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Que Publishing
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Introduction

“Any sufficiently advanced technology is indistinguishable from magic.”

—**Arthur C. Clarke**

SORCERERS have their magic wands—powerful, potentially dangerous tools with lives of their own. Witches have their familiars—creatures disguised as household beasts that could, if they choose, wreak the witches’ havoc. Mystics have their golems—beings built of wood and tin brought to life to do their masters’ bidding.

We have our personal computers.

PCs, too, are powerful creations that often seem to have a life of their own. Usually, they respond to a wave of a mouse or a spoken incantation by performing tasks we couldn’t imagine doing ourselves without some sort of preternatural help. But even as computers successfully carry out our commands, it’s often difficult to quell the feeling that there’s some wizardry at work here.

And then there are the times when our PCs, like malevolent spirits, rebel and open the gates of chaos onto our neatly ordered columns of numbers, our carefully wrought sentences, and our beautifully crafted graphics. When that happens, we’re often convinced that we are, indeed, playing with power not entirely under our control. We become sorcerers’ apprentices, whose every attempt to right things leads to deeper trouble.

Whether our personal computers are faithful servants or imps, most of us soon realize there’s much more going on inside those silent boxes than we really understand. PCs are secretive. Open their tightly sealed cases and you’re confronted with poker-faced components. Few give any clues as to what they’re about. Most of them consist of sphinx-like microchips that offer no more information about themselves than some obscure code printed on their impenetrable surfaces. The maze of circuit tracings etched on the boards is fascinating, but meaningless, hieroglyphics. Some crucial parts, such as the hard drive and power supply, are sealed with printed omens about the dangers of peeking inside—omens that put to shame the warnings on a pharaoh’s tomb.

This book is based on two ideas. One is that the magic we understand is safer and more powerful than the magic we don’t. This is not a hands-on how-to book. Don’t look for any instructions for taking a screwdriver to this part or the other. But perhaps your knowing more about what’s going on inside all those stoic components makes them a little less formidable when something does go awry. The second idea behind this book is that knowledge, in itself, is a worthwhile and enjoyable goal. This book is written to respond to your random musings about the goings-on inside that box you sit in front of several hours a day. If this book puts your questions to rest—or raises new ones—it will have done its job.

At the same time, however, I’m trusting that knowing the secrets behind the magician’s legerdemain won’t spoil the show. This is a real danger. Mystery is often as compelling as knowledge. I’d hate to think that anything you read in this book takes away that sense of wonder you have when you manage to make your PC do some grand, new trick. I hope that, instead, this book makes you a more confident sorcerer.

Before You Begin

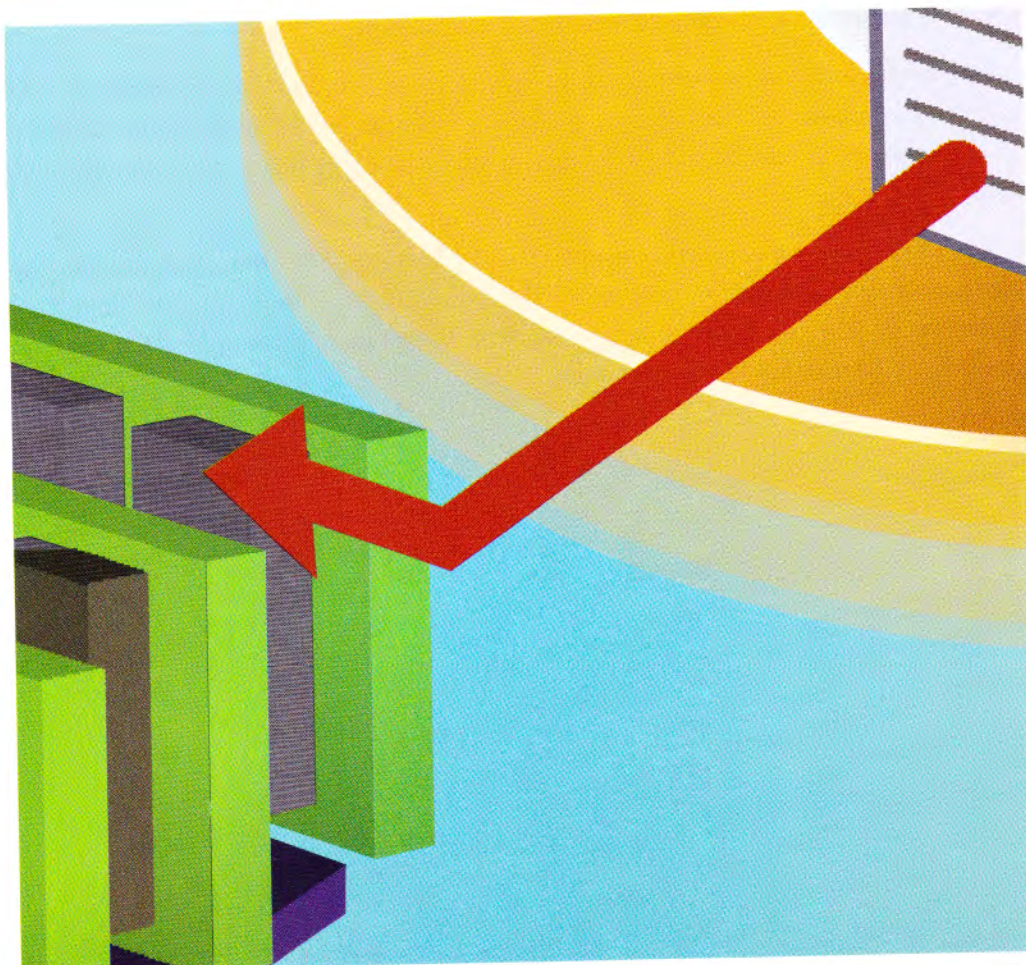
THIS book has been written with a certain type of personal computer in mind—the Wintel, a PC most often built around an Intel processor and running Microsoft Windows. Many of the specifics in these explanations apply only to that class of computer and those components.

In more general terms, the explanations also apply to Macintosh computers, Unix workstations, and even minicomputers and mainframes. But I've made no attempt to devise universal explanations of how computers work. To do so would, of necessity, detract from the understanding that comes from inspecting specific components.

Even so, there is so much variety even within the Intel/Microsoft world of PCs that, at times, I've had to limit my explanations to particular instances or stretch the boundaries of a particular situation to make an explanation as generic as possible. If you spot anything that doesn't seem quite right in this book, I hope that my liberties with the particulars is the only cause.

Ron White

San Antonio, Texas



30,000 B.C.

Paleolithic peoples in central Europe record numbers by notching tallies on animal bones, ivory, and stone.

2600 B.C.

The Chinese introduce the abacus. It was used in China for calculating the census as recently as A.D. 1982.

260 B.C.

The Maya develop a sophisticated base-20 system of mathematics that includes zero.

1500

Mechanical calculator invented by Leonardo da Vinci.

1621

William Oughtred invents the slide rule, which does not become obsolete for nearly 350 years.

1670

Gottfried Leibniz improves upon Pascaline by adding multiplication, division, and square root capabilities.

3400 B.C.

Egyptians develop a symbol for the number 10, simplifying the representation of large numbers.

300 B.C.

Euclid's Elements summarizes all the mathematical knowledge of the Greeks. It is used for the next 2,000 years.

1614

John Napier describes the nature of logarithms. He also builds Napier's Bones, the forerunner to the slide rule.

1642

Blaise Pascal invents Pascaline, the first mechanical calculator. It was hand turned and could only add and subtract.

1679

Leibniz introduces binary arithmetic.

PART

1

Boot-Up Process

CHAPTERS

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1822

Charles Babbage invents the Difference Engine, a large mechanical calculator capable of addition and subtraction.

1890

Herman Hollerith creates an electric tabulating system for U.S. Census Bureau.

1902-1905

Albert Einstein discovers Theory of Relativity. He publishes it in dissertation at University of Zurich.

1926

Patent for semiconductor transistor that allowed electrical currents to flow through computer, passing data.

