

# chapter 3

## Storage

After completing this chapter, you will be able to do the following:

1. Name several general characteristics of storage systems.
2. Describe the two most common types of hard drives and what they are used for today.
3. Discuss the various types of optical discs available today and how they differ from each other.
4. Identify some flash memory storage devices and media and explain how they are used today.
5. List at least three other types of storage systems.
6. Summarize the storage alternatives for a typical personal computer.

## outline

### Overview

#### Storage Systems Characteristics

- Storage Media and Storage Devices
- Volatility
- Random vs. Sequential Access
- Logical vs. Physical Representation
- Type of Storage Technology Used

#### Hard Drives

- Magnetic Hard Drives and Solid-State Drives (SSDs)
- Internal and External Hard Drives
- Hard Drive Speed, Disk Caching, and Hybrid Hard Drives
- Hard Drive Partitioning and File Systems
- Hard Drive Interface Standards

#### Optical Discs and Drives

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- Recordable Optical Discs: CD-R, DVD-R, DVD+R, and BD-R Discs
- Rewritable Optical Discs: CD-RW, DVD-RW, DVD+RW, and BD-RE Discs

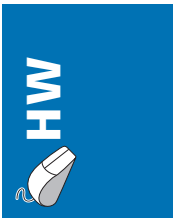
#### Flash Memory Storage Systems

- Embedded Flash Memory
- Flash Memory Cards and Readers
- USB Flash Drives

#### Other Types of Storage Systems

- Network Storage and Online/Cloud Storage Systems
- Smart Cards
- Holographic Storage
- Storage Systems for Large Computer Systems

#### Evaluating Your Storage Alternatives



## OVERVIEW

In Chapter 2, we discussed the role of RAM, the computer's main memory. RAM temporarily holds program instructions, data, and output while they are needed by the computer. For instance, when you first create a letter or other word processing document on your computer, both the word processing program and the document are temporarily stored in RAM. But when the word processing program is closed, the computer no longer needs to work with the program or the document, and so they are both erased from RAM. Consequently, anything (such as your word processing document) that needs to be preserved for future use needs to be stored on a more permanent medium. Storage systems fill this role.

We begin this chapter with a look at the characteristics common among all storage systems. Then, we discuss the primary storage for most personal computers—the hard drive. From there, we turn our attention to optical discs, including how they work and the various types of optical discs available today. Next, we discuss flash memory storage systems, followed by a look at a few other types of storage systems, including network and online/cloud storage, smart cards, holographic storage, and the storage systems used with large computer systems. The chapter concludes with a discussion about evaluating the storage alternatives for a typical personal computer. ■

## STORAGE SYSTEMS CHARACTERISTICS

All *storage systems* have specific characteristics, such as including both a *storage medium* and a *storage device*, how portable and volatile the system is, how data is accessed and represented, the type of storage technology used, and so on. These characteristics are discussed in the next few sections.

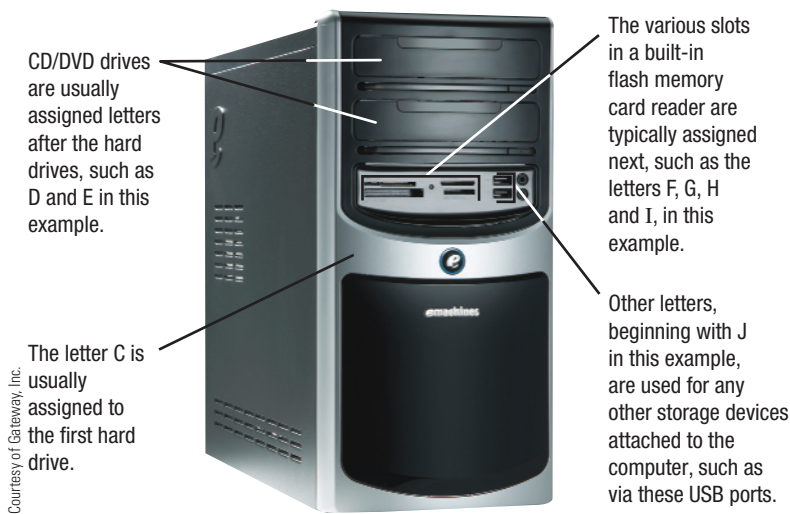
### Storage Media and Storage Devices

There are two parts to any storage system: the **storage medium** and the **storage device**. A storage medium is the hardware where data is actually stored (for example, a *DVD* or a *flash memory card*); a storage medium is inserted into its corresponding storage device (such as a *DVD drive* or a *flash memory card reader*) in order to be read from or written to. Often the storage device and storage medium are two separate pieces of hardware (that is, the storage medium is *removable*), although with some systems—such as a *hard drive* or most *USB flash drives*—the two parts are permanently sealed together to form one piece of hardware.

Storage devices can be *internal* (located inside the system unit), *external* (plugged into an external port on the system unit), or *remote* (located on another computer, such as a network server or Web server). Internal devices have the advantage of requiring no additional

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>**Storage medium.** The part of a storage system, such as a DVD disc, where data is stored. >**Storage device.** A piece of hardware, such as a DVD drive, into which a storage medium is inserted to be read from or written to.



**FIGURE 3-1**

**Storage device identifiers.**

To keep track of storage devices in an unambiguous way, the computer system assigns letters of the alphabet or names to each of them.

**TIP**

Although most computers today typically do not include a *floppy drive* (an older drive that was used with small *floppy disks*), the drive letters A and B are still often reserved for floppy drives so you may not have a drive A or B on your computer.

desk space and are usually faster than their external counterparts. External devices, however, can be easily transported from one location to another (such as to share data with others, to transfer data between a work computer and a home computer, or to take digital photos to a photo store). They can also be removed from the computer and stored in a secure area (such as for backup purposes or to protect sensitive data). Remote devices are accessed over a network. Some remote storage devices, such as those accessed via the Internet, have the additional advantage of being accessible from any computer with an Internet connection.

Regardless of how storage devices are connected to a computer, letters of the alphabet and/or names are typically assigned to each storage device so that the user can identify each device easily when it needs to be used (see Figure 3-1). Some drive letters, such as the letter C typically used with the primary hard drive, are usually consistent from computer to computer and do not change even if more storage devices are added to the computer.

The rest of the drive letters on a computer may change as new devices are added either permanently (such as when an additional hard drive is installed inside the computer) or temporarily (such as when a USB flash drive, digital camera, or portable digital media player is connected to the computer). When a new storage device is detected, the computer just assigns and reassigns drive letters, as needed.

**Volatility**

As discussed in Chapter 2, conventional RAM is volatile so programs and documents held in RAM are erased when they are no longer needed by the computer or when the power to the computer is turned off. Storage media, however, are nonvolatile, so the data remains on the media even when the power to the computer or storage device is off. Consequently, storage media are used for anything that needs to be saved for future use.

**Random vs. Sequential Access**

When the computer receives an instruction that requires data located on a storage medium, it must go to the designated location on the appropriate storage medium and retrieve the requested data. This procedure is referred to as access. Two basic access methods are available: *random* and *sequential*.

*Random access*, also called *direct access*, means that data can be retrieved directly from any location on the storage medium, in any order. A random access device works in a manner similar to a CD or DVD player used to play music or movies; that is, it can jump directly to a particular location on the medium when data located at that location is needed. Virtually all storage devices used with computers today for day-to-day storage—including hard drives, CD/DVD drives, and USB flash drives—are random access devices.

