

1.3.1 Moore's Law

Every year, you probably expect to pay at least a little more for most products and services. The opposite has been the case in the computer and communications fields, especially with regard to the costs of hardware supporting these technologies. For many decades, hardware costs have fallen rapidly. Every year or two, the capacities of computers have approximately *doubled* inexpensively. This remarkable trend often is called **Moore's Law**, named for the person who identified it in the 1960s, Gordon Moore, co-founder of Intel—the leading manufacturer of the processors in today's computers and embedded systems. Moore's Law and related observations apply especially to the amount of memory that computers have for programs, the amount of secondary storage (such as disk storage) they have to hold programs and data over longer periods of time, and their processor speeds—the speeds at which computers execute their programs (i.e., do their work). Similar growth has occurred in the communications field, in which costs have plummeted as enormous demand for communications bandwidth (i.e., information-carrying capacity) has attracted intense competition. We know of no other fields in which technology improves so quickly and costs fall so rapidly. Such phenomenal improvement is truly fostering the *Information Revolution*.

1.3.2 Computer Organization

Regardless of differences in *physical* appearance, computers can be envisioned as divided into various **logical units** or sections (Fig. 1.2).

Logical unit	Description
Input unit	This “receiving” section obtains information (data and computer programs) from input devices and places it at the disposal of the other units for processing. Most information is entered into computers through keyboards, touch screens and mouse devices. Other forms of input include receiving voice commands, scanning images and barcodes, reading from secondary storage devices (such as hard drives, DVD drives, Blu-ray Disc™ drives and USB flash drives—also called “thumb drives” or “memory sticks”), receiving video from a webcam and having your computer receive information from the Internet (such as when you stream videos from YouTube™ or download e-books from Amazon). Newer forms of input include position data from a GPS device, and motion and orientation information from an accelerometer in a smartphone or game controller (such as Microsoft® Kinect™, Wii™ Remote and Sony's PlayStation® Move).
Output unit	This “shipping” section takes information that the computer has processed and places it on various output devices to make it available for use outside the computer. Most information that's output from computers today is displayed on screens, printed on paper (“going green” discourages this), played as audio or video on PCs and media players (such as Apple's popular iPods) and giant screens in sports stadiums, transmitted over the Internet or used to control other devices, such as robots and “intelligent” appliances.

Fig. 1.2 | Logical units of a computer. (Part 1 of 2.)

Logical unit	Description
Memory unit	This rapid-access, relatively low-capacity “warehouse” section retains information that has been entered through the input unit, making it immediately available for processing when needed. The memory unit also retains processed information until it can be placed on output devices by the output unit. Information in the memory unit is <i>volatile</i> —it’s typically lost when the computer’s power is turned off. The memory unit is often called either memory or primary memory . Main memories on desktop and notebook computers commonly contain as much as 16 GB (GB stands for gigabytes; a gigabyte is approximately one billion bytes).
Arithmetic and logic unit (ALU)	This “manufacturing” section performs <i>calculations</i> , such as addition, subtraction, multiplication and division. It also contains the <i>decision</i> mechanisms that allow the computer, for example, to compare two items from the memory unit to determine whether they’re equal. In today’s systems, the ALU is usually implemented as part of the next logical unit, the CPU.
Central processing unit (CPU)	This “administrative” section coordinates and supervises the operation of the other sections. The CPU tells the input unit when information should be read into the memory unit, tells the ALU when information from the memory unit should be used in calculations and tells the output unit when to send information from the memory unit to certain output devices. Many of today’s computers have multiple CPUs and, hence, can perform many operations simultaneously. A multi-core processor implements multiple processors on a single integrated-circuit chip—a <i>dual-core processor</i> has two CPUs and a <i>quad-core processor</i> has four CPUs. Today’s desktop computers have processors that can execute billions of instructions per second.
Secondary storage unit	This is the long-term, high-capacity “warehousing” section. Programs or data not actively being used by the other units normally are placed on secondary storage devices (e.g., your <i>hard drive</i>) until they’re again needed, possibly hours, days, months or even years later. Information on secondary storage devices is <i>persistent</i> —it’s preserved even when the computer’s power is turned off. Secondary storage information takes much longer to access than information in primary memory, but the cost per unit of secondary storage is much less than that of primary memory. Examples of secondary storage devices include CD drives, DVD drives and flash drives, some of which can hold up to 768 GB. Typical hard drives on desktop and notebook computers can hold up to 2 TB (TB stands for terabytes; a terabyte is approximately one trillion bytes).

Fig. 1.2 | Logical units of a computer. (Part 2 of 2.)

1.4 Data Hierarchy

Data items processed by computers form a **data hierarchy** that becomes larger and more complex in structure as we progress from bits to characters to fields, and so on. Figure 1.3 illustrates a portion of the data hierarchy. Figure 1.4 summarizes the data hierarchy’s levels.