1943

British build Colossus, a machine to break German codes.

1830

Charles Babbage conceives of the Analytical Engine but dies before its completion.

1896

Hollerith forms the Tabulating Machine Company, which later becomes International Business Machines.

1904

John Ambrose Fleming develops vacuum tubes.

1936

Konrad Zuse creates a programmable, digital computing machine that introduces use of binary system and valves.

1943-45

U.S. Army builds ENIAC computer to calculate weapons' trajectories.

"I think there is a world market for maybe five computers."

—Thomas Watson, chairman of IBM, 1943

BEFORE your personal computer is turned on, it is a dead collection of sheet metal, plastic, metallic tracings, and tiny flakes of silicon. When you push the On switch, one little burst of electricity—only about 3–5 volts—starts a string of events that magically brings to life what would otherwise remain an oversized paperweight.

Even with that spark of life in it, however, the PC is still stupid at first. It has some primitive sense of self as it checks to see what parts are installed and working, like those patients who've awakened from a coma and check to be sure they have all their arms and legs and that all their joints still work. But beyond taking inventory of itself, the newly awakened PC still can't do anything really useful; certainly nothing we would even remotely think of as intelligent.

At best, the newly awakened PC can search for intelligence—intelligence in the form of an operating system that gives structure to the PC's primitive, amoebic existence. Then comes a true education in the form of application software—programs that tell the PC how to do tasks faster and more accurately than we could. The PC becomes a student who has surpassed its teacher.

But not all kinds of computers have to endure such a torturous rebirth each time they're turned on. You encounter daily many computers that spring to life fully formed at the instant they're switched on. You might not think of them as computers, but they are: calculators, your car's electronic ignition, the timer in the microwave, and the unfathomable programmer in your DVR. The difference between these and the big box on your desk is hard-wiring. Computers built to accomplish only one task—and they are efficient about doing that task—are hard-wired. But that means they are more like idiot savants than sages.

What makes your PC such a miraculous device is that each time you turn it on, it is a tabula rasa, capable of doing anything your creativity—or, more usually, the creativity of professional programmers—can imagine for it to do. It is a calculating machine, an artist's canvas, a magical typewriter, an unerring accountant, and a host of other tools. To transform it from one persona to another merely requires setting some of the microscopic switches buried in the hearts of the microchips, a task accomplished by typing a command or by clicking with your mouse on some tiny icon on the screen.

1944

Harvard University and IBM develop the Mark 1, which uses IBM punched cards.

1948

ENIAC scientists create Electronic Control, the first computer firm, and begin to build UNIVAC for Census Bureau.

1951

UNIVAC delivered to U.S. Census Bureau three years late. It uses magnetic tape for input instead of punched paper.

1952

UNIVAC predicts landslide victory for Eisenhower on CBS. Human forecasts predict tight race. UNIVAC wins.

1954

IBM brings out 650, the first mass-produced computer. It's a great success, with 120 installations in first year.

1958

Control Data Corporation introduces Seymour Cray's 1604. At \$1.5 million, it's half the cost of the IBM computer.

1945

John von Neumann describes a general purpose electronic digital computer with a stored program.

1949

Popular Mechanics predicts: "Computers in the future may weigh no more than 1.5 tons."

1952

A complaint is filed against IBM, alleging monopolistic practices in its computer business.

1954

Texas Instruments announces the start of commercial production of silicon transistors.

1956

Massachusetts Institute of Technology builds the first transistorized computer.

1958

Jack Kilby completes first integrated circuit, containing five components on a single piece of silicon.

Such intelligence is fragile and short-lived. All those millions of microscopic switches are constantly flipping on and off in time to dashing surges of electricity. All it takes is an errant instruction or a stray misreading of a single switch to send this wonderful golem into a state of catatonia. Or press the Off switch and what was a pulsing artificial life dies without a whimper.

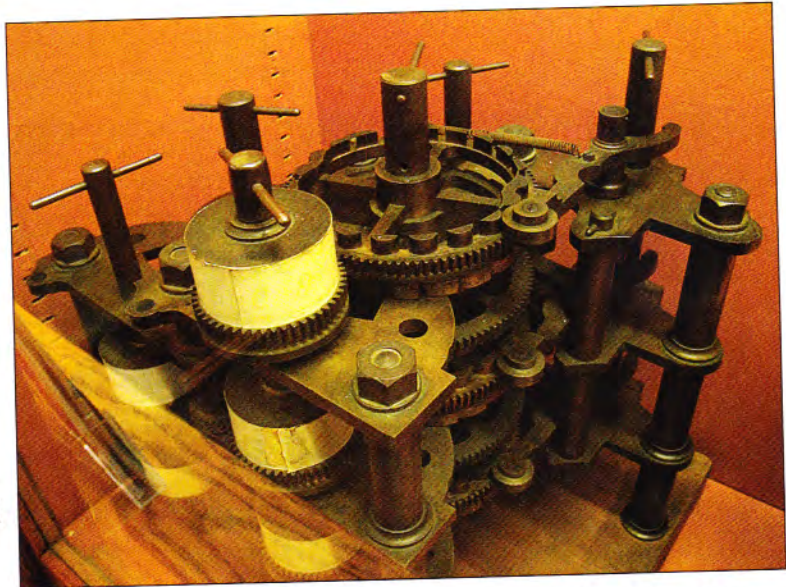
Then the next time you turn it on, birth begins all over again.

How Computers Used to Work

At the beginning of the 21st century, computers are such complex beasts—despite their relative youth—that it's difficult to imagine how such elaborate contraptions could have sprung fully grown from the brows of their creators. The explanation is, of course, that they didn't. The development of computers has been an evolutionary process, and often it's well nigh impossible to figure out which came first, the chicken of software or the egg of hardware.

Human attempts to create tools to manipulate data date back at least as far as 2600 B.C. when the Chinese came up with the abacus. Later on, Leonardo da Vinci created a mechanical calculator. When the slide rule was invented in 1621, it remained the mathematician's tool of choice until the electronic calculator took over in the early 1970s.

All the early efforts to juggle numbers had two things in common: They were mechanical and they were on a human scale. They were machines made of parts big enough to assemble by hand. Blaise Pascal's Arithmetic Machine used a system of gears turned by hand to do subtraction and addition. It also used punch cards to store data, a method that's survived well into the 20th century.



This portion of the Difference Engine #1, a forerunner to Charles Babbage's Analytical Engine—the first true computer—was completed in 1821. It contained 2,000 handmade brass parts. The entire machine would have used 25,000 parts and would have weighed 3 tons. The Analytical Engine was never completed, although part of it was built by Babbage's son, Henry, in 1910, and was found to be "buggy."

Courtesy of IBM

1960

2,000 computers are in use in the United States.

1970

Xerox creates the Palo Alto Research Center (PARC), which gave birth to many essential computer technologies.

1973

Architecture using CP/M operating system becomes the standard for the next eight years until MS-DOS is introduced.

1975

The first known use of the word Micro-soft appears in a letter from Bill Gates to his future partner, Paul Allen.

1977

Radio Shack introduces the TRS-80 Model 1, lovingly referred to by its hobbyist fans as the Trash 80.

1982

Compaq introduces the first IBM PC clone computer. Personal Computer is Time's "Man of the Year."

1986

Microsoft goes public at \$21 a share, raises \$61 million.

1965

Digital Equipment Company's first successful minicomputer, the PDP-8. At \$18,000, soon 50,000 are sold.

1971

Intel's Ted Hoff designs 4004 chip, the first micro-processor. Price \$200, with 2,300 transistors and 60,000 OPS.

1975

Popular Electronics announces the Altair 8800, the first personal computer.

1976

Stephen Jobs and Steve Wozniak show first Apple computer at Home Brew Computer Club, later known as Silicon Valley.

1981

IBM introduces its personal computer, which uses Intel's 16-bit 8086 processor.

1984

Apple introduces the Macintosh, a computer using a mouse and graphic interface.

