ", n times
`  Console.WriteLine();`	then press Enter
`}`	

The computer will print:

```
Here is a short laugh: ha ha
Here is a longer laugh: ha ha ha ha ha
```

Average Let's define the "average" of a pair of integers, so that "average(3, 7)" means the average of 3 and 7 (which is 5), and so a Main routine saying "i = average(3, 7)" makes i be 5.

This subroutine defines the "average" of all pairs of integers:

```
static int average(int a, int b)
{
    return (a + b) / 2;
}
```

The top line says, "Here's how to find the average of any two integers, a and b, and make the average be an integer." The next line says, "Return to the main routine, with this answer: (a + b) / 2."

Here's a complete program:

Program	**Meaning**
`using System;`	
`using System.Collections.Generic;`	
`using System.Linq;`	
`using System.Text;`	
`using System.Threading.Tasks;`	
`namespace Joan`	
`{`	
`  class Program`	
`  {`	
`    static void Main(string[] args)`	**Here's the main routine:**
`    {`	
`      int i;`	make i be an integer
`      i = average(3, 7);`	make i be average(3, 7)
`      Console.WriteLine(i);`	write i
`      Console.ReadKey();`	
`    }`	
`    static int average(int a, int b)`	**Here's how to compute average(a, b):**
`    {`	
`      return (a + b) / 2;`	return this answer: (a + b) / 2
`    }`	
`  }`	
`}`	

In that program, the Main routine is:

`int i;`	make i be an integer
`i = average(3, 7);`	make i be average(3, 7)
`Console.WriteLine(i);`	write i
`Console.ReadKey();`	

You can shorten it, like this:

`int i = average(3, 7);`	make the integer i be average(3, 7)
`Console.WriteLine(i);`	write i
`Console.ReadKey();`	

You can shorten it further, like this:

`Console.WriteLine(average(3, 7));`	write average(3, 7)
`Console.ReadKey();`	

To make that program handle double-precision numbers instead of integers, change each int to double. After changing to double, the program will still work, even if you don't change 3 to 3.0 and don't change 7 to 7.0.

Windows forms

Like Visual Basic, C# lets you easily create Windows forms. Here's how.

Start C# (by typing "vi" in the Windows 10 Search box, then clicking "Visual Studio 2015: Desktop app" then "New Project" then "Visual C#").

Click "Windows Forms Application".

Double-click in the Name box (which is near the screen's bottom). Type a name for your project (such as Joymaker). At the end of your typing, press the Enter key.

You see an **object**, called the **Form1** window. Double-click in that window (below "Form1"). That tells the computer you want to write a program (subroutine) about that window.

The computer starts writing the **subroutine** for you. The computer writes:

```
using System;
using System.Collections.Generic;
using System.ComponentModel;
using System.Data;
using System.Drawing;
using System.Linq;
using System.Text;
using System.Threading.Tasks;
using System.Windows.Forms;

namespace Joymaker
{
    public partial class Form1 : Form
    {
        public Form1()
        {
            InitializeComponent();
        }

        private void Form1_Load(object sender, EventArgs e)
        {

        }
    }
}
```

The line saying "private void Form1_Load" is the subroutine's **header**. Below that, between the **braces** (the symbols "{" and "}"), insert lines that tell the computer what to do when Form1 is **loaded** (appears). The lines you insert are called the subroutine's **body**.

Simplest example

Let's make the Form1 window say "I love you". To do that, type this line —

```
        Text = "I love you";
```

The computer automatically indents that line for you, so the subroutine becomes:

```
        private void Form1_Load(object sender, EventArgs e)
        {
            Text = "I love you";
        }
```

To run your program, click "Start" (which is at the screen's top center). Then you see the Form1 window again; but instead of saying "Form1", it tries to say the text:

```
I love you
```

(To see all that, maximize that Form1 window by clicking its **Maximize button**, which is left of its X.)

When you've finished admiring the Form1 window, stop the program by clicking the Form1 window's X button. Then you see the subroutine again:

```
        private void Form1_Load(object sender, EventArgs e)
        {
            Text = "I love you";
        }
```

If you wish, edit the subroutine. For example, try changing the Text line to this:

```
            Text = "I hate cabbage";
```

Math

The Text line can include math calculations, but you must convert the answer to a string, since Text must be a string. For example, to make the computer write the answer to 4 + 2, type this line:

```
            Text = Convert.ToString(4 + 2);
```

Message box

To create a message box saying "Your hair is messy", type this line:

```
            MessageBox.Show("Your hair is messy");
```

To create a message box saying the answer to 4 + 2, type this line:

```
            MessageBox.Show(Convert.ToString(4 + 2));
```

Property list

Click the "Form1.cs [Design]" tab, so you see the Form1 window itself. Then click (just once) in the middle of the Form1 window.

Then the screen's bottom-right corner shows a list whose title is:

```
Properties
Form1 System.Windows.Forms.Form
```

That list is called **Form1's main property list** (or **property window**). It looks the same as if you were using Visual Basic. To explore it, reread my chapter about Visual Basic.

See the toolbox

Click the "**Form1.vb [Design]**" tab then "**View**" (which is near the screen's top-left corner) then "**Toolbox**". Then you see 10 **toolbox categories**:

```
All Windows Forms
Common Controls
Containers
Menus & Toolbas
Data
Components
Printing
Dialogs
WPF Interoperability
General
```

(If you don't see that whole list yet, scroll down.)

The toolbox looks the same way as if you were using Visual Basic. To explore how to use its tools, reread pages 576-584, starting with "See common controls".

Exotic languages

The previous 6 chapters explained 6 popular computer languages: **Basic** (especially the versions called QBasic & QB64), **Visual Basic**, **JavaScript** (especially the JScript version), **Java**, **Visual C#**, and **Visual C++**.

Those 6 languages are just the tip of the iceberg. Programmers have invented *thousands* of others.

This table shows how to give popular commands in 26 languages:

Language	Assign variable	Condition	Start a counting loop	Output	Declare an array	Comment
Basic	`j = k + 2`	`IF x = 4.3 THEN`	`FOR i = 5 TO 17`	`PRINT k`	`DIM x(4)`	`'wow`
Visual Basic	`j = k + 2`	`If x = 4.3 Then`	`For i = 5 To 17`	`Console.WriteLine(k)`	`Dim x(4)`	`'wow`
Java	`j=k+2`	`if (x==4.3)`	`for (int i=5; i<=17; ++i)`	`System.out.println(k)`	`double[] x=new double[4]`	`//wow`
JavaScript	`j=k+2`	`if (x==4.3)`	`for (int i=5; i<=17; ++i)`	`document.write(k)`	`x=Array(4)`	`//wow`
C	`j=k+2`	`if (x==4.3)`	`for (i=5; i<=17; ++i)`	`printf("%d",k)`	`float x[4]`	`/* wow */`
C++ & Visual C++	`j=k+2`	`if (x==4.3)`	`for (int i=5; i<=17; ++i)`	`cout <<k`	`double x[4]`	`//wow`
Visual C#	`j = k + 2`	`if (x==4.3)`	`for (int i = 5; i <=17; ++i)`	`Console.WriteLine(k)`	`double[] x = new double[4]`	`//wow`
Perl	`$j=$k+2`	`if ($x==4.3)`	`for ($i=5; $i<=17; ++$i)`	`print $k`	`@x=(1..4)`	`#wow`
PHP	`$j=$k+2`	`if ($x==4.3)`	`for ($i=5; $i<=17; ++$i)`	`echo $k`	`$x=range(1,4)`	`//wow`
Algol	`J:=K+2`	`IF X=4.3 THEN`	`FOR I := 5 STEP 1 UNTIL 17 DO`	`PRINT(k)`	`REAL ARRAY X[1:4]`	`COMMENT WOW`
Pascal & Delphi	`J:=K+2`	`IF X=4.3 THEN`	`FOR I := 5 TO 17 DO`	`WRITELN(k)`	`X: ARRAY[1..4] OF REAL`	`{WOW}`
Modula	`J:=K+2`	`IF X=4.3 THEN`	`FOR I := 5 TO 17 DO`	`WRITEINTEGER(K,6)`	`X: ARRAY[1..4] OF REAL`	`(*WOW*)`
Ada	`J:=K+2`	`IF X=4.3 THEN`	`FOR I IN 5..17 LOOP`	`PUT(K)`	`X: ARRAY(1..4) OF FLOAT`	`--WOW`
Python	`j=k+2`	`if x==4.3:`	`for i in range(5,18):`	`k`	`x=zeros(4)`	`#wow`
Ruby	`j=k+2`	`if x==4.3`	`for i in 5..17`	`puts k`	`x=(1..4)`	`#wow`
Fortran	`J=K+2`	`IF (X .EQ. 4.3)`	`DO 10 I=5,17`	`PRINT *, K`	`DIMENSION X(4)`	`C WOW`
PL/I	`J=K+2`	`IF X=4.3 THEN`	`DO I = 5 TO 17`	`PUT LIST(K)`	`DECLARE X(4)`	`/* WOW */`
Cobol	`COMPUTE J = K + 2`	`IF X = 4.3`	`PERFORM L VARYING I FROM 5 BY 1 UNTIL I>17`	`DISPLAY K`	`X OCCURS 4 TIMES`	`*WOW`
dBase	`J=K+2`	`IF X=4.3`	not available	`? K`	`DECLARE X[4]`	`&&WOW`
Easy	`LET J=K+2`	`IF X=4.3`	`LOOP I FROM 5 TO 17`	`SAY K`	`PREPARE X(4)`	`'WOW`
Snobol	`J = K + 2`	`EQ(X,4.3) :S(`	not available	`OUTPUT = K`	`X = ARRAY(4)`	`*WOW`
Pilot	`C:#J=#K+2`	`(#X=4.3)`	not available	`T:#K`	`DIM:#X(4)`	`R:WOW`
Lisp	`(SETQ J (PLUS K 2))`	`IF :X=4.3`	not available	`K`	`(ARRAY ((X (4) LIST)))`	`;WOW`
Logo	`MAKE "J :K+2`	`IF :X=4.3`	not available	`PRINT :K`	`DEFAR "X 4 1`	`!WOW`

That table clumps the languages into groups. For example, the first group includes Basic and Visual Basic.

In each group, I list the languages in the order they were invented. For example, in the first group, QBasic was invented before Visual Basic, so QBasic is listed first.

The bottom 4 (Snobol, Pilot, Lisp, and Logo) differs wildly from the others. They're called **radical languages**; the other 22 languages are called **mainstream**.

Two other radical languages are **APL** and **Forth**. They're so weird they won't fit in that table!

Each of those 28 languages is flexible enough to program anything. Which language you choose is mainly a matter of personal taste.

Other languages are more specialized. For example, a language called **GPSS** is designed specifically to analyze how many employees to hire, to save your customers from waiting in long lines for service. **Dynamo** analyzes social interactions inside your company and city and throughout the world then graphs your future. **Prolog** lets you store answers to your questions and act as an **expert system**.

This table reveals more details about all those languages:

Name	What the name stands for	Original use	Version 1 arose at	When	Names of new versions
	Mainstream languages				
Fortran	**For**mula **Tran**slating	sciences	IBM	1954-1957	Fortran 2008, Lahey Fortran
Algol	**Algo**rithmic **L**anguage	sciences	international	1957-1958	Algol W, Algol 68, Balgol
Cobol	**Co**mmon **B**usiness-**O**riented **L**anguage	business	Defense Department	1959-1960	Cobol 2014
Basic	**B**eginners **A**ll-purp. **S**ymbolic **I**nstruc. **C**ode	sciences	Dartmouth College	1963-1964	GW Basic, QBasic, QB64, BBC Basic
PL/I	**P**rogramming **L**anguage **O**ne	general	IBM	1963-1966	PL/I Optimizer, PL/C, Ansi PL/I
Pascal	Blaise **Pascal**	general	Switzerland	1968-1970	Turbo Pascal, Delphi
Modula	**Modula**r programming	systems programming	Switzerland	1975	Modula-2, Oberon
C	beyond B	systems programming	AT&T's Bell Labs	1971-1973	Ansi C, Objective-C
Ada	**Ada** Lovelace	military equipment	France	1977-1980	Ada final version
dBase	**D**ata **Base**	database management	Jet Prop'n Lab & Ashton-T.	1978-1980	dBase Plus 11, Visual FoxPro 9
Easy	**Easy**	general	Secret Guide	1972-1982	Easy
C++	**C** increased	systems programming	AT&T's Bell Labs	1979-1983	Borland C++, ISO C++
Perl	**P**ractical **E**xtraction and **R**eport **L**anguage	systems programming	Unisys	1987	Perl 6
Python	as fun as Monty **Python**'s Flying Circus	systems programming	Netherlands	1989	Python 3
Java	as stimulating as **Java** coffee	Web-page animation	Sun Microsystems	1990-1995	Java 7, JBuilder, Visual J++, J#
Visual Basic	**Basic** for creating Windows **Visual**ly	Windows-form design	Microsoft	1991	Visual Basic 2015
Visual C++	**C++** for creating Windows **Visual**ly	Windows-form design	Microsoft	1993	Visual C++ 2015
Delphi	oracle at **Delphi**	general	Borland	1993-1995	Delphi 2007, Oxygene
Ruby	the birthstone beyond Pearl	systems programming	Japan	1993-1996	Ruby 2.1, Ruby on Rails
PHP	**P**ersonal **H**ome **P**age	Web-page design	Canada	1994-1995	PHP 5.5
JavaScript	**Java** for creating simple **script**s	Web-page calculations	Netscape	1996	JScript
Visual C#	**C** sharp for creating Windows **Visual**ly	Windows-form design	Microsoft	1999-2000	Visual C# 2015
	Radical languages				
Lisp	**Lis**t **P**rocessing	artificial intelligence	MIT	1958-1960	Common Lisp
Snobol	**S**tri**n**g-**O**riented sym**bo**lic **L**anguage	string processing	AT&T's Bell Labs	1962-1963	Snobol 4B
APL	**A P**rogramming **L**anguage	sciences	Harvard & IBM	1956-1966	APLSV, APL Plus, APL 2, J
Logo	**Logo**	general	Bolt Beranek Newman	1967	Terrapin Logo, LCSI MicroWorlds Pro
Forth	**Fourth**-generation language	business & astronomy	Stanford Univ. & Mohasco	1963-1968	Forth 83, Fig-Forth, MMS Forth
Pilot	**P**rogrammed **I**nquiry, **L**earning, **O**r **T**eaching	tutoring kids	U. of Cal. at San Francisco	1968	Atari Pilot
	Specialized languages				
Dynamo	**Dyna**mic **M**odels	simulation	MIT	1959	Dynamo 4, Stella
GPSS	**G**eneral-**P**urpose **S**imulation **S**ystem	simulation	IBM	1961	GPSS 5
Prolog	**Pro**gramming in **Log**ic	artificial intelligence	France	1972	Arity Prolog, Turbo Prolog

Within each category ("mainstream", "radical", and "specialized"), I listed the languages in chronological order.

Of those 31 languages, 6 were invented in Europe (Algol, Pascal, Modula, Ada, Python, and Prolog), 1 in Japan (Ruby), and 1 in Canada (PHP). The other 23 were invented in the USA.

4 were invented at IBM (Fortran, PL/I, APL, and GPSS), 3 at Microsoft (Visual Basic, Visual C++, and Visual C#), 3 at AT&T's Bell Labs (C, C++, and Snobol), 2 at MIT (Lisp and Dynamo), and 2 by Professor Niklaus Wirth in Switzerland (Pascal and Modula). The rest were invented by geniuses elsewhere.

Mainstream languages

The first mainstream languages were **Fortran**, **Algol**, and **Cobol**. They were the **big 3**.

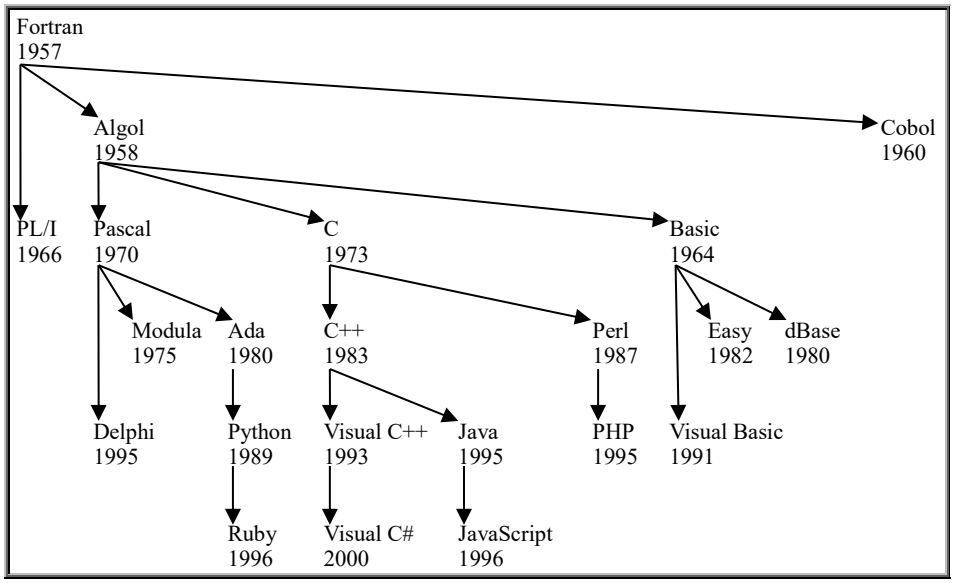
IBM invented **Fortran**, which appealed to engineers.

An international committee invented **Algol**, which appealed to logicians.

A committee based at the Pentagon invented **Cobol**, which appealed to government bureaucrats and business managers.

Beyond the big 3

Other mainstream languages came after the big 3 and were just slight improvements of the big 3. This family tree shows how the mainstream languages influenced each other:



In that tree, a vertical line means "a direct influence" (like a parent); a slanted line means "an indirect influence" (like an aunt or uncle). For each language, I show the year when the language's first version was complete. As each language grew, it stole features from other languages (just like English stole the word "restaurant" from French); the tree shows just history's main thrust.

The tree's third row has 4 languages: PL/I, Pascal, C, and Basic. Here's why they were invented.…

Why PL/I? After inventing **Fortran** and further improvements (called Fortran II, Fortran III, Fortran IV, and Fortran V), IBM decided to invent the "ultimate" improvement: a language that would include all the important words of Fortran V and **Algol** and **Cobol**. At first, IBM called it "Fortran VI"; but since it included the best of everything and was the first *complete* language ever invented, IBM changed its name to **Programming Language One** (written as **PL/I**).

IBM bragged that PL/I was eclectic, but most programmers considered it a confusing mishmash and continued using the original 3 languages (Fortran, Algol, and Cobol), which were pure and simple.

Why Pascal? Among the folks who disliked PL/I was Niklaus Wirth, who preferred **Algol**. At a Swiss university, he invented an improved Algol and called it **Pascal**. Then he invented **Modula**, which he thinks is even better, but critics disagree. Pascal is the most popular of that trio. (Hardly anybody uses the original Algol anymore, and Modula is considered a controversial experiment.)

A company called **Borland** became famous by developing **Turbo Pascal** (a Pascal version that runs fast on DOS) then **Delphi** (which resembles Turbo Pascal but run on Windows and lets you create your own windows).

The Department of Defense happily used Cobol to run the military's paperwork bureaucracy but needed a more science-oriented language, to control missiles and other military equipment. The Department held a contest to develop such a language and said it wanted the language to resemble PL/I, Algol, and Pascal. (It didn't know about Modula, which was still being developed.) The winner was a French company. The Department adopted that company's language and called it **Ada**. It resembled Modula but included more commands — and therefore consumed more RAM and was more expensive. Critics complain that Ada, like PL/I, is too big and complex. But Ada inspired **Python** and **Ruby**, which are smaller and popular.

Why Basic? Two professors at Dartmouth College combined Fortran with Algol, to form **Basic**. It was designed for students, not professionals: it included just the *easiest* parts of Fortran and Algol. Students liked it because it was easy to learn, but professionals complained it lacked advanced features.

Basic's first version ran on a maxicomputer. Later, Digital Equipment Corporation (DEC) invented versions for minicomputers, and Microsoft invented many microcomputer versions, such as **QBasic**.

After Microsoft invented Windows, Microsoft invented **Visual Basic**, which runs on Windows, lets you create your own windows, and includes advanced features.

Basic inspired me to invent a language called **Easy**, which is even easier to learn than Basic but hasn't yet been put on any computer fully.

Inspired by languages such as Basic and PL/I, Wayne Ratliff invented **dBase**. Like Basic, dBase is easy. What makes dBase unique is its wonderful commands for manipulating databases.

Why C? Fancy languages, such as PL/I and Modula, require lots of RAM. At AT&T's Bell Labs, researchers needed a language small enough to fit in the tiny RAM of a minicomputer or microcomputer. They developed the ideal tiny language and called it **C**. Like PL/I, it borrows from Fortran, Algol, and Cobol; but it lacks PL/I's frills. It's "lean and mean" and runs very fast.

Later, Bell Labs invented an improved C, called **C++**, which includes extra commands. Microsoft invented **Visual C++**, which adds commands for manipulating windows. Then Anders Hejlsberg (the Danish programmer who developed Turbo Pascal and Delphi at Borland) moved to Microsoft, where he invented **Visual C#**, which tries to combine the best features of Visual C++, Turbo Pascal, and Delphi.

Sun Microsystems invented a C++ variant called **Java**, to handle Web-page programming (such as animation). Netscape invented **JavaScript**, which resembles Java but is simpler and more limited. C also led to **Perl** & **PHP**, which handle Web-page programming and compete against Java & JavaScript.

Look back! Let's take a closer look at the oldest of those mainstream languages, the ones invented up through 1983.…

Fortran

During the early 1950's, the only available computer languages were specialized or awkward. **Fortran** was the first computer language good enough to be considered mainstream. Algol and Cobol came shortly afterwards. Fortran, Algol, and Cobol were so good they made all earlier languages obsolete.

Fortran's nature On pages 507-561, I explained how to program in QBasic. Fortran resembles QBasic but is weirder — because Fortran was invented before programmers learned how to make programming languages pleasant.

For example, suppose you want to add 2+2. In QBasic, you can say just:

```
PRINT 2+2
```

In Fortran, you must lengthen the program, so it looks like this instead:

```
      N=2+2
      PRINT *, N
      END
```

Here's why:

Fortran requires the program's bottom line to say END.

Fortran requires each line to be indented 6 spaces.

Fortran is too stupid to do math in the middle of a PRINT statement, so you must do the math first, in a separate line (N=2+2).

Fortran expects you to comment about *how* to print the answer. If you have no comment on that topic, put an asterisk and comma in the PRINT statement. The asterisk and comma mean: no comment.

That's how the typical version of Fortran works. Some versions are different. For example, some versions require you to say STOP above END, like this:

```
      N=2+2
      PRINT *, N
      STOP
      END
```

Some versions want you to say TYPE instead of PRINT.

Some old versions won't accept "no comment" about printing. They require you to say:

```
      N=2+2
      PRINT 10, N
10    FORMAT (1X,I1)
      END
```

That PRINT line means: PRINT, using the FORMAT in line 10, the value of N. In line 10, the 1X means "normal"; the I1 means "an integer that's just one digit". Those details drive beginners nuts, but experienced Fortran programmers are used to such headaches and take them in stride, just like Frenchmen are used to conjugating French verbs and Germans are used to conjugating German adjectives. Yuck!

Like QBasic, Fortran lets you do math by using these symbols:

```
+   -   *   /
```

But Fortran is harder to learn than QBasic:

To divide 399 by 100 in QBasic, you can write 399/100 to get the correct answer, 3.99. But in Fortran, requesting 399/100 makes the computer assume you don't care about decimal points (since you didn't mention any), so it says just 3; if you want the computer to say 3.99 instead, you must insert a decimal point into the original problem, by asking for 399.0/100.0 (or at least asking for 399./100, if you're lazy).

QBasic lets you use the symbol < to mean "less than". Fortran is afraid to use fancy symbols (since ancient keyboards didn't have them), so Fortran wants you to write .LT. instead, like this….
QBasic: IF x < 4.3 THEN
Fortran: IF (X .LT. 4.3) THEN
Likewise, Fortran requires you to say .GT. instead of > for "greater than", say .LE. for "less than or equal to", say .GE. for "greater than or equal to", and, for consistency, say .EQ. for "equals" in an IF statement.…
QBasic: IF x = 4.3 THEN
Fortran IF (X .EQ. 4.3) THEN

In QBasic, the symbol ^ means exponents (for example, 4.7 ^ 3 means "4.7 times 4.7 times 4.7"). Since Fortran's afraid of fancy symbols, Fortran uses ** instead of ^ (like this: 4.7 ** 3).