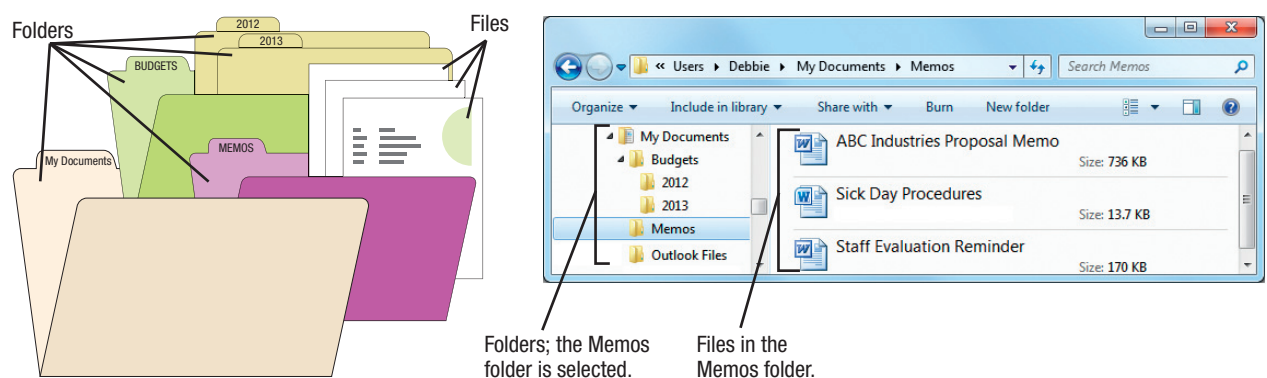
Media that allow random access are sometimes referred to as *addressable* media. This means that the storage system can locate each piece of stored data at a unique *address*, which is determined by the computer system. With *sequential access*, however, the data can only be retrieved in the order in which it is physically stored on the medium. One type of storage device that is sometimes used with computers for backup purposes and that uses sequential access is a *magnetic tape drive*. Computer tapes work like audiocassette tapes or videotapes—to get to a specific location on the tape, you must play or fast forward through all of the tape that comes before the location you want to access.

## Logical vs. Physical Representation

Anything (such as a program, letter, digital photograph, or song) stored on a storage medium is referred to as a **file**. Data files are also often called *documents*. When a document that was just created (such as a memo or letter in a word processing program) is saved, it is stored as a new file on the storage medium that the user designates. During the storage process, the user is required to give the file a name, called a **filename**; that filename is used to retrieve the file when it is needed at a later time.

To keep files organized, related documents are often stored in **folders** (also called *directories*) located on the storage medium. For example, one folder might contain memos to business associates while another might hold a set of budgets (see Figure 3-2). To organize files further, you can create *subfolders* (*subdirectories*) within a folder. For instance, you might create a subfolder within the *Budgets* subfolder for each fiscal year. In Figure 3-2, both *Budgets* and *Memos* are subfolders inside the *My Documents* folder; the *Budgets* subfolder contains two additional subfolders (*2012* and *2013*).

Although both the user and the computer use drive letters, folder names, and filenames to save and retrieve documents, they perceive them differently. The user typically views how data is stored (what has been discussed so far in this section and what appears in the *Windows Explorer* file management program screen shown in Figure 3-2) using *logical file representation*. That is, individuals view a document stored as one complete unit in a particular folder on a particular drive. Computers, however, use *physical file representation*; that is, they access a particular document stored on a storage medium using its physical location or locations. For example, the *ABC Industries Proposal Memo* file shown in Figure 3-2 is *logically* located in the *Memos* folders in the *My Documents* and *Debbie* folders on the hard drive C, but the content of this file could be *physically* stored in many different pieces scattered across that hard drive. When this occurs, the computer keeps track of the various physical locations used to store that file, as well as the logical representations (filename, folder names, and drive letter) used to identify that file, in order to retrieve the entire file when needed. Fortunately, users do not have to be concerned with how files are physically stored on a storage medium because the computer keeps track of that information and uses it to retrieve files whenever they are requested.



**FIGURE 3-2**  
Organizing data.  
Folders are used to organize related items on a storage medium.

> **File.** Something stored on a storage medium, such as a program, a document, or an image. > **Filename.** A name given to a file by the user; it is used to retrieve the file at a later time. > **Folder.** A named place on a storage medium into which files can be stored to keep the files stored on that medium organized.

**TIP**

Use the term *disks* when referring to magnetic media; use the term *discs* when referring to optical media.

## Type of Storage Technology Used

Data is stored *magnetically* or *optically* on many types of storage media. With magnetic storage systems, such as conventional hard drives, data is stored magnetically on the storage medium, which means the data (0s and 1s) is represented using different magnetic alignments. The storage device can change the magnetic alignment when needed, so data can be written to the medium, deleted from the medium, or rewritten to the medium. Optical storage media (such as CDs and DVDs) store data optically using laser beams. On some optical media, the laser burns permanent marks to represent 0s and 1s into the surface of the medium so the data cannot be erased or rewritten. With *rewritable* optical media, the laser changes the reflectivity of the medium to represent 0s and 1s but it does not permanently alter the disc surface so the reflectivity of the medium can be changed back again as needed. Consequently, the data stored on a rewritable optical disc can be changed.

Some storage systems use a combination of magnetic and optical technology. Others use a different technology altogether, such as *flash memory storage systems* that represent data using *electrons* (electrons are either trapped or not trapped inside *flash memory cells* to represent 0s and 1s). Some of the most widely used storage systems are discussed next.

## HARD DRIVES

With the exception of computers designed to use only network storage devices (such as network computers and some Internet appliances), virtually all personal computers come with a **hard drive** that is used to store most programs and data. *Internal hard drives* (those located inside the system unit) are not designed to be removed, unless they need to be repaired or replaced. *External hard drives* typically connect to a computer via a USB or FireWire port and are frequently used for additional storage (such as for digital photos, videos, and other large multimedia files), to move files between computers, and for backup purposes. In addition to being used with computers, hard drives are also increasingly being incorporated into other consumer products, such as mobile phones, portable digital media players, digital video recorders (DVRs), gaming consoles, digital camcorders, and more.

For security purposes, both internal and external hard drives today are increasingly coming with built-in *encryption* that automatically encrypts (essentially scrambles) all data stored on the hard drive and limits access to the hard drive to only authorized users, typically via a *password* or fingerprint scan (see Figure 3-3). Encryption, passwords, and fingerprint readers are discussed in detail in Chapter 9.

### Magnetic Hard Drives and Solid-State Drives (SSDs)

Traditional hard drives are *magnetic hard drives* that contain *magnetic hard disks*, *read/write heads*, and an *access mechanism*. Data is written to the magnetic hard disks by read/write heads, which magnetize particles a certain way on the surface of the disks to represent the data's 0s and 1s. The particles retain their magnetic orientation until the orientation is changed again, so files can be stored, retrieved, rewritten, and deleted as needed. Storing data on a magnetic disk is illustrated in Figure 3-4.

A newer type of hard drive is the *solid-state drive (SSD)* that uses flash memory technology instead of magnetic technology to store data

**FIGURE 3-3**  
**Encrypted hard drives.** The data stored on this external hard drive is protected by a fingerprint scanner.



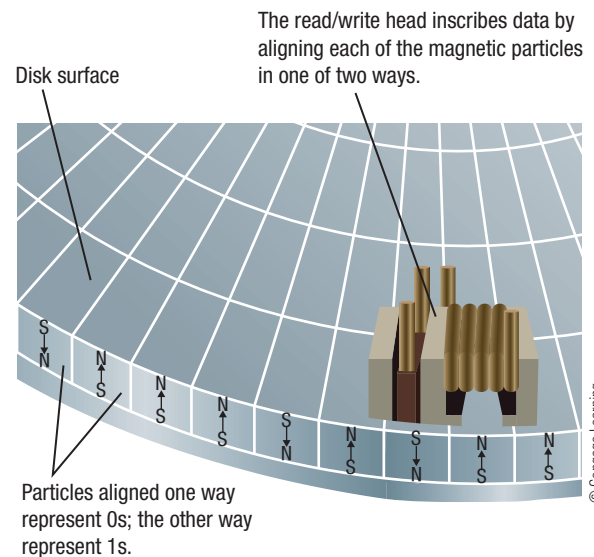
Courtesy of Apricorn

> **Hard drive.** The primary storage system for most computers; used to store most programs and data used with a computer.

(for a look at how flash memory technology works, see the How It Works box). While magnetic hard drives are currently less expensive and are currently available in larger capacities than SSDs, the use of SSDs is growing rapidly—especially with portable computers (like notebook and netbook computers) and mobile devices. This is because the flash memory technology that SSDs are based on allows for faster operation (one study showed a ninefold increase in performance over conventional magnetic hard drives), reduced power consumption (SSDs use at least 50% less power than magnetic hard drives use), and increased shock-resistance since they have no moving parts.