In 1830, Charles Babbage invented—on paper—the Analytical Engine, which was different from its predecessors because, based on the results of its own computations, it could

make decisions such as sequential control, branching, and looping. But Babbage's machine was so complex that he died in 1871 without finishing it. It was built between 1989 and 1991 by dedicated members of the Science Museum in London. The physical size and complex mechanics of these mechanisms limited their usefulness; they were good for only a few tasks, and they were not something that could be mass produced.

Mechanical devices of all types flourished modestly during the first half of the 20th century. Herman Hollerith invented a mechanized system of paper cards with holes in them to tabulate the U.S. Census. Later, in 1924, Hollerith's Computing-Tabulating-Recording Company changed its name to



In 1888, Herman Hollerith, the founder of what was to become IBM, created a machine that used punched cards to tabulate the 1890 U.S. Census. The device tabulated the results in six weeks instead of the seven years it had taken to compile the census by hand.

Courtesy of Smithsonian Institute

International Business Machines.

Although no one could have known it at the time, the first breakthrough to the modern computer occurred in 1904 when John Ambrose Fleming created the first commercial diode vacuum tube, something Thomas Edison had discovered and discarded as worthless. The significance of the vacuum tube is that it was the first step beyond the human scale of machines. Until it came along, computations were made first by gears and then by switches. The vacuum tube could act as a switch turning on and off thousands of times faster than mechanical contraptions.

Vacuum tubes were at the heart of Colossus, a computer created by the British during World War II to break the codes produced by the Germans' Enigma encrypting machine. And the Germans reportedly came up with a general-purpose computer—one not limited to a specific task as Colossus was. But the German invention was lost or destroyed in the war.

The war also gave birth to ENIAC (Electronic Numerical Integrator Analyzer and Computer), built between 1943 and 1945 by the U.S. Army to produce missile trajectory tables. ENIAC performed 5,000 additions a second, although a problem that took two seconds to solve required two days to set up. ENIAC cost \$500,000, weighed 30 tons, and was 100 feet long and 8 feet high. It contained 1,500 relays and 17,468 vacuum tubes.

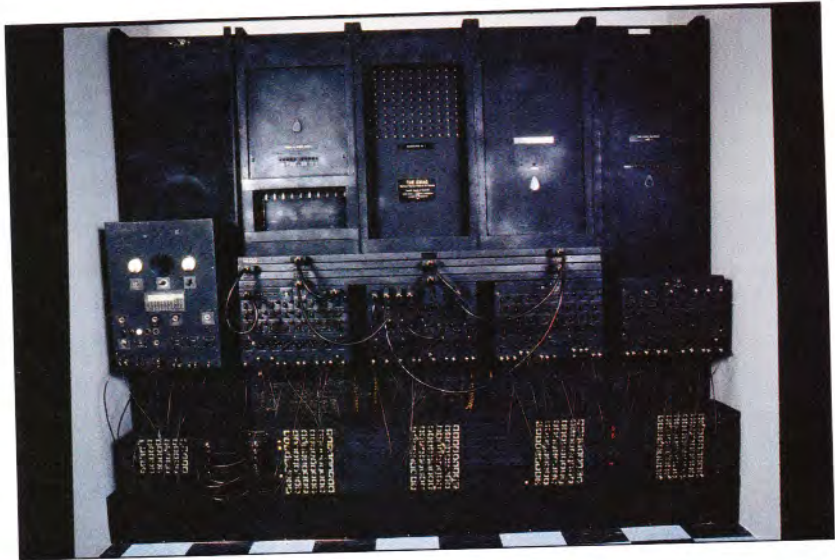
Those same tubes that made ENIAC possible in the first place were also its Achilles' heel. Consuming 200 kilowatts of electricity each hour, the tubes turned the computer into an oven, constantly cooking its own components. Breakdowns were frequent. What was needed was something that did the job of the tubes without the heat, bulk, and fragility. And that something had been around since 1926.

In 1926, the first semiconductor transistor was invented, but it wasn't until 1947, when Bell Labs' William Shockley patented the modern solid-state, reliable transistor, that a new era in computing dawned. The transistor did essentially the same thing a vacuum tube did—control the flow of electricity—but it was the size of a pea and generated little heat. Even with the transistor, the few computers built then still used tubes. It wasn't until 1954, when Texas Instruments created a way to produce silicon transistors commercially, that the modern computer took off. That same year IBM introduced the 650, the first mass-produced computer. Businesses and the government bought 120 of them the first year.

Four years later, Texas Instruments built the first integrated circuit by combining five separate components and the circuitry connecting them on a piece of germanium half an inch long. The integrated circuit led to the modern processor and has made a never-ending contribution to smaller and smaller computers.

The computer grew increasingly smaller and more powerful, but its cost, complexity, and unswerving unfriendliness kept it the tool of the technological elite. It wasn't until 1975 that something resembling a personal computer appeared. The January issue of Popular Electronics featured on its cover something called the Altair 8800, made by Micro Instrumentation and Telemetry Systems (MITS). For \$397, customers got a kit that included an Intel 8080 microprocessor and 256 bytes of memory. There was no keyboard; programs and data were both entered by clicking switches on the front of the Altair. There was no monitor. Results were read by interpreting a pattern of small red lights. But it was a real computer cheap enough for anyone to afford. MITS received orders for 4,000 Altair systems within a few weeks.

The new computer was at first a toy for hobbyists and hackers. They devised clever ways to expand the Altair and similar microcomputers with keyboards, video displays, magnetic tape, and then diskette storage. Then two hackers—Stephen Jobs and Steve Wozniak—created a personal computer that came complete with display, built-in keyboard, and disk storage, and began hawking it at computer clubs in California. They called it the Apple, and it was the first personal computer that was powerful enough,



The ENIAC, built between 1943 and 1945, was the first all-electronic computer. It used so much power that legend says the lights of surrounding Philadelphia dimmed when the ENIAC was switched on.

Courtesy of Smithsonian Institute



The first computer cheap enough for individuals to afford was the Altair 8800, created by a small New Mexico firm, MITS. It cost \$397 without a keyboard or screen.

Courtesy of The Computer Museum

and friendly enough, to be more than a toy. The Apple, along with computers from Radio Shack and Commodore, began appearing in businesses, sometimes brought in behind the backs of the people in white lab coats who ran the “real” mainframe computers in a sealed room down the hall. The information services—or IS, as the professional computer tenders came to be called—disparaged the

new computers as toys, and at the same time they saw microcomputers as a threat to their turf.



The Apple, introduced in 1976, was an immediate hit partially because a program called VisiCalc, which did the math of an electronic ledger sheet, justified the computer as a business cost.

Courtesy of Apple Corp.

residing in a single chip that defined how software was to interact with the PC’s hardware. The competition could create their own PCs as long as they duplicated the operations of IBM’s BIOS without directly copying it.

While Apple continued to keep its design proprietary, IBM’s openness encouraged the creation of IBM clones that could use the same software and hardware add-ons the PC used. And the clones, while competing with IBM, at the same time helped establish the IBM architecture as the machine for which software and add-on hardware developers would design.

KEY CONCEPTS

BIOS (basic input/output system) A collection of software codes built into a PC that handle some of the fundamental tasks of sending data from one part of the computer to another.

boot or boot-up The process that takes place when a PC is turned on and performs the routines necessary to get all the components functioning properly and the operating system loaded. The term comes from the concept of lifting yourself by your bootstraps.

circuit board Originally, wires ran from and to any component in any electrical device, not just computers. A circuit board replaces the need for separate wiring with the metallic traces printed on the board—sometimes also on the bottom of the board and in a hidden middle layer. The traces lead to connections for processors, resistors, capacitors, and other electrical components. The importance of the circuit board is that its entire creation can be automated, and the board packs more components into an ever-smaller space.

clock A microchip that regulates the timing and speed of all the computer's functions. The chip includes a crystal that vibrates at a certain frequency when electricity is applied to it. The shortest length of time in which a computer can perform some operation is one *clock*, or one vibration of the clock chip. The speed of clocks—and therefore, computers—is expressed in megahertz (MHz). One megahertz is 1 million cycles, or vibrations, a second. Thus, a PC can be described as having a 200 or 300 MHz processor, which means that the processor has been designed to work with a clock chip running at that speed.