In QBasic, a variable can be any letter of the alphabet (such as n) or a longer name (up to 40 characters long). In Fortran, each variable's name must be short (no longer than 6 characters), because Fortran is supposed to run even on primitive old computers having little memory.

QBasic assumes each variable is single-precision real (unless you specifically indicate otherwise, such as by putting a $ at the end of the variable's name to indicate the variable's a string). Fortran is more complicated: it assumes any variable whose name begins with I, J, K, L, M, or N is an integer, and all other variables are single-precision real (unless you indicate otherwise). Since Fortran assumes that variables beginning with I, J, K, L, M, or N are integers, Fortran programmers purposely misspell variable names. For example, if a Fortran variable's purpose is to count, call it KOUNT (rather than COUNT) to make it an integer. If you want a Fortran variable to be an integer that measures a position, call it LOCATN (rather than POSITN) to make it an integer. If a Fortran variable measures an object's mass as a real number, call it AMASS (rather than MASS) to make it a real.

Since Fortran's purpose was just to do math, Fortran's original version didn't include any string variables. Later, many manufacturers added string commands, but they're much more awkward than QBasic's.

Fortran can handle complex numbers (such as the square root of -1). Fortran's ability to handle complex numbers make it better for advanced math & engineering than QBasic.

Fortran did well at handling math functions (such as square roots) and subroutines (for handling statistics, calculus computations, and other math challenges). Many programmers created Fortran math functions and subroutines, organized them into libraries, and sold them to other programmers. A whole culture developed of programmers writing Fortran routines. If you didn't know Fortran, you weren't part of the "in" crowd.

How Fortran arose In 1954, an IBM committee planned a new computer language to help engineers make the computer handle math formulas. The committee called the language **Fortran**, to emphasize that the language would be particularly good for **tran**slating **for**mulas into computer notation.

Those original plans for Fortran were modest:

They did *not* allow long variable names, subroutines, long function definitions, double precision, complex numbers, or apostrophes. A variable's name had to be short: just two letters. A function's definition had to fit on a single line. To print 'PLEASE KISS ME', the programmers had to write that string as 14HPLEASE KISS ME instead of 'PLEASE KISS ME'; the 14H warned the computer that a 14-character string was coming.

Then came improvements:

Fortran's first working version (1957) allowed longer variable names: 6 characters.
Fortran II (1958) allowed subroutines and long function definitions.
IBM experimented with Fortran III but never released it to the public.
Fortran IV (1962) allowed double precision and complex numbers.
Apostrophes around strings weren't allowed until later.

The original plans said you'd be able to add an integer to a real. That didn't work in Fortran I, Fortran II, and Fortran IV but works now.

The original plans said an IF statement would compare any two numbers. Fortran I and Fortran II required the second number to not be zero, but Fortran IV removed that restriction.

IBM tried to convince everyone that Fortran was easier than previous methods of programming. IBM succeeded: Fortran became popular. Fortran was easy enough so that, for the first time, engineers who weren't computer specialists could write programs.

Other manufacturers sold their own variations of IBM's Fortran. Those variations annoyed engineers, who wished manufacturers would all use a single, common version of Fortran. So the engineers turned to the **American National Standards Institute (Ansi)**, which is a non-profit group of engineers that sets standards.

"Ansi" is pronounced "an see". It sets standards for practically all equipment in your life. For example, Ansi sets the standard for screws: to tighten a screw, you turn it clockwise, not counterclockwise.

In 1966, Ansi decided on a single version of Fortran IV to be used by all manufacturers. Afterwards, each manufacturer obeyed the Ansi standard but also added extra commands, to try to outclass the other manufacturers. After several years had gone by, engineers asked Ansi to meet again and develop a common standard for those extras. Ansi finished developing the standard in 1977 and called it **Fortran 77**. Then came **Fortran 90**, **Fortran 95**, **Fortran 2003**, and **Fortran 2008**. Ansi is trying to develop **Fortran 2015**.

Fortran's popularity. During the 1960's and 1970's, Fortran was the most popular computer language among engineers, scientists, mathematicians, and college students. Colleges required all freshman computer-science majors to learn Fortran.

But at the end of the 1970's, Fortran's popularity began to drop.

Engineers switched to newer languages, such as Basic (which is easier), Pascal (more logical), and C (faster and consuming less RAM). Though Fortran 77 included extra commands to make Fortran resemble Basic and Pascal, those commands were "too little, too late": Fortran's new string commands weren't quite as good as Basic's, and Fortran's new IF command wasn't quite as good as Pascal's.

Now high-school kids study Basic or Pascal or Java, college kids study C++ or C#, and hardly anybody studies Fortran. People who still program in Fortran are called "old-fashioned".

But in these ways, Fortran's still the best for engineering:

Fortran includes more commands for handling "complex numbers".

Fortran programmers have developed libraries containing *thousands* of Fortran subroutines, which you can use in your own Fortran programs. Such large libraries haven't been developed for other languages yet.

Algol

In 1955, a committee in Germany began inventing a computer language. Though the committee spoke German, it decided the computer language should use English words instead, since English was the international language for science.

In 1957 those Germans invited Americans to join them. In 1958 other European countries joined also, to form an international committee, which proposed a new computer language, called "IAL" (International Algebraic Language).

The committee eventually changed the language's name to **Algol 58** (the **Algo**rithmic **l**anguage invented in 19**58**), then created an improved version called **Algol 60**, then created a further revision called **Algol 60 Revised**, and disbanded. Today, programmers who mention "Algol" usually mean the committee's last report, Algol 60 Revised.

Algol differs from Fortran in many little ways.…

How to end a statement At the end of each statement, Fortran requires you to press the Enter key. Algol requires you to type a semicolon instead.

Algol's advantage: you can type many statements on the same line, by putting semicolons between the statements. Algol's disadvantage: those ugly semicolons are a nuisance to type and make your program look cluttered.

Integer variables To tell the computer that a person's AGE is an integer (instead of a real number), Fortran expects you to put the letter I, J, K, L, M, or N before the variable's name, like this: IAGE. Algol requires you to insert a note saying "INTEGER AGE" at the top of your program instead.

Algol's advantage: it doesn't encourage you to write unpronounceable gobbledygook such as "IAGE". Algol's disadvantage: whenever you create a new variable, Algol forces you to go back to the program's top and insert a line saying "INTEGER" or "REAL".

Assignment statements In Fortran, you can say J=7. In Algol, you must insert a colon and say J:=7 instead. To increase K by 1 in Fortran, you say K=K+1. In Algol, you say K:=K+1.

Algol's disadvantage: the colon is a nuisance to type. Fortran's disadvantage: according to the rules of algebra, it's impossible for K to equal K+1, so the Fortran command K=K+1 looks like an impossibility.

Algol's beauty Here's how Algol avoids Fortran's ugliness:

In Algol, a variable's name can be practically as long as you like. In Fortran, a variable's name must be short: no more than 6 characters.

Algol lets you write 2 instead of 2.0, without affecting the computer's answer. In Fortran, if you write 1/2 instead of 1/2.0, you get 0 instead of .5; and if you write SQRT (9) instead of SQRT (9.0), you get nonsense.

Algol's IF statement is very flexible: it can include the words ELSE, BEGIN, and END, and it lets you insert as many statements as you want between BEGIN and END. Algol even lets you put an IF statement in the middle of an equation, like this: X:=2+(IF Y<5 THEN 8 ELSE 9). The IF statement in Fortran I, II, III, and IV was very limited; the IF statement in Fortran 77 copies some of Algol's power, but not yet all.

Algol's FOR statement is very flexible. To make X be 3.7, then be Y+6.2, then go from SQRT(Z) down to 5 in steps of .3, you can say "FOR X:=3.7, Y+6.2, SQRT(Z) STEP -.3 UNTIL 5 DO". Fortran's DO is more restrictive; some versions of Fortran even insist that the DO statement contain no reals, no negatives, and no arithmetic operations.

At the beginning of a Fortran program, you can say DIMENSION X(20) but not DIMENSION X(N). Algol permits the "DIMENSION X(N)" concept; in Algol you say ARRAY X[1:N].

Algol's popularity When Algol was invented, programmers loved it. Europeans began using Algol more than Fortran. The American computer association (called the **Association for Computing Machinery, ACM**) said all programs in its magazine would be in Algol.

But since IBM refused to put Algol on its computers, most American programmers couldn't use Algol.

That created a ridiculous situation: American programmers programmed in Fortran but submitted Algol translations to the ACM's magazine, which published the programs in Algol, which the magazine's readers had to translate back to Fortran to run on IBM computers. IBM computers eventually swept over Europe, so even Europeans had to use Fortran instead of Algol.

In 1966 the ACM gave in and agreed to publish programs in Fortran; but since Algol was prettier, everybody continued to submit Algol versions anyway. IBM gave in also and put Algol on its computers; but IBM's version of Algol was so limited and awkward that nobody took it seriously, and IBM stopped selling it. In 1972 Stanford University invented **Algol W** (a better Algol for IBM computers), but Algol W came too late: universities and businessmen had already tired of waiting for a good IBM Algol and committed themselves to Fortran.

Critics blamed IBM for Algol's demise. But here's IBM's side of the story:

IBM had invested 25 man-years to develop the first version of Fortran. By the time the Algol committee finished the report on Algol 60 Revised, IBM had also developed Fortran II and Fortran III and made plans for Fortran IV. IBM was proud of its Fortrans and wanted to elaborate on them. Moreover, IBM realized that **computers run Fortran programs faster than Algol**.

When asked why it didn't support Algol, IBM replied that the committee's description of Algol was incomplete. IBM was right; the Algol 60 Revised Report had 3 loopholes:

The report didn't say what words to use for input and output, because the committee couldn't agree. So computers differ. If you want to transfer an Algol program from one computer to another, you must change all the input and output instructions.

The report uses symbols such as ÷ and ∧, which most keyboards lack. The report underlines keywords; most keyboards can't underline. To type Algol programs on a typical keyboard, you must substitute other symbols for ÷, ∧, and underlining. Manufacturers differ in what to substitute. To transfer an Algol program to different manufacturer, you must change symbols.

Some features of Algol are hard to teach to a computer. Even now, no computer understands all of Algol. When a manufacturer says its computer "understands Algol", you must ask, "*Which* features of Algol?"

Attempts to improve Algol Long after the original Algol committee wrote the Algol 60 Revised Report, two other Algol committees were formed.

One committee developed suggestions on how to do input and output, but its suggestions were largely ignored.

The other committee tried to invent a much fancier Algol. That committee wrote its preliminary report in 1968 and revised it in 1975. Called **Algol 68 Revised**, that weird report requires you to spell words backwards: to mark the end of the IF statement, you say FI; to mark the end of the DO statement, you say OD. The committee's decision was far from unanimous: several members refused to endorse the report.

Algol now Few programmers still use Algol, but many use Pascal (which is very similar to Algol 60 Revised) and Basic (which is a compromise between Algol and Fortran).

Cobol

If you're going to give a speech or write a paper, teachers recommend you organize your thinking by creating an outline. Back in the 1950's, managers of computer departments got together and decided programmers should organize programs in the same way: create an outline before writing the program, especially since a well-organized program is easier for the company to analyze and improve when the original programmer gets fired.

Those managers invented a computer language that lets the programmer just fill in an outline and feed the outline to the computer. The outline itself acts as the program. No further programming is necessary.

That outline-oriented computer language is used for handling tough programming problems in business accounting (such as payroll, inventory, accounts payable, and accounts receivable), so it was named the **Co**mmon **B**usiness-**O**riented **L**anguage (whose abbreviation is **Cobol**, which is pronounced "koe ball"). But cynics complain that "Cobol" also stands for **Completely Obsolete Business-Oriented Language** and **Compiles Only Because Of Luck**.

4 parts To write a program in Cobol, just fill in an outline that has 4 parts:

In the first part, called the **IDENTIFICATION DIVISION**, you give your name (so your boss knows who to fire when the program doesn't work) and comments about when you wrote the program, the program's name, and security (who's allowed to see this program). The computer ignores everything you say in the IDENTIFICATION DIVISION, but writing that stuff makes your boss happy.

In the second part, called the **ENVIRONMENT DIVISION**, you say what kind of environment you wrote the program for: which computer it runs on, which devices the program's files use (disks? tapes? printers? punched cards?), and whether decimal points should be printed as commas instead (since people in France, Italy, and Germany want you to do that).

In the third part, called the **DATA DIVISION**, you list all the program's variables. For each numeric variable, you must say how many digits it should store (to the left and right of the decimal point) and how to format the number (for example, say whether to print a dollar sign before the number). For example, if you want N to be a 3-digit integer (from 000 to 999) without special formatting, say N PICTURE IS 999 (which means N is a variable whose picture is at most the number 999). If you want N to be a 7-digit integer (from 0000000 to 9999999), say N PICTURE IS 9999999. If you want N to be a 7-character string, say N PICTURE IS XXXXXXX. You can abbreviate: you can say just PIC instead of PICTURE IS, and you can say X(7) instead of XXXXXXX.

In the fourth and final part, called the **PROCEDURE DIVISION**, you finally write the procedures you want to the computer to perform, using commands such as READ, WRITE, DISPLAY, ACCEPT, IF, GO TO, SORT, MERGE, and PERFORM. Each command's an English sentence that includes a verb and ends in a period. You organize the PROCEDURE DIVISION into paragraphs, invent a name for each paragraph, treat each paragraph as a separate procedure/subroutine, and tell the computer in what order to PERFORM the paragraphs. One line in the PROCEDURE DIVISION must say "STOP RUN": when the computer encounters that line, the computer stops running the program.

Unfortunately, that idea of dividing a program into 4 divisions is wrong-headed: when you write or read a Cobol program, your eye must keep hopping between the PROCEDURE DIVISION (where the action is) and the DATA DIVISION (which tells what the variables mean), while taking an occasional peek at the ENVIRONMENT DIVISION (which tells what devices are involved). Other programming languages, developed later, use better ways to organize thoughts.

How Cobol arose During the 1950's, several organizations developed languages to solve problems in business. The most popular business languages were IBM's **Commercial Translator** (developed from 1957-1959), Honeywell's **Fact** (1959-1960), Sperry Rand's **Flow-matic** (1954-1958), and the Air Force's **Aimaco** (1958).

In April 1959, a group of programmers and manufacturers met at the University of Pennsylvania, decided to develop a *single* business language for *all* computers, and asked the Department of Defense to sponsor the research. The Department agreed.

In a follow-up meeting held at the Pentagon in May, the group tentatively decided to call the new language "CBL" (for "Common Business Language") and created 3 committees.

The Short-Range Committee would meet immediately to develop a temporary language. A Medium-Range Committee would meet later to develop a more thoroughly thought-out language. Then a Long-Range Committee would develop the ultimate language.

The Short-Range Committee met immediately and created a language nice enough so the Medium-Range and Long-Range Committees never bothered to meet.

The Short-Range Committee wanted a more pronounceable name for the language than "CBL". At a meeting in September 1969, the committee members proposed 6 names:

"BUSY" (BUsiness SYstem)
"BUSYL" (BUsiness SYstem Language)
"INFOSYL" (INFOrmation SYstem Language)
"DATASYL" (DATA SYstem Language)
"COSYL" (COmmon SYstem Language)
"COCOSYL" (COmmon COmputer SYstem Language)

But the next day, a member of the committee suggested "Cobol" (**Co**mmon **B**usiness-**O**riented **L**anguage), and the rest of the committee agreed.

I wish they'd have kept the name "BUSY", because it's easier to pronounce and remember than "Cobol". Today, Cobol programmers are still known as "BUSY bodies".

From Sperry Rand's Flow-matic, the new language (called "Cobol") borrowed 2 rules:

Begin each statement with an English verb.
Put data descriptions in a different program division than procedures.

From IBM's Commercial Translator, Cobol borrowed fancy IF statements, COMPUTE formulas, PICTURE symbols (for showing how to format the numbers and strings), and group items (called 01 and 02, which let a variable stand for a whole collection of data).

Compromises On some issues, the committee's members had to compromise.

For example, some members wanted Cobol to let programmers write mathematical formulas by using these symbols:

+	-	*	/	=	(	)

But other members of the committee disagreed: they said that since Cobol is for stupid businessmen who fear formulas, Cobol should use the words ADD, SUBTRACT, MULTIPLY, and DIVIDE instead. The committee compromised:

When you write a Cobol program, you can use the words ADD, SUBTRACT, MULTIPLY, and DIVIDE. You can use a formula instead but just if you warn the computer by putting the word COMPUTE before the formula.

Can Cobol handle long numbers? How long? The committee decided that Cobol would handle any **number up to 18 digits long** and handle any **variable name up to 30 characters long**. So the limits of Cobol are "18 digits, 30 characters". Here's why:

Some manufacturers wanted "16 digits, 32 characters", because their computers were based on the numbers 16 and 32; but other manufacturers wanted other combinations (such as "24 digits, 36 characters"). The committee, hunting for a compromise, chose "18 digits, 30 characters" because *nobody* wanted it, and so it would give no manufacturer an unfair advantage over competitors. Yes, Cobol was designed to be equally terrible for everybody! That's politics!

Cobol's popularity In 1960, the Defense Department announced it would buy just computers that understand Cobol, unless a manufacturer can demonstrate why Cobol isn't helpful. In 1961, Westinghouse Electric Corp. made a similar announcement. Other companies followed. Cobol became the most popular computer language.

Today it's still the most popular computer language for maxicomputers, though programmers on minicomputers and microcomputers have switched to newer languages.

Improvements The original version of Cobol was finished in 1960 and called **Cobol 60**. Then came an improvement, called **Cobol 61**. In 1962, the verb SORT and a "Report Writer" feature were added. Then came **Cobol 65**, **Cobol 68**, **Cobol 74**, and **Cobol 85**.

Cobol's most obvious flaw Cobol requires you to put info about file labeling into the **data division**'s FD command. But since file labeling describes the environment, not the data, Cobol should have put file labeling in the **environment division** instead.

Jean Sammet, who headed some of the Short-Term Committee's subcommittees, admits her group goofed when it put file labeling in the data division. But Cobol's too old to change now.

Basic

The first version of **Basic** was developed in 1963 and 1964 by a genius (**John Kemeny**) and his friend (**Tom Kurtz**).

How the genius grew up John Kemeny was a Jew born in Hungary in 1926. In 1940, he & his parents fled the Nazis and came to America. When he began high school in New York City, he knew hardly any English; but he learned enough so he graduated as the top student in the class. 4 years later, he graduated from Princeton **summa cum laude** even though he had to spend 1½ of those years in the Army, where he helped solve equations for the atom bomb.

2 years after his B.A., Princeton gave him a Ph.D. in mathematics *and* philosophy, because his thesis on symbolic logic combined both fields.

While working for the Ph.D., he was Einstein's youngest assistant. He told Einstein he wanted to quit math and instead hand out leaflets for world peace, but Einstein said leafleting would waste his talents: the best way for him to help world peace would be to become a famous mathematician, so people would *listen* to him, as they had to Einstein. He took Einstein's advice and stayed with math.

After getting his Ph.D., he taught symbolic logic in Princeton's philosophy department. In 1953, most of Dartmouth College's math professors were retiring, so Dartmouth asked him to come to Dartmouth, chair the department, and bring his friends. He accepted the offer and brought his friends. That's how Dartmouth stole Princeton's math department.

At Dartmouth, Kemeny invented several new branches of math. Then Kemeny's department got General Electric to sell Dartmouth a computer at a 90% discount, in return for which his department had to invent programs for that computer and let General Electric use them. To write the programs, Kemeny invented his own little computer language in 1963 and showed it to his colleague Tom Kurtz, who knew less about philosophy but more about computers. Kurtz added features from Algol & Fortran and called the combination **Basic**.

After inventing Basic, Kemeny got bored and thought of quitting Dartmouth. Then Dartmouth asked him to become the college's president. He accepted.

Later, when the 3-Mile Island nuclear power plant almost exploded, President Jimmy Carter told Kemeny to head the investigation, because of Kemeny's reputation for philosophical & scientific impartiality. Kemeny's report was impartial — and sharply critical of the nuclear industry.

Basic versus Algol & Fortran Basic is simpler than both Algol and Fortran in two ways:

In Algol and Fortran, you must tell the computer which variables are integers and which are reals. In Algol, you do that by saying INTEGER or REAL. In Fortran, you do that by choosing an appropriate first letter for the variable's name. **In Basic, the computer assumes all variables are real**, unless you specifically say otherwise.

In Algol and Fortran, output is a hassle. In Fortran, you have to worry about FORMATs. In Algol, each computer handles output differently — and in most cases strangely. **Basic's PRINT statement automatically invents a good format.**

Is Basic closer to Algol than to Fortran?

On the one hand, Basic uses the Algol words FOR, STEP, and THEN and the Algol symbol ↑ (or ^).

On the other hand, Basic uses the Fortran words RETURN and DIMENSION (abbreviated DIM); and Basic's "FOR I = 1 TO 9 STEP 2" puts the step size at the *end* of the statement, like FORTRAN's "DO 30 I = 1,9,2" and unlike Algol's "FOR I:=1 STEP 2 UNTIL 9".

Basic versus Joss Basic is *not* the simplest computer language. **Joss**, which was developed a year earlier by the Rand Corporation, is simpler to learn. But Joss runs slower, requires more memory, lacks string variables, and doesn't let you name your programs (you must give each program a number instead, and remember what the number was).

A few programmers still use Joss and 3 of its variants, called **Aid**, **Focal**, and **Mumps**.

Aid appealed to high-school kids; Focal appealed to scientists; Mumps appealed to doctors designing databases of patient records. Mumps *does* have string variables and other modern features but is being replaced by newer database languages, such as dBase.

6 versions Kemeny & Kurtz finished the **original version** of Basic in May 1964. It included just these statements:

PRINT, GO TO, IF...THEN, FOR...NEXT, DATA...READ, GOSUB...RETURN, DIM, LET (for commands such as LET X=3), REM (for REMarks and comments), DEF (to DEFine your own functions), and END

In that version, the only punctuation allowed in the PRINT statement was the comma.

The **2nd version** of Basic (October 1964) added the semicolon.

The **3rd version** (1966) added the words INPUT, RESTORE, and MAT. (The word MAT helps you manipulate a "MATrix", which means an "array". Now most versions of Basic omit the word MAT because its definition consumes too much RAM.)

All those versions, let you use numeric variables. (A numeric variable is a letter that stands for a number For example, you could say LET X=3.) The **4th version** (1967) added a new concept: string variables (such as A$). That version also added TAB (to improve printing), RANDOMIZE (to improve RND), and "ON...GO TO".

The **5th version** (1970) added data files (sequential access and random access).

The **6th version** (1971) added PRINT USING (to format the printing) and a sophisticated way to handle subroutines.

How Basic became popular During the 1960's and 1970's, Kemeny & Kurtz worked on Basic with a fervor that was almost religious.

They believed *every* college graduate should know how to program a computer and become as literate in Basic as in English.

They convinced Dartmouth to spend as much on its computer as on the college library. They put computer terminals in most college buildings, even the dorms. Altogether, the campus had about 300 terminals. Over 90% of all Dartmouth students used Basic before they graduated.

Dartmouth let all the town's children come onto campus and use the terminals. Dartmouth trained high-school teachers to use Basic. Many New England colleges, high schools, and prep schools had terminals connected to Dartmouth's computer by phone.

Dartmouth's computer was built by General Electric, which eventually quit making computers and sold its computer factory to Honeywell. The National Science Foundation funded Dartmouth's research on Basic, so Basic was in the public domain and could be used by other computer makers without paying royalties.

DEC The first company to copy Dartmouth's ideas was **Digital Equipment Corporation** (**DEC**, pronounced "deck").

DEC put Basic on DEC's first popular minicomputer, the PDP-8.

DEC invented fancier minicomputers (the PDP-11 and Vax) and maxicomputers (the DECsystem-10 and DECsystem-20) and put Basic on all of them. Though the versions put on the PDP-8 were primitive (almost as bad as Dartmouth's first edition), the versions put on DEC's fancier computers were sophisticated. Eventually, DEC put decent versions of Basic even on the PDP-8.

DEC's best version of Basic was **Vax Basic**, which worked just on Vax computers. DEC's second-best version of Basic was **Basic-Plus-2**, which worked on the Vax, the PDP-11, and the DECsystem-20. DEC's third-best version of Basic was **Basic-Plus**, which works just on the PDP-11.

HP Soon after DEC started putting Basic on its computers, Hewlett-Packard (HP) did likewise.

HP put Basic on the HP-2000 computer then put a better version on the HP-300 computer.

Unfortunately, HP's Basic was more awkward than DEC's. On HP computers, each time you used a string you had to write a "DIM statement" that warned the computer how many characters the string would contain.