### Magnetic Hard Drives

A **magnetic hard drive** (usually what individuals are referring to when they use the term *hard drive*) contains one or more metal *hard disks* or *platters* that are coated with a magnetizable substance. These hard disks are permanently sealed inside the hard drive case, along with the *read/write heads* used to store (*write*) and retrieve (*read*) data and an *access mechanism* used to move the read/write heads in and out over the surface of the hard disks (see Figure 3-5). Hard drives designed for desktop computers (sometimes referred to as *desktop hard drives*) typically use 2.5-inch or 3.5-inch hard disks and notebook hard drives typically use 2.5-inch hard disks. Portable digital media players, mobile phones, and other mobile devices that include a magnetic hard drive typically use tiny 1.5-inch or smaller hard drives instead. Regardless of the size, one hard drive usually contains a stack of several hard disks; if so, there is a read/write head for each hard disk surface (top and bottom), as illustrated in Figure 3-5, and these heads move in and out over the disk surfaces simultaneously.



**FIGURE 3-4**  
Storing data on magnetic disks.

**FIGURE 3-5**  
Magnetic hard drives.



#### MOUNTING SHAFT

The mounting shaft spins the hard disks at a speed of several thousand revolutions per minute while the computer is turned on.

#### READ/WRITE HEADS

There is a read/write head for each hard disk surface, and they move in and out over the disks together.

#### HARD DISKS

There are usually several hard disk surfaces on which to store data. Most hard drives store data on both sides of each disk.

#### SEALED DRIVE

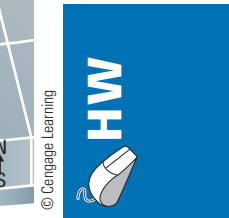
The hard disks and the drive mechanism are hermetically sealed inside a case to keep them free from contamination.

#### INSIDE A 3.5-INCH HARD DRIVE

#### ACCESS MECHANISM

The access mechanism moves the read/write heads in and out together between the hard disk surfaces to access required data.

> **Magnetic hard drive.** A hard drive consisting of one or more metal magnetic disks permanently sealed, along with an access mechanism and read/write heads, inside its drive.



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Courtesy of Hitachi Global Storage Technologies; Courtesy Western Digital

## HOW IT WORKS

### Flash Memory

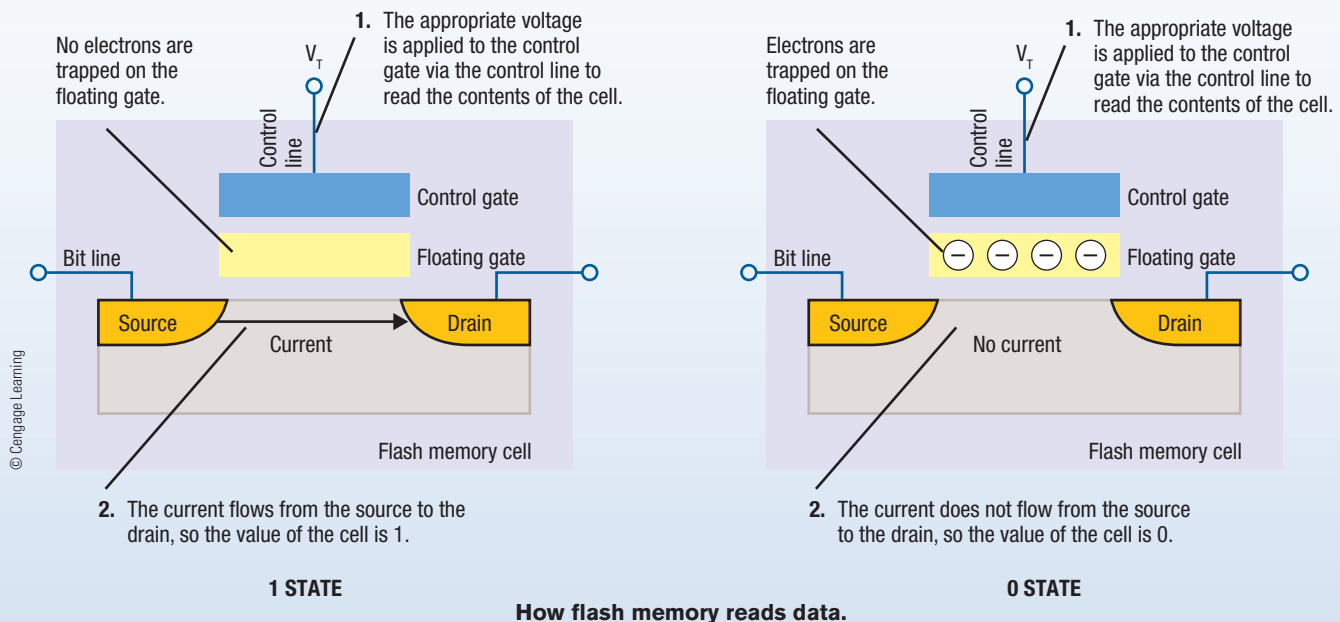
Instead of representing data magnetically or optically, flash memory devices represent data with electrical charges stored within *flash memory cells*. Flash memory cells are arranged in grids of rows and columns with two *gates* (the parts of a transistor's circuits) within each cell and two *lines* or wires connecting the flash memory cell to the circuitry surrounding the flash memory cell. One of the gates (the *control gate*) is connected to one of the wires (typically called the *control line* or *word line*). The other gate (the *floating gate*) is completely surrounded by an *oxide* layer and is not connected electrically to the other flash memory cell components. Since the floating gate is isolated electrically from the rest of the cell components, any electrical charge placed on the floating gate remains there until it is removed, even when the power to the flash memory device is off. The cell also has a *source* and *drain* that are connected via a wire (usually called the *bit line*) to the circuitry surrounding the flash memory cell. Under certain conditions, as described shortly, electrical current can flow from the source to the drain; this current is controlled by the voltage applied to the control gate.

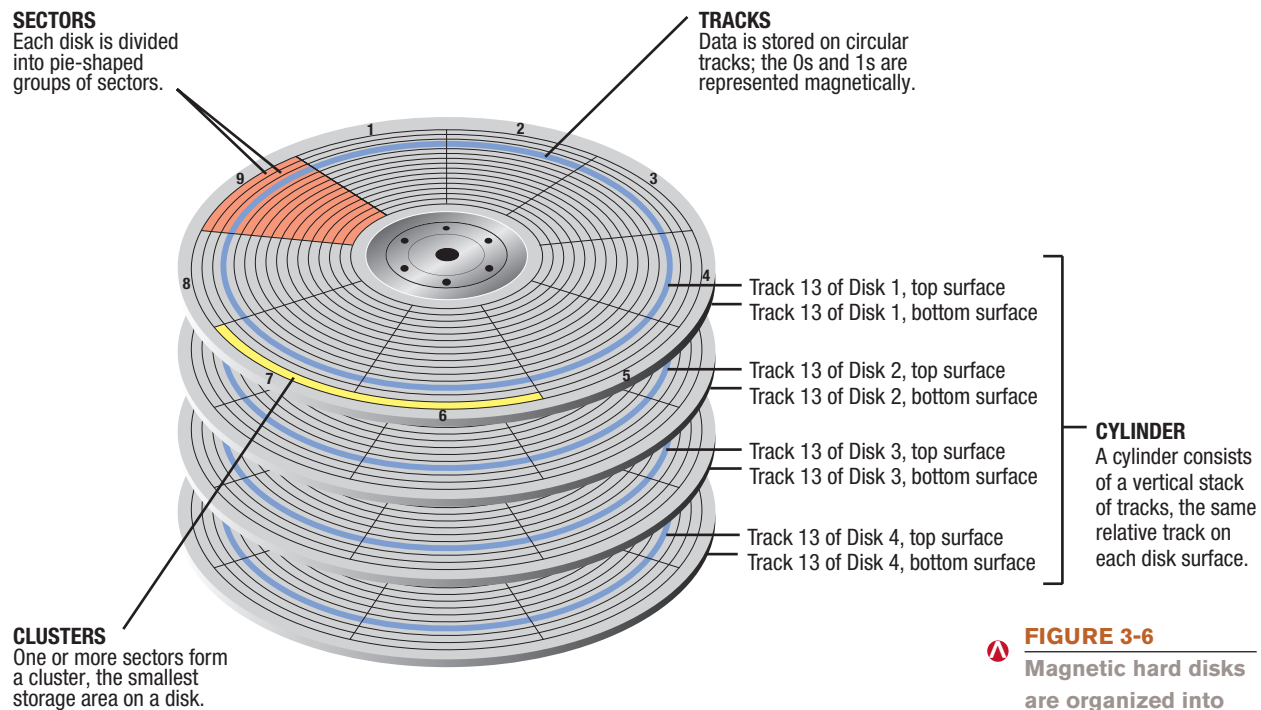
To store data in a flash memory cell, a large amount of voltage is applied to the control gate. When the appropriate amount

of voltage is applied, electrons are able to tunnel through the oxide layer surrounding the floating gate and become trapped on the floating gate. To remove those electrons, voltage of the opposite polarity is applied to the control gate and the electrons tunnel off the floating gate back through the oxide.