CMOS An acronym for *complementary metaloxide semiconductor*—a term that describes how a CMOS microchip is manufactured. Powered by a small battery, the CMOS chip retains crucial information about what hardware a PC comprises even when power is turned off.

CPU An acronym for *central processing unit*, it is used to mean the *microprocessor*—also, *processor*—which is a microchip that processes the information and the code (instructions) used by a computer. The “brains” of a computer.

expansion slot Most PCs have unused slots into which the owner can plug circuit boards and hardware to add to the computer's capabilities. Most slots today are personal computer interface (PCI) or its next-generation sibling PCI-Express (PCI-E). One other slot, the accelerated graphics port (AGP), accepts a video card designed to move images out of memory quickly, although it is fast being replaced by PCI-E—you might also see shorter slots on older computers. These are industry standard architecture (ISA), the only type of slots on the first PC.

motherboard A sheet of plastic onto which metallic circuits have been printed and to the rest of the PC's components are connected. These components could be connected via a socket, such as with the CPU, a slot, as with graphics cards and memory modules or they may be built directly onto the motherboard, as with external ports, such as USB.

operating system Software that exists to control the operations of hardware. Essentially, the operating system directs any operation, such as writing data to memory or to disk, and regulates the use of hardware among several application programs that are running at the same time. This frees program developers from having to write their own code for these most basic operations.

ROM and RAM Acronyms for Read Only Memory and Random Access Memory. ROM is memory chips or data stored on disks that can be read by the computer's processor. The PC cannot write new data to those chips or disk drives. RAM is memory or disks that can be both read and written to. Random access memory really is a misnomer because even ROM can be accessed randomly. The term was originally used to distinguish RAM from data and software that was stored on magnetic tape, and which could be accessed only sequentially. That is, to get to the last chunk of data or code on a tape, a computer must read through all the information contained on the tape until it finds the location where it stored the data or code for which it is looking. In contrast, a computer can jump directly to any information stored in random locations in RAM chips or on disk.

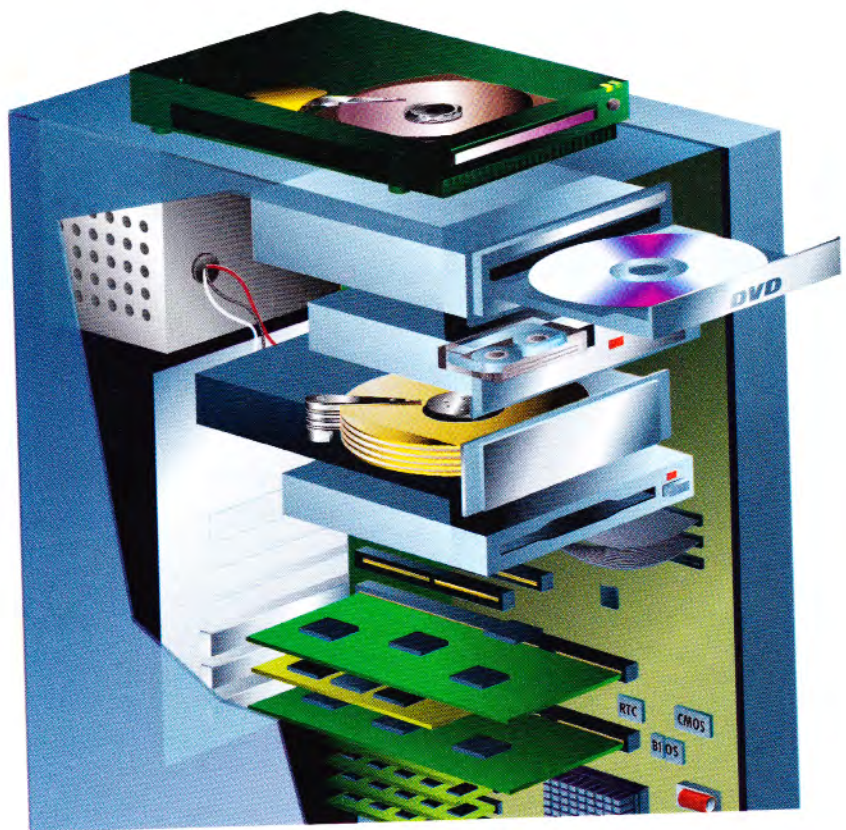
system files Small disk files that contain software code that are the first files a computer reads from disk when it is booted. The system files contain the information needed, following the initial hardware boot, to load the rest of an operating system.

write and read Writing is the process by which a computer stores data in either RAM chips or on a disk drive. Reading is the process by which a computer transfers data or software code from a drive to RAM or from RAM to the microprocessor.

CHAPTER

1

Getting to Know the Hardware



THE handy thing about gears, pulleys, and the wheel—man’s first tools—is that even someone who hasn’t seen them before can quickly figure out what they are and how they’re used. Humankind’s latest and greatest tool—the computer—isn’t nearly as obliging. It is made up of tiny rectangular blocks of plastic and cylinders of metal and ceramics that hide their inner workings. It has a maze of metallic lines, wires, and cables that would drive a lab rat schizo. The bigger components are encased in metal jackets that hide their purpose and operation. And the computer is as mute as a sphinx. The numbers and letters found on components certainly are not a part of any language you and I use.

But then, first meetings are always the most awkward. The purpose of this chapter is to get you and your PC beyond the sticky introductions so that you’re on a first name basis with most of those mysterious components. As in any relationship, somebody’s the boss. Let’s be sure it’s you by opening up your PC for a quick tour. All you’ll need is a screwdriver. Check the screws sealing the case of your PC to determine what kind of screwdriver you’ll need. Some PCs don’t even require a screwdriver; instead they employ twistable thumbscrews that require no tools at all. A flashlight will also help. One of those little mirrors dentists use will enable you to see some of the more bashful components as well.

Now, before you do anything, touch a metal portion of the computer while it’s still plugged in to discharge any static electricity that might have built up in your body and clothing. The components in your PC work with minute amounts of electrical current. A zap between your finger and some unsuspecting microchip after you’ve shuffled across a carpet on a cold, dry day is like sending the chip to the electric chair. You might not even feel the shock that kills your PC’s components, so you should always take this precaution when working on your PC.

Then shut down your PC and unplug it. This is another safety precaution, but one to protect you instead of the machine. I don’t know of anyone who has been fried by a PC, but don’t take chances. Now you can undo the screws holding your case shut. They’re usually around the edge of the back of your PC. The screws will run away if you’re not careful, so put them somewhere where they can’t get away from you. Slide off the chassis’s cover. This is not always easy, but take some comfort from the fact that taking off the cover is easier than putting it back on.

Now shine your light into the bowels of the beast. What you’re looking at is a mechanical organism of enormous complexity. If you counted the transistors in a modern PC as people, and the circuits connecting them as highways, you would be looking at something twice as enormous and intertwined as the United States—and you’re the new kid in town. The illustration on the next two pages is a map to the major landmarks of a personal computer. It tells you what each does and why you would want it on your PC. Don’t worry if you don’t have everything shown in the picture. I’ve stuffed the example with more components than most computers have in the interest of thoroughness. The components in your PC might be located in different positions, but generally they will look like the components in the illustration. Following your tour of the inside of your PC, we’ll linger at another illustration to get a close-up view of those highways of circuitry.