How Microsoft Basic arose The first popular *micro*computer was the Altair 8800, which used a version of Basic invented by a 20-year-old kid named **Bill Gates**. His version imitated DEC's.

The Altair computer was manufactured by a company called **Mits**, which didn't treat Bill Gates fairly, so he broke away from Mits and formed his own company, called **Microsoft**.

Bill Gates and his company, Microsoft, invented many versions of Basic.

The first was called **4K Basic** because it consumed just 4K of memory chips (RAM or ROM). Then came **8K Basic** (which included a bigger vocabulary) then came **Extended Basic** (which included an even bigger vocabulary and consumed 14K). All those versions were intended for primitive microcomputers that used tapes instead of disks. Finally came **Disk Basic**, which came on a disk and included all commands for handling disks.

All those versions of Basic were written for computers that contained an 8080 or Z-80 CPU. Simultaneously, he wrote **6502 Basic**, for computers containing a 6502 CPU.

The Apple 2 version of 6502 Basic was called **Applesoft BASIC**. Commodore's version of 6502 Basic was called **Commodore BASIC**.

Unfortunately, 6502 Basic was primitive, resembling his 8K Basic.

After writing 6502 Basic, Bill wrote a souped up version of it, called **6809 Basic**, just for Radio Shack's Color Computer. Radio Shack called it **Extended Color Basic**.

Texas Instruments (TI) asked Bill to write a version of Basic for TI computers. Bill said "yes"; but when TI told Bill what kind of Basic it wanted, Bill's company (Microsoft) found 90 ways that TI's desires would contradict Microsoft's traditions. Microsoft convinced TI to change its mind and remove 80 of those 90 contradictions, but TI stood firm on the other 10.

So TI Basic (which was on the TI-990 and TI-99/4A computers) contradicted all other versions of Microsoft Basic in 10 ways. For example, in TI Basic, the INPUT statement used a colon instead of a semicolon, and a multi-statement line uses a double colon (::) instead of a single colon.

Because of those differences, TI's computers became unpopular, and TI stopped making them. Moral: if you contradict Bill, you die!

Later, Bill invented an amazingly wonderful version of Basic, better than all earlier versions. He called it **Gee-Whiz Basic (GW Basic)**. It ran just on the IBM PC and clones.

When you bought PC-DOS from IBM, you typically got GW Basic at no extra charge. (IBM called it **BasicA**.) When you bought MS-DOS for an IBM clone, the typical dealer included GW Basic at no extra charge.

Beyond GW Basic GW Basic was the last version of Basic that Bill developed personally. All Microsoft's later improvements were done by his assistants.

They created **Microsoft Basic for the Mac**, **Amiga Microsoft Basic** (for the Commodore's Amiga computer), **Quick Basic** (for the IBM PC and clones), **QBasic** (which you got instead of GWBasic when you bought MS-DOS version 5 or 6), and **Visual Basic** (which lets you create Windows programs, so the human can use a mouse and pull-down menus).

Those Basics are harder to learn than GW Basic but run faster, have a better editor, include more words from Algol and Pascal, and produce fancier output.

While developing those versions of Basic, Microsoft added 3 new commands: SAY, END IF, and SUB.

The SAY command makes the computer talk by using a voice synthesizer. For example, to make the computer's voice say "I love you", type this command:

```
SAY TRANSLATE$("I LOVE YOU")
```

That makes the computer translate "I love you" into phonetics then say the phonetics. That command works just on Amiga computers.

The END IF command lets you make the IF statement include many lines, like this:

```
IF AGE<18 THEN
        PRINT "YOU ARE STILL A MINOR."
        PRINT "AH, THE JOYS OF YOUTH!"
        PRINT "I WISH I COULD BE AS YOUNG AS YOU!"
END IF
```

The SUB command lets you give a subroutine a name.

Divergences Microsoft's versions of Basic are wonderful.

Over the years, several microcomputer manufacturers tried to invent their own versions of Basic, to avoid paying royalties to Bill Gates. They were sorry!

Radio Shack hired somebody else to write Radio Shack's Basic. That person quit in the middle of the job, so Radio Shack's original Basic was never finished. Nicknamed "Level 1 Basic", it was a half-done mess. Radio Shack, like an obedient puppy dog, then went to Bill, who finally wrote a decent version of Basic for Radio Shack; Bill's version was called "Level 2".

Apple's original attempt at Basic was called "Apple Integer Basic". It was written by Steve Wozniak and terrible: it couldn't handle decimals and made the mistake of imitating HP instead of DEC (because he'd worked at HP). Eventually, he wised up and hired Bill, who wrote Apple's better Basic, called **Applesoft** (which means "Apple Basic by Microsoft"). Applesoft was intended for tapes, not disks. Later, when Steve Wozniak wanted to add disks to the Apple 2 computer, he made the mistake of not rehiring Bill — which is why the Apple 2's disk system was worse than Radio Shack's.

Atari made the mistake of hiring the inventor of Apple's disastrous DOS. That guy's Basic, called **Atari Basic**, resembles HP's Basic. Like Apple's DOS, it looks pleasant at first glance but turns into a nightmare when you try to do advanced programming. As a result, Atari's computers became less popular than Atari hoped, and the Atari executive who "didn't want to hire Bill" was fired. Atari finally hired Bill's company, Microsoft, which wrote **Atari Microsoft Basic version 2**.

Two other microcomputer manufacturers — **North Star Computers** and **APF** — developed their own versions of Basic to avoid paying royalties to Bill. Since their versions of Basic were lousy, they went out of business.

While DEC, HP, Microsoft, and idiots were developing their own versions of Basic, professors back at Dartmouth College were still tinkering with Dartmouth Basic version 6. In 1976, Professor Steve Garland added more commands from Algol, PL/I, and Pascal to Dartmouth Basic. He called his version **Structured Basic (SBasic)**.

One of Basic's inventors, Professor Tom Kurtz, became chairman of an Ansi committee to standardize Basic. His committee published two reports:

The 1977 report defined **Ansi Standard Minimal Basic**, a minimal standard that all advertised versions of "Basic" should live up to. That report was reasonable; everybody agreed to abide by it. (Microsoft's old Basic versions were written before that report came out. Microsoft Disk Basic version 5 was Microsoft's first version to obey that standard.)

In 1985, Ansi created a more ambitious report, to standardize Basic's most advanced features. The report said Basic's advanced features should closely imitate SBasic. But Bill Gates, who invented Microsoft Basic and was also on the committee, disliked SBasic and quit the committee. (He was particularly annoyed by the committee's desire to include Dartmouth's MAT commands, which consume lots of RAM.) He refused to follow the committee's recommendations.

That left two standards for advanced Basic: the "official" standard (defined by the Ansi committee) and the "de facto" standard (Bill Gates' Microsoft Basics, such as GW Basic).

For example, in GW Basic you say:

```
10 INPUT "WHAT IS YOUR NAME"; A$
```

But in Ansi Basic, you must say this instead:

```
10 INPUT PROMPT "WHAT IS YOUR NAME? ": A$
```

Notice Ansi Basic requires you to insert the word PROMPT and a question mark, put a blank space after the question mark, and type a colon instead of a semicolon.

Tom Kurtz (who chaired the Ansi committee) and John Kemeny (who invented Basic with Tom Kurtz) put Ansi Basic onto Dartmouth's computer. So Ansi Basic became Dartmouth's 7th official version of Basic. Then Kurtz & Kemeny left Dartmouth and formed their own company, which invented **True Basic** (an Ansi Basic version for the IBM PC & Mac).

Since Microsoft's Basic versions had become the de facto standard and since True Basic wasn't much better, hardly anybody bothered switching from Microsoft Basic to True Basic.

Comparison Here are 9 commands in advanced Basic:

USING, LINE, CIRCLE, SOUND, PLAY, SAY, ELSE, END IF, SUB

Here's what they accomplish:

"USING" lets you control how many digits print after the decimal point.
"LINE" makes the computer draw a diagonal line across the screen.
"CIRCLE" makes the computer draw a circle as big as you wish.
"SOUND" and "PLAY" make the computer create music.
"SAY" makes the computer talk.
"ELSE" and "END IF" let you create fancy IF statements.
"SUB" lets you name subroutines.

This list shows which Basics understood those 9 commands:

IBM PC with QBasic (and Visual Basic's version 2 and later)
understood **8** of the commands (all except SAY)

Commodore Amiga with Microsoft Basic
understood **8** of the commands (all except PLAY)

Apple Mac with Quick Basic
understood **7** of the commands (all except SAY and PLAY)

IBM PC (with GW Basic), Commodore 128, and Radio Shack TRS-80 Color
understood **6** of the commands (all except SAY, END IF, and SUB)

Atari ST
understood **5** of the commands (all except PLAY, SAY, END IF, and SUB)

Atari XE (or XL) with Microsoft Basic
understood just **4** commands (USING, LINE, SOUND, and ELSE)

Radio Shack TRS-80 Model 3, 4, 4P, and 4D
understood just **2** commands (USING and ELSE)

Apple 2, 2+, 2e, 2c, 2c+, and 2GS understood just **1** command (LINE)

Commodore 64 and Vic-20 understood **no** commands

Notice that the Commodore 128 and Radio Shack TRS-80 Color Computer understood 6 of the commands, while the more expensive Apple 2c understood just 1 command. If schools would have bought Commodore 128 and Radio Shack TRS-80 Color Computers instead of Apple 2c's, students would have become better programmers!

PL/I

During the early 1960's, IBM sold two kinds of computers: one kind for scientists, the other kind for business bookkeepers.

For the scientific kind of computer, the most popular language was Fortran.
For the business kind of computer, the most popular language was Cobol.

In 1962, IBM secretly began working on a project to create a single, big computer that could be used by everybody: scientists and businesses. IBM called it the **IBM 360**, because it could handle the full circle of applications.

What language should the IBM 360 be programmed in? IBM decided to invent a single language that could be used for both science and business.

IBM's first attempt at such a language was "Fortran V". It ran all Fortran IV programs but added commands for handling strings and fields in data files.

Instead of announcing Fortran V, IBM began working in 1963 on an even more powerful language, "Fortran VI", which would resemble Fortran but be much more powerful and modern (and hence incompatible). It would also include all important features of Cobol & Algol.

As work on Fortran VI progressed, IBM realized it differed so much from traditional Fortran that it should get a different name. In 1964, IBM changed the name to "NPL" (New Programming Language), since the language was intended for the IBM 360 and the rest of IBM's New Product Line. But IBM discovered the letters "NPL" already stood for the National Physics Laboratory in England, so IBM changed the language's name to **Programming Language One (PL/I)**, to brag it was the first good programming language and all predecessors were worth zero by comparison.

Troubles The committee that invented PL/I had a hard time.

The committee had to meet just on weekends and just in hotel rooms in New York State and California. The first meeting was in October 1963. IBM wanted the language design to be finished in 2 months (a rush job!), but the committee took 4 months, finishing in February 1964.

After the design was finished, the language still had to be put on the computer. Since that took 2½ more years of programming and polishing, the language wasn't available for sale to IBM's customers until August 1966.

That was too late.

It was *after* IBM began shipping the IBM 360. The 360's customers continued using Fortran and Cobol, since PL/I wasn't available yet. After those customers bought, installed, and learned how to use Fortran and Cobol on the 360, they refused to take the trouble to switch to PL/I, especially since PL/I was expensive (requiring twice as much RAM as Cobol, 4 times as much RAM as Fortran) and ran slowly (1½ times as long to compile as Cobol, twice as long as Fortran). Most programmers already knew Fortran or Cobol, were satisfied with those languages, and weren't willing to spend the time to learn something new.

Some programmers praised PL/I for being amazingly powerful, but others called it just a scheme to make people buy more RAM. Critics call it a disorganized mess, an "ugly kitchen sink of a language", thrown together by a committee that was too rushed.

Since PL/I is so big, hardly anybody understands it all.

As a PL/I programmer, you study just the part of the language you plan to use. But if you make a mistake, the computer might not gripe: instead, it might think you're trying to give a different PL/I command from a language part you never studied. Instead of griping, the computer will perform an instruction that wasn't what you meant.

Stripped versions In 1972, Cornell University developed a stripped-down version of PL/I for students. That version, called **PL/Cornell (PL/C)**, is a compromise between PL/I's power and Algol's pure simplicity.

In 1975, The University of Toronto developed an even *more* stripped-down PL/I version, called **SP/k**. It ran faster and printed messages that were more helpful. SP/k came in several sizes: the tiniest was SP/1; the largest was SP/8.

Stripped-down versions of PL/I stayed popular in universities until about 1980, when universities switched to Pascal.

Digital Research invented a tiny version of PL/I for microcomputers and called it **PL/M**. It couldn't handle decimals.

Full PL/I is still used on big IBM computers, because full PL/I is the only language including enough commands to let programmers unleash IBM's full power.

PL/I's statements are borrowed from Fortran, Algol, and Cobol.

from Fortran:	FORMAT, STOP, CALL, RETURN, DO
from Algol:	IF, GO, PROCEDURE, BEGIN, END
from Cobol:	OPEN, CLOSE, READ, WRITE, DISPLAY, EXIT

Like Algol, PL/I requires a semicolon at the end of each statement.

Pascal

In 1968, a European committee invented "Algol 68," which was strange: it even required you to spell some commands backwards. Some committee members disagreed with the majority and thought Algol 68 was nuts. One of those dissidents, Niklaus Wirth, quit the committee and created his own Algol version, which he called **Pascal**. Now most computerists feel he was right: Pascal is better than Algol 68.

He wrote Pascal in Switzerland on a CDC maxicomputer. His version of Pascal couldn't handle video screens, couldn't handle random-access data files, and couldn't handle strings well. Those 3 limitations were corrected in later Pascal versions, especially the one invented at the **University of California at San Diego (UCSD)**.

Apple's Pascal Apple Computer Company got permission to sell an Apple version of UCSD Pascal. Apple ran full-page ads bragging that the Apple 2 was the only popular microcomputer that could handle Pascal.

Apple Computer Company sold an Apple 2 add-on called the **Apple Language System**, whose $495 price included disks for Pascal & advanced Basic, plus 16K of extra RAM. Many people who bought that system were disappointed when they realized Pascal is *harder* to learn than Basic.

Pascal is helpful just if the program you're writing is long. Pascal helps you organize and dissect long programs more easily than Basic. But the average Apple 2 owner never wrote long programs and never needed Pascal. Many of Apple's customers felt "ripped off", since they spent $495 uselessly.

Pascal's rise Many programmers who wrote big Fortran programs for big computers switched to Pascal, because Fortran is archaic and Pascal helps organize long programs. Many programmers who used PL/I switched to Pascal, because Pascal consumes less RAM than PL/I and fits in smaller computers. Many colleges required freshman computer-science majors to learn Pascal, so the College Entrance Examination Board's **Advanced Placement Test in Computer Science** required knowing Pascal. High-school students studied Pascal to pass that test and prepare for college.

Pascal's fall Basic improved, by incorporating many features from Pascal, so Pascal stopped having much advantage over Basic. Now students skip Pascal: after learning Basic, they skip past Pascal to tougher languages: Java and C++. Now the Advanced Placement Test in Computer Science requires knowing Java instead of Pascal.

Pascal is ignored.

Modula

After Niklaus Wirth invented Pascal, he designed a more ambitious language, called **Modula**. He designed the Modula's first version in 1975, then **Modula-2** in 1979. When today's programmers discuss "Modula", they mean Modula-2.

Modula-2 resembles Pascal. Like Pascal, Modula-2 requires each program's main routine to begin with the word BEGIN; but Modula-2 does *not* require you to say BEGIN after DO WHILE or IF THEN:

Pascal

```
IF AGE<18 THEN
   BEGIN
   WRITELN('YOU ARE STILL A MINOR');
   WRITELN('AH, THE JOYS OF YOUTH');
   END
ELSE
   BEGIN
   WRITELN('GLAD YOU ARE AN ADULT');
   WRITELN('WE CAN HAVE ADULT FUN');
   END;
```

Modula-2

```
IF AGE<18 THEN
   WRITESTRING("YOU ARE STILL A MINOR");
   WRITESTRING("AH, THE JOYS OF YOUTH");
ELSE
   WRITESTRING("GLAD YOU ARE AN ADULT");
   WRITESTRING("WE CAN HAVE ADULT FUN")
END;
```

That example shows 4 ways that Modula-2 differs from Pascal: Modula-2 says **WRITESTRING** instead of WRITELN, uses **regular quotation marks (")** instead of apostrophes, lets you **omit the word BEGIN** after IF ELSE (and WHILE DO), and lets you **omit the word END** before ELSE.

Advanced programmers like Modula-2 more than Pascal because Modula-2 includes extra commands for handling subroutines.

C

Many programmers use **C**.

How C arose In 1963 at England's Cambridge University and the University of London, researchers developed a "practical" version of Algol and called it the **Combined Programming Language (CPL)**. In 1967 at Cambridge University, Martin Richards invented a simpler, stripped-down version of CPL and called it **Basic CPL (BCPL)**. In 1970 at Bell Labs, Ken Thompson developed a version that was even more stripped-down and simpler; since it included just the most critical part of BCPL, he called it **B**.

Ken had stripped down the language *too* much. It no longer contained enough commands to do practical programming. In 1971, his colleague Dennis Ritchie added a few commands to B, to form a more extensive language, which he called **New B**. Then he added even more commands and called the result **C**, because it came after B.

Most of C was invented in 1972. In 1973, it improved enough so it was used for something practical: developing a new version of the **Unix** operating system. (The original version of Unix had been created at Bell Labs by using B. Beginning in 1973, Unix versions were created using C.)

So C is a souped-up version of New B, which is a souped-up version of B, which is a stripped-down version of BCPL, which is a stripped-down version of CPL, which is a "practical" version of Algol.

C's peculiarities Like B, C is a tiny language.

C doesn't even include any words for input or output. When you buy C, you also get a **library** of routines that can be added to C. The library includes words for output (such as printf), input (such as scanf), math functions (such as sqrt), and other goodies.

When you write a program in C, you can choose whichever parts of the library you need: the other parts of the library don't bother to stay in RAM. So if your program uses just a *few* of the library's functions, running it will consume very little RAM. It will consume less RAM than if the program were written in Basic or Pascal.

In Basic, if you reserve 20 RAM locations for X (by saying DIM X(20)) and then say X(21)=3.7, the computer will gripe, because you haven't reserved a RAM location for X(21). If you use C instead, the computer will *not* gripe about that kind of error; instead, the computer will store the number 3.7 in the RAM location immediately after X(20), even if that location's already being used by another variable, such as Y. As a result, Y will get messed up. Moral: **C programs run quickly and dangerously, because in C the computer never bothers to check your program's reasonableness.**

In your program, which variables are integers? Which are real?

Basic assumes all variables are real.

Fortran & PL/I assume all variables beginning with I, J, K, L, M, and N are integers and the rest are real.

Algol & Pascal make no assumptions; they require you to declare "integer" or "real" for each variable.

C assumes all variables are integers, unless you specifically say otherwise.

Ada

In 1975, the U.S. Department of Defense decided it wanted a better kind of computer language and wrote a list of requirements the language would have to meet.

The original list of requirements was called the Strawman Requirements (1975). Then came improved versions, called Woodenman (1975), Tinman (1976), Ironman (1978), and finally Steelman (1979).

While the Department was moving from Strawman to Steelman, it checked whether any existing computer language could meet such requirements. The Department decided that no existing computer language came even close to meeting the requirements, so a new language would have to be invented. The Department required the new language to resemble Pascal, Algol 68, or PL/I but be better.

Contest In 1977, the Department held a contest, to see which software company could invent a language meeting such specifications (which were in the process of changing from Tinman to Ironman).

16 companies entered the contest.

The Department selected 4 semifinalists and paid them to continue their research for 6 more months. The semifinalists were CII-Honeywell-Bull (which is French and owned partly by Honeywell), Intermetrics (in Cambridge, Massachusetts), SRI International, and Softech.

In 1978, the semifinalists submitted improved designs, which were all souped-up versions of Pascal (instead of Algol 68 or PL/I). To make the contest fair and prevent bribery, the judges weren't told which design belonged to which company. The 4 designs were called "Green", "Red", "Yellow", and "Blue".

Yellow and Blue lost. The winning designs were Green (designed by CII-Honeywell-Bull) and Red (designed by Intermetrics).

The Department paid the two winning companies to continue their research for one more year. In 1979, those two companies submitted their improved versions. The winner was the Green language, designed by CII-Honeywell-Bull.

The Department decided the Green language would be called **Ada** to honor Ada Lovelace, the woman who was the world's first programmer. So Ada is a Pascal-like language developed by a French company (CII-Honeywell-Bull) under contract to the U.S. Department of Defense.

Ada's too big to be practical. Researchers have made computers understand just *part* of Ada.

dBase

dBase was invented by Wayne Ratliff because he wanted to bet on which football teams would win the 1978 season.

To bet wisely, he needed to know how each team scored in previous games, so every Monday he clipped pages of football scores from newspapers. Soon his room was covered with newspaper clippings. To reduce the clutter, he decided to write a data-management program to handle all the statistics.

He worked at the **Jet Propulsion Laboratory (JPL)**. His coworkers had invented a data-management system called the **JPL Display and Information System (JPLDIS)**, which imitated IBM's **Retrieve**. Unfortunately, Retrieve and JPLDIS required maxicomputers. Working at home, he invented **Vulcan**, a stripped-down version of JPLDIS small enough to run on the CP/M microcomputer in his house and good enough to compile football statistics — though by then he'd lost interest in football and was more interested in the theory of data management and business applications.

In 1979, he advertised his Vulcan data-management system in Byte Magazine. The mailman delivered so many orders to his house that he didn't have time to fill them all — especially since he still had a full-time job at JPL. He stopped advertising, to give himself a chance to catch up filling the orders.

In 1980, the owners of Discount Software phoned him, visited his home, examined Vulcan, and offered to market it for him. He agreed.

Since "Discount Software" was the wrong name to market Vulcan under, Discount Software's owners — Hal Lashlee and George Tate — thought of marketing Vulcan under the name "Lashlee-Tate Software". But since "Lashlee" sounded wimpy, they changed the name to *Ashton*-Tate Software.

Instead of selling Vulcan's original version, Ashton-Tate Software decided to sell Wayne's further improvement, called **dBase 2**.

At Ashton-Tate, George Tate did the managing. Hal Lashlee was a silent partner who just contributed capital.

Ad George Tate hired Hal Pawluck to write an ad for dBase 2. Hal's clever ad showed a photo of a bilge pump (which removes water from a ship's bilge). The ad's headline was: "dBase versus the Bilge Pump". The ad went on to say that most database systems are like bilge pumps: they suck! That explicit ad appeared in *Infoworld*, a weekly newspaper read by all computer experts. Suddenly, all experts knew that dBase was the database-management system that claimed not to suck.

The ad generated just one big complaint — from the company that manufactured the bilge pump!

George Tate offered to add a footnote saying "*This* bilge pump does *not* suck". The pump manufacturer didn't like that either but stopped complaining.

Beyond dBase 2 The original dBase 2 ran on computers using the CP/M operating system. It worked well. When IBM began selling the IBM PC, Wayne invented an IBM PC version of dBase 2, but it was buggy.

He created those early versions of dBase by using assembly language. By using C instead, he finally created an IBM PC version that worked reliably and included extra commands. He called it **dBase 3**.

dBase 2 and dBase 3 were sold as programming languages, but many people wanting databases didn't want to learn programming, so Ashton-Tate created a new version, called **dBase 3 Plus**, which you can control by using menus instead of typing programming commands; but those menus are hard to learn how to use and incomplete: they don't let you tap dBase 3 Plus's full power, which requires you to learn programming.

In 1988, Ashton-Tate shipped **dBase 4**, which includes extra programming commands.

Some dBase 4 commands were copied from a database language called **Structured Query Language (SQL)**, which IBM invented for mainframes. dBase 4 also boasted better menus than dBase 3 Plus. Unfortunately, Ashton-Tate priced dBase 4 high: $795 for the plain version, $1295 for the "developer's" version.

Over the years, Ashton-Tate became a stodgy bureaucracy. George Tate died, Wayne Ratliff quit, the company's list price for dBase grew ridiculously high, and the company was callous to dBase users.

In 1991, Borland bought Ashton-Tate. In 1994, Borland began selling **dBase 5**, then further improvements.

In 1999, Borland gave up trying to sell dBase; Borland transferred all dBase rights to **KSoft**, which sold **Visual dBase 7.5** and tried to develop **dBase 2000 (DB2K)**. The newest version of dBase is **dBase Plus 11** (for Windows), published by dBase LLC (31 Front St., Binghamton NY 13905, phone 607-729-0960, dBase.com).

Other companies make dBase clones that work better than dBase itself! The most popular clone is **Visual FoxPro 9**: it runs faster than dBase, includes extra commands, and is marketed by Microsoft.