To read data stored in a flash memory cell, a smaller amount of voltage is applied to the control gate. When this occurs, it causes current to flow from the source to the drain if there are no electrons trapped on the floating gate. If electrons are trapped on the floating gate, they will prevent the current from flowing. Whether or not the current flows from the source to the drain (and therefore, whether or not there are electrons on the floating gate) determines the value of the data (0 or 1) stored in that cell, as shown in the accompanying illustration.

Flash memory originally held a single bit per memory cell, called *single-level cell (SLC) flash*. To increase storage capacity and reduce its cost, manufacturers are increasingly using multiple bits per cell, called *multilevel cell (MLC) flash*. To increase speed, *NAND flash memory* (the type of memory used in flash memory cards, USB flash drives, and most other types of flash memory-based storage media and devices) reads and writes data in small blocks called pages, instead of in single bytes.





The surface of a hard disk is organized into **tracks** (concentric rings) and pie-shaped groups of **sectors** (small pieces of tracks), as shown in Figure 3-6. On most computer systems, the smallest storage area on a hard drive is a **cluster**—one or more adjacent sectors. The computer numbers the tracks, sectors, and clusters so it can keep track of where data is stored. The computer uses a *file system* to record where each file is physically stored on the hard drive and what filename the user has assigned to it. When the user requests a document (always by filename), the computer uses its file system to retrieve it. Since a cluster is the smallest area on a hard drive that a computer can access, everything stored on a hard drive always takes up at least one cluster of storage space.

In addition to tracks, sectors, and clusters, hard drives are also organized into **cylinders** (refer again to Figure 3-6). A cylinder is the collection of one specific track located on each hard disk surface. In other words, it is the area on all of the hard disks inside a hard drive that can be accessed without moving the read/write access mechanism, once it has been moved to the proper position. For example, the hard drive shown in Figure 3-6 contains four hard disks, which means there are eight possible recording surfaces (using both sides of each hard disk). Consequently, a cylinder for that hard drive would consist of eight tracks, such as track 13 on all eight surfaces. Because all of the read/write heads move together, all of the tracks in a cylinder are accessible at the same time.

Traditionally, the magnetic particles on a hard disk have been aligned horizontally, parallel to the hard disk's surface (referred to as *longitudinal magnetic recording*). To increase capacity and reliability, most new hard drives today use *perpendicular magnetic recording (PMR)*, in which the bits are placed upright (as in Figure 3-4) to allow them to be closer together than is possible with a horizontal layout. For instance, PMR currently allows a recording density up to 400 *gigabits per square inch (Gb/inch<sup>2</sup>)*, which results in internal hard drives with capacities up to 2 TB. Researchers believe that the theoretical limit for

>**Track.** A concentric path on a disk where data is recorded. >**Sector.** A small piece of a track. >**Cluster.** One or more sectors; the smallest addressable area of a disk. >**Cylinder.** The collection of tracks located in the same location on a set of hard disk surfaces.





## ASK THE EXPERT

Courtesy of Seagate Technology LLC



**Josh Tinker**, Product Planning Manager,  
Seagate Technology

### What do you expect will be the capacity of a typical internal desktop hard drive in five years?

The top capacity of an internal desktop hard drive today is 3 TB, but by 2016 we expect the top capacity of internal desktop hard drives to exceed 7 TB and possibly approach 12 TB. Today, a common consumer internal desktop hard drive capacity is 1 TB. By 2015, the hard drive industry could provide a similarly priced internal hard drive that holds 2 TB or even 3 TB.

recording density with today's hard drive technology will be 1 *terabit per square inch* ( $Tb/inch^2$ ), which translates into about 4 TB of storage for a 3.5-inch hard drive, 1 TB for a 2.5-inch hard drive, and 100 GB for a 1-inch hard drive.

To allow for higher capacities in the future, new hard drive technologies are under development. For instance, *Heat-Assisted Magnetic Recording (HAMR)*, which uses lasers to temporarily heat the surface of the hard disks when storing data in order to pack more data onto the surface than is normally possible, may eventually boost the storage capacity of a hard drive to 50  $Tb/inch^2$ .

It is important to realize that a magnetic hard drive's read/write heads never touch the surface of the hard disks at any time, even during reading and writing. If the read/write heads do touch the surface (for example, if a desktop computer is bumped while the hard drive is spinning or if a

foreign object gets onto the surface of a hard disk), a *head crash* occurs, which typically does permanent damage to the hard drive. Because the read/write heads are located extremely close to the surface of the hard disks (less than one-half millionth of an inch above the surface), the presence of a foreign object the width of a human hair or even a smoke particle on the surface of a hard disk is like placing a huge boulder on a road and then trying to drive over it with your car. When hard drives containing critical data become damaged, *data recovery firms* may be able to help out, as discussed in the Inside the Industry box.

### CAUTION CAUTION CAUTION CAUTION CAUTION CAUTION CAUTION CAUTION

Because you never know when a head crash or other hard drive failure will occur—there may be no warning whatsoever—be sure to *back up* the data on your hard drive on a regular basis. Backing up data—that is, creating a second copy of important files—is critical not only for businesses but also for individuals and is discussed in detail in Chapter 5 and Chapter 15.



### ONLINE VIDEO

Go to the Chapter 3 page of the **UC14 CourseMate** to watch the “The DriveSavers Data Recovery Service” video clip.



### TIP

Because of the fast access and low power consumption of SSDs, online social networks like Facebook and MySpace are beginning to use these types of hard drives to be able to quickly deliver data to thousands of users simultaneously.

### Solid-State Drives (SSDs)

**Solid-state drives (SSDs)** are hard drives that use flash memory technology instead of spinning hard disk platters and magnetic technology; consequently, data is stored as electrical charges on flash memory media and SSDs have no moving parts. These characteristics mean that SSDs (along with the other types of flash memory storage systems discussed later in this chapter) are not subject to mechanical failures like magnetic hard drives, and are, therefore, more resistant to shock and vibration. They also consume less power, generate less heat, make no noise, and are faster. Consequently, SSDs are an especially attractive option for portable computers and mobile devices. Although previously too expensive for all but specialty applications, prices of SSDs (also sometimes called *flash memory hard drives*) have fallen significantly over the past few years and they are becoming the norm for netbooks, mobile devices, and other very portable devices. One disadvantage of SSDs is that flash memory cells can wear out with repeated use.

> **Solid-state drive (SSD).** A hard drive that uses flash memory media instead of metal magnetic hard disks.

## INSIDE THE INDUSTRY

### Data Recovery Experts

It happens far more often than most people imagine. A home computer crashes and all the family's digital photos are lost, a notebook computer is dropped and the files are no longer accessible, a mobile phone falls into a pool and no longer works, or a business is flooded and the computers storing the business's critical files are damaged. If the data on a damaged device is backed up, then it is fairly easy and inexpensive to restore it onto a new hard drive or device. If the data is not backed up, however, it is time to seek help from a data recovery expert.

Professional data recovery firms, such as DriveSavers in California, specialize in recovering critical data from damaged storage devices (see the accompanying photos). Engineers open the damaged device (in a *Class 100 clean room* to minimize contamination and maximize data recovery) and then make an image of the data located on that device, bit by bit, onto a target drive. The target drive is then used to reconstruct the data; if the file directory is not recovered, engineers try to match the jumbled data to file types in order to reconstruct the original files. Once the data recovery process is complete, the customer receives the data on a new hard drive. To ensure data is safe and remains confidential, DriveSavers has numerous security certifications; in fact, it is used by government agencies to recover critical data.