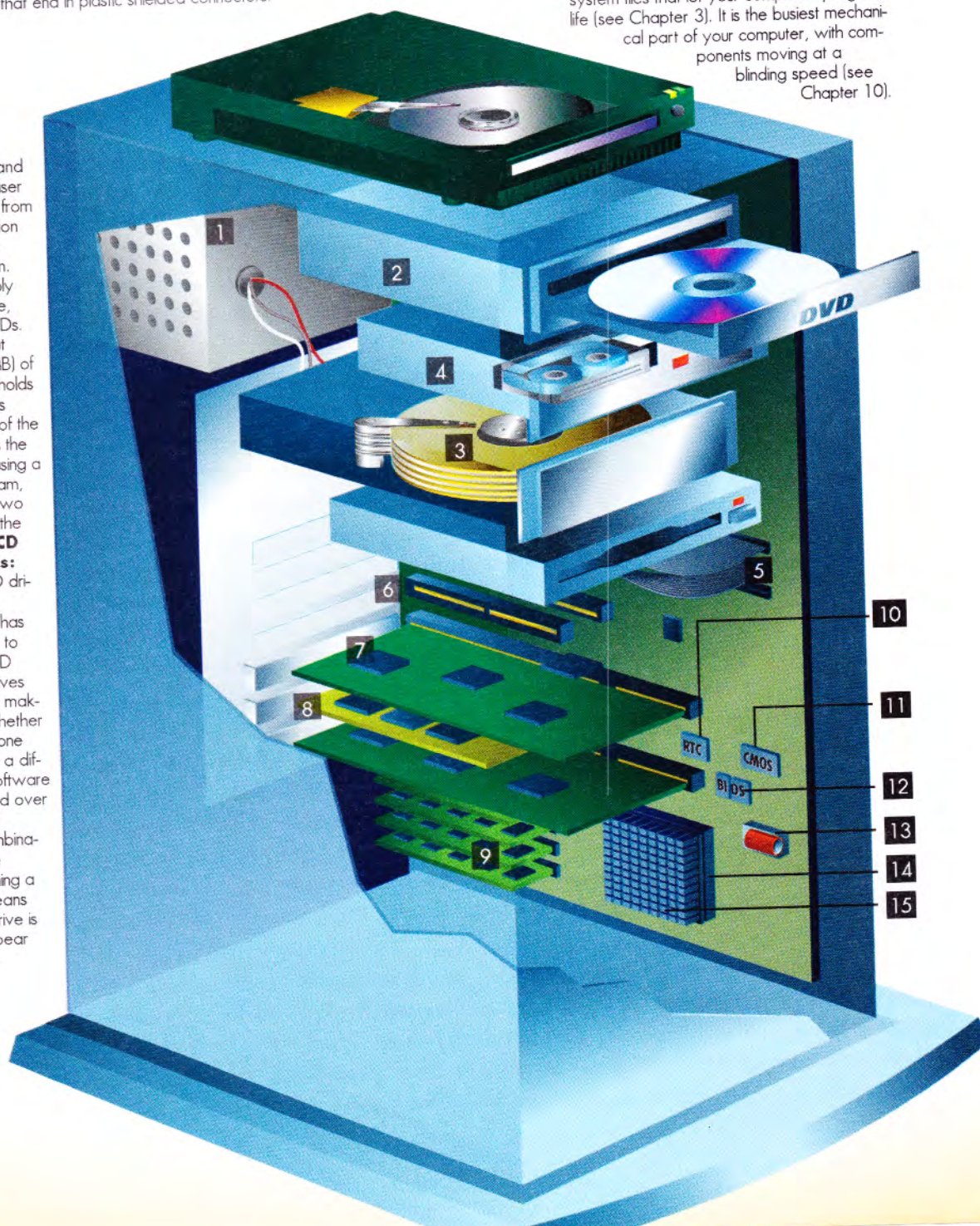
Finally, don’t worry about damaging the computer. Unless you do something really stupid—such as throwing a glass of Coke into the computer while it’s running—you won’t hurt your PC. The only component that you could conceivably damage—if you don’t count chips zapped by the homicidal static electricity—is the hard drive. The platters inside it are spinning at a breathtaking rate within fractions of a millimeter from other parts that could, if jostled, collide like race cars on Memorial Day. But don’t worry. This is going to be a midnight run.

Inside the Personal Computer

1 Power Supply: All electricity enters your PC through this shielded metal box. Inside it, a transformer converts the current that comes from standard outlets into the voltages and current flows needed by various parts of the computer. All other components, from the motherboard to disk drives, get their power through the main supply via colored wires that end in plastic shielded connectors.

3 Hard Drive: This is the main repository—in the form of magnetic recordings on hard, thin platters—of your programs and the documents on which you work. It also contains the system files that let your computer spring to life (see Chapter 3). It is the busiest mechanical part of your computer, with components moving at a blinding speed (see Chapter 10).

2 CD-ROM/DVD-ROM Drive: CD and DVD drives use a laser beam to read data from a spiral of indentation and flat areas on a layer of metallic film. New PCs now simply feature a DVD drive, which also reads CDs. The CD holds about 650 megabytes (MB) of data. A DVD disc holds about 4.7 gigabytes (GB) on each side of the disc. The DVD gets the extra storage by using a narrower laser beam, which reads from two separate layers in the DVD. **Writable CD and DVD drives:** Both CD and DVD drives are read-only devices, but each has versions that write to blank CD and DVD discs. Different drives record differently, making it uncertain whether a DVD made on one drive will play on a different drive. All software today is distributed over the Internet or on CD/DVD. In combination with writable CD/DVD becoming a standard, this means that the floppy drive is starting to disappear from the PC (see Chapter 12).



4 Floppy Drive: Here you insert a 3.5-inch floppy disk (see Chapter 11). Most floppy disks hold 1.44 MB of data, the equivalent of 500 pages of typed, unformatted, double-spaced text—a short novel. It's also used to make backup copies of files in case something happens to the original files on the hard drive, but the size of hard drives and the universal inclusion of more capacious CD and DVD drives is driving floppies into extinction (see Chapter 10).

5 Disk Controllers: The motherboards of most new PCs have two types of connections for passing data and instructions to disk drives. The older IDE controller is used for floppy and optical drives, which are inherently slower than the controllers' ability to pass signals to the drives via flat, wide ribbons containing 40-80 wires. The newer Serial-ATA (SATA) connectors are reserved for hard drives, which take better advantage of the speed with which SATA passes information along a slim four-wire cable.

6 Expansion Slot: Like disk controllers, expansion slots used to integrate new circuit boards into the motherboard, are combinations of the newest technology and legacy slots for compatibility with expansion boards still lagging behind in the engineering.

7 Video Card: Translates image information into the varying electrical currents needed to display an image on the monitor (see Chapter 17).

8 Sound Card: Contains the circuitry for recording and reproducing multimedia sound. This might be an expansion card or some computers might have it built into a few chips on the motherboard and attached by cables to external connections for amplified speakers, headphones, microphone, and CD player input (see Chapter 22).

9 RAM: Random Access Memory is a collection of microchips aligned on small circuit boards that fit into slots with a couple of hundred or more connectors. RAM is where the computer stores programs and data while it uses them. When the computer is turned off, the contents of RAM are lost (see Chapter 4).

10 Real-Time Clock: A vibrating crystal in this component is the drummer that sets the pace and synchronizes the work of all the other components (see Chapter 2).

11 CMOS: This is a special type of memory chip that uses a small battery to retain information about your PC's hardware configuration even while the computer is turned off (see Chapter 2).

12 BIOS: If the microprocessor is your PC's brains, this is the heart. It is one or two chips that define the personality, or individuality, of your computer. The BIOS (*Basic Input/Output System*) knows the details of how your PC was put together and serves as an intermediary between the operating software running your computer and the various hardware components (see Chapter 3).

13 CMOS Battery: Rarely needs changing, but if you ever have to, be sure you have a file backup of the information the CMOS chip contains (see Chapter 2).

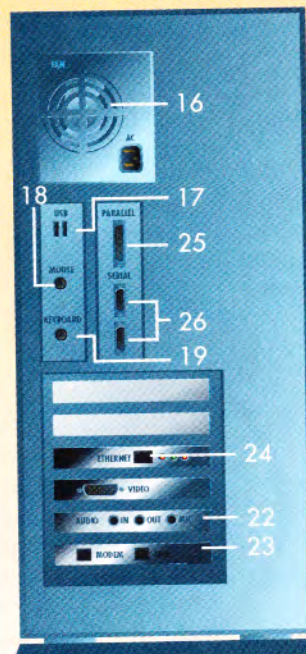
14 Microprocessor: Often called the brains of a computer, the microprocessor or central processing unit (CPU) is a tight, complex collection of transistors arranged so that they can be used to manipulate data. The processor handles most operations of your computer, the design of which dictates how software must be written to work correctly (see Chapter 5).