Easy

Easy is a language I developed several years ago. It combines the best features of all other languages. It's easy to learn, because it uses just these 12 keywords:

```
SAY & GET         LET
REPEAT & SKIP     HERE
IF & PICK         LOOP
PREPARE & DATA    HOW
```

Here's how to use them.…

The computer will say the answer:

```
4
```

SAY Easy uses the word SAY instead of Basic's word PRINT, because SAY is briefer. If you want the computer to say the answer to 2+2, give this command:

```
SAY 2+2
```

Whenever the computer prints, it automatically prints a blank space afterwards but does *not* press the Enter key. So if you run this program —

```
SAY "LOVE"
SAY "HATE"
```

the computer will say:

```
LOVE HATE
```

Here's a fancier example:

```
SAY "LOVE" AS 3 AT 20 15 TRIM !
```

The "AS 3" is a format: it makes the computer print just the first 3 letters of LOVE. The "AT 20 15" makes the computer begin printing LOVE at the screen's pixel whose X coordinate is 20 and whose Y coordinate is 15. The computer usually prints a blank space after everything, but the word TRIM suppresses that blank space. The exclamation point makes the computer press the Enter key afterwards.

Here's another example:

```
SAY TO SCREEN PRINTER HARRY
```

It means that henceforth, whenever you give a SAY command, the computer will print the answer simultaneously onto your screen, onto your printer, and onto a disk file named HARRY. If you ever want to cancel that "SAY TO" command, give a "SAY TO" command that contradicts it.

GET Easy uses the word GET instead of Basic's word INPUT, because GET is briefer. The command GET X makes the computer wait for you to input the value of X. Above the GET command, you typically put a SAY command that makes the computer ask a question.

You can make the GET command fancy, like this:

```
GET X AS 3 AT 20 15 WAIT 5
```

The "AS 3" tells the computer that X will be just 3 characters; the computer waits for you to type just 3 characters and doesn't require you to press the Enter key afterwards. The "AT 20 15" makes the computer move to pixel 20 15 before your typing begins, so your input appears at that part of the screen. The "WAIT 5" makes the computer wait just 5 seconds for your response. If you reply within 5 seconds, the computer sets TIME equal to how many seconds you took. If you do *not* reply within the 5 seconds, the computer sets TIME equal to -1.

LET The LET statement resembles Basic's. For example, you can say:

```
LET R=4
```

To let R be a random decimal, type:

```
LET R=RANDOM
```

To let R be a random integer from 1 to 6, type:

```
LET R=RANDOM TO 6
```

To let R be a random integer from -3 to 5, type:

```
LET R=RANDOM FROM -3 TO 5
```

REPEAT If you put the word REPEAT at the bottom of your program, the computer will repeat the entire program again and again, forming an infinite loop.

SKIP If you put the word SKIP in the middle of your program, the computer will skip the bottom part of the program. SKIP is like BASIC's END or STOP.

HERE In your program's middle, you can say:

```
HERE IS FRED
```

An earlier line can say SKIP TO FRED. A later line can say REPEAT FROM FRED. The SKIP TO and REPEAT FROM are like Basic's GO TO.

IF In your program, a line can say:

```
IF X<3
```

Underneath that line, you must put some indented lines, which the computer will do if X<3.

Suppose you give a student a test on which the score can be between 0 and 100. If the student's score is 100, let's make the computer say "PERFECT"; if the score is below 100 but at least 70, let's make the computer say the score and also say "OKAY THOUGH NOT PERFECT"; if the score is below 70, let's make the computer say "YOU FAILED". Here's how:

```
IF SCORE=100
  SAY "PERFECT"
IF SCORE<100 AND SCORE>=70
  SAY SCORE
  SAY "OKAY THOUGH NOT PERFECT"
IF SCORE<70
  SAY "YOU FAILED"
```

To shorten the program, use the words NOT and BUT:

```
IF SCORE=100
  SAY "PERFECT"
IF NOT BUT SCORE>=70
  SAY SCORE
  SAY "OKAY THOUGH NOT PERFECT"
IF NOT
  SAY "YOU FAILED"
```

The phrase "IF NOT" is like Basic's ELSE. The phrase "IF NOT BUT" is like Basic's ELSE IF.

PICK You can shorten that example even further, by telling the computer to pick just the first IF that's true:

```
PICK SCORE
  IF 100
    SAY "PERFECT"
  IF >=70
    SAY SCORE
    SAY "OKAY THOUGH NOT PERFECT"
  IF NOT
    SAY "YOU FAILED"
```

LOOP If you put the word LOOP above indented lines, the computer will do those lines repeatedly. For example, this program makes the computer say the words CAT and DOG repeatedly:

```
LOOP
  SAY "CAT"
  SAY "DOG"
```

This program makes the computer say 5, 8, 11, 14, and 17:

```
LOOP I FROM 5 BY 3 TO 17
  SAY I
```

That LOOP statement is like Basic's "FOR I = 5 TO 17 STEP 3". If you omit the "BY 3", the computer will assume "BY 1". If you omit the "FROM 5", the computer will assume "FROM 1". If you omit the "TO 17", the computer will assume "to infinity".

To make the computer count down instead of up, insert the word DOWN, like this:

```
LOOP I FROM 17 DOWN BY 3 TO 5
```

PREPARE To do an unusual activity, you should PREPARE the computer for it. For example, if you want to use subscripted variables such as X(100), you should tell the computer:

```
PREPARE X(100)
```

In that example, PREPARE is like Basic's DIM.

DATA Easy's DATA statement resembles Basic's. But instead of saying READ X, say:

```
LET X=NEXT
```

HOW In Easy, you can give any command you wish, such as:

```
PRETEND YOU ARE HUMAN
```

If you give that command, you must also give an explanation that begins with the words:

```
HOW TO PRETEND YOU ARE HUMAN
```

Interrelated features In the middle of a loop, you can abort the loop. To skip out of the loop (and progress to the rest of the program), say SKIP LOOP. To hop back to the beginning of the loop (to do the next iteration of loop), say REPEAT LOOP.

Similarly, you can say SKIP IF (which makes the computer skip out of an IF) and REPEAT IF (which makes the computer repeat the IF statement, and thereby imitate Pascal's WHILE).

Apostrophe Like Basic, Easy uses an apostrophe to begin a comment. The computer ignores everything to the right of an apostrophe, unless the apostrophe is between quotation marks or in a DATA statement.

Comma If two statements begin with the same word, you can combine them into a single statement, by using a comma.

For example, instead of saying —

```
LET X=4
LET Y=7
```

you can say:

```
LET X=4, Y=7
```

Instead of saying —

```
PRETEND YOU ARE HUMAN
PRETEND GOD IS DEAD
```

you can say:

```
PRETEND YOU ARE HUMAN, GOD IS DEAD
```

More info I stopped working on Easy in 1982 but hope to continue development again. To get on my mailing list of people who want details and updated info about Easy, phone me at 603-666-6644.

C++

An improved C, called **C++**, was invented in 1985 at Bell Labs by **Bjarne Stroustrup**.

He was born in Denmark (where he studied at Aarhus University). Then he moved to England (where he got a Ph.D. from Cambridge University). Then he moved to New Jersey (to work at Bell Labs, where he invented C++).

To pronounce his name, say "Bee-ARE-nuh STRAH-stroop", but say the "Bee" and "STRAH-stroop" fast, so it sounds closer to "BYAR-nuh STROV-strup".

C++ uses the same fundamental commands as C but adds extra commands. Some of those extra commands are for advanced programming; others make regular programming more pleasant. Unlike C, C++ lets you use **object-oriented programming (OOP)**, in which you define "objects" and give those objects "properties".

For input and output, C++ offers different commands than C. C++'s input/output commands are more pleasant. Most C programmers have switched to C++ or a further improvement, called **C#**.

C++ became the most popular language for creating advanced programs. The world's biggest software companies switched to C++ from assembly language, though many are starting to go a step further and switch to C#.

If you become an expert C++ or C# programmer, you can help run those rich software companies and get rich yourself!

Radicals

Let's examine the radical languages, beginning with the oldest radical — the oldest hippie — Lisp.

Lisp

Lisp is the only language made specially to handle lists of concepts. It's the most popular language for research into artificial intelligence.

It's the father of Logo, which is "oversimplified Lisp" and the most popular language for young children. It inspired Prolog, which is a Lisp-like language that lets you make the computer imitate a wise expert and become an **expert system**.

Beginners love to play with Logo and Prolog, which are easier and more fun than Lisp. But professionals continue to use Lisp because it's more powerful than its children.

Lisp's original version was called **Lisp 1**. Then came **Lisp 1.5** (which wasn't different enough from LISP 1 to rate the title "LISP 2"). Then came **Lisp 1.6**. Lisp's newest version, called **Common Lisp**, runs on maxicomputers, minicomputers, and microcomputers.

I'll explain "typical" Lisp, which is halfway between Lisp 1.6 and Common Lisp.

Typical Lisp uses these symbols:

Basic	Lisp
5+2	(PLUS 5 2)
5-2	(DIFFERENCE 5 2)
5*2	(TIMES 5 2)
5/2	(QUOTIENT 5 2)
5^2	(EXPT 5 2)
"LOVE"	'LOVE old versions say (QUOTE LOVE)

If you want the computer to add 5 and 2, just type:

```
(PLUS 5 2)
```

When you press the Enter key at the end of that line, the computer will print the answer. (You do *not* have to say PRINT or any other special word.) The computer will print:

```
7
```

If you type —

```
(PLUS 1 3 1 1)
```

the computer will add 1, 3, 1, and 1 and print:

```
6
```

If you type —

```
(DIFFERENCE 7 (TIMES 2 3))
```

the computer will find the difference between 7 and 2*3 and print:

```
1
```

If you type —

```
'LOVE
```

the computer will print:

```
LOVE
```

Note you must type an apostrophe before LOVE but must *not* type an apostrophe afterwards. The apostrophe is called a **single quotation mark** (or a **quote**).

You can put a quote in front of a word (such as 'LOVE) or in front of a parenthesized list of words, such as:

```
'(LAUGH LOUDLY)
```

That makes the computer print:

```
(LAUGH LOUDLY)
```

Lisp 1, Lisp 1.5, and Lisp 1.6 don't understand the apostrophe. On those old versions of Lisp, say (QUOTE LOVE) instead of 'LOVE, and say (QUOTE (LAUGH LOUDLY)) instead of '(LAUGH LOUDLY).

The theory of lists Lisp can handle lists. Each list must begin and end with a parenthesis.

Here's a list of numbers: (5 7 4 2).
Here's a list of words:
(LOVE HATE WAR PEACE DEATH).

Here's a list of numbers and words:
(2 WOMEN KISS 7 MEN).
That list has five items:
2, WOMEN, KISS, 7, and MEN.
Here's a list of four items:
(HARRY LEMON (TICKLE MY TUBA TOMORROW AT TEN) RUSSIA).
The first item is HARRY; the second is LEMON; the third is a list; the fourth is RUSSIA.

In a list, **the first item is called the CAR, and the rest of the list is called the CDR** (pronounced "could er" or "cudder" or "coo der"). For example, the CAR of (SAILORS DRINK WHISKEY) is SAILORS, and the CDR is (DRINK WHISKEY).

To make the computer find the CAR of (SAILORS DRINK WHISKEY), type this:

```
(CAR '(SAILORS DRINK WHISKEY))
```

The computer will print:

```
SAILORS
```

If you type —

```
(CDR '(SAILORS DRINK WHISKEY))
```

the computer will print:

```
(DRINK WHISKEY)
```

If you type —

```
(CAR (CDR '(SAILORS DRINK WHISKEY)))
```

the computer will find the CAR of the CDR of (SAILORS DRINK WHISKEY). Since the CDR of (SAILORS DRINK WHISKEY) is (DRINK WHISKEY), whose CAR is DRINK, the computer will print:

```
DRINK
```

You can insert an extra item at the beginning of a list, to form a longer list. For example, you can insert MANY at the beginning of (SAILORS DRINK WHISKEY), to form (MANY SAILORS DRINK WHISKEY). To do that, tell the computer to CONStruct the longer list, by typing:

```
(CONS 'MANY '(SAILORS DRINK WHISKEY))
```

The computer will print:

```
(MANY SAILORS DRINK WHISKEY)
```

Notice that CONS is the opposite of CAR and CDR. The CONS combines MANY with (SAILORS DRINK WHISKEY) to form (MANY SAILORS DRINK WHISKEY). The CAR and CDR break down (MANY SAILORS DRINK WHISKEY), to form MANY and (SAILORS DRINK WHISKEY).

Variables To make X stand for the number 7, say:

```
(SETQ X 7)
```

Then if you say —

```
(PLUS X 2)
```

the computer will print 9.

To make Y stand for the word LOVE, say:

```
(SETQ Y 'LOVE)
```

Then if you say —

```
Y
```

the computer will say:

```
LOVE
```

To make STOOGES stand for the list (MOE LARRY CURLEY), say:

```
(SETQ STOOGES '(MOE LARRY CURLEY))
```

Then if you say —

```
STOOGES
```

the computer will say:

```
(MOE LARRY CURLEY)
```

To find the first of the STOOGES, say:

```
(CAR STOOGES)
```

The computer will say:

```
MOE
```

Your own functions You can define your own functions. For example, you can define (DOUBLE X) to be 2*X, by typing this:

```
(DEFUN DOUBLE (X)
       (TIMES 2 X)
)
```

Then if you say —

```
(DOUBLE 3)
```

the computer will print:

```
6
```

REPEAT Let's define REPEAT to be a function, so that (REPEAT 'LOVE 5) is (LOVE LOVE LOVE LOVE LOVE), and (REPEAT 'KISS 3) is (KISS KISS KISS), and (REPEAT 'KISS 0) is ().

If N is 0, we want (REPEAT X N) to be ().

If N is larger than 0, we want (REPEAT X N) to be a list of N X's.

That's X followed by N-1 more X's.
That's the CONS of X with a list of N-1 more X's.
That's the CONS of X with (REPEAT X (DIFFERENCE N 1)).
That's (CONS X (REPEAT X (DIFFERENCE N 1))).
That's (CONS X (REPEAT X (SUB1 N))), since (SUB1 N) means N-1 in LISP.

You can define the answer to (REPEAT X N) as follows: if N is 0, the answer is (); if N is *not* 0, the answer is (CONS X (REPEAT X (SUB 1 N))). Here's how to type that definition:

```
(DEFUN REPEAT (X N)
       (COND
              ((ZEROP N) ())
              (T (CONS X (REPEAT X (SUB1 N))))
       )
)
```

The top line says you're going to DEfine a FUNction called REPEAT (X N). The next line says the answer depends on CONDitions. The next line gives one of those conditions: *if N is ZERO*, the answer is (). The next line says: *otherwise*, the value is (CONS X (REPEAT X (SUB1 N))). The next line closes the parentheses opened in the second line. The bottom line closes the parentheses opened in the top line.

Then if you type —

```
(REPEAT 'LOVE 5)
```

the computer will print:

```
(LOVE LOVE LOVE LOVE LOVE)
```

The definition is almost circular: the definition of REPEAT assumes you already know what REPEAT is. For example:

(REPEAT 'KISS 3) is defined as the CONS of KISS with the following:
(REPEAT 'KISS 2), which is defined as the CONS of KISS with the following:
(REPEAT 'KISS 1), which is defined as the CONS of KISS with the following:
(REPEAT 'KISS 1), which is defined as the CONS of KISS with the following:
(REPEAT 'KISS 0), which is defined as ().

That kind of definition, which is almost circular, is called **recursive**.

You can say "The definition of REPEAT is **recursive**", or "REPEAT is **defined recursively**", or "REPEAT is **defined by recursion**", or "REPEAT is **defined by induction**", or "REPEAT is a **recursive function**".

Lisp was the first popular language that allowed recursive definitions.

When the computer uses a recursive definition, the computer refers to the definition *repeatedly* before getting out of the circle. Since the computer repeats, it's performing a loop. In traditional Basic and Fortran, the only way to make the computer perform a loop is to say GO TO or FOR or DO. Although Lisp contains a go-to command, Lisp programmers avoid it and write recursive definitions instead.

ITEM As another example of recursion, let's define the function ITEM so (ITEM N X) is the N^{th} item in list X, and so (ITEM 3 '(MANY SAILORS DRINK WHISKEY)) is the 3^{rd} item of (MANY SAILORS DRINK WHISKEY), which is DRINK.

If N is 1, (ITEM N X) is the first item in X, which is the CAR of X, which is (CAR X).

If N is larger than 1, (ITEM N X) is the N^{th} item in X. That's the $(N-1)^{th}$ item in the CDR of X. That's (ITEM (SUB1 N) (CDR X)).

So define (ITEM N X) as follows:

If N is 1, the answer is (CAR X).
If N is not 1, the answer is (ITEM (SUB 1 N) (CDR X)).

Here's what to type:

```
(DEFUN ITEM (N X)
       (COND
              ((ONEP N) (CAR X))
              (T (ITEM (SUB1 N) (CDR X)))
       )
)
```

If your computer doesn't understand (ONEP N), say (EQUAL 1 N) instead.

Snobol

Snobol lets you analyze strings more easily than any other language. It can handle numbers also.

Simple example Here's a simple Snobol program:

```
        A = -2
        B = A + 10.6
        C = "BODY TEMPERATURE IS 9" B
        OUTPUT = "MY " C
END
```

When you type the program, indent each line except END. Indent *at least* one space; you can indent more spaces if you wish. Put spaces around the symbols = and + and other operations.

The first line says A is the integer -2. The next line says B is the real number 8.6. The next line says C is the string "BODY TEMPERATURE IS 98.6". The next line makes the computer print:

```
BODY TEMPERATURE IS 98.6
```

In Snobol, a variable's name can be short (like A or B or C) or as long as you wish. The variable's name can even contain periods, like this:

```
NUMBER.OF.BULLIES.I.SQUIRTED
```

Loop This program's a loop:

```
FRED    OUTPUT = "CAT"
        OUTPUT = "DOG" :(FRED)
END
```

The first line (whose name is FRED) makes the computer print:

```
CAT
```

The next line makes the computer print —

```
DOG
```

and then go to FRED. Altogether the computer will print:

```
CAT
DOG
CAT
DOG
CAT
DOG
etc.
```

Replace Snobol lets you replace a phrase easily.

```
        X = "SIN ON A PIN WITH A DIN"
        X "IN" = "UCK"
        OUTPUT = X
END
```

The first line says X is the string "SIN ON A PIN WITH A DIN". The next line says: in X, replace the first "IN" by "UCK". So X becomes "SUCK ON A PIN WITH A DIN". The next line says the output is X, so the computer will print:

```
SUCK ON A PIN WITH A DIN
```

That program changed the *first* "IN" to "UCK". Here's how to change *every* "IN" to "UCK":

```
        X = "SIN ON A PIN WITH A DIN"
        X "IN" = "UCK"
        X "IN" = "UCK"
        X "IN" = "UCK"
        OUTPUT = X
END
```

The first line says X is "SIN ON A PIN WITH A DIN". The second line replaces an "IN" by "UCK", so X becomes "SUCK ON A PIN WITH A DIN". The next line replaces another "IN" by "UCK", so X becomes "SUCK ON A PUCK WITH A DIN". The next line replaces another "IN", so X becomes "SUCK ON A PUCK WITH A DUCK", which the next line prints.

This program does the same thing:

```
        X = "SIN ON A PIN WITH A DIN"
LOOP    X "IN" = "UCK" :S(LOOP)
        OUTPUT = X
END
```

Here's how it works:

The first line says X is "SIN ON A PIN WITH A DIN". The next line replaces "IN" successfully, so X becomes "SUCK ON A PIN WITH A DIN". At the end of the line, the :S(LOOP) means: if Successful, go to LOOP. So the computer goes back to LOOP. The computer replaces "IN" successfully again, so X becomes "SUCK ON A PUCK WITH A DIN", and the computer goes back to LOOP. The computer replaces "IN" successfully again, so X becomes "SUCK ON A PUCK WITH A DUCK", and the computer goes back to LOOP. The computer does not succeed. So the computer ignores the :S(LOOP) and proceeds instead to the next line, which prints:

```
SUCK ON A PUCK WITH A DUCK
```

Delete This program deletes the first "IN":

```
        X = "SIN ON A PIN WITH A DIN"
        X "IN" =
        OUTPUT = X
END
```

The second line says to replace an "IN" by nothing, so the "IN" gets deleted. X becomes "S ON A PIN WITH A DIN", which the computer will print.

This program deletes *every* "IN":

```
        X = "SIN ON A PIN WITH A DIN"
LOOP    X "IN" = :S(LOOP)
        OUTPUT = X
END
```

The computer will print:

```
S ON A P WITH A D
```

Count Let's count how often "IN" appears in "SIN ON A PIN WITH A DIN". To do that, delete each "IN"; but each time you delete one, increase the COUNT by 1:

```
        X = "SIN ON A PIN WITH A DIN"
        COUNT = 0
LOOP    X "IN" = :F(ENDING)
        COUNT = COUNT + 1 :(LOOP)
ENDING  OUTPUT = COUNT
END
```

The third line tries to delete an "IN": *if successful*, the computer proceeds to the next line, which increases the COUNT and goes back to LOOP; *if failing* (because no "IN" remains), the computer goes to ENDING, which prints the COUNT. The computer will print:

```
3
```

How Snobol developed At MIT during the 1950's, Noam Chomsky invented a notation called **transformational-generative grammar**, which helps linguists analyze English and translate between English and other languages. His notation was nicknamed "linguist's algebra", because it helped linguists just as algebra helped scientists. (A decade later, he became famous for also starting the rebellion against the Vietnam War.)

Chomsky's notation was for pencil and paper. In 1957 and 1958, his colleague Victor Yngve developed a computerized version of Chomsky's notation: the computerized version was a language called **Comit**. It was nicknamed "linguist's Fortran", because it helped linguists just as Fortran helped engineers.

Comit manipulated strings of *words*. In 1962 at Bell Telephone Laboratories (Bell Labs), Chester Lee invented a variant called **Symbolic Communication Language (SCL)**, which manipulated strings of *math symbols* instead of words and helped mathematicians do abstract math.

A team at Bell Labs decided to invent a simplified SCL that would also include features from Comit. The team started to call their new language "SCL7" then renamed it "Sexi" (which stands for **S**tring **Ex**pression **I**nterpreter); but Bell Labs' management didn't like sex. Then, as a joke, the team named it **Snobol**, using the flimsy excuse that Snobol stands for **S**tri**n**g-**O**riented sym**bo**lic **L**anguage; but here's the real reason it got named "Snobol": the team feared it didn't have "a snowball's chance in hell" of success.

Snobol was used mainly to write programs that translate between computer languages. (For example, you could write a Snobol program that translates Fortran to Basic.)

Which is better: Comit or Snobol?

People who like Chomsky's notation (such as linguists) prefer Comit. People who like algebra (such as scientists) prefer Snobol.

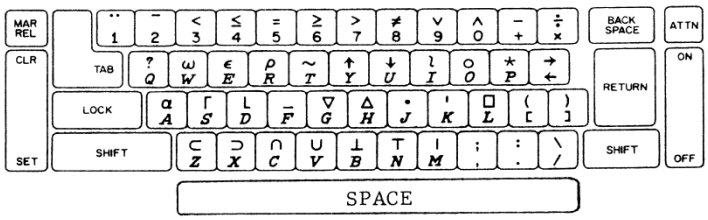
Snobol's supporters were more active than Comit's: they produced Snobol 2, Snobol 3, Snobol 4, and Snobol 4B, put Snobol on newer computers, wrote books about Snobol, and emphasized that Snobol can solve *any* problem about strings, even if the problem has nothing to do with linguistics. They won: more people use Snobol than Comit.

Most new versions of Snobol are named after baseball pitching methods — such as Fasbol, Slobol, and Spitbol. (Spitbol stands for **Sp**eedy **I**mplemen**t**ation of Sno**bol**.)

APL

APL lets you manipulate lists of numbers more easily than any other language.

APL uses special characters that aren't on a normal keyboard.



To compute 8+9, type this:

```
      8+9
```

Notice the line is indented. Whenever it's your turn to type, the computer automatically indents the line for you.