Professional data recovery firms are also used when hard drives and other storage media simply stop working. In fact, DriveSavers estimates that 75% of its business is due to malfunctioning devices. With the vast amounts of digital data (such as photos, music, home videos, personal documents, and school papers) that the average person stores today, data recovery firms are increasingly being used by individuals to

recover personal data, in addition to being used by businesses to recover critical company data.

Data loss can happen to any business or individual, even to the rich and famous. A few celebrity clients of DriveSavers include Bruce Willis, Conan O'Brien, Harrison Ford, Sean Connery, and Bill Oakely, the executive producer of *The Simpsons*, whose computer crashed taking scripts for 12 episodes of the show with it. In some cases, data loss is a result of a natural disaster or an unusual circumstance; for instance an iMac computer that contained the only digital pictures of a survivor's family was destroyed by the recent Japanese tsunami; a laptop was trapped for two days beneath a sunken cruise ship in the Amazon River; and a server went down at a Fortune 500 company, which caused them to lose all its financial data and stockholder information. In all of these cases, DriveSavers was able to recover all of the lost data.

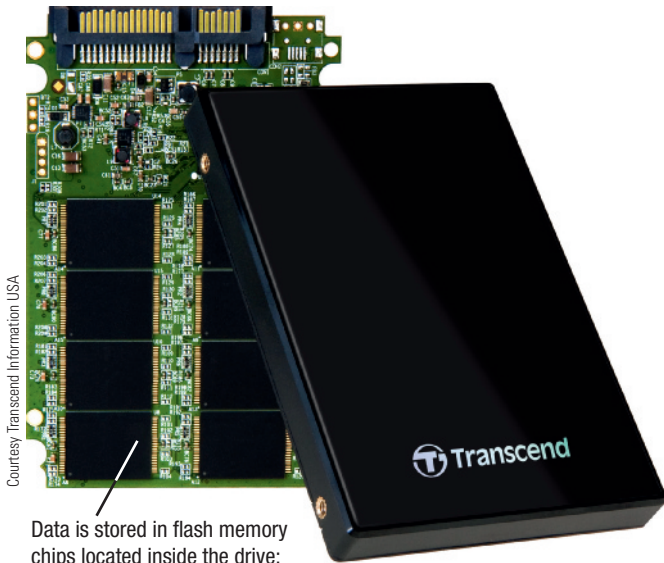
Data recovery firms stress the importance of backing up data to avoid data loss. According to Scott Gaidano, president of DriveSavers, "The first thing we tell people is back up, back up, back up. It's amazing how many people don't back up." It is also important to make sure the backup procedure is working. For instance, the Fortune 500 company mentioned previously performed regular backups and kept the backup media in a fire-resistant safe, but the backup system failed after its server crashed since all the backup media were blank.

Because potentially losing all the data on a storage medium can be so stressful and traumatic, DriveSavers has its own data-crisis counselor, a former suicide hotline worker. Fortunately for its clients, DriveSavers has an extremely high recovery rate. While the services of data recovery experts are not cheap, when the data on a damaged device is critical data, using a data recovery expert is your best chance for getting your data back.



Courtesy of DriveSavers, Inc. www.drivesavers.com

**Data recovery.** The data on this destroyed computer (left) was recovered by data recovery experts in a clean room (right).



Courtesy Transcend Information USA

Data is stored in flash memory chips located inside the drive; unlike magnetic drives, there are no moving parts.

**FIGURE 3-7**  
Solid-state drives (SSDs).

**FIGURE 3-8**  
External hard drives.

SSDs are available in the same dimensions as a conventional magnetic 2.5-inch hard drive (see Figure 3-7) so they can easily be used instead of conventional magnetic hard drives in notebooks, netbooks, and other personal computers. There are also smaller 1.8-inch SSDs available that can be used when a smaller physical size is needed, such as for a portable digital media player or mobile phone. SSDs are also available as expansion card drives. SSDs are currently available in capacities up to 1 TB but most are 256 GB or less.

### Internal and External Hard Drives

*Internal hard drives* are permanently located inside a computer's system unit and typically are not removed unless there is a problem with them. Virtually all computers have at least one internal hard drive (either a magnetic hard drive or an SSD) that is used to store programs and data. In addition, a variety of *external hard drives* are available (see Figure 3-8). External hard drives are commonly used to transport a large amount of data from one computer to another (by moving the entire hard drive to another computer), for backup purposes, and for additional storage.

Today, because of their large capacity, full-sized external hard drives (which typically are magnetic hard drives and hold between 500 GB and 4 TB) are often used by individuals to store their digital photos, digital music, home movies, recorded TV shows, and other multimedia content. To distribute multimedia to the computers and entertainment devices located in the home, special hard drive products (typically called *home servers* or *media servers*) are available. These special hard drives are designed to be connected to a home network to serve as a centralized storage device for all the computers in the home, as well as to back up the data

on those computers automatically. There are also *DVR extender* hard drives designed to add additional storage to an individual's digital video recorder (DVR).

Full-sized external hard drives can be moved from computer to computer when needed; however, *portable hard drives* are smaller external hard drives specifically designed for that purpose. Unlike full-sized hard drives (which typically need to be plugged into a power outlet to be used), portable hard drives are often powered via the computer they are being used with instead. Portable magnetic hard drives typically hold up to 1 TB; the capacity of portable SSD hard drives at the present time is smaller—up to 256 GB. Most external desktop and portable hard drives connect to the computer via a USB connection. However, some can connect via a wired or wireless networking connection instead, and *ExpressCard hard drives* connect via an ExpressCard slot (refer again to Figure 3-8).



Image courtesy of Iomega an EMC company

**FULL-SIZED EXTERNAL HARD DRIVES**  
Are about the size of a 5 by 7-inch picture frame, but thicker; this drive holds 3 TB.



Image courtesy of Iomega an EMC company

**PORTABLE HARD DRIVES (MAGNETIC)**  
Are about the size of a 3 by 5-inch index card, but thicker; this drive holds 1.5 TB.



Courtesy Transcend Information USA

**PORTABLE HARD DRIVES (SSD)**  
Are about the size of a credit card, but thicker; this drive holds 256 GB.



Courtesy Transcend Information USA

**EXPRESSCARD HARD DRIVES**  
Fit into an ExpressCard slot; this drive holds 32 GB.

## Hard Drive Speed, Disk Caching, and Hybrid Hard Drives

The hard disks inside a magnetic hard drive typically spin continually at a rate of between 5,200 and 15,000 revolutions per minute. The total time that it takes for a hard drive to read or write data is called the **disk access time** and requires the following three steps:

1. Move the read/write heads to the cylinder that contains (or will contain) the desired data—called *seek time*.
2. Rotate the hard disks into the proper position so that the read/write heads are located over the part of the cylinder to be used—called *rotational delay*.
3. Move the data, such as reading the data from the hard disk and transferring it to memory, or transferring the data from memory and storing it on the hard disk—called *data movement time*.

A typical magnetic disk access time is around 8.5 milliseconds (ms). To minimize disk access time, magnetic hard drives usually store related data on the same cylinder. This strategy reduces seek time and, therefore, improves the overall access time. Because SSDs do not have to move any parts to store or retrieve data, they don't require seek time or rotational delay and their access time is much faster than magnetic hard drives—essentially instantaneous at about 0.1 ms on some benchmark tests.

To speed up magnetic hard drive performance, *disk caching* is often used. A *cache* (pronounced “cash”) is a place to store something temporarily. For instance, in Chapter 2, you learned that cache memory is very fast memory used by the CPU to store data and instructions that might be needed in order to speed up processing. A **disk cache** is similar in concept—it stores copies of data or programs that are located on the hard drive and that might be needed soon in memory in order to avoid having to retrieve the data or programs from the hard drive when they are requested. Since the hard disks do not have to be accessed if the requested data is located in the disk cache and since retrieving data from memory is much faster than from a magnetic hard disk, disk caching can speed up performance. Disk caching also saves wear and tear on the hard drive and, in portable computers, can also extend battery life.