15 Heat Sink: Because microprocessors produce so much heat, a heat sink is used to dissipate the heat so that internal components of the chip don't melt.

16 Fan: A fan built into the power supply draws cool air over the heat-critical components inside the case. Be sure the opening to the fan is not blocked.

17 USB Ports: *Universal serial bus* ports are a solution to PCs' lack of interrupts and other system resources to let

software connect directly to peripherals. USBs can connect keyboards, input devices (mice, trackballs, etc.), flash memory drives, printers, and other devices without encountering resource conflicts (see Chapter 16).



18 Mouse Port: Also called a PS2 port, this is a standard, but waning, feature on all current PCs. Personal computers can use a mouse that connects to a serial port or USB port.

19 Keyboard Port: Keyboards are usually separate from the CPU housing and connect to a mini-DIN port, which looks identical to the PS2 port. The keyboard connection might be a larger, 5-pin round port on older systems and a USB port on newer systems.

20 Network Connector: The network connector allows you to connect your PC to a local area network (LAN) or a broadband cable or DSL modem for high-speed Internet access (see Chapter 27).

21 Parallel Port: Although falling into disuse, when the parallel port is used, it's most often to connect a printer, but some drives and other peripherals can piggyback on the port.

22 Serial Ports: Some PCs still have one or two serial ports, but they are all but obsolete because of the USB port. A PC can have four serial ports, but only two are usable at one time because one pair uses the same hardware resources as the other pair.

23 Sound Card Connections: External jacks on the sound card or motherboard enable you to attach a microphone, speakers, or an external sound source. The PC's optical drive (CD or DVD) is attached to the sound card internally (see Chapter 22).

24 Modem: Connects your PC to a telephone line so that you can get to information services and the Internet. Modems also come as external devices that connect to a serial port (see Chapter 26).

How Notebook PCs Come Together

Built-in speaker, limited in size and sometimes only monophonic, provides only basic sound capabilities.

Audio controller is built into the motherboard and leads to one or two built-in speakers.

AC adapter allows the laptop to plug into an electrical outlet, converting electricity into direct current to operate the laptop and recharge batteries.

Batteries are usually bulky and the heaviest single part of a laptop PC. Lithium-ion batteries provide the best battery life. Some notebook PCs provide a slot to include a secondary battery for longer battery time.

Fan draws heat out of the cramped quarters, where temperatures can build swiftly to a point where components would be painful to touch.

Pointing stick, which looks like a pencil eraser crammed among the keys, is used on some portables to replace the mouse.

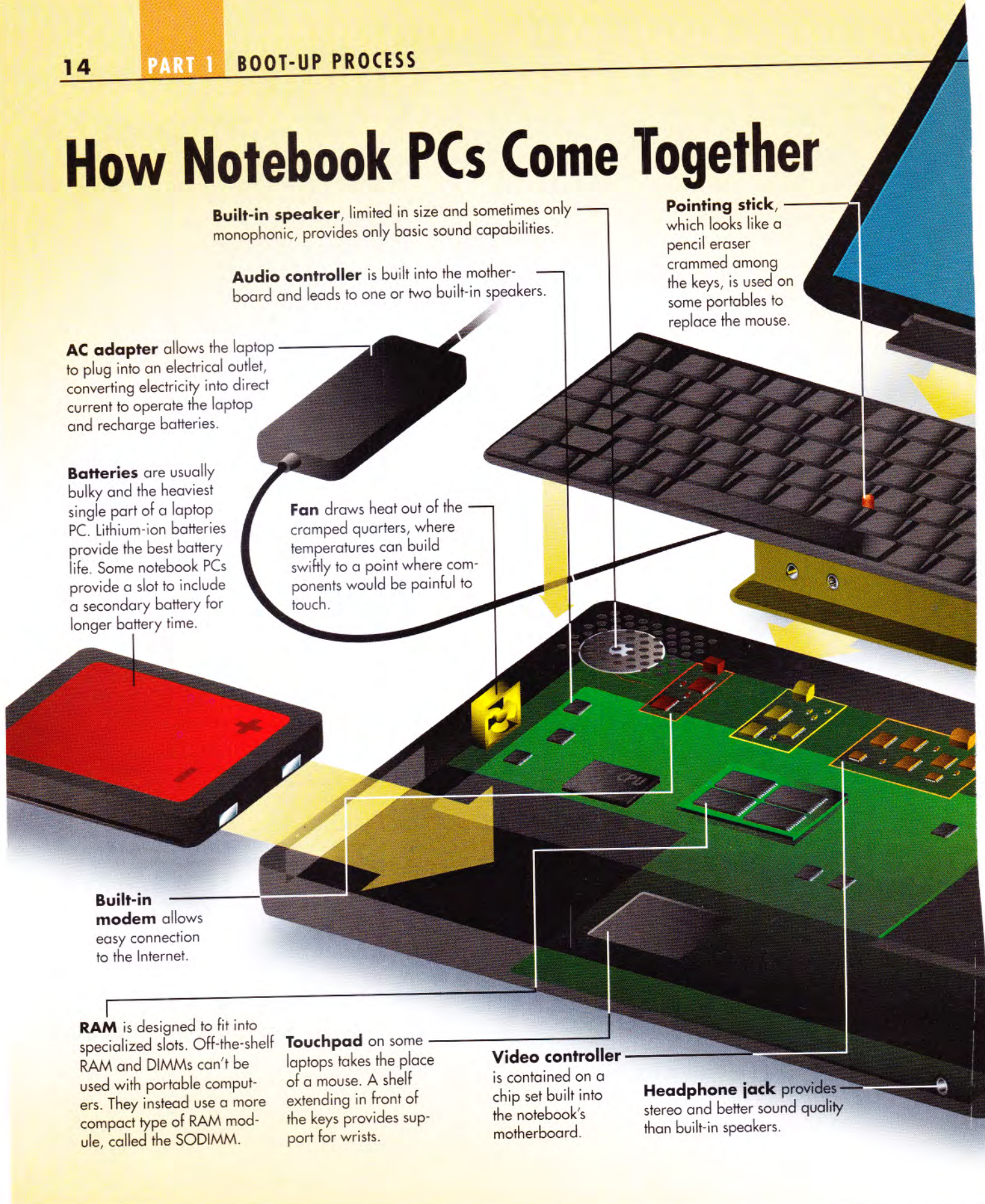
Built-in modem allows easy connection to the Internet.

RAM is designed to fit into specialized slots. Off-the-shelf RAM and DIMMs can't be used with portable computers. They instead use a more compact type of RAM module, called the SODIMM.

Touchpad on some laptops takes the place of a mouse. A shelf extending in front of the keys provides support for wrists.

Video controller is contained on a chip set built into the notebook's motherboard.

Headphone jack provides stereo and better sound quality than built-in speakers.





Liquid crystal display (LCD), a screen type that eliminates the bulkiness of desktop cathode ray tube (CRT) monitors, is **backlit** by a panel that shines light through liquid crystal cells toward the user.

Keyboards might have smaller keys to fit them all on a laptop PC's surface. The keys might also have a shorter **travel**, the distance they can be depressed.

External bus is used to connect portable PC to a **docking station**, where it can access ordinary desktop monitor, keyboard, mouse, hard drive, and printer. In addition, separate jacks on the back allow direct connection to mouse, printer, external modem, monitor, and keyboard.

Infrared port allows file transfers between a laptop and a desktop PC.

Floppy drive and Optical drive often are combined into one component, or they can be separate components that take turns using a **drive bay**. Most portables include a DVD-ROM/CD-RW drive, although many high-end notebook systems include a rewritable DVD drive.