When you press the Return key at the end of that line, the computer will print the answer. (You don't have to say PRINT or any other special word.) The computer will print:

```
17
```

Scalar operators APL uses these **scalar operators**:

APL name	Symbol	Meaning
PLUS	A+B	add
identity	+B	same as just B
MINUS	A-B	subtract
negative	-B	negative
TIMES	A×B	multiply
signum	×B	1 if B>0; ¯1 if B<0; 0 if B=0
DIVIDE	A÷B	divide
reciprocal	÷B	1 divided by B
POWER	A*B	A raised to the Bth power; A^B
exponential	*B	e raised to the Bth power, where e is 2.718281828459045
LOG	A⍟B	logarithm, base A, of B
natural log	⍟B	logarithm, base e, of B
CEILING	⌈B	B rounded up to an integer
maximum	A⌈B	A or B, whichever is larger
FLOOR	⌊B	B rounded down to an integer
minimum	A⌊B	A or B, whichever is smaller
MAGNITUDE	|B	the absolute value of B
residue	A|B	the remainder when you divide A into B; so 4|19 is 3
FACTORIAL	!B	1 times 2 times 3 times 4 times… times B
combinations	A!B	how many A-element subsets you can form from a set of B
ROLL	?B	a random integer from 1 to B
deal	A?B	list of A random integers, each from 1 to B, no duplicates
PI TIMES	○B	π times B
circular	A○B	sin B if A=1; arcsin B if A=¯1 cos B if A=2; arccos B if A=¯2 tan B if A=3; arctan B if A=¯3 sinh B if A=5; arcsinh B if A=¯5 cosh B if A=6; arccosh B if A=¯6 tanh B if A=7; arctanh B if A=¯7 square root of $1+B^2$ if A= 4 square root of $1-B^2$ if A= 0 square root of B^2-1 if A=¯4
EQUAL	A=B	1 if A equals B; otherwise 0
not equal	A≠B	1 if A is not equal to B; otherwise 0
LESS	A<B	1 if A is less than B; otherwise 0
less or equal	A≤B	1 if A is less than or equal to B; otherwise 0
GREATER	A>B	1 if A is greater than B; otherwise 0
greater or equal	A≥B	1 if A is greater than or equal to B; otherwise 0
AND	A∧B	1 if A and B are both 1; otherwise 0
nand	A⍲B	1 if A and B are not both 1; otherwise 0
OR	A∨B	1 if A or B is 1; otherwise 0
nor	A⍱B	1 if neither A nor B is 1; otherwise 0
NOT	~B	1 if B is 0; otherwise 0

To make the symbol ⍟, type the symbol *, then press the BACKSPACE key, then type the symbol o.

Order of operations Unlike all other popular languages, APL makes the computer do all calculations *from right to left*. For example, if you type —

```
      2×3+5
```

the computer will start with 5, add 3 (to get 8), and then multiply by 2 (to get 16). The computer will print:

```
16
```

In Basic and most other languages, the answer would be 11 instead.

If you type —

```
      9-4-3
```

the computer will start with 3, subtract it from 4 (to get 1), and then subtract from 9 (to get 8). The computer will print:

```
8
```

In most other languages, the answer would be 2 instead.

You can use parentheses. Although 9-4-3 is 8, (9-4)-3 is 2.

Compare these examples:

```
-4+6  is ¯10
¯4+6  is 2
```

In both examples, the 4 is preceded by a negative sign; but in the second example, the negative sign is raised, to be as high as the 4. (To make the raised negative, tap the 2 key while holding down the Shift key. To make a regular negative, tap the + key while holding down the Shift key.) The first example makes the computer start with 6, add 4 (to get 10), and then negate it (to get ¯10). The second example makes the computer start with 6 and add ¯4, to get 2.

Double precision APL is super-accurate. It does all calculations by using double precision.

Variables You can use variables:

```
      X←3
      X+2
```

The first line says X is 3. The second line makes the computer print X+2. The computer will print:

```
5
```

A variable's name can be long: up to 77 letters and digits. The name must begin with a letter.

Vectors A variable can stand for a list of numbers:

```
      Y←5 2 8
      Y+1
```

The first line says Y is the **vector** 5 2 8. The next line makes the computer add 1 to each item and print:

```
6  3  9
```

This program prints the same answer:

```
      5 2 8+1
```

The computer will print:

```
6  3  9
```

This program prints the same answer:

```
      1+5 2 8
```

You can add a vector to another vector:

```
      A←5 2.1 6
      B←3 2.8 ¯7
      A+B
```

The computer will add 5 to 3, and 2.1 to 2.8, and 6 to ¯7, and print:

```
8  4.9  ¯1
```

This program prints the same answer:

```
      5 2.1 6+3 2.8 ¯7
```

This program prints the same answer:

```
A←5 2.1 6
B←3 2.8 ¯7
C←A+B
C
```

Here's something different:

```
X←4 2 3
+/X
```

The first line says X is the vector 4 2 3. The next line makes the computer print the sum, 9.

This program prints the same answer:

```
Y←+/4 2 3
Y
```

You can combine many ideas on the same line, but remember that the computer goes from right to left:

```
219-1 4 3+6×+/5 1 3×2 4 7
```

The computer will start with 2 4 7, multiply it by 5 1 3 (to get 10 4 21), find the sum (which is 35), multiply by 6 (to get 210), add 1 4 3 (to get 211 214 213), and then subtract from 219 (to get 8 5 6). The computer will print:

```
8  5  6
```

Each of APL's scalar operators works like addition. Here are examples:

`2 4 10×3 7 9`	is 6 28 90
`÷2 4 10`	is .5 .25 .1
`-2 4 10`	is ¯2 ¯4 ¯10
`×/2 4 10`	is 2×4×10, which is 80
`-/9 5 3`	is 9-5-3, which is 7 (since computer works right-to-left)
`⌊/6.1 2.7 4.9`	is 6.1⌊2.7⌊4.9, which is 2.7 (since ⌊ means minimum)
`⌊6.1 2.7 4.9`	is ⌊6.1 then ⌊2.7 then ⌊4.9, which is 6 2 4 (since ⌊ means floor)

Love or hate? Some programmers love APL, because its notation is brief. Other programmers hate it, because its notation is hard for a human to read. The haters are winning, and the percentage of programmers using APL is decreasing.

Logo

Logo began in 1967, during an evening at Dan Bobrow's home in Belmont, Massachusetts. He'd gotten his Ph.D. from MIT and was working for a company called **Bolt, Beranek, and Newman (BBN)**. In his living room were 3 of his colleagues from BBN (Wally Feurzeig, Cynthia Solomon, and Dick Grant) and an MIT professor: Seymour Papert. BBN had tried to teach young kids how to program by using BBN's own language (Telcomp), which was a variation of Joss. BBN had asked Professor Seymour Papert for his opinion. The group was all gathered in Dan's house to hear Seymour's opinion.

Seymour chatted with the group, which agreed with Seymour on these points:

> Telcomp was *not* a great language for kids. It placed too much emphasis on math formulas. Instead of struggling with math, kids should have fun by programming the computer to handle strings instead.
>
> The group also agreed that the most sophisticated language for handling strings was Lisp, but that Lisp was too complex for kids. The group concluded that a new, simplified Lisp should be invented for kids and called **Logo**.

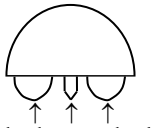
That's how Logo began. Seymour Papert was the guiding light, and all other members of the group gave helpful input during the conversation.

That night, after his guests left, Dan went to his bedroom, where he started writing a program (in Lisp) to make the computer understand Logo.

That's how Logo was born. Work on Logo continued. The 3 main researchers who continued improving Logo were Seymour (the MIT guru), Wally (from BBN), and Cynthia (also from BBN). Logo resembled Lisp but required fewer parentheses.

After helping BBN for a year, Seymour returned to MIT. Cynthia and several other BBN folks worked with him at MIT's Artificial Intelligence Laboratory to improve Logo.

Turtles At first, Logo was as abstract and boring as most other computer languages. But in the spring of 1970, a strange creature walked into the Logo lab. It was a big yellow mechanical turtle. It looked like "half a grapefruit on wheels" and had a pen in its belly:



It also had a horn, feelers, and several other fancy attachments. To use it, you put paper all over the floor then programmed it to roll across the paper. As it rolled, the pen in its belly drew pictures on the paper. The turtle was controlled remotely by a big computer programmed in Logo.

Suddenly, Logo became a fun language whose main purpose was to control the turtle. Kids watching the turtle screamed with delight and wanted to learn how to program it. Logo became a favorite programming game for kids. Even kids who were just 7 years old started programming in Logo. Those kids were barely old enough to read, but reading and writing were *not* prerequisites for learning how to program in Logo. All the kids had to know was:

> **FD 3** makes the turtle go forward 3 steps
> **RT 30** makes the turtle turn to the right 30 degrees

As for the rest of Logo — all that abstract stuff about strings, numbers, and Lisp-like lists — the kids ignored it. They wanted to use just the commands "FD" and "RT" that moved the turtle.

The U.S. Government's National Science Foundation donated money, to help MIT improve Logo further. Many kids came into the Logo lab to play with the turtles.

The turtles were expensive, and so were the big computers that controlled them. But during the early 1970's, computer screens got dramatically cheaper; so to save money, MIT stopped building mechanical turtles and instead bought cheap computer screens that showed pictures of turtles. Those pictures were called "mock turtles".

Cheaper computers Logo's first version was done on BBN's expensive weird computer (the MTS 940). Later versions were done on the PDP-1, the PDP-10, and finally on a cheaper computer: the PDP-11 minicomputer (in 1972).

At the end of the 1970's, companies such as Apple and Radio Shack began selling microcomputers, which were even cheaper. MIT wanted to put Logo on microcomputers but ran out of money to pay for the research.

Texas Instruments (TI) came to the rescue.…

TI Logo TI agreed to pay MIT to research how to put Logo on TI's microcomputer (the TI-99/4).

TI and MIT thought that would be easy, since MIT already wrote a Pascal program that could make computers understand Logo, and since TI already wrote a version of Pascal for the CPU chip inside the TI-99/4. MIT worried because its Pascal program running on MIT's PDP-10 computer handled Logo too slowly; but TI claimed TI's Pascal was faster than the PDP-10's and so Logo would run fast enough on the TI.

TI was wrong. TI's Pascal didn't make Logo run fast enough, and TI's Pascal also required too much RAM. So TI had to take MIT's research (on the PDP-10) and laboriously translate it into TI's assembly language, by hand. The hand translation went slower that TI expected. TI became impatient and took a short-cut: it omitted parts of Logo, such as decimals. TI began selling its version of Logo, which understood just integers.

MIT Apple Logo After TI started selling its Logo, the MIT group invented a version of Logo for the Apple. The Apple version included decimals but omitted **sprites** (animated creatures that carry objects across the screen) because Apple's hardware couldn't handle sprites fast enough.

MIT wanted to sell the Apple version, since more schools owned Apples than TI computers. But if MIT were to make money from selling the Apple version, MIT might get into legal trouble, since MIT was supposed to be non-profit. And anyway, who "owned" Logo? Possible contenders were:

MIT, which did most of the research
BBN, which trademarked the name "Logo" and did the early research
Uncle Sam, whose National Science Foundation paid for much research
TI, which also paid for much research

Eventually, MIT solved the legal problems and sold the rights for "MIT Apple Logo" to two companies: Krell and Terrapin.

Krell was strictly a marketing company. It sold MIT Apple Logo to schools but made no attempt to improve Logo further.

Terrapin, on the other hand, was a research organization that had built mechanical turtles for several years. Terrapin hired MIT graduates to improve Logo further.

LCSI versus competitors Back when MIT was waiting for its lawyers to determine who owned Apple Logo, a group of MIT's faculty and students (headed by Cynthia Solomon) left MIT and formed a company called **Logo Computer Systems Incorporated (LCSI)**. That company invented its own version of Logo for the Apple. LCSI became successful and was hired by Apple, IBM, Atari, and Microsoft to invent Logo versions for those systems. Commodore hired Terrapin instead.

For the Apple 2c (and 2e and 2+), you could buy 3 Logo versions:

official Apple Logo (sold by Apple Computer Inc. and created by LCSI)
"Terrapin Logo for the Apple" (sold by Terrapin)
original "MIT Logo for the Apple" (sold by Krell)

Krell became unpopular, leaving Terrapin and LCSI as the main Logo versions. LCSI's versions were daring (resulting from wild experiments), while Terrapin's versions were conservative (closer to the MIT original).

The two companies had different styles:

Terrapin was small & friendly and charged little.
LCSI was big & rude and charged more.

Terrapin's owners had financial difficulties and sold the company to **Harvard Associates** (which had invented a Logo version called "PC Logo"). So Terrapin became part of Harvard Associates (run by Bill Glass, who's friendly).

To find out about his Terrapin Logo, look at his Web site (TerrapinLogo.com) then phone him at 800-774-Logo (or 508-487-4141) or write to 955 Massachusetts Ave. #365, Cambridge MA 02139-3233.

LCSI's newest, daring version of Logo is **MicroWorlds Pro**.

To find out about it, look at LCSI's Web site (LCSI.ca) then phone LCSI at 800-321-5646. LCSI is based in Montreal, Canada but accepts U.S. mail at PO Box 162, Highgate Springs VT 05460.

Logo versus Basic Most of Logo's designers *hate* Basic and want to eliminate Basic from schools altogether. They believe Logo's easier to learn than Basic, encourages a kid to be more creative, and lets a kid think in a more organized fashion. They also argue that since Logo is best for little kids, and since switching languages is difficult, kids should continue using Logo until they graduate from high school and never use Basic.

That argument is wrong, for 2 reasons:

Knowing Basic is *essential* to understanding our computerized society. Most programs are still written in Basic, not Logo, because Basic consumes less RAM and because Basic's newest versions contain many practical features (for business, science, and graphics) that Logo lacks.

Logo suffers from awkward notation. For example, Basic lets you type a formula such as —

```
A=B+C
```

but in Logo you must type:

```
MAKE "A :B+:C
```

Notice how ugly the Logo command looks! You must put a quotation mark *before* the A but *not afterwards!* Look at those frightful colons! Anybody who thinks such notation is great for kids is a fool.

Extensible One of Logo's nicest features is: you can modify Logo and turn it into your *own* language, because Logo lets you invent your own commands and add them to the Logo language.

A language (such as Logo) that lets you invent your own commands is called an **extensible language**. Though some earlier languages (such as Lisp) were extensible also, Logo is *more* extensible and pleasanter.

Forth

Like Logo, Forth is extensible. But Forth has two advantages over Logo:

Forth consumes less memory: you can easily run Forth on a computer having just 8K of RAM.

Forth runs faster: the computer handles Forth almost as fast as assembly language.

Since Forth is extensible and consumes so little of the computer's memory & time, professional programmers used Forth often. Famous programs written in Forth include **Easywriter** (a word-processing program), **Valdocs** (the operating system for Epson's first computer), and **Rapid File** (an easy-to-learn data-management system).

Unfortunately, the original versions of Easywriter and Valdocs contained many bugs, but that's because their programmers were careless.

In Forth, if you want to add 2 and 3 (to get 5) you do *not* type 2+3. Instead, you must type:

```
2 3 +
```

The idea of putting the plus sign afterwards (instead of in the middle) is called **postfix notation**. The postfix notation (2 3 +) has two advantages over infix notation (2+3): the computer handles postfix notation faster, and you never need to use parentheses for "order of operations". But postfix notation hard for humans to read.

Like Forth, ancient HP pocket calculators used postfix notation. If you used such as calculator, you'll find Forth easy.

Postfix notation is the reverse of **prefix notation** (+ 2 3), which was invented around 1926 by the Polish mathematician Lukasiewicz. So postfix notation is called **reverse Polish notation**. Since Forth is so difficult for a human to read, cynics call it "an inhuman Polish joke".

Forth was invented by Chuck Moore in his spare time while he worked at many schools and companies. He wanted to name it "Fourth", because he considered it to be an ultra-modern "fourth-generation" language; but since his old IBM 1130 computer couldn't handle a name as long as "Fourth", he omitted the letter "u".

Pilot

Pilot was invented in 1968 by John Starkweather at the University of California's San Francisco branch. It's easier to learn than Basic but intended to be programmed by teachers, not students. Teachers using Pilot can easily make the computer teach students about history, geography, math, French, and other schoolbook subjects.

For example, suppose you're a teacher and want to make the computer chat with your students. Here's how to do it in Pilot:

Basic program

```
PRINT "I AM A COMPUTER"
INPUT "DO YOU LIKE COMPUTERS";A$
IF A$="YES" OR A$="YEAH" OR A$="YEP" OR A$="SURE" OR A$="SURELY" OR A$="I SURE
DO" THEN PRINT "I LIKE YOU TOO" ELSE PRINT "TOUGH LUCK"
```

Pilot program	What the computer will do
T:I AM A COMPUTER	Type "I AM A COMPUTER".
T:DO YOU LIKE COMPUTERS?	Type "DO YOU LIKE COMPUTERS?"
A:	Accept the human's answer.
M:YE,SURE	Match. (See whether answer contains "YE" or "SURE".)
TY:I LIKE YOU TOO	If there was a match, type "I LIKE YOU TOO".
TN:TOUGH LUCK	If no match, type "TOUGH LUCK".

The Pilot program is briefer than Basic.

Atari, Apple, and Radio Shack sold versions of Pilot including commands to handle graphics. Atari's version is the best, since it includes the fanciest graphics & music and even a Logo-like turtle, and it's also the easiest version to learn how to use.

Though Pilot' easier than Basic, most teachers prefer Basic because it's available on more computers, costs less, and accomplishes a greater variety of tasks. Hardly anybody uses Pilot.

Specialists

For specialized applications, use a special language.

Dynamo

Dynamo uses these symbols:

Symbol	Meaning
.J	a moment ago
.K	now
.JK	during the past moment
.KL	during the next moment
DT	how long "a moment" is

For example, suppose you want to explain to the computer how population depends on birth rate. If you let P be the population, BR be the birth rate, and DR be the death rate, here's what to say in Dynamo:

```
P.K=P.J+DT*(BR.JK-DR.JK)
```

The equation says: Population now = Population before + (how long "a moment" is) times (Birth Rate during the past moment - Death Rate during the past moment).

World Dynamics The most famous Dynamo program is the **World Dynamics Model**, which Jay Forrester programmed at MIT in 1970. His program has 117 equations that describe 112 variables about our world.

Here's how the program begins:

```
* WORLD DYNAMICS
L P.K=P.J+DT*(BR.JK-DR.JK)
N P=PI
C PI=1.65E9
R BR.KL=P.K*FIFGE(BRN,BRN1,SWT1,TIME.K)*BRFM.K*BRMM.K*BRCM.K*BRPM.K
etc.
```

The first line gives the program's title. The next line defines the Level of Population, in terms of Birth Rate and Death Rate.

The second equation defines the iNitial Population to be PI (Population Initial). The next equation defines the Constant PI to be 1.65e9, because the world's population was 1.65 billion in 1900.

The next equation says the Rate BR.KL (the Birth Rate during the next moment) is determined by the Population now and several other factors, such as the BRFM (Birth-Rate-from-Food Multiplier), the BRMM (Birth-Rate-from-Material Multiplier), the BRCM (Birth-Rate-from-Crowding Multiplier), and the BRPM (Birth-Rate-from-Pollution Multiplier). Each of those factors is defined in later equations.

When you run the program, the computer automatically solves all the equations simultaneously and draws graphs showing how the population, birth rate, etc. will change during the next several decades. The graphs show the quality of life will decrease (because of the overpopulation, pollution, and dwindling natural resources). Although the material standard of living will improve for a while, it too will eventually decrease, as will industrialization (capital investment).

The bad outlook is caused mainly by dwindling natural resources. Suppose scientists suddenly make a "new discovery" that lets us reduce our usage of natural resources by 75%. Will our lives be better? The computer predicted that if the "new discovery" were made in 1970, this would happen:

> People will live well, so in 2030 the population is almost 4 times what it was in 1970. But the large population generates too much pollution. In 2030, the pollution is being created faster than it can dissipate. From 2040 to 2060, a pollution crisis occurs: the pollution increases until it's 40 times as great as in 1970 and kills most people on earth, so the world's population in 2060 is a sixth of what it was in 2040. After the crisis, the few survivors create little pollution and enjoy a very high quality of life.

Forrester tried other experiments on the computer. To improve the quality of life, he tested the effect of requiring birth control, reducing pollution, and adopting other strategies. Each of those simple strategies backfired. The graphs showed that the only way to maintain a high quality of life is to adopt a *combination* strategy immediately:

> reduce natural resource usage by 75%
> reduce pollution generation by 50%
> reduce the birth rate by 30%
> reduce capital-investment generation by 40%
> reduce food production by 20%

Other popular applications Although the World Dynamics Model is Dynamo's most famous program, Dynamo's been applied to many other problems.

The first Dynamo programs were aimed at helping managers run companies. Plug your policies about buying, selling, hiring, and firing into the program's equations; when you run the program, the computer draws a graph showing what will happen to your company during the coming months and years. If you dislike the computer's prediction, change your policies, put them into the equations, and see whether the computer's graphs are more optimistic.

How Dynamo developed Dynamo developed from research at MIT.

At MIT in 1958, Richard Bennett invented a language called **Simple**, which stood for "Simulation of Industrial Management Problems with Lots of Equations". In 1959, Phyllis Fox and Alexander Pugh III invented Dynamo as an improvement on Simple. At MIT in 1961, Jay Forrester wrote a book called *Industrial Dynamics*, which explained how Dynamo can help you manage a company.

MIT is near Boston, whose mayor from 1960 to 1967 was John Collins. When his term as mayor ended, he became a visiting professor at MIT. His office happened to be next to Forrester's. He asked Forrester whether Dynamo could solve the problems of managing a city. Forrester organized a conference of urban experts and got them to turn urban problems into 330 Dynamo equations involving 310 variables.

Forrester ran the program and made the computer graph the consequences. The results were surprising:

> The graph showed that if you try to help the underemployed (by giving them low-cost housing, job-training programs, and artificially created jobs), the city becomes better for the underemployed — but then more underemployed people move to the city, the percentage of the city that's underemployed increases, and the city is worse than before the reforms were begun. So socialist reform just backfires.
>
> Another example: free public transportation creates *more* traffic, because it encourages people to live farther from their jobs.
>
> The graphs show the only long-term solution to the city's problems is to do this instead: knock down slums, fund new "labor-intensive export" businesses (businesses that will hire many workers, occupy little land, and produce goods that can be sold outside the city), and let the underemployed fend for themselves in this new environment.
>
> Another surprise: any city-funded housing program makes matters *worse* (regardless of whether the housing is for the underemployed, the workers, or the rich) because more housing creates less space for industry, so fewer jobs.

If you ever become a mayor or President, use the computer's recommendations cautiously: they'll improve the cities, but only by driving the underemployed out to the suburbs, which will worsen.

In 1970 Forrester created the World Dynamics Model to help "The Club of Rome", a private club of 75 people who try to save the world from ecological calamity.

GPSS

A **queue** is a line of people who are waiting. **GPSS** analyzes queues. For example, let's use GPSS to analyze the customers waiting in "Quickie Joe's Barbershop".

Joe's the only barber in the shop, and he spends exactly 7 minutes on each haircut. (That's why he's called "Quickie Joe".)

About once every 10 minutes, a new customer enters the barbershop. More precisely, the number of minutes before another customer enters is a random number between 5 and 15.

To make the computer imitate the barbershop and analyze what happens to the first 100 customers, type this program:

```
        SIMULATE
        GENERATE    10,5        A new customer comes every 10 minutes ± 5 minutes.
        QUEUE       JOEQ        He waits in the queue, called JOEQ.
        SEIZE       JOE         When his turn comes, he seizes JOE,
        DEPART      JOEQ            which means he leaves the JOEQ.
        ADVANCE     7           After 7 minutes go by,
        RELEASE     JOE             he releases JOE (so someone else can use JOE)
        TERMINATE   1               and leaves the shop.
        START       100         Do all that 100 times.
        END
```

Indent so that the word SIMULATE begins in column 8 (preceded by 7 spaces) and the "10,5" begins in column 19.

When you run the program, the computer will tell you the following.…

Joe was working 68.5% of the time. The rest of the time, his shop was empty and he was waiting for customers.

There was never more than 1 customer waiting. "On the average", .04 customers were waiting.

There were 101 customers. (The 101st customer stopped the experiment.) 79 of them (78.2% of them) obtained Joe immediately and didn't have to wait.

The "average customer" had to wait in line .405 minutes. The "average not-immediately-served customer" had to wait in line 1.863 minutes.

Alternative languages For most problems about queues, GPSS is the easiest language to use. But if your problem is complex, you might have to use **Simscript** (based on Fortran) or **Simula** (an elaboration of Algol) or **Simpl/I** (an elaboration of PL/I).

Prolog

In 1972, **Prolog** was invented in France at the **University of Marseilles**. In 1981, a different version of Prolog arose in Scotland at the **University of Edinburgh**. In 1986, **Turbo Prolog** was created in California by Borland International (which also created Turbo Pascal).

Those versions of Prolog are called **Marseilles Prolog**, **Edinburgh Prolog**, and **Turbo Prolog**.