While the memory used for disk caching can be a designated portion of RAM, today's hard drives typically use a disk cache consisting of memory chips located on a circuit board inside the hard drive case. When a magnetic hard drive uses disk caching (as most do today), any time the hard drive is accessed the computer copies the requested data, as well as extra data located in neighboring areas of the hard drive (such as all of the data located on the cylinder being accessed), to the disk cache. When the next data is requested, the computer checks the disk cache first to see if the data it needs is already there. If it is, the data is retrieved for processing; if not, the computer retrieves the requested data from the hard disks.

Most conventional magnetic hard drives today include a flash memory-based disk cache ranging in size from 8 MB to 64 MB built into the hard drive case. However, **hybrid hard drives**—essentially a combination flash memory/magnetic hard drive (see Figure 3-9)—use a much larger amount of flash memory (typically 4 GB today). In addition to using the flash

### TIP

There are also special external hard drives designed for mobile devices, such as the iPad that has a 32 GB limit on external storage media connected via the camera connector. For instance, the *HyperDrive iPad Hard Drive* holds up to 750 GB, but is divided into 32 GB virtual drives to get around the iPad size limit.

**FIGURE 3-9**  
**Hybrid hard drives.**

Hybrid hard drives contain both magnetic hard disks and a large quantity of flash memory for increased performance.



#### MAGNETIC HARD DRIVE

This drive contains 2 hard disks and 4 read/write heads that operate in a manner similar to a conventional hard drive.

#### FLASH MEMORY DISK CACHE

This drive contains 4 GB of flash memory to duplicate data as it is stored on the hard disks so the data can be accessed when the hard disks are not spinning.

Courtesy of Seagate Technology, LLC

>**Disk access time.** The time it takes to locate and read data from (or position and write data to) a storage medium. >**Disk cache.** Memory used in conjunction with a magnetic hard drive to improve system performance. >**Hybrid hard drive.** A hard drive that contains both a large amount of flash memory and magnetic hard disks.

memory to reduce the number of times the hard disks in a hybrid hard drive need to be read, hybrid hard drives can also use the flash memory to temporarily store (cache) data to be written to the hard disks, which can further extend the battery life of portable computers and mobile devices. The additional flash memory in a hybrid hard drive can also allow encryption or other security measures to be built into the drive.

## Hard Drive Partitioning and File Systems

*Partitioning* a hard drive enables you to divide the physical capacity of a single hard drive logically into separate areas, called *partitions* or *volumes*. Partitions function as independent hard drives and are sometimes referred to as *logical drives* because each partition is labeled and treated separately (such as C drive and D drive) when viewed in a file management program such as Windows Explorer, but they are still physically one hard drive. One or more partitions are created when a hard drive is first *formatted* (prepared for data storage). For instance, many new personal computers

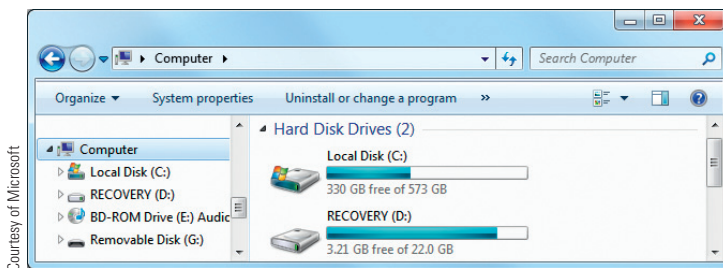
come with two partitions: a C drive partition ready to use for programs and data and a D drive partition set up as a *recovery partition*. A recovery partition (see Figure 3-10) contains the data necessary to restore a hard drive back to its state at the time the computer was purchased and is designed to be used only if the computer malfunctions.

In the past, operating systems could only use hard drives up to 512 MB, so hard drives larger than that limit had to use multiple partitions. While today's operating systems can use much larger hard drives and, therefore,

do not require the use of multiple partitions, partitioning a large hard drive can make it function more efficiently. This is because operating systems typically use a larger cluster size with a larger hard drive. Since even tiny files have to use up one entire cluster of storage space, disk space is often wasted when a large cluster size is used. When a hard drive is partitioned, each logical drive can use a smaller cluster size, since each logical drive is smaller than the original hard drive.

Users can create additional partitions on a hard drive if desired, but they should be careful when partitioning a hard drive since deleting a partition erases all data contained on that partition. One reason advanced users may partition a primary hard drive is to be able to use two different operating systems on the same hard drive—such as Windows and Linux (these and other operating systems are discussed in detail in Chapter 5). With a *dual-boot system* such as this, the user specifies the operating system to be run each time the computer boots. Another reason for partitioning a hard drive is to create the appearance of having separate hard drives for file management, multiple users, or other purposes. For instance, some users choose to partition a new second or external hard drive into multiple logical drives to organize their data before storing data on that hard drive. Storing data files on a separate physical hard drive or logical partition makes it easier for the user to locate data files. It also enables users to back up all data files simply by backing up the entire hard drive or partition containing the data.

The partition size, cluster size (on magnetic hard drives), maximum drive size, and maximum file size that can be used with a hard drive are determined by the *file system* being used. For instance, Windows users have three file system options to choose from: the original *FAT* file system (not commonly used with hard drives today, though it is used with some removable storage devices like USB flash drives), the newer *FAT32* file system, and the newest *NTFS* file system. The recommended file system for computers running current versions of Windows is NTFS because it supports much larger hard drives and files than either FAT or FAT32 and it includes better security and error-recovery capabilities. Computers with older versions of Windows have to use FAT32, which has a maximum partition size of 32 GB and a maximum file size of 4 GB.



Courtesy of Microsoft

**FIGURE 3-10**

**Hard drive partitions.** New personal computers today often come with the primary hard drive divided into two partitions.

### TIP

Windows 7 users can choose to create and boot from virtual hard drives, so they can boot from different operating systems without creating multiple partitions.

### ONLINE VIDEO

Go to the Chapter 3 page of the **UC14 CourseMate** to watch the “How to Upgrade Your Laptop Drive in Three Easy Steps” video clip.

## Hard Drive Interface Standards

Hard drives connect, or interface, with a computer using one of several different standards. The most common internal *hard drive interface standard* for desktop computers today is *serial ATA (SATA)*. The SATA standard was designed to replace the older, slower *parallel ATA (PATA)* standard, which is also referred to as *Fast ATA* and *EIDE (Enhanced Integrated Drive Electronics)*. SATA is faster (up to 6 Gbps for *SATA III* devices) than PATA and uses thinner cables, which means SATA hard drives take up less room inside the system unit. External hard drives most often connect to the computer via a USB or FireWire port, though an *eSATA (External SATA)* interface can be used to connect to the computer via an eSATA port if faster speeds are desired.

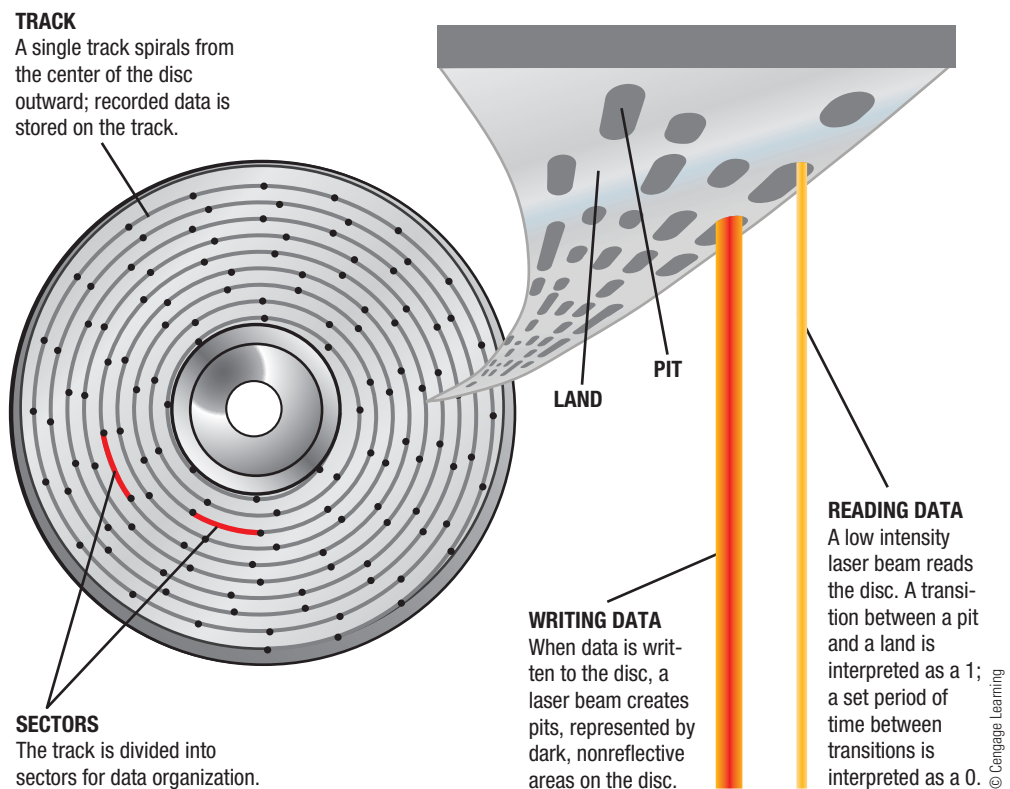
The most common hard drive interfaces used with servers are *serial attached SCSI (SAS)*, which is a newer version of the SCSI interface, and *Fibre Channel*, which is a reliable, flexible, and very fast standard geared for long-distance, high-bandwidth applications. For network storage, new standards, such as *Internet SCSI (iSCSI)* and *Fibre Channel over Ethernet (FCoE)*, have evolved that communicate over the Internet or another network using the *TCP/IP* networking standard. Networks and networking standards are discussed in Chapter 7.