PC card slot allows other peripherals to be added easily. A PC card can serve the functions of a hard drive, modem, wireless network connection, or connection to an external CD-ROM drive. Many laptops have two PC card slots.

How Tablet PCs Set You Free

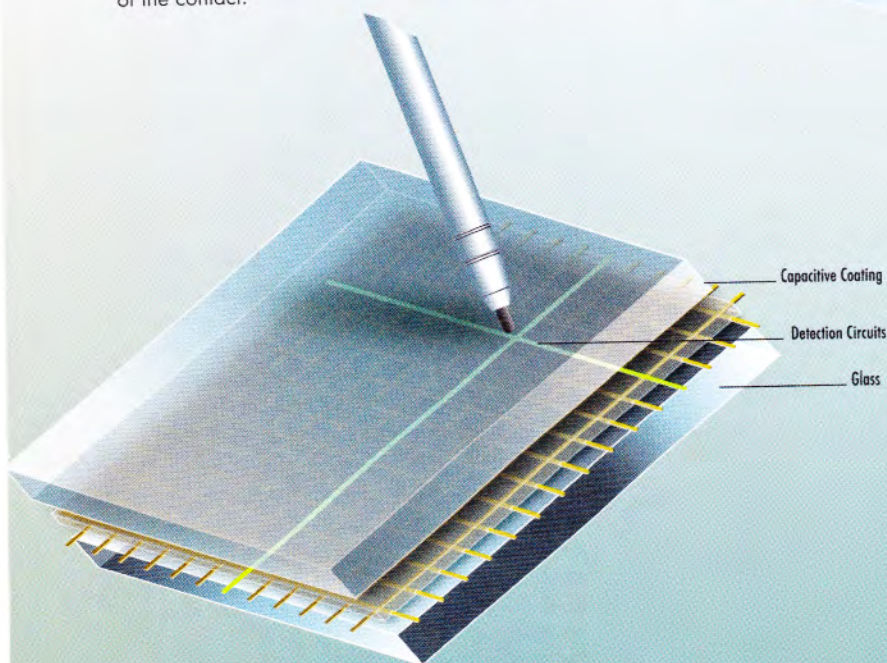
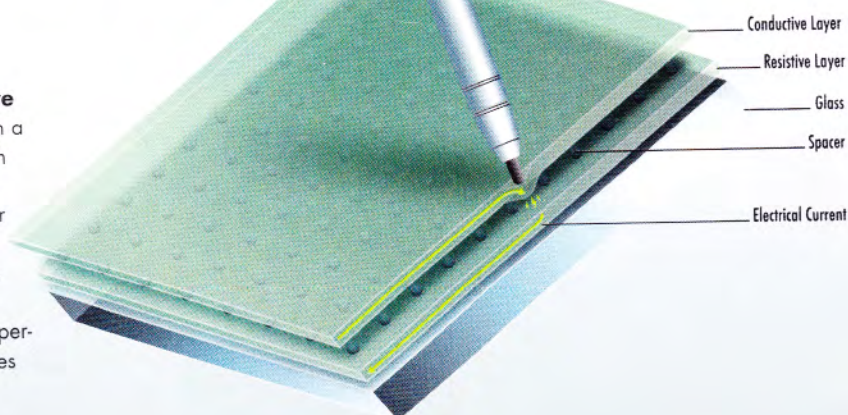
The deskless PC has long been computing's holy grail, a computer that slips the bounds of keyboard and cables, of monitor and mouse, to soar free as a bird—a bird endowed with a constant feed from the Internet, applications that will run a multinational corporation, and an easy abandon that lets it go with you anywhere, like a parrot perched on a pirate in pinstripe. Two factors foiled that quest—networking, which required an electronic umbilical cord, and haphazard human handwriting, which required a keyboard for intelligible communications. After a few false starts, the grail overflows with WiFi for always-on Internet and handwriting recognition that doesn't require you to learn a new way of writing.

How Screens Feel Your Touch

Of the dozen or so ways to design touchscreens, most of them follow a similar scheme: Within or above the layers of glass and plastic that make up the tablet computer's LCD screen—electrical capacitance, electrical resistance, light, infrared light, or sound waves. When a stylus or finger disrupts whatever makes up the field, sensors measure the disruption and calculate where it must have happened. There are a couple of exceptions to this, as we'll see while we look at some of the more common implementations of touchscreens.

Resistive System

The screen on a tablet PC using the **resistive system** includes a glass panel covered with a thin metallic layer made of a substance, such as indium tin oxide, that conducts electricity. Spacers on the layer support a metallic layer that resists the flow of electricity. When you touch the screen with your finger or a stylus, the two layers make contact, changing the electrical field produced by the layers. This permits the computer to calculate the coordinates of the contact.

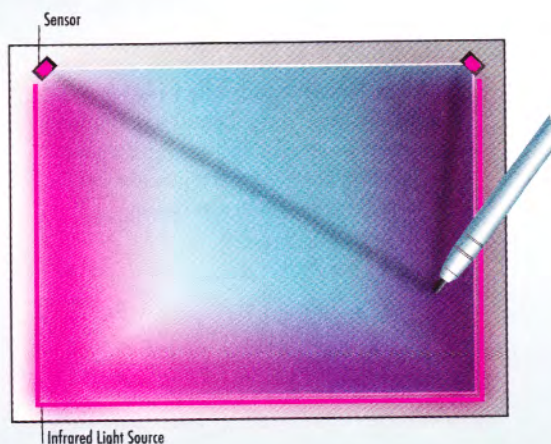
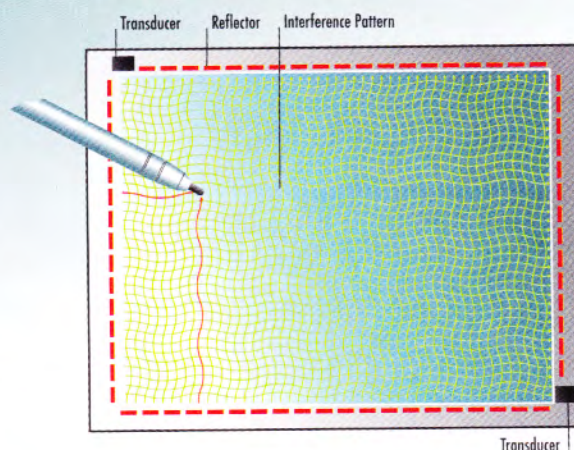


Capacitive Touchscreen

In a **capacitive system**, a transparent material that stores an electrical charge covers the screen's glass panel. When you touch the monitor, some of the charge is transferred to your finger and the capacitive layer's charge decreases. Circuits at each corner of the screen constantly measure the change in the charge reaching them. From those measurements, the computer calculates where the touch occurred.

Surface Acoustic Wave

A tablet PC using a **surface acoustic wave system** has two **transducers**, such as piezoelectric devices, that translate energy into movement and back again. Placed on the X and Y axes of the screen, one transducer converts electrical signals into ultrasonic vibrations that travel through the screen to the second transducer, which converts the vibrations back into electrical current. Also on the screens are reflectors, which reflect the vibrations. Because the reflected vibrations travel different paths, they arrive at the receiving transducer **out of phase**, producing an interference pattern. Something touching the screen's face also produces an interference pattern. The computer deciphers the changes in the signals' wave pattern to determine exactly where the screen was touched.

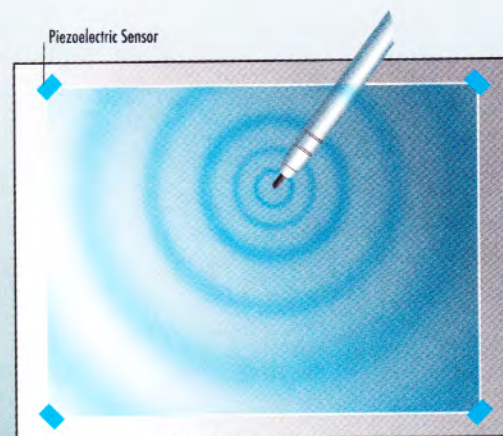


Optical Imaging

Two or more simple **image sensors** overlook the screen, usually from the corners. Opposite the sensors are infrared backlights positioned so the sensors constantly detect the infrared lights. A touch on the screen is detected as a shadow by the sensors. By coordinating the position of the shadow as detected by each sensor, a signal processor built into the screen determines where the touch took place.