Prolog programmers call Marseilles Prolog the "old classic", Edinburgh Prolog the "current standard", and Turbo Prolog the "radical departure".

Turbo Prolog has two advantages over its predecessors: it runs programs extra-fast, and it uses English words instead of weird symbols. On the other hand, it requires extra lines at the beginning of your program, to tell the computer which variables are strings.

The ideal Prolog would be a compromise, incorporating the best features of Marseilles, Edinburgh, and Turbo. Here's how to use the ideal Prolog and how the various versions differ from it.…

Creating the database Prolog analyzes relationships. Suppose Alice loves tennis and sailing, Tom loves everything that Alice loves, and Tom also loves football (which Alice does *not* love). To feed all those facts to the computer, give these Prolog commands:

```
loves(alice,tennis).
loves(alice,sailing).
loves(tom,X) if loves(alice,X).
loves(tom,football).
```

The top two lines say Alice loves tennis and sailing. In the third line, the "X" means "something", so that line says: Tom loves something if Alice loves it. The bottom line says Tom loves football.

When you type those lines, be careful about capitalization.

> You must capitalize variables (such as X). You must *not* capitalize specifics (such as tennis, sailing, football, alice, tom, and love).

At the end of each sentence, put a period.

That's how to program by using ideal Prolog. Here's how other versions of Prolog differ.…

For Edinburgh Prolog, type the symbol ":-" instead of the word "if".

For Marseilles Prolog, replace the period by a semicolon, and replace the word "if" by an arrow (->), which you must put in every line:

```
loves(alice,tennis)->;
loves(alice,sailing)->;
loves(tom,X) -> loves(alice,X);
loves(tom,football)->;
```

For Turbo Prolog, you must add extra lines at the top of your program, to warn the computer that the person and sport are strings ("symbols"), and the word "loves" is a verb ("predicate") that relates a person to a sport:

```
domains
        person,sport=symbol
predicates
        loves(person,sport)
clauses
        loves(alice,tennis).
        loves(alice,sailing).
        loves(tom,X) if loves (alice,X).
        loves(tom,football).
```

(To indent, press the Tab key. To stop indenting, press the left-arrow key.) When you've typed all that, press the Esc key (which means Escape) then the R key (which means Run).

Simple questions After you've fed the database to the computer, you can ask the computer questions about it.

Does Alice love tennis? To ask the computer that question, type this:

```
loves(alice,tennis)?
```

The computer will answer:

```
yes
```

Does Alice love football? Ask this:

```
loves(alice,football)?
```

The computer will answer:

```
no
```

That's how the ideal Prolog works. Other versions differ. *Marseilles Prolog* is similar to the ideal Prolog. *Turbo Prolog* omits the question mark, says "true" instead of "yes", and says "false" instead of "no". *Edinburgh Prolog* puts the question mark at the beginning of the sentence instead of the end, like this:

```
?-loves(alice,tennis).
```

Advanced questions What does Alice love? Does Alice love something? Ask this:

```
loves(alice,X)?
```

The computer will answer:

```
X=tennis
X=sailing
2 solutions
```

What does Tom love? Does Tom love something? Ask:

```
loves(tom,X)?
```

The computer will answer:

```
X=tennis
X=sailing
X=football
3 solutions
```

Who loves tennis? Ask:

```
loves(X,tennis)?
```

The computer will answer:

```
X=alice
X=tom
2 solutions
```

Does anybody love hockey? Ask:

```
loves(X,hockey)?
```

The computer doesn't know of anybody who loves hockey, so the computer will answer:

```
no solution
```

Does Tom love something that Alice doesn't? Ask:

```
loves(tom,X) and not (loves(alice,X))?
```

The computer will answer:

```
X=football
1 solution
```

That's ideal Prolog.

> *Turbo Prolog* is similar to ideal Prolog. For *Marseilles Prolog*, replace the word "and" by a blank space.
>
> For *Edinburgh Prolog*, replace the word "and" by a comma. After the computer finds a solution, type a semicolon, which tells the computer to find others; when the computer can't find any more solutions, it says "no" (which means "no more solutions") instead of printing a summary message such as "2 solutions".

Prolog's popularity After being invented in France, Prolog quickly became popular throughout Europe.

Its main competitor was Lisp, which was invented in the United States before Prolog. Long after Prolog's debut, Americans continued to use Lisp and ignored Prolog.

In the 1980's, the Japanese launched the **Fifth Generation Project**, which was an attempt to develop a more intelligent kind of computer. To develop that computer's software, the Japanese used Prolog instead of Lisp, because Prolog was non-American and therefore furthered the project's purpose, which was to one-up the Americans.

When American researchers heard that the Japanese chose Prolog as a software weapon, the Americans got scared and launched a counter-attack by learning Prolog also.

Speed When Borland — an American company — developed Turbo Prolog, American researchers were thrilled, since Turbo Prolog ran faster than any other Prolog. It ran faster on a cheap IBM PC than Japan's Prolog ran on Japan's expensive maxicomputers!

Assembler

Let's look deeper into the computer to see how circuits can "think".

Number systems

Most humans use the **decimal system**, which consists of ten digits (0, 1, 2, 3, 4, 5, 6, 7, 8, 9), because humans have ten fingers. The computer does not have fingers, so it prefers other number systems instead. Here they are.…

Binary

Look at these powers of 2:

$2^0 = 1$
$2^1 = 2$
$2^2 = 4$
$2^3 = 8$
$2^4 = 16$
$2^5 = 32$
$2^6 = 64$

Now try an experiment. Pick your favorite positive integer, and try to write it as a sum of powers of 2.

For example, suppose you pick 45; you can write it as 32+8+4+1. Suppose you pick 74; you can write it as 64+8+2. Suppose you pick 77. You can write it as 64+8+4+1. *Every* positive integer can be written as a sum of powers of 2.

Let's put those examples in a table:

Original number	Written as sum of powers of 2	Does the sum contain… 64?	32?	16?	8?	4?	2?	1?
45	32+8+4+1	no	yes	no	yes	yes	no	yes
74	64+8+2	yes	no	no	yes	no	yes	no
77	64+8+4+1	yes	no	no	yes	yes	no	yes

To write those numbers in the **binary system**, replace "no" by 0 and "yes" by 1:

Decimal system	Binary system
45	0101101 (or simply 101101)
74	1001010
77	1001101

The **decimal system** uses the digits 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9 and uses these columns:

thousands	hundreds	tens	units

For example, the decimal number 7105 means "7 thousands + 1 hundred + 0 tens + 5 units".

The **binary system** uses just the digits 0 and 1, and uses these columns:

sixty-fours	thirty-twos	sixteens	eights	fours	twos	units

For example, the binary number 1001101 means "1 sixty-four + 0 thirty-twos + 0 sixteens + 1 eight + 1 four + 0 twos + 1 unit". In other words, it means seventy-seven.

In elementary school, you were taught how to do arithmetic in the decimal system. You had to memorize the addition and multiplication tables:

DECIMAL ADDITION

	0	1	2	3	4	5	6	7	8	9
0	0	1	2	3	4	5	6	7	8	9
1	1	2	3	4	5	6	7	8	9	10
2	2	3	4	5	6	7	8	9	10	11
3	3	4	5	6	7	8	9	10	11	12
4	4	5	6	7	8	9	10	11	12	13
5	5	6	7	8	9	10	11	12	13	14
6	6	7	8	9	10	11	12	13	14	15
7	7	8	9	10	11	12	13	14	15	16
8	8	9	10	11	12	13	14	15	16	17
9	9	10	11	12	13	14	15	16	17	18

DECIMAL MULTIPLICATION

	0	1	2	3	4	5	6	7	8	9
0	0	0	0	0	0	0	0	0	0	0
1	0	1	2	3	4	5	6	7	8	9
2	0	2	4	6	8	10	12	14	16	18
3	0	3	6	9	12	15	18	21	24	27
4	0	4	8	12	16	20	24	28	32	36
5	0	5	10	15	20	25	30	35	40	45
6	0	6	12	18	24	30	36	42	48	54
7	0	7	14	21	28	35	42	49	56	63
8	0	8	16	24	32	40	48	56	64	72
9	0	9	18	27	36	45	54	63	72	81

In the binary system, the only digits are 0 and 1, so the tables are briefer:

BINARY ADDITION

	0	1
0	0	1
1	1	10

because two is written "10" in binary

BINARY MULTIPLICATION

	0	1
0	0	0
1	0	1

If society had adopted the binary system instead of the decimal system, you'd have been spared many hours of memorizing!

Usually, when you ask the computer to perform a computation, it converts your numbers from the decimal system to the binary system, performs the computation by using the binary addition and multiplication tables, and then converts the answer from the binary system to the decimal system, so you can read it. For example, if you ask the computer to print 45+74, it will do this:

```
 45  converted to binary is    101101
+74  converted to binary is   +1001010
                              1110111   converted to decimal is  119
                                 ↑
                                 because 1+1=10
```

The conversion from decimal to binary and then back to decimal is slow. But the computation itself (in this case, addition) is quick, since the binary addition table is so simple. The only times the computer must convert is during input (decimal to binary) and output (binary to decimal). The rest of the execution is performed quickly, entirely in binary.

You know fractions can be written in the decimal system, by using these columns:

units	point	tenths	hundredths	thousandths

For example, $1\frac{5}{8}$ can be written as 1.625, which means "1 unit + 6 tenths + 2 hundredths + 5 thousandths".

To write fractions in the binary system, use these columns instead:

units	point	halves	fourths	eighths

For example, $1\frac{5}{8}$ is written in binary as 1.101, which means "1 unit + 1 half + 0 fourths + 1 eighth".

You know 1/3 is written in the decimal system as 0.3333333…, which unfortunately never terminates. In the binary system, the situation is no better: 1/3 is written as 0.010101…. Since the computer stores just a finite number of digits, it can't store 1/3 accurately — it stores just an approximation.

A more distressing example is 1/5. In the decimal system, it's .2, but in the binary system it's .0011001100110011…. So the computer can't handle 1/5 accurately, even though a human can.

Most of today's microcomputers and minicomputers are inspired by a famous maxicomputer built by DEC and called the DECsystem-10 (or PDP-10). Though DEC is no longer in business, its influence lives on!

Suppose you run this Basic program on a DECsystem-10 computer:

```
10 PRINT "MY FAVORITE NUMBER IS";4.001-4
20 END
```

The computer will try to convert 4.001 to binary. Unfortunately, it can't be converted exactly; the computer's binary approximation of it is slightly too small. The computer's final answer to 4.001-4 is therefore slightly less than the correct answer. Instead of printing MY FAVORITE NUMBER IS .001, the computer will print MY FAVORITE NUMBER IS .000999987.

If your computer isn't a DECsystem-10, its approximation will be slightly different. To test your computer's accuracy, try 4.0001-4, and 4.00001-4, and 4.000001-4, etc. You might be surprised at its answers.

Let's see how the DECsystem-10 handles this:

```
10 FOR X = 7 TO 193 STEP .1
20     PRINT X
30 NEXT X
40 END
```

The computer will convert 7 and 193 to binary accurately, but will convert .1 to binary just approximately; the approximation is slightly too large. The last few numbers it should print are 192.8, 192.9, and 193, but because of the approximation it will print slightly more than 192.8, then slightly more than 192.9, and then stop (since it is not allowed to print anything over 193).

There are just two binary digits: 0 and 1. A **b**inary digi**t** is called a **bit**. For example, .001100110011 is a binary approximation of 1/5 that consists of twelve bits. A sixteen-bit approximation of 1/5 would be .0011001100110011. A bit that is 1 is called **turned on**; a bit that is 0 is **turned off**. For example, in the expression 11001, three bits are turned on and two are off. We also say three of the bits are **set** and two are **cleared**.

In a computer, all info is coded as bits:

Location	What's 1?	What's 0?
wire	high voltage	low voltage
flashing light	the light is on	the light is off
punched paper tape	a hole in the tape	no hole
punched IBM card	a hole in the card	no hole
magnetic drum	a magnetized area	not magnetized
core memory	a core (iron doughnut) magnetized clockwise	counterclockwise

For example, to represent 11 on part of a punched paper tape, the computer punches two holes close together. To represent 1101, the computer punches two holes close together, and then another hole farther away.

Octal

Octal is a shorthand notation for binary:

Octal	Meaning
0	000
1	001
2	010
3	011
4	100
5	101
6	110
7	111

Each octal digit stands for three bits. For example, the octal number 72 is short for this:

```
111010
└┘└┘
 7  2
```

To convert a binary integer to octal, divide the number into chunks of three bits, starting at the right. For example, here's how to convert 11110101 to octal:

```
 11110101
└┘└┘└┘
 3  6  5
```

To convert a binary real number to octal, divide the number into chunks of three bits, starting at the decimal point and working in both directions:

```
 10100001.10011
└┘└┘└┘ └┘└┘
 2  4  1 . 4  6
```

Hexadecimal

Hexadecimal is another short-hand notation for binary:

Hexadecimal	Meaning
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
A	1010
B	1011
C	1100
D	1101
E	1110
F	1111

For example, the hexadecimal number 4F is short for this:

```
01001111
└──┘└──┘
  4    F
```

To convert a binary number to hexadecimal, divide the number into chunks of 4 bits, starting at the decimal point and working in both directions:

```
 11010110100.1111111
└──┘└──┘└──┘ └──┘└──┘
  6    B    4 .  F    E
```

Character codes

To store a character in a string, the computer uses a code.

Ascii

The most famous code is the **American Standard Code for Information Interchange (Ascii)**, which has 7 bits for each character. Here are examples:

Character	Ascii code	Ascii code in hexadecimal
space	0100000	20
!	0100001	21
"	0100010	22
#	0100011	23
$	0100100	24
%	0100101	25
&	0100110	26
‘	0100111	27
(	0101000	28
)	0101001	29
*	0101010	2A
+	0101011	2B
,	0101100	2C
-	0101101	2D
.	0101110	2E
/	0101111	2F
0	0110000	30
1	0110001	31
2	0110010	32
etc.		
9	0111001	39
:	0111010	3A
;	0111011	3B
<	0111100	3C
=	0111101	3D
>	0111110	3E
?	0111111	3F
@	1000000	40
A	1000001	41
B	1000010	42
C	1000011	43
etc.		
Z	1011010	5A
[	1011011	5B
\	1011100	5C
]	1011101	5D
^	1011110	5E
_	1011111	5F

“Ascii” is pronounced “ass key”.

Many variants of Ascii were invented.

Most **terminals** (which connect to a maxicomputer or minicomputer) use that 7-bit Ascii, unmodified.

Most **microcomputers** and **PDP-11** minicomputers use an “8-bit Ascii” formed by putting a 0 before 7-bit Ascii.

PDP-8 minicomputers use mainly a “6-bit Ascii” (formed by eliminating 7-bit Ascii’s leftmost bit) but can also handle an “8-bit Ascii” formed by putting a 1 before 7-bit Ascii.

PDP-10 maxicomputers use mainly 7-bit Ascii but can also handle a “6-bit Ascii” formed by eliminating Ascii’s second bit. For example, the 6-bit Ascii code for the symbol $ is 0 00100.

Bytes

Nowadays, a “**byte**” usually means 8 bits. For example, here’s a byte: 10001011.

For old computers using 7-bit Ascii, programmers sometimes define a byte to be 7 bits instead of 8. For old computers using 6-bit Ascii, programmers sometimes define a byte to be 6 bits. So if someone tries to sell you an old computer whose memory can hold “16,000 bytes”, he probably means 16,000 8-bit bytes but might mean 7-bit bytes or 6-bit bytes.

To be more precise, some computerists call 8 bits an **octet** instead of a byte.

Nibbles

A **nibble** is 4 bits. It’s half of an 8-bit byte. Since a hexadecimal digit stands for 4 bits, **a hexadecimal digit stands for a nibble**.

Unicode

To store a character, the Internet uses **Unicode**, which lets each character’s code contain *many* bits. Unlike Ascii, which handles just English, Unicode can also handle European languages (which have accents above and below the characters) and the wild characters used in Greek, Russian, Chinese, Japanese, and Korean.

To store each character as bits, Unicode uses a trick called the **Unicode Transformation Format’s 8-bit version (UTF-8)**. Here’s how the computer reads bits sent by another computer using UTF-8.

Byte beginning with 0 If a byte begins with 0, the next 7 bits are the same as 7-bit Ascii code.

For example, suppose the computer receives this byte: 00100100. Since it begins with 0, the next 7 bits (0100100) are a 7-bit Ascii code. The computer looks up 0100100 in a table and discovers 0100100 is the Ascii code for a dollar sign ($), so the computer puts a dollar sign on your screen.

Byte beginning with 1 If a byte begins with 1, the computer does this analysis:

If the byte begins with 110,	the code will be 2 bytes long.
If the byte begins with 1110,	the code will be 3 bytes long.
If the byte begins with 11110,	the code will be 4 bytes long.

For example, suppose the computer receives this byte: **1110**0010. Since the byte begins with 1110, the code will be 3 bytes long, so the computer must look at 3 bytes altogether to read the character.

Suppose the 3 bytes are **1110**0010 **10**000010 **10**101100. The first byte begins with this warning: **1110** (which means “the code will be 3 bytes long”). The second byte begins with this warning: **10** (which means “this byte is continuing a code that was started earlier”). The third byte begins with the same warning: **10** (which means “this byte is continuing a code that was started earlier”).

The parts of the 3-byte code that are *not* warnings are: 0010 000010 101100. The computer looks up that in a table and discovers 0010 000010 101100 is the Unicode for a Euro sign (€), so the computer puts a Euro sign on your screen.

Unicode was created to be efficient:

The most popular characters (the Ascii characters) consume just 1 byte.
Characters that are somewhat less popular consume 2 or 3 bytes.
Characters that are used rarely consume 4 bytes.

If the computer encounters a byte that begins with **10**, the computer knows that the byte is *not* a character’s *first* byte, so the computer must hunt back to find the character’s first byte — or request that another computer retransmit the character.

EBCDIC

Instead of using Ascii, IBM mainframes use the **Extended Binary-Coded-Decimal Interchange Code (EBCDIC)**, which has 8 bits for each character. Here are examples:

Character	EBCDIC code in hexadecimal	Character	EBCDIC code in hexadecimal
space	40	A	C1
¢	4A	B	C2
<	4C	C	C3
(	4D	etc.	
+	4E	I	C9
|	4F	J	D1
&	50	K	D2
!	5A	L	D3
$	5B	etc.	
*	5C	R	D9
)	5D	S	E2
;	5E	T	E3
¬	5F	U	E4
-	60	etc.	
/	61	Z	E9
,	6B	0	F0
%	6C	1	F1
_	6D	2	F2
>	6E	etc.	
?	6F	9	F9
:	7A		
#	7B		
@	7C		
'	7D		
=	7E		
"	7F		

"EBCDIC" is usually pronounced "ebb sih Dick," though programmers hating it say "Ed sucks Dick."

IBM 360 computers can also handle an "8-bit Ascii", formed by copying Ascii's first bit after the second bit. For example, the 8-bit Ascii code for the symbol $ is 01000100. But IBM 370 computers (which are newer than IBM 360 computers) don't bother with Ascii: they stick strictly with EBCDIC.

80-column IBM cards use **Hollerith code**, which resembles EBCDIC but has 12 bits instead of 8. 96-column IBM cards use a 6-bit code that's an abridgement of Hollerith code.

Here's a program written in old Basic:

```
10 IF "9"<"A" THEN 100
20 PRINT "CAT"
30 STOP
100 PRINT "DOG"
110 END
```

Which will the computer print: CAT or DOG? The answer depends on whether the computer uses Ascii or EBCDIC.

Suppose the computer uses 7-bit Ascii. Then the code for "9" is hexadecimal 39, and the code for "A" is hexadecimal 41. Since 39 is less than 41, the computer considers "9" to be less than "A", so the computer prints DOG.

But if the computer uses EBCDIC instead of Ascii, the code for "9" is hexadecimal F9, and the code for "A" is hexadecimal C1; since F9 is greater than C1, the computer considers "9" to be greater than "A", so the computer prints CAT.

Sexy assembler

In this chapter, you'll learn the fundamental concepts of assembly language, quickly and easily.

Unfortunately, different CPUs have different assembly languages.

I've invented an assembly language that combines the best features of all the other assembly languages. My assembly language is called **Sexy Ass**, because it's a **S**imple, **Ex**cellent, **Y**ummy **Ass**embler.

After you study the mysteries of the Sexy Ass, you can easily get your rear in gear and become the dominant master of the assemblers sold for IBM, Apple, and competitors. Mastering them will become so easy that you'll say, "Assembly language is a piece of cheesecake!"

Bytes in my ASS

Let's get a close-up view of the Sexy Ass.…

CPU registers The computer's guts consist of two main parts: the brain (which is called the **CPU**) and the **main memory** (which consists of RAM and ROM).

Inside the CPU are many electronic boxes, called **registers**. Each register holds several electrical signals; each signal is called a **bit**; so each register holds several bits. Each bit is either 1 or 0.

A "1" represents a high voltage; a "0" represents a low voltage.
If the bit is 1, the bit is said to be **high** or **on** or **set** or **true**.
If the bit is 0, the bit is said to be **low** or **off** or **cleared** or **false**.

The CPU's most important register is called the **accumulator (A)**. In the Sexy Ass system, the accumulator consists of 8 bits, which is 1 byte. (Later, I'll explain how to make the CPU handle several bytes simultaneously; but the accumulator itself holds just 1 byte.)

Memory locations Like the CPU, the main memory consists of electronic boxes. The electronic boxes *in the CPU* are called **registers**, but the electronic boxes *in the main memory* are called **memory locations** instead. Because the main memory acts like a gigantic post office, the memory locations are also called **addresses**. In the Sexy Ass system, each memory location holds 1 byte. There are many *thousands* of memory locations; they're numbered 0, 1, 2, 3, etc.

Number systems When using Sexy Ass, you can type numbers in decimal, binary, or hexadecimal. (For Sexy Ass, octal isn't useful.) For example, the number "twelve" is written "12" in decimal, "1100" in binary, and "C" in hexadecimal. To indicate which number system you're using, **put a percent sign in front of each binary number, and put a dollar sign in front of each hexadecimal number.** For example, in Sexy Ass you can write the number "twelve" as either 12 or %1100 or $C. (In that respect, Sexy Ass copies the 6502 assembly language, which also uses the percent sign and the dollar sign.)

Most of the time, we'll be using hexadecimal, so let's quickly review what hexadecimal is all about. **To count in hexadecimal, just start counting as you learned in elementary school** ($1, $2, $3, $4, $5, $6, $7, $8, $9); **but after $9, you continue counting by using the letters of the alphabet** ($A, $B, $C, $D, $E, and $F). **After $F (which is fifteen), you say $10** (which means sixteen), then say $11 (which means seventeen), then $12, then $13, then $14, etc., until you reach $19; then come $1A, $1B, $1C, $1D, $1E, and $1F. Then come $20, $21, $22, etc., up to $29, then $2A, $2B, $2C, $2D, $2E, $2F, $30. Eventually, you get up to $99, then $9A, $9B, $9C, $9D, $9E, and $9F. Then come $A0, $A1, $A2, etc., up to $AF. Then come $B0, $B1, $B2, etc., up to $BF. You continue that pattern, until you reach $FF. Get together with your friends, and try counting up to $FF. (Don't bother pronouncing the dollar signs.) Yes, you too can count like a pro!

Since each hexadecimal digit represents 4 bits, an 8-bit byte requires *two* hexadecimal digits. So a byte can be anything from $00 to $FF.

Main segment I said the main memory consists of *thousands* of memory locations, numbered 0, 1, 2, etc. The main memory's most important part is called the **main memory bank** or **main segment**: that part consists of 65,536 memory locations (64K), which are numbered from 0 to 65,535. Programmers usually number them in hexadecimal; the hexadecimal numbers go from $0000 from $FFFF. ($FFFF in hexadecimal is the same as 65,535 in decimal.) Later, I'll explain how to use other parts of the memory; but for now, let's restrict our attention to just 64K main segment.

How to copy a byte Here's a simple, one-line program, written in the SEXY ASS assembly language:

```
        LOAD    $7000
```

It makes the computer copy one byte, from memory location $7000 to the accumulator. So after the computer obeys that instruction, the accumulator will contain the same data as the memory location. For example, if the memory location contains the byte %01001111 (which can also be written as $4F), so will the accumulator.

Notice the wide space before and after the word LOAD. To make the wide space, press the TAB key.

The word LOAD tells the computer to copy from a memory location to the accumulator. The opposite of the word LOAD is the word STORE: it tells the computer to copy from the accumulator to a memory location. For example, if you type —

```
        STORE   $7000
```

the computer will copy a byte from the accumulator to memory location $7000.