## OPTICAL DISCS AND DRIVES

Data on **optical discs** (such as *CDs* and *DVDs*) is stored and read *optically*; that is, using laser beams. General characteristics of optical discs are discussed next, followed by a look at the various types of optical discs available today.

### Optical Disc Characteristics

Optical discs are thin circular discs made out of *polycarbonate substrate*—essentially a type of very strong plastic—that are topped with layers of other materials and coatings used to store data and protect the disc. Data can be stored on one or both sides of an optical disc, depending on the disc design, and some types of discs use multiple recording layers on each side of the disc to increase capacity. An optical disc contains a single spiral track (instead of multiple tracks like magnetic disks), and the track is divided into sectors to keep data organized. As shown in Figure 3-11, this track (sometimes referred to as a *groove* in order to avoid confusion with the



### FURTHER EXPLORATION

GO

Go to the Chapter 3 page of the **UC14 CourseMate** for links to information about hard drives.



>**Optical disc.** A type of storage medium read from and written to using a laser beam.

term *tracks* used to refer to songs on an audio CD) begins at the center of the disc and spirals out to the edge of the disc.

Advantages of optical discs include relatively large capacity for their size (as discussed shortly) and durability (they are more durable than magnetic media and don't degrade with use, like some magnetic media do). However, the discs should be handled carefully and stored in their cases when they are not in use, in order to protect the recorded surfaces of the discs from scratches, fingerprints, and other marks that can interfere with the usability of the discs. Optical discs are the standard today for software delivery; they are also commonly used for backup purposes, and for storing and/or transporting music, photo, video, and other large files.

### Representing Data on an Optical Disc

Data is written to an optical disc in one of two ways. With *read-only optical discs* like movie, music, and software CDs and DVDs, the surface of the disc is molded or stamped appropriately to represent the data. With *recordable* or *rewritable optical discs* that can be written to using an *optical drive* such as a *CD drive* or *DVD drive*, as discussed shortly, the reflectivity of the disc is changed using a laser to represent the data. In either case, the disc is read with a laser and the computer interprets the reflection of the laser off the disc surface as 1s and 0s.

To accomplish this with molded or stamped optical discs, tiny depressions (when viewed from the top side of the disc) or bumps (when viewed from the bottom) are created on the disc's surface. These bumps are called *pits*; the areas on the disc that are not changed are called *lands*. Although many people think that each individual pit and land represents a 1 or 0, that idea is not completely accurate—it is the transition between a pit and land that represents a 1. When the disc is read, the amount of laser light reflected back from the disc changes when the laser reaches a transition between a pit and a land. When the optical drive detects a transition, it is interpreted as a 1; no transition for a specific period of time indicates a 0.

With a CD or DVD that is recorded using a CD or DVD drive, the recording laser beam changes the reflectivity of the appropriate areas on the disc to represent the data stored there—dark, nonreflective areas are pits; reflective areas are lands, as illustrated in Figure 3-11. The transition between a pit and a land still represents a 1 and no transition for a specific distance along the track represents a 0. Different types of optical discs use different types of laser beams. Conventional **CD discs** use *infrared* lasers; conventional **DVD discs** use *red* lasers, which allow data to be stored more compactly on the same size disc; and high-definition **Blu-ray Discs (BD)** use *blue-violet lasers*, which can store data even more compactly on a disc.

#### TIP

The × in the specifications for an optical drive represents the speed of that optical drive compared to the original version, such as 18× for a DVD drive, meaning that the DVD drive is 18 times faster than the original DVD drives.

### Optical Drives

Optical discs in each of the three categories (CD, DVD, and BD) can be read-only, recordable, or rewritable; they can use the + or – standard; and they can be either *single-layer* or *dual-layer (DL) discs*. Optical discs are designed to be read by **optical drives**, such as *CD, DVD, and BD drives*, and the type of optical drive being used must support the type of optical disc being used. Most optical drives today support multiple types of optical discs—some support all possible types. Optical drives are almost always *downward-compatible*, meaning they can be used with lower (older) types of discs but not higher (newer) ones. So, while a DVD drive would likely support all types of CD and DVD discs, it cannot be used with BD discs, but most BD drives today support all types of CD, DVD, and BD discs.

- > **CD disc.** A low capacity (typically 650 MB) optical disc that is often used to deliver music and software, as well as to store user data.
- > **DVD disc.** A medium capacity (typically 4.7 GB or 8.5 GB) optical disc that is often used to deliver software and movies, as well as to store user data.
- > **Blu-ray Disc (BD).** A high-capacity (typically 25 GB or 50 GB) that is often used to deliver high-definition movies, as well as to store user data.
- > **Optical drive.** A drive used with optical discs, such as CD or DVD discs.

To use an optical disc, it is inserted into an appropriate optical drive. Purchased optical discs often have a title and other text printed on one side; if so, they are inserted into the optical drive with the printed side facing up. Two-sided commercial discs typically identify each side of a disc by printing that information on the disc close to the inner circle.

The process of recording data onto a recordable or rewritable optical disc is called *burning*. To burn an optical disc, the optical drive being used must support burning and the type of disc being used. In addition, *CD-burning* or *DVD-burning* software is required. Many burning programs are available commercially, and recent versions of operating systems (including Windows and Mac OS) include burning capabilities. In addition, most CD and DVD drives come bundled with burning software. Some optical drives—such as *LightScribe-enabled drives*—are even capable of burning label information on the surface of a disc after the content has been recorded. (To do this, you first burn the data to the disc, and then you flip the disc over and burn the desired label information on the other side of the disc.) Most personal computers today come with an internal optical drive; one exception is netbooks, which typically do not include an optical drive. An *external optical drive* that connects via a USB port (see Figure 3-12) can be used with these computers whenever an optical drive is temporarily needed.