Dispersive Signal Sensing

Touchscreens equipped with **dispersive signal sensing** technology work without special layers or elements that emit a field of signals to be disrupted by a touch. Instead, this system measures the strengths of **bend waves** produced in the screen's glass surface by the pressure placed on the screen when it is touched. As the waves **disperse** through the glass, they become **smeared**—the faster high frequencies separate from the slower low frequencies. The farther the waves travel, the more they are smeared. Piezoelectric sensors positioned at each corner convert the smeared waves into electrical impulses a processor uses to determine the position of the touch.

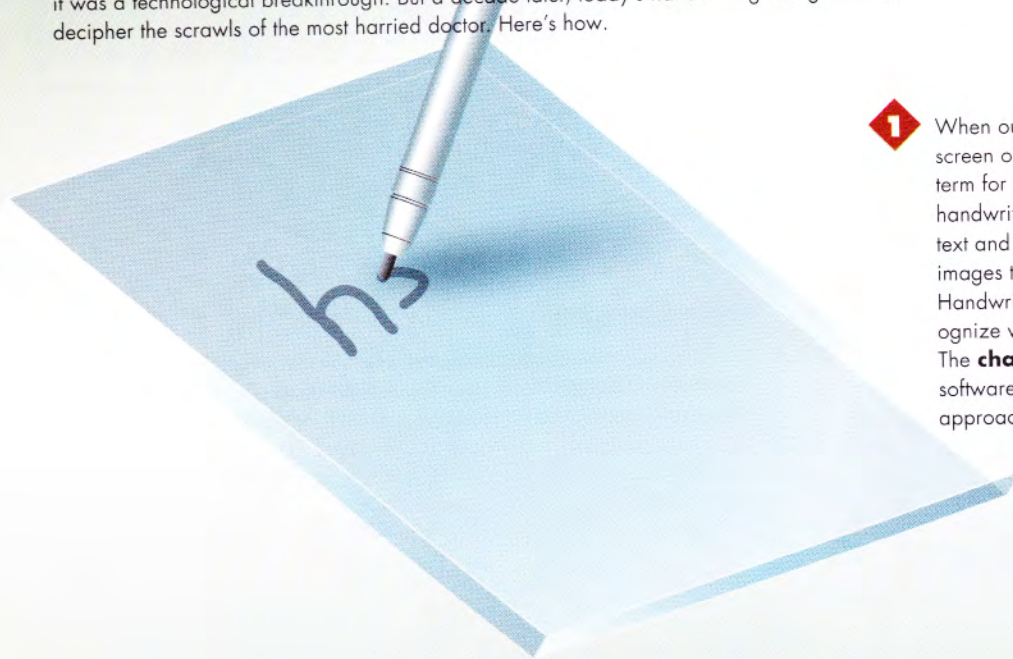


What's Got the Touch?

Not all objects register equally well on all types of touch-sensitive screens. Just about anything will work with a resistive system, provided it makes the two metallic layers touch each other. But a capacitive system registers only touches from objects that have their own electromagnetic fields. That can be your finger or a stylus that picks up an electrical charge from your hand. The wave system is similar to a resistor touchscreen except it does not accurately register hard, small objects such as the tip of a stylus. Both image sensing and dispersive signal processing have the advantage that no light-absorbing layers are embedded in the screen, making the screen's image brighter.

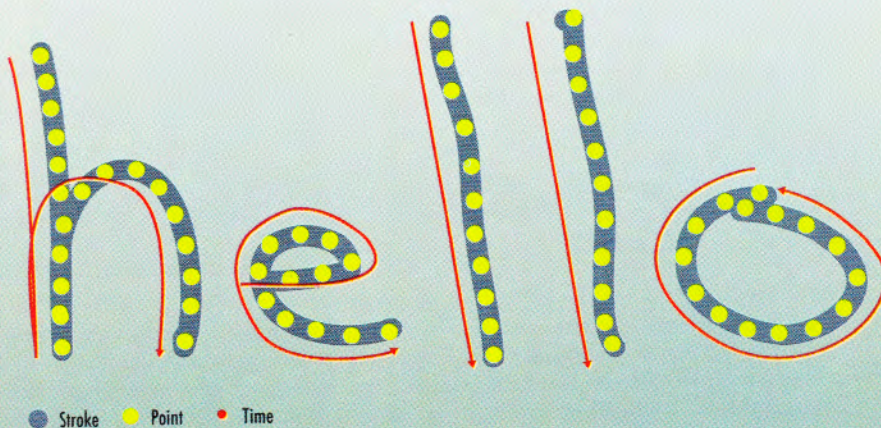
How Tablet PCs Read Your Handwriting

Early attempts at a computer screen that could convert handwriting into editable text, such as the Palm, required users to write in a special alphabet. As awkward as that seems today, at the time, it was a technological breakthrough. But a decade later, today's handwriting recognition can decipher the scrawls of the most harried doctor. Here's how.

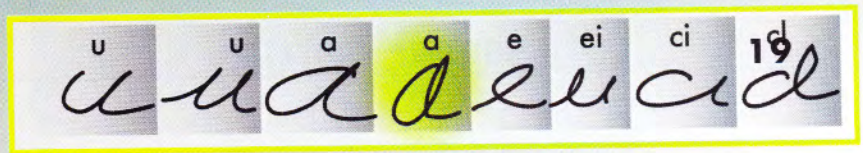


1 When our hypothetical doctor writes on the screen of a tablet PC, he creates **ink**, the term for both a touchscreen's display of handwriting before it is turned into digital text and for drawings, arrows, and other images that should not be turned into text. Handwriting recognition's first job is to recognize what is handwriting and what isn't. The **character expert** in the recognition software begins with a two-pronged approach.

2 One approach is **stroke timing**. An ink pattern is interpreted as a sequence of points on a flat surface. Their sequence is based on the timing with which each point appeared. The ink not only has a shape, but it has a trajectory that aids in determining what the ink represents. A lowercase "g" and "q" can both contain closed loops whose distinctions are too subtle for a computer to recognize. But given the trajectories of the strokes in the two characters, a tablet PC can easily discern the two.



● Stroke ● Point ● Time



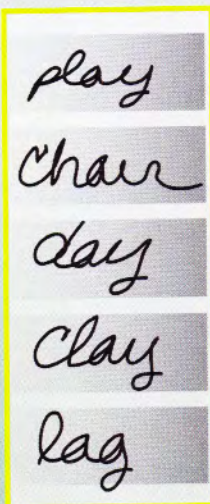
3 The other approach is a **spatial matrix**. The recognition software plots the digital ink on a matrix with X and Y axes and a point of origin. The software compares the matrix plot to a database of shapes, any of which may be used to represent a specific letter, and selects the closest match.

clay

4 Because a tablet is designed to recognize script handwriting as well as printed block letters, a **segmentation expert** analyzes the ink to decide where a continuous stream of ink should be divided to yield individual characters. For example, if the doctor writes "clay" in script as one continuous application of ink, the work can be divided at least three ways.



5 As in the example of "clay," there is no way to determine the correct translation of ink to text by visual examination alone. The recognition software relies on the **language expert** to identify the word by comparing it to an exhaustive database of words, lexicons, regular expressions, idioms, and language models. If only one choice emerges, the expert picks that choice unaided. If there is some ambiguity, the software presents the doctor with a list of alternative possibilities. This method of recognizing words by looking at them in context is more accurate than recognizing individual letters when the words written by the doctor are in the expert's database.



clay

6 In Windows XP, users could not train their computer to better recognize their handwriting. The only way to get better results was for users to retrain themselves to write more carefully. In Windows Vista, however, the handwriting engine gives users the option of correcting specific errors and then it learns from the corrections. The software also pays attention to the words used in email and incorporates them into its dictionaries.



clay