Problem: write an assembly-language program that copies a byte from memory location $7000 to memory location $7001. Solution: you must do it in two steps. First, copy from memory location $7000 to the accumulator (by using the word LOAD); then copy from the accumulator to memory location $7001 (by using the word STORE). Here's the program:

```
        LOAD    $7000
        STORE   $7001
```

Arithmetic

If you say —

```
        INC
```

the computer will **increment** (increase) the number in the accumulator, by adding 1 to it. For example, if the accumulator contains the number $25, and you then say INC, the accumulator will contain the number $26. For another example, if the accumulator contains the number $39, and you say INC, the accumulator will contain the number $3A (because, in hexadecimal, after 9 comes A).

Problem: write a program that increments the number that's in location $7000; for example, if location $7000 contains $25, the program should change that data, so that location $7000 contains $26 instead. Solution: copy the number from location $7000 to the accumulator, then increment the number, then copy it back to location $7000.…

```
        LOAD    $7000
        INC
        STORE   $7000
```

That example illustrates the fundamental rule of assembly-language programming, which is: **to manipulate a memory location's data, copy the data to the accumulator, manipulate the accumulator, and then copy the revised data from the accumulator to memory.**

The opposite of INC is DEC: it **decrements** (decreases) the number in the accumulator, by subtracting 1 from it.

If you say —

```
        ADD     $7000
```

the computer will change the number in the accumulator, by adding to it the number that was in memory location $7000. For example, if the accumulator had contained the number $16, and memory location $7000 had contained the number $43, the number in the accumulator will change and become the sum, $59. The number in memory location $7000 will remain unchanged: it will still be $43.

Problem: find the sum of the numbers in memory locations $7000, $7001, and $7002, and put that sum into memory location $7003. Solution: copy the number from memory location $7000 to the accumulator, then add to the accumulator the numbers from memory locations $7001 and $7002, so that the accumulator to memory location $7003.…

```
        LOAD    $7000
        ADD     $7001
        ADD     $7002
        STORE   $7003
```

The opposite of ADD is SUB, which means SUBtract. If you say SUB $7000, the computer will change the number in the accumulator, by subtracting from it the number in memory location $7000.

Immediate addressing

If you say —

```
LOAD    #$25
```

the computer will put the number $25 into the accumulator. The $25 is the data. In the instruction "LOAD #$25", the symbol "#" tells the computer that the $25 is the data instead of being a memory location.

If you were to omit the #, the computer would assume the $25 meant memory location $0025, and so the computer would copy data from memory location $0025 to the accumulator.

An instruction that contains the symbol # is said to be an **immediate** instruction; it is said to use **immediate** addressing. Such instructions are unusual.

The more usual kind of instruction, which does *not* use the symbol #, is called a **direct** instruction.

Problem: change the number in the accumulator, by adding $12 to it. Solution:

```
ADD     #$12
```

Problem: change the number in memory location $7000, by adding $12 to that number. Solution: copy the number from memory location $7000 to the accumulator, add $12 to it, and then copy the sum back to the memory location.…

```
LOAD    $7000
ADD     #$12
STORE   $7000
```

Problem: make the computer find the sum of $16 and $43, and put the sum into memory location $7000. Solution: put $16 into the accumulator, add $43 to it, and then copy from the accumulator to memory location $7000.…

```
LOAD    #$16
ADD     #$43
STORE   $7000
```

Video RAM

The video RAM is part of the computer's RAM and holds a copy of what's on the screen.

For example, suppose you're running a program that analyzes taxicabs, and your computer's screen shows information about various cabs. If the upper-left corner of the screen shows the word CAB, the video RAM contains the Ascii code numbers for the letters C, A, and B. Since the Ascii code number for C is 67 (which is $43), and the Ascii code number for A is 65 (which is $41), and the Ascii code number for B is 66 (which is $42), the video RAM contains $43, $41, and $42. The $43, $41, and $42 represent the word CAB.

Suppose that the video RAM begins at memory location $6000. If the screen's upper-left corner shows the word CAB, memory location $6000 contains the code for C (which is $43); the next memory location ($6001) contains the code for A (which is $41); and the next memory location ($6002) contains the code for B (which is $42).

Problem: assuming that the video RAM begins at location $6000, make the computer write the word CAB onto the screen's upper-left corner. Solution: write $43 into memory location $6000, write $41 into memory location $6001, and write $42 into memory location $6002.…

```
LOAD    #$43
STORE   $6000
LOAD    #$41
STORE   $6001
LOAD    #$42
STORE   $6002
```

The computer knows that $43 is the code number for "C". When you're writing that program, if you're too lazy to figure out the $43, you can simply write "C"; the computer will understand. So you can write the program like this:

```
LOAD    #"C"
STORE   $6000
LOAD    #"A"
STORE   $6001
LOAD    #"B"
STORE   $6002
```

That's the solution if the video RAM begins at memory location $6000. On *your* computer, the video RAM might begin at a different memory location instead. To find out about *your* computer's video RAM, look at the back of the technical manual that came with your computer. There you'll find a **memory map**: it shows which memory locations are used by the video RAM, which memory locations are used by other RAM, and which memory locations are used by the ROM.

Flags

The CPU contains **flags**. Here's how they work.

Carry flag A byte consists of 8 bits. The smallest number you can put into a byte is %00000000. The largest number you can put into a byte is %11111111, which in hexadecimal is $FF; in decimal, it's 255.

What happens if you try to go higher than %11111111? To find out, examine this program:

```
LOAD    #%10000001
ADD     #%10000010
```

In that program, the top line puts the binary number %10000001 into the accumulator. The next line tries to add %10000010 to the accumulator. But **the sum, which is %100000011, contains 9 bits instead of 8, and therefore can't fit into the accumulator.**

The computer splits that sum into two parts: the left bit (1) and the remaining bits (00000011). The left bit (1) is called the carry bit; the remaining bits (00000011) are called the **tail**. Since the tail contains 8 bits, it fits nicely into the accumulator; so the computer puts it into the accumulator. **The carry bit is put into a special place inside the CPU; that special place is called the carry flag.**

So that program makes the accumulator become 00000011, and makes the carry flag become 1.

Here's an easier program:

```
LOAD    #%1
ADD     #%10
```

The top line puts %1 into the accumulator; so the accumulator's 8 bits are %00000001. The bottom line adds %10 to the number in the accumulator; so the accumulator's 8 bits become %00000011. Since the numbers involved in that addition were so small, there was no need for a 9th bit — no need for a carry bit. To emphasize that no carry bit was required, the carry flag automatically becomes 0.

Here's the rule: if an arithmetic operation (such as ADD, SUB, INC, or DEC) gives a result that's too long to fit into 8 bits, the carry flag becomes 1; otherwise, the carry flag becomes 0.

Negatives The largest number you can fit into a byte %11111111, which in decimal is 255. Suppose you try to add 1 to it. The sum is %100000000, which in decimal is 256. But since %100000000 contains 9 bits, it's too long to fit into a byte. So the computer sends the leftmost bit (the 1) to the carry flag, and puts the tail (the 00000000) into the accumulator. As a result, the accumulator contains 0.

So in assembly language, if you tell the computer to do %11111111+1 (which is 255+1), the accumulator says the answer is 0 (instead of 256).

In assembly language, %11111111+1 is 0. In other words, %11111111 solves the equation x+1=0.

According to high school algebra, the equation x+1=0 has this solution: x=-1. But we've seen that in the assembly language, the equation x+1=0 has the solution x=%11111111. Conclusion: in assembly language, -1 is the same as %11111111.

Now you know that -1 is the same as %11111111, which is 255. Yes, -1 is the same as 255. Similarly, -2 is the same as 254; -3 is the same as 253; -4 is the same as 252. Here's the general formula: -n is the same as 256-n. (That's because 256 is the same as 0.)

%11111111 is 255 and is also -1. Since -1 is a shorter name than 255, we say that %11111111 is *interpreted as* -1. Similarly, %11111110 is 254 and also -2; since -2 is a shorter name than 254, we say that %11111110 is interpreted as -2. At the other extreme, %00000010 is 2 and is also -254; since 2 is a shorter name than -254, we say that %11111110 is interpreted as 2. Here's the rule: if a number is "almost" 256, it's interpreted as a negative number; otherwise, it's interpreted as a positive number.

How high must a number be, in order to be "almost" 256, and therefore to be interpreted as a negative number? The answer is: if the number is at least 128, it's interpreted as a negative number. Putting it another way, if the number's leftmost bit is 1, it's interpreted as a negative number.

That strange train of reasoning leads to this definition: **a negative number is a byte whose leftmost bit is 1**.

A byte's leftmost bit is therefore called the **negative bit** or the **sign bit**.

Flag register You've seen that the CPU contains a register called the **accumulator**. The CPU also contains a second register, called the **flag register**. In the Sexy Ass system, the flag register contains 8 bits (one byte). Each of the 8 bits in the flag register is called a **flag**; so the flag register contains 8 flags.

Each flag is a bit: it's either 1 or 0. If the flag is 1, the flag is said to be **up** or **raised** or **set**. If the flag is 0, the flag is said to be **down** or **lowered** or **cleared**.

One of the 8 flags is the carry flag: it's raised (becomes 1) whenever an arithmetic operation requires a 9th bit. (It's lowered whenever an arithmetic operation does *not* require a 9th bit.)

Another one of the flags is **the negative flag: it's raised whenever the number in the accumulator becomes negative**. For example, if the accumulator becomes %11111110 (which is -2), the negative flag is raised (i.e. the negative flag becomes 1). It's lowered whenever the number in the accumulator becomes *non*-negative.

Another one of the flags is **the zero flag: it's raised whenever the number in the accumulator becomes zero**. (It's lowered whenever the number in the accumulator becomes *non*-zero.)

Jumps

You can give each line of your program a name. For example, you can give a line the name FRED. To do so, put the name FRED at the beginning of the line, like this:

```
FRED    LOAD    $7000
```

The line's name (FRED) is at the left margin. The command itself (LOAD $7000) is indented by pressing the TAB key. In that line, FRED is called the **label**, LOAD is called the **operation** or **mnemonic**, and $7000 is called the **address**.

Languages such as BASIC let you say "GO TO". **In assembly language, you say "JUMP" instead of "GO TO".** For example, to make the computer GO TO the line named FRED, say:

```
        JUMP    FRED
```

The computer will obey: it will JUMP to the line named FRED.

You can say —

```
        JUMPN   FRED
```

That means: JUMP to FRED, if the Negative flag is raised. So the computer will JUMP to FRED if a negative number was recently put into the accumulator. (If a *non*-negative number was recently put into the accumulator, the computer will *not* jump to FRED.)

JUMPN means "JUMP if the Negative flag is raised." JUMPC means "JUMP if the Carry flag is raised." JUMPZ means "JUMP if the Zero flag is raised."

JUMPNL means "JUMP if the Negative flag is Lowered." JUMPCL means "JUMP if the Carry flag is Lowered." JUMPZL means "JUMP if the Zero flag is Lowered."

Problem: make the computer look at memory location $7000; if the number in that memory location is negative, make the computer jump to a line named FRED. Solution: copy the number from memory location $7000 to the accumulator, to influence the Negative flag; then JUMP if Negative.…

```
        LOAD    $7000
        JUMPN   FRED
```

Problem: make the computer look at memory location $7000. If the number in that memory location is negative, make the computer print a minus sign in the upper-left corner of the screen; if the number is positive instead, make the computer print a plus sign instead; if the number is zero, make the computer print a zero. Solution: copy the number from memory location $7000 to the accumulator (by saying LOAD); then analyze that number (by using JUMPN and JUMPZ); then LOAD the Ascii code number for either "+" or "-" or "0" into the accumulator (whichever is appropriate); finally copy that Ascii code number from the accumulator to the video RAM (by saying STORE).…

```
        LOAD    $7000
        JUMPN   NEGAT
        JUMPZ   ZERO
        LOAD    #"+"
        JUMP    DISPLAY
NEGAT   LOAD    #"-"
        JUMP    DISPLAY
ZERO    LOAD    #"0"
DISPLAY STORE   $6000
```

Machine language

I've been explaining assembly language. **Machine language** resembles assembly language; what's the difference?

To find out, let's look at a machine language called **Sexy Macho** (because it's a **S**imple, **Ex**cellent, **Y**ummy **Mach**ine-language **O**riginal).

Sexy Macho resembles Sexy Ass; here are the main differences:

In Sexy Ass assembly language, you use words such as LOAD, STORE, INC, DEC, ADD, SUB, and JUMP. Those words are called *operations* or *mnemonics*. In Sexy Macho machine language, you replace those words by code numbers: the code number for LOAD is 1; the code number for STORE is 2; INC is 3; DEC is 4; ADD is 5; SUB is 6; and JUMP is 7. The code numbers are called the **operation codes** or **op codes**.

In Sexy Ass assembly language, the symbol "#" indicates immediate addressing; a lack of the symbol "#" indicates direct addressing instead. In Sexy Macho machine language, you replace the symbol "#" by the code number 1; if you want direct addressing instead, you must use the code number 0.

In Sexy Macho, all code numbers are hexadecimal.

For example, look at this Sexy Ass instruction:

```
ADD      #$43
```

To translate that instruction into Sexy Macho machine language, just replace each symbol by its code number. Since the code number for ADD is 5, and the code number for # is 1, the Sexy Macho version of that line is:

```
5143
```

Let's translate STORE $7003 into Sexy Macho machine language. Since the code for STORE is 2, and the code for direct addressing is 0, the Sexy Macho version of that command is:

```
207003
```

In machine language, you can't use words or symbols: you must use their code numbers instead. To translate a program from assembly language to machine language, you must look up the code number of each word or symbol.

An **assembler** is a program that makes the computer translate from assembly language to machine language.

The CPU understands just machine language: it understands just numbers. It does *not* understand assembly language: it does not understand words and symbols. **If you write a program in assembly language, you must buy an assembler, which translates your program from assembly language to machine language**, so that the computer can understand it.

Since assembly language uses English words (such as LOAD), assembly language seems more "human" than machine language (which uses code numbers). Since programmers are humans, programmers prefer assembly language over machine language. Therefore, the typical programmer writes in assembly language then uses an assembler to translate the program to machine language, which is the language that the CPU ultimately requires.

Here's how the typical assembly-language programmer works:

The programmer types the assembly-language program and uses a word processor to help edit it. The word processor puts the assembly-language program onto a disk.

Then the programmer uses the assembler to translate the assembly-language program into machine language. The assembler puts the machine-language version of the program onto the disk.

Now the disk contains *two* versions of the program: the disk contains the original version (in assembly language) and also contains the translated version (in machine language). The original version (in assembly language) is called the **source code**; the translated version (in machine language) is called the **object code**.

Finally, the programmer gives a command that makes the computer copy the machine-language version (the object code) from the disk to the RAM and run it.

Here's how the assembler translate "JUMP FRED" into machine language:

The assembler realizes that FRED is the name for a line in your program. The assembler hunts through your program, to find the line labeled FRED.

When the assembler finds that line, it analyzes that line, to figure out where that line will be in the RAM after the program is translated into machine language and running. For example, suppose the line that's labeled FRED will become a machine-language line which, when the program is running, will be in the RAM at memory location $2053. Then "JUMP FRED" must be translated into this command: "jump to the machine-language line that's in the RAM at memory location $2053". So "JUMP FRED" really means:

```
JUMP     $2053
```

Since the code number for JUMP is **7**, and the addressing isn't immediate (and so has code **0** instead of 1), the machine-language version of JUMP FRED is:

702053

System software

The computer's main memory consists of RAM and ROM. In a typical computer, the first few memory locations ($0000, $0001, $0002, etc.) are ROM: they permanently contain a program called the **bootstrap**, which is written in machine language.

When you turn on the computer's power switch, the computer automatically runs the bootstrap program. If your computer uses disks, the bootstrap program makes the computer start reading information from the disk in the main drive. In fact, it makes the computer copy a machine-language program from the disk to the RAM. The machine-language program that it copies is called the **disk operating system (DOS)**.

After the DOS has been copied to the RAM, the computer starts running the DOS program. The DOS program makes the computer print a message on the screen (such as "Welcome to CP/M" or "Welcome to MS-DOS" or "Windows XP"), print a symbol on the screen (such as "A>" or a Start button), and then wait for you to give a command.

That whole procedure is called **bootstrapping** (or **booting up**), because of the phrase "pull yourself up by your own bootstraps". By using the bootstrap program, the computer pulls itself up to new intellectual heights: it becomes a CP/M machine or MS-DOS machine or Windows machine.

After booting up, you can start writing programs in Basic. But how does the computer understand the Basic words, such as PRINT, INPUT, IF, THEN, and GO TO? Here's how:

While you're using Basic, the computer is running a machine-language program, that makes the computer *seem* to understand Basic. That machine-language program, which is in the computer's ROM or RAM, is called the **Basic language processor** or **Basic interpreter**. If your computer uses **Microsoft** Basic, the Basic interpreter is a machine-language program that was written by Microsoft Incorporated.

How assemblers differ

In a microcomputer, the CPU is a single chip, called the **microprocessor**. The most popular microprocessors have been the **8088**, the **68000**, and the **6502**.

The **8088**, designed by Intel, hides in the IBM PC and clones. (The plain version is called the 8088; souped-up versions are called the **80286**, the **386**, the **486**, and the **Pentium**.)

The **68000**, designed by Motorola, hides in older computers that rely on mice: the Apple Mac, Commodore Amiga, and Atari ST. (The plain version is called the 68000; a souped-up version, called the **68020**, is in the Mac 2; an even fancier version, called the **68030**, is in fancier Macs.)

The **6502**, designed by MOS Technology (which has become part of Commodore), hides in old-fashioned cheap computers: the Apple 2 family, the Commodore 64 & 128, and the Atari XL & XE.

Let's see how their assemblers differ from Sexy Ass.

Number systems Sexy Ass assumes all numbers are written in the decimal system, unless preceded by a dollar sign (which means hexadecimal) or percent sign (which means binary).

68000 and 6502 assemblers resemble Sexy Ass, except they don't understand percent signs and binary notation. Some stripped-down 6502 assemblers don't understand the decimal system either: they require all numbers to be in hexadecimal.

The 8088 assembler comes in two versions:

The full version of the 8088 assembler is called the **M**icrosoft Macro **As**se**m**bler **(Masm)**. It lists for $150, but discount dealers sell it for just $83. It assumes all numbers are written in the decimal system, unless followed by an H (which means hexadecimal) or B (which means binary). For example, the number twelve can be written as 12 or as 0CH or as 1100B. It requires each number to begin with a digit: so to say twelve in hexadecimal, instead of saying CH you must say 0CH.

A stripped-down 8088 assembler, called the **Debug mini-assembler**, is part of classic Dos; so you get it at no extra charge when you buy classic Dos. It requires all numbers to be written in hexadecimal. For example, it requires the number twelve to be written as C. Do *not* put a dollar sign or H next to the C.

Accumulator Each microprocessor contains *several* accumulators, so you must say *which* accumulator to use. The main 8-bit accumulator is called "A" in the 6502, "AL" in the 8088, and "D0.B" in the 68000.

Labels Sexy Ass and the other full assemblers let you begin a line with a label, such as FRED. For the 8088 full assembler (Masm), add a colon after FRED. Mini-assemblers (such as 8088 Debug) don't understand labels.

Commands Here's how to translate from Sexy Ass to the popular assemblers:

Computer's action	Sexy Ass	6502	68000	8088 Masm
put 25 in accumulator	LOAD #$25	LDA #$25	MOVE.B #$25,D0	MOV AL,25H
copy location 7000 to accumulator	LOAD $7000	LDA $7000	MOVE.B $7000,D0	MOV AL,[7000H]
copy accumulator to location 7000	STORE $7000	STA $7000	MOVE.B D0,$7000	MOV [7000H],AL
add location 7000 to accumulator	ADD $7000	ADC $7000	ADD.B $7000,D0	ADD AL,[7000H]
subtract location 7000 from acc.	SUB $7000	SBC $7000	SUB.B $7000,D0	SUB AL,[7000H]
increment accumulator	INC	ADC #$1	ADDQ.B #1,D0	INC AL
decrement accumulator	DEC	SBC #$1	SUBQ.B #1,D0	DEC AL
put character C in accumulator	LOAD #"C"	LDA #'C	MOVE.B #'C',D0	MOV AL,"C"
jump to FRED	JUMP FRED	JMP FRED	JMP FRED	JMP FRED
jump, if negative, to FRED	JUMPN FRED	BMI FRED	BMI FRED	JS FRED
jump, if carry, to FRED	JUMPC FRED	BCS FRED	BCS FRED	JC FRED
jump, if zero, to FRED	JUMPZ FRED	BEQ FRED	BEQ FRED	JZ FRED
jump, if neg. lowered, to FRED	JUMPNL FRED	BPL FRED	BPL FRED	JNS FRED
jump, if carry lowered, to FRED	JUMPCL FRED	BCC FRED	BCC FRED	JNC FRED
jump, if zero lowered, to FRED	JUMPZL FRED	BNE FRED	BNE FRED	JNZ FRED

Notice that in 6502 assembler, each mnemonic (such as LDA) is 3 characters long.

To refer to an Ascii character, Sexy Ass and 8088 Masm put the character in quotes, like this: "C". 68000 assembler uses apostrophes instead, like this: 'C'. 6502 assembler uses just a single apostrophe, like this: 'C.

Instead of saying "jump if", 6502 and 68000 programmers say "branch if" and use mnemonics that start with B instead of J. For example, they use mnemonics such as BMI (which means "Branch if MInus"), BCS ("Branch if Carry Set"), and BEQ ("Branch if EQual to zero").

To make the 68000 manipulate a byte, put ".B" after the mnemonic. (If you say ".W" instead, the computer will manipulate a 16-bit word instead of a byte. If you say ".L" instead, the computer will manipulate long data containing 32 bits. If you don't specify ".B" or ".W" or ".L", the assembler assumes you mean ".W".)

8088 assemblers require you to put each memory location in brackets. So whenever you refer to location 7000 hexadecimal, you put the 7000H in brackets, like this: [7000H].

Inside the CPU

Let's peek inside the CPU and see what lurks within!

Program counter

Each CPU contains a special register called the **program counter**.

The program counter tells the CPU which line of your program to do next. For example, if the program counter contains the number 6 (written in binary), the CPU will do the line of your program that's stored in the 6th memory location.

More precisely, here's what happens if the program counter contains the number 6:

A. The CPU moves the content of the 6th memory location to the CPU's **instruction register**. (That's called **fetching** the instruction.)

B. The CPU checks whether the instruction register contains a complete instruction written in machine language. If not — if the instruction register contains just *part* of a machine-language instruction — the CPU fetches the content of the 7th memory location also. (The instruction register is large enough to hold the content of memory locations 6 and 7 simultaneously.) If the instruction register still doesn't contain a complete instruction, the CPU fetches the content of the 8th memory location also. If the instruction register still doesn't contain a complete instruction, the CPU fetches the content of the 9th memory location also.

C. The CPU changes the number in the program counter. For example, if the CPU has fetched from the 6th and 7th memory locations, it makes the number in the program counter be 8; if the CPU has fetched from the 6th, 7th, and 8th memory locations, it makes the number in the program counter be 9. (That's called **updating the program counter**.)

D. The CPU figures out what the instruction means. (That's called **decoding** the instruction.)

E. The CPU obeys the instruction. (That's called **executing** the instruction.) If it's a "GO TO" type of instruction, the CPU makes the program counter contain the address of the memory location you want to go to.

After the CPU completes steps A, B, C, D, and E, it looks at the program counter and moves on to the next instruction. For example, if the program counter contains the number 9 now, the CPU does steps A, B, C, D, and E again, but by fetching, decoding, and executing the 9th memory location instead of the 6th.

The CPU repeats steps A, B, C, D, and E again and again; each time, the number in the program counter changes. Those five steps form a loop, called the **instruction cycle**.

Arithmetic/logic unit

The CPU contains two parts: the **control unit** (which is the boss) and the **arithmetic/logic unit (ALU)**. When the control unit comes to step D of the instruction cycle, and decides some arithmetic or logic needs to be done, it sends the problem to the ALU, which sends back the answer.

Here's what the ALU can do:

Operation's name	Example	Explanation
plus, added to, +	10001010 +10001001 100010011	add, but remember that 1+1 is 10 in binary
minus, subtract, -	10001010 -10001001 00000001	subtract, but remember that 10-1 is 1 in binary
negative, -, the two's complement of	-10001010 01110110	*left of the rightmost 1,* do this: replace each 0 by 1, and each 1 by 0
not, ~, the complement of, the one's complement of	~10001010 01110101	replace each 0 by 1, and each 1 by 0
and, &, ∧	10001010 ∧10001001 10001000	put 1 wherever both original numbers had 1
or, inclusive or, ∨	10001010 ∨10001001 10001011	put 1 wherever some original number had 1
eXclusive OR, XOR, ⊻	10001010 ⊻10001001 00000011	put 1 wherever the original numbers differ

Also, the ALU can shift a register's bits. For example, suppose a register contains 10111001. The ALU can shift the bits toward the right:

```
before  10111001
          ↘↘↘↘↘↘↘
after   01011100
```

It can shift the bits toward the left:

```
before  10111001
          ↙↙↙↙↙↙↙
after   01110010
```

It can rotate the bits toward the right:

```
before  10111001
        ↘↘↘↘↘↘↘↘
after   11011100
```

It can rotate the bits toward the left:

```
before  10111001
          ↙↙↙↙↙↙↙↙
after   01110011
```

It can shift the bits toward the right **arithmetically**:

```
before  10111001
        ↘↘↘↘↘↘↘
after   11011100
```

It can shift the bits toward the left arithmetically:

```
before  10111001
          ↓↙↙↙↙↙
after   11110010
```

Doubling a number is the same as shifting it left arithmetically. For example, doubling six (to get twelve) is the same as shifting six left arithmetically:

```
six     00000110
          ↓↙↙↙↙↙
twelve  00001100
```

Halving a number is the same as shifting it right arithmetically. For example, halving six (to get three) is the same as shifting six right arithmetically:

```
six     00000110
          ↘↘↘↘↘↘↘
three   00000011
```

Halving negative six (to get negative three) is the same as shifting negative six right arithmetically:

```
negative six    11111010
                ↘↘↘↘↘↘↘
negative three  11111101
```

Using the ALU, the control unit can do operations such as:

A. Find the number in the 6th memory location, and move its negative to a register.

B. Change the number in a register, by adding to it the number in the 6th memory location.

C. Change the number in a register, by subtracting from it the number in the 6th memory location.

Most computers require each operation to have one source and one destination. In operations A, B, and C, the source is the 6th memory location; the destination is the register.

The control unit can*not* do a command such as "add together the number in the 6th memory location and the number in the 7th memory location, and put the sum in a register", because that operation would require two sources. Instead, you must give two shorter commands:

1. Move the number in the 6th memory location to the register.
2. Then add to that register the number in the 7th memory location.

Flags

The CPU contains a **flag register**, which comments on what the CPU is doing. In a typical CPU, the flag register has 6 bits, named as follows:

the Negative bit
the Zero bit
the Carry bit
the Overflow bit
the Priority bit
the Privilege bit

When the CPU performs an operation (such as addition, subtraction, shifting, rotating, or moving), the operation has a source and a destination. The number that goes into the destination is the operation's **result**. The CPU automatically analyzes that result.

Negative bit If the result is a negative number, the CPU turns on the **Negative bit**. In other words, it makes the Negative bit be 1. (If the result is a number that's *not* negative, the CPU makes the Negative bit be 0.)

Zero bit If the result is zero, the CPU turns on the **Zero bit**. In other words, it makes the Zero bit be 1.

Carry bit When the ALU computes the result, it also computes an extra bit, which becomes the **Carry bit**.

For example, here's how the ALU adds 7 and -4:

```
 7 is                00000111
-4 is                11111100
binary addition gives100000011
                      ↑
                   Carry result
```

So the result is 3, and the Carry bit becomes 1.

Overflow bit If the ALU can't compute a result correctly, it turns on the **Overflow bit**.

For example, in elementary school you learned that 98+33 is 131; so in binary, the computation should look like this:

	128	64	32	16	8	4	2	1	
98 is		1	1	0	0	0	1	0	
33 is			1	0	0	0	0	1	
the sum is	1	0	0	0	0	0	1	1	which is 131

But here's what an 8-bit ALU will do:

	sign	64	32	16	8	4	2	1
98 is		1	1	0	0	0	1	0
33 is		0	0	1	0	0	0	1
the sum is	0	1	0	0	0	0	1	1

Carry result

Unfortunately, the result's leftmost 1 is in the position marked **sign**, instead of the position marked 128; so the result looks like a negative number.

To warn you that the result is incorrect, the ALU turns on the Overflow bit. If you're programming in a language such as Basic, the interpreter or compiler keeps checking whether the Overflow bit is on; when it finds that the bit's on, it prints the word OVERFLOW.

Priority bit While your program's running, it might be interrupted. Peripherals might interrupt, in order to input or output the data; the **real-time clock** might interrupt, to prevent you from hogging too much time, and to give another program a chance to run; and the computer's sensors might interrupt, when they sense that the computer is malfunctioning.

When something wants to interrupt your program, the CPU checks whether your program has priority, by checking the **Priority bit**. If the Priority bit is on, your program has priority and cannot be interrupted.

Privilege bit On a computer that's handling several programs at the same time, some operations are dangerous: if your program makes the computer do those operations, the other programs might be destroyed. Dangerous operations are called **privileged instructions**; to use them, you must be a **privileged user**.

When you walk up to a terminal attached to a large computer, and type HELLO or LOGIN, and type your user number, the operating system examines your user number to find out whether you are a privileged user. If you are, the operating system turns on the Privilege bit. When the CPU starts running your programs, **it refuses to do privileged instructions unless the Privilege bit is on**.

Microcomputers omit the Privilege bit and can't prevent you from giving dangerous commands. But since the typical microcomputer has just one terminal, the only person your dangerous command can hurt is yourself.

Levels of priority & privilege Some computers have *several* levels of priority and privilege.

If your priority level is "moderately high", your program is immune from most interruptions, but not from all of them. If your privilege level is "moderately high", you can order the CPU to do most of the privileged instructions, but not all of them.

To allow those fine distinctions, large computers devote *several* bits to explaining the priority level, and *several* bits to explaining the privilege level.

Where are the flags? The bits in the flag register are called the **flags**. To emphasize that the flags comment on your program's status, people sometimes call them **status flags**.

In the CPU, the program counter is next to the flag register. Instead of viewing them as separate registers, some programmers consider them to be parts of a single big register, called the **program status word**.

Tests You can give a command such as, "Test the 3rd memory location". The CPU will examine the number in the 3rd memory location. If that number is negative, the CPU will turn on the Negative bit; if that number is zero, the CPU will turn on the Zero bit.

You can give a command such as, "Test the difference between the number in the 3rd register and the number in the 4th. The CPU will adjust the flags according to whether the difference is negative or zero or carries or overflows.

Saying "if" The CPU uses the flags when you give a command such as, "If the Negative bit is on, go do the instruction in memory location 6".

Speed

Computers are fast. To describe computer speeds, programmers use these words:

Word	Abbreviation	Meaning
millisecond	msec or ms	thousandth of a second; 10^{-3} seconds
microsecond	μsec or μs	millionth of a second; 10^{-6} seconds
nanosecond	nsec or ns	billionth of a second; 10^{-9} seconds
picosecond	psec or ps	trillionth of a second; 10^{-12} seconds

1000 picoseconds is a nanosecond; 1000 nanoseconds is a microsecond; 1000 microseconds is a millisecond; 1000 milliseconds is a second.

On page 671 I explained that the **instruction cycle** has five steps:

A. Fetch the instruction.
B. Fetch additional parts for the instruction.
C. Update the program counter.
D. Decode the instruction.
E. Execute the instruction.

To do that entire instruction cycle, an old-fashioned computer takes about a microsecond; a modern computer takes about a nanosecond. The exact time depends on the quality of the CPU, the quality of the main memory, and the difficulty of the instruction.

Here are 5 ways to make a computer act faster:

Method	Meaning
multiprocessing	The computer holds more than one CPU. (All the CPUs work simultaneously. They share the same main memory. The operating system decides which CPU works on which program. The collection of CPUs is called a **multiprocessor**.)
instruction lookahead	While the CPU is finishing an instruction cycle (by doing steps D and E), it simultaneously begins working on the next instruction cycle (steps A and B).
array processing	The CPU holds at least 16 ALUs. (All the ALUs work simultaneously. For example, when the control unit wants to solve 16 multiplication problems, it sends each problem to a separate ALU; the ALUs compute the products simultaneously. The collection of ALUs is called an **array processor**.)
parallel functional units	The ALU is divided into several functional units: an addition unit, a multiplication unit, a division unit, a shift unit, etc. All the units work simultaneously; while one unit is working on one problem, another unit is working on another.
pipeline architecture	The ALU (or each ALU functional unit) consists of a "first stage" and a "second stage". When the control unit sends a problem to the ALU, the problem enters the first stage, then leaves the first stage and enters the second stage. But while the problem is going through the second stage, a new problem starts going through the first stage. (Such an ALU is called a **pipeline processor**.)

Parity

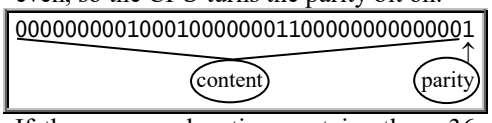
Most large computers put an extra bit at the end of each memory location. For example, a memory location in the PDP-10 holds 36 bits, but the PDP-10 puts an extra bit at the end, making 37 bits altogether. The extra bit is called the **parity bit**.

If the number of ones in the memory location is even, the CPU turns the parity bit on. If the number of ones in the memory location is odd, the CPU turns the parity bit off.

For example, if the memory location contains these 36 bits —

```
000000000100010000000110000000000000
```

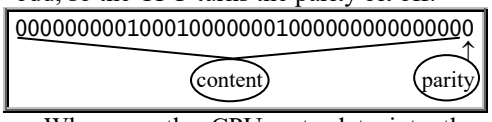
there are 4 ones, so the number of ones is even, so the CPU turns the parity bit on:



If the memory location contains these 36 bits instead —

```
000000000100010000000100000000000000
```

there are 3 ones, so the number of ones is odd, so the CPU turns the parity bit off:



Whenever the CPU puts data into the main memory, it also puts in the parity bit. Whenever the CPU grabs data from the main memory, it checks whether the parity bit still matches the content.

If the parity bit doesn't match, the CPU knows there was an error, and tries once again to grab the content and the parity bit. If the parity bit disagrees with the content again, the CPU decides that the memory is broken, refuses to run your program, prints a message saying PARITY ERROR, and then sweeps through the whole memory, checking the parity bit of every location; if the CPU finds another parity error (in your program or anyone else's), the CPU shuts off the whole computer.

Cheap microcomputers (such as the Apple 2c and Commodore 64) lack parity bits, but the IBM PC has them.

UAL

Universal Assembly Language (UAL) is a notation I invented that makes programming in assembly language easier.

UAL uses these symbols:

Symbol	Meaning
`M5`	the number in the 5th memory location
`R2`	the number in the 2nd register
`P`	the number in the program counter
`N`	the Negative bit
`Z`	the Zero bit
`C`	the Carry bit
`V`	the oVerflow bit
`PRIORITY`	the PRIORITY bits
`PRIVILEGE`	the PRIVILEGE bits
`F`	the content of the entire flag register
`F[5]`	the 5th bit in the flag register
`R2[5]`	the 5th bit in R2
`R2[LEFT]`	the left half of R2; in other words, the left half of the data in the 2nd register
`R2[RIGHT]`	the right half of R2
`M5 M6`	long number whose left half is in 5th memory location, right half is in 6th location

Here are the UAL statements:

Statement	Meaning
`R2=7`	Let number in the 2nd register be 7 (by moving 7 into the 2nd register).
`R2=M5`	Copy the 5th memory location's contents into the 2nd register.
`R2= = M5`	Exchange R2 with M5. (Put 5th location's content into 2nd register and vice versa.)
`R2=R2+M5`	Change the integer in 2nd register, by adding to it the integer in 5th location.
`R2=R2-M5`	Change the integer in 2nd register, by subtracting the integer in 5th location.
`R2=R2*M5`	Change the integer in 2nd register, by multiplying it by integer in 5th location.
`R2 REM R3=R2/M5`	Change R2, by dividing it by the integer M5. Put division's remainder into R3.
`R2=-M5`	Let R2 be the negative of M5.
`R2=NOT M5`	Let R2 be the one's complement of M5.
`R2=R2 AND M5`	Change R2, by performing the AND operation.
`R2=R2 OR M5`	Change R2, by performing the OR operation.
`R2=R2 XOR M5`	Change R2, by performing the XOR operation.
`SHIFTL R2`	Shift left.
`SHIFTR R2`	Shift right.
`SHIFTRA R2`	Shift right arithmetically.
`SHIFTR3 R2`	Shift right, 3 times.
`SHIFTR (R7) R2`	Shift right, R7 times.
`ROTATEL R2`	Rotate left.
`ROTATER R2`	Rotate right.
`TEST R2`	Examine number in 2nd register, and adjust flag register's Negative and Zero bits.
`TEST R2-R4`	Examine the difference between R2 and R4, and adjust the flag register.
`CONTINUE`	No operation. Just continue on to the next instruction.
`WAIT`	Wait until an interrupt occurs.
`IF R2<0, P=7`	If the number in the 2nd register is negative, put 7 into the program counter.
`IF R2<0, M5=3, P=7`	If R2<0, do both of the following: let M5 be 3, and P be 7.

M5 can be written as M(5) or M(2+3). It can be written as M(R7), if R7 is 5 — in other words, if register 7 contains 5.

Addressing modes

Suppose you want the 2nd register to contain the number 6. You can accomplish that goal in one step, like this:

```
R2=6
```

Or you can accomplish it in two steps, like this:

```
M5=6
R2=M5
```

Or you can accomplish it in three steps, like this:

```
M5=6
M3=5
R2=M(M3)
```

Or you can accomplish it in an even weirder way:

```
M5=6
R3=1
R2=M(4+R3)
```

Each of those methods has a name. The first method (R2=6), which is the simplest, is called **immediate addressing**. The second method (R2=M5), which contains the letter M, is called **direct addressing**. The third method (R5=M(M3)), which contains the letter M twice, is called **indirect addressing**. The fourth method (R5=M(4+R3)), which contains the letter M and a plus sign, is called **indexed addressing**.

In each method, the 2nd register is the destination. In the last three methods, the 5th memory location is the source. In the fourth method, which involves R3, the 3rd register is called the **index register**, and R3 itself is called the **index**.

Each of those methods is called an **addressing mode**. So you've seen four addressing modes: immediate, direct, indirect, and indexed.

Program counter To handle the program counter, the computer uses other addressing modes instead.

For example, suppose P (the number in the program counter) is 2073, and you want to change it to 2077. You can accomplish that goal simply, like this:

```
P=2077
```

Or you can accomplish it in a weirder way, like this:

```
P=P+4
```

Or you can accomplish it in an even weirder way, like this:

```
R3=20
P=R3 77
```

The first method (P=2077), which is the simplest, is called **absolute addressing**.

The second method (P=P+4), which involves addition, is called **relative addressing**. The "+4" is the **offset**.

The third method (P=R3 77) is called **base-page addressing**. R3 (which is 20) is called the **page number** or **segment number**, and so the 3rd register is called the **page register** or **segment register**.

Intel's details

The first **microprocessor** (CPU on a chip) was invented by Intel in 1971 and called the **Intel 4004**. Its accumulator was so short that it held just 4 bits! Later that year, Intel invented the **Intel 8008**, whose accumulator held 8 bits. In 1973 Intel invented the **Intel 8080**, which understood more op codes, contained more registers, could handle more RAM (64K instead of 16K), and ran faster. Drunk on the glories of that 8080, Microsoft adopted the phone number VAT-8080, and the Boston Computer Society adopted the soberer phone number DOS-8080.

In 1978 Intel invented the **8086**, which had a 16-bit accumulator and handled even more RAM & ROM (totalling 1 megabyte). Out of the 8086 came 16 wires (called the **data bus**), which transmitted 16 bits simultaneously from the accumulator to other computerized devices, such as RAM and disks. Since the 8086 had a 16-bit accumulator and 16-bit data bus, Intel called it a **16-bit CPU**.

But computerists complained that the 8086 was impractical, since nobody had developed RAM, disks, or other devices for the 16-bit data bus yet. So in 1979 Intel invented the **8088**, which understands the same machine language as the 8086 but has an 8-bit data bus. To transmit 16-bit data through the 8-bit bus, the 8088 sends 8 of the bits first, then sends the other 8 bits shortly afterwards. That technique of using a few wires (8) to imitate many (16) is called **multiplexing**.

When 16-bit data buses later became popular, Intel invented a slightly souped-up 8086, called the **80286** (nicknamed the **286**).

Then Intel invented a 32-bit version called the **80386** (nicknamed **386**). Intel also invented a multiplexed version called the **386SX**, which understands the same machine language as the 386 but transmits 32-bit data through a 16-bit bus (by sending 16 of the bits first, then sending the other 16). The letters "SX" mean "SiXteen-bit bus". The original 386, which has a 32-bit bus, is called the **386DX**; the letters "DX" mean "Double the siXteen-bit bus".

Then Intel invented a slightly souped-up 386DX, called the **486**. It comes in two versions: the fancy version (called the **486DX**) includes a **math coprocessor**, which is circuitry that understands commands about advanced math; the stripped-down version (called the **486SX**) lacks a math coprocessor.

Finally, Intel invented a souped-up 486DX, called a **Pentium**.

Here's how to use the 8088 and 8086. (The 286, 386, 486, and Pentium include the same features plus more.)

Registers

The CPU contains fourteen 16-bit registers:

accumulator (AX), base register (BX), count register (CX), data register (DX)
flag register (which UAL calls F)
program counter (which UAL calls P but Intel calls "instruction pointer" or IP)
stack pointer (which UAL calls S but Intel calls SP), base pointer (BP)
source index (SI), destination index (DI)
code segment (CS), data segment (DS), stack segment (SS), extra segment (ES)

In each of those registers, the sixteen bits are numbered from right to left, so the rightmost bit is called **bit 0** and the leftmost bit is called **bit fifteen**.

The AX register's low-numbered half (bits 0 through 7) is called **A low** (or **AL**). The AX register's high half (bits 8 through fifteen) is called **A high (AH)**.

In the flag register, bit 0 is the carry flag (which UAL calls **C**), bit 2 is for parity, bit 6 is the zero flag **(Z)**, bit 7 is the negative flag (which UAL calls **N** but Intel calls **sign** or **S**), bit eleven is the overflow flag **(V)**, bits 4, 8, 9, and ten are special (**auxiliary carry**, **trap**, **interrupts**, and **direction**), and the remaining bits are unused.

Memory locations

Each memory location contains a byte. In UAL, the 6th memory location is called **M6** or **M(6)**. The pair of bytes M7 M6 is called **memory word 6**, which UAL writes as **MW(6)**.

Instruction set

This page shows the set of instructions that the 8088 understands. For each instruction, I've given the assembly-language mnemonic and its translation to UAL, where all numbers are hexadecimal.

The first line says that INC (which stands for INCrement) is the assembly-language mnemonic that means x=x+1. For example, INC AL means AL=AL+1.

The eighth line says that IMUL (which stands for Integer Multiply) is the assembly-language mnemonic that means x=x*y. For example, IMUL AX,BX means AX=AX*BX.

In most equations, you can replace the x and y by registers, half-registers, memory locations, numbers, or more exotic entities. To find out what you can replace x and y by, experiment!

For more details, read the manuals from Intel and Microsoft. They also explain how to modify an instruction's behavior by using flags, segment registers, other registers, and three **prefixes**: REPeat, SEGment, and LOCK.

Math

INCrement	x=x+1
DECrement	x=x-1
ADD	x=x+y
ADd Carry	x=x+y+C
SUBtract	x=x-y
SuBtract Borrow	x=x-y-C
MULtiply	x=x*y UNSIGNED
Integer MULtiply	x=x*y
DIVide	AX=AX/x UNSIGNED
Integer DIVide	AX=AX/x
NEGate	x=-x
Decimal Adjust Add	IF AL[RIGHT]>9, AL=AL+6 IF AL[LEFT]>9, AL=AL+60
Decimal Adjust Subtr	IF AL[RIGHT]>9, AL=AL-6 IF AL[LEFT]>9, AL=AL-60
Ascii Adjust Add	IF AL[RIGHT]>9, AL=AL+6, AH=AH+1 AL[LEFT]=0
Ascii Adjust Subtract	IF AL[RIGHT]>9, AL=AL-6, AH=AH-1 AL[LEFT]=0
Ascii Adjust Multiply	AH REM AL=AL/0A
Ascii Adjust Divide	AL=AL+(0A*AH) AH=0

Logic

AND	x=x AND y
OR	x=x OR y
XOR	x=x XOR y
CoMplement Carry	C=NOT C
SHift Left	SHIFTL(y) x
SHift Right	SHIFTR(y) x
Shift Arithmetic Right	SHIFTRA(y) x
ROtate Left	ROTATEL(y) x
ROtate Right	ROTATER(y) x
Rotate Carry Left	ROTATEL(y) C x
Rotate Carry Right	ROTATER(y) C x
CLear Carry	C=0
CLear Direction	DIRECTION=0
CLear Interrupts	INTERRUPTS=0
SeT Carry	C=1
SeT Direction	DIRECTION=1
SeT Interrupts	INTERRUPTS=1
TEST	TEST x AND y
CoMPare	TEST x-y
SCAn String Byte	TEST AL-M(DI); DI=DI+1-(2*DIRECTION)
SCAn String Word	TEST AX-MW(DI); DI=DI+2-(4*DIRECTION)
CoMPare String Byte	TEST M(SI)-M(DI) SI=SI+1-(2*DIRECTION) DI=DI+1-(2*DIRECTION)
CoMPare String Word	TEST MW(SI)-MW(DI) SI=SI+2-(4*DIRECTION) DI=DI+2-(4*DIRECTION)

Moving bytes

MOVe	x=y
Load AH from F	AH=F[RIGHT]
Store AH to F	F[RIGHT]=AH
Load register and DS	x=MW(y); DS=MW(y+2)
Load register and ES	x=MW(y); ES=MW(y+2)
LOaD String Byte	AL=M(SI); SI=SI+1-(2*DIRECTION)
LOaD String Word	AX=MW(SI); SI=SI+2-(4*DIRECTION)
STOre String Byte	M(DI)=AL; DI=DI+1-(2*DIRECTION)
STOre String Word	MW(DI)=AX; DI=DI+2-(4*DIRECTION)
MOVe String Byte	M(DI)=M(SI); DI=DI+1-(2*DIRECTION) SI=SI+1-(2*DIRECTION)
MOVe String Word	MW(DI)=MW(SI) DI=DI+2-(4*DIRECTION) SI=SI+2-(4*DIRECTION)
Convert Byte to Word	AH=-AL[7]
Convert Word to Dbl	DX=-AX[0F]
PUSH	S=S-2; MW(S)=x
PUSH F	S=S-2; MW(S)=F
POP	x=MW(S); S=S+2
POP F	F=MW(S); S=S+2
IN	x=PORT(y)
OUT	PORT(x)=y
ESCape	BUS=x
eXCHanGe	x= =y
XLATe	AL=M(BX+AL)
Load Effective Address	x=ADDRESS(y)

Program counter

JuMP	P=x
Jump if Zero	IF Z=1, P=x
Jump if Not Zero	IF Z=0, P=x
Jump if Sign	IF N=1, P=x
Jump if No Sign	IF N=0, P=x
Jump if Overflow	IF V=1, P=x
Jump if Not Overflow	IF V=0, P=x
Jump if Parity	IF PARITY=1, P=x
Jump if No Parity	IF PARITY=0, P=x
Jump if Below	IF C=1, P=x
Jump if Above or Eq	IF C=0, P=x
Jump if Below or Eq	IF C=1 OR Z=1, P=x
Jump if Above	IF C=0 AND Z=0, P=x
Jump if Greater or Eq	IF N=V, P=x
Jump if Less	IF N<>V, P=x
Jump if Greater	IF N=V AND Z=0, P=x
Jump if Less or Equal	IF N<>V OR Z=1, P=x
Jump if CX Zero	IF CX=0, P=x
LOOP	CX=CX-1; IF CX<>0, P=x
LOOP if Zero	CX=CX-1; IF CX<>0 AND Z=1, P=x
LOOP if Not Zero	CX=CX-1; IF CX<>0 AND Z=0, P=x
CALL	S=S-2; MW(S)=P; P=x
RETurn	P=MW(S); S=S+2
INTerrupt	S=S-6; MW(S)=P; MW(S+2)=CS; MW(S+4)=F; P=MW(4*x); CS=MW(4*x+2) INTERRUPTS=0; TRAP=0
INTerrupt if Overflow	IF V=1, S=S-6, MW(S)=P, MW(S+2)=CS, MW(S+4)=F, P=MW(10), CS=MW(12), INTERRUPTS=0, TRAP=0
Interrupt RETurn	P=MW(S); CS=MW(S+2); F=MW(S+4); S=S+6
No Operation	CONTINUE
HaLT	WAIT
WAIT	WAIT FOR COPROCESSOR