### Optical Disc Shapes, Sizes, and Capacities

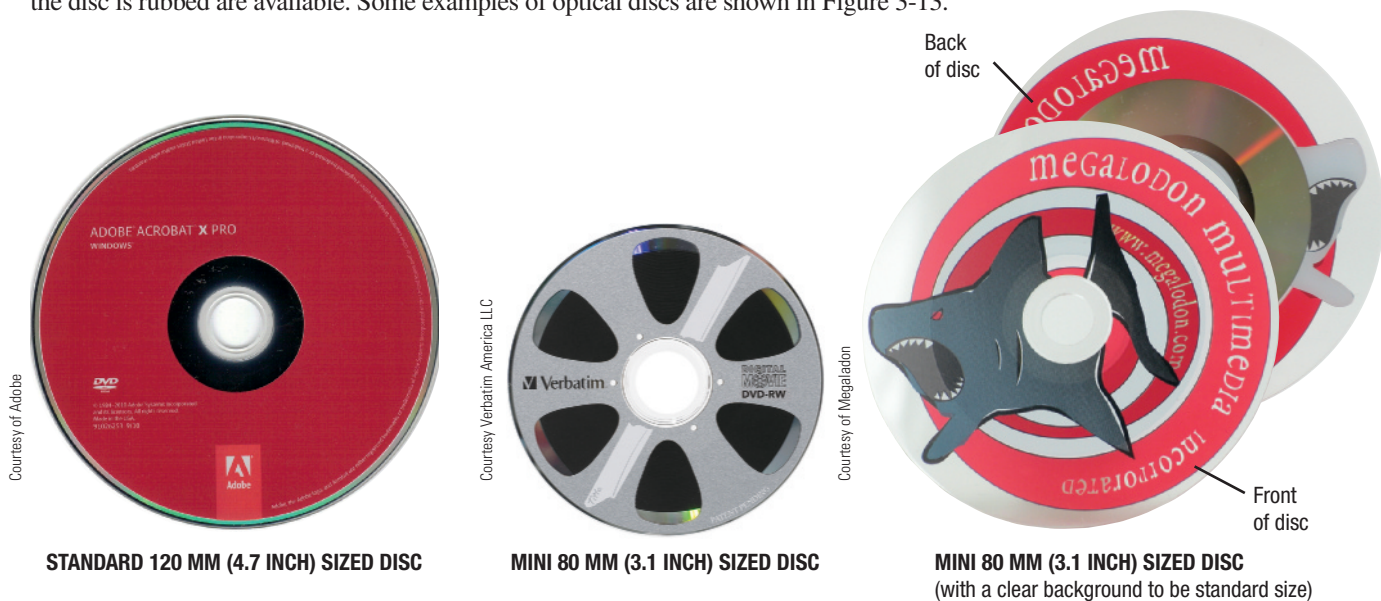
Standard-sized optical discs are 120-mm (approximately 4.7-inch) discs. There are also smaller 80-mm (approximately 3-inch) *mini discs*, which use either that smaller form factor or are surrounded by clear material to be the same physical size as a standard disc to better fit in optical disc drives (see Figure 3-13). Because the track starts at the center of the disc and the track just stops when it reaches an outer edge of the disc, optical discs theoretically can be made into a variety of sizes and shapes—such as a heart, a triangle, an irregular shape, or a hockey-rink shape appropriate for *business card CDs* (discs with business card information printed on the outside that contain a résumé, portfolio, or other digital documents). However, an ongoing patent battle regarding changing the shape of any normally round storage media (a process an individual claims to have patented) has resulted in these shapes not being available by any CD or DVD manufacturer until the patent issue is resolved. The practice of using optical discs to replace ordinary objects, such as business cards and mailed advertisements, is becoming more common. In addition, *scented discs* that have a specific scent (such as a particular perfume, popcorn, pine trees, or a specific fruit) added to the label that is released when the surface of the disc is rubbed are available. Some examples of optical discs are shown in Figure 3-13.



Image courtesy of Iomega an EMC company

**FIGURE 3-12**  
External optical drives. Can be connected as needed, typically via a USB port, such as to the netbook shown here.

**FIGURE 3-13**  
Optical discs are available in a variety of sizes, appearances, and capacities.



Courtesy of Adobe

STANDARD 120 MM (4.7 INCH) SIZED DISC

Courtesy Verbatim America LLC

MINI 80 MM (3.1 INCH) SIZED DISC

Courtesy of Megalodon

MINI 80 MM (3.1 INCH) SIZED DISC  
(with a clear background to be standard size)





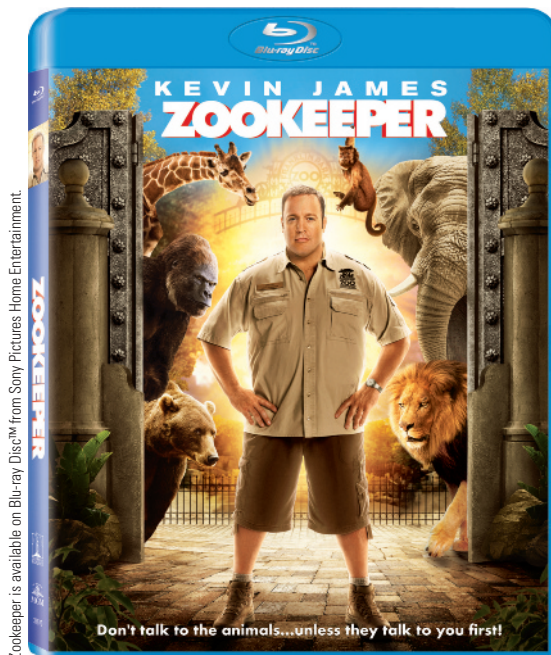
**FURTHER EXPLORATION**

Go to the Chapter 3 page of the **UC14 CourseMate** for links to information about DVD technology.

One of the biggest advantages of optical discs is their large capacity. To further increase capacity, many discs are available as *dual-layer discs* (also called *double-layer discs*) that store data in two layers on a single side of the disc, so the capacity is approximately doubled. For an even larger capacity, discs with more than two layers are in development. Standard-sized CD discs are normally single-layer and hold either 650 MB or 700 MB, standard-sized DVD discs hold 4.7 GB (single-layer discs) or 8.5 GB (dual-layer discs), and standard-sized BD discs hold either 25 GB (single-layer discs) or 50 GB (dual-layer discs). Discs can also be *double sided*, which doubles the capacity; however, the disc must be turned over to access the second side. Double-sided discs are most often used with movies and other prerecorded content, such as to store a *widescreen version* of a movie on one side of a DVD disc and a *standard version* on the other side. Small optical discs have a smaller storage capacity than their larger counterparts: typically, single-layer, single-sided 3-inch mini CD, DVD, and BD discs hold about 200 MB, 1.4 GB, and 7.5 GB, respectively, and business card-sized CD and DVD discs hold about 50 MB and 325 MB, respectively.

As with magnetic disks, researchers are continually working to increase the capacity of optical discs without increasing their physical size. One promising recent development is a discovery by a Harvard research team that narrows the width of the laser beam used to record data on an optical disc. This is significant because a narrower beam means that more data can be stored on a disc. Although products based on this technology may be 10 years away, researchers predict that this new technique could eventually result in regular-sized optical discs that hold 3 TB—roughly 600 times more than a standard DVD today. Closer on the horizon is a possible new BD standard (*BDXL*), which uses more layers to boost capacity to 128 GB. Another potential new standard under consideration (*IH-BD*) adds a rewritable layer to a regular BD disc in order to enable the disc to store status information and other temporary data. However, neither standard is compatible with today's BD drives.

**FIGURE 3-14**  
High-definition movies are available on Blu-ray Discs (BDs).



### Read-Only Optical Discs: CD-ROM, DVD-ROM, and BD-ROM Discs

**CD-ROM** (*compact disc read-only memory*) discs and **DVD-ROM** (*digital versatile disc read-only memory*) discs are *read-only optical discs* that come prerecorded with commercial products, such as software programs, clip art and other types of graphics collections, music, and movies. For high-definition content (such as feature films—see Figure 3-14), **BD-ROM** (*Blu-ray Disc read-only memory*) discs are available. There are also additional read-only disc formats for specific gaming devices, such as the proprietary discs used with the Wii, Xbox, and PlayStation gaming consoles. The data on a read-only disc cannot be erased, changed, or added to because the pits that are molded into the surface of the disc when the disc is produced are permanent.

### Recordable Optical Discs: CD-R, DVD-R, DVD+R, and BD-R Discs

*Recordable optical discs* (also sometimes called *write-once discs*) can be written to, but the discs cannot be erased and reused. Recordable CDs are referred to as **CD-R discs**. Single-layer recordable DVDs are called either

> **CD-ROM disc.** A CD that can be read from, but not written to, by the user. > **DVD-ROM disc.** A DVD that can be read from, but not written to, by the user. > **BD-ROM disc.** A Blu-ray Disc that can be read from, but not written to, by the user. > **CD-R disc.** A recordable CD.

**DVD-R discs** or **DVD+R discs**, depending on the standard being used, and dual-layer recordable DVDs are called *DVD+R DL* or *DVD-R DL discs*. Recordable BD discs are also available in both single-layer and dual-layer (**BD-R discs** and *BD-R DL discs*, respectively). The capacities of recordable optical discs are the same as the read-only formats (see Figure 3-15).

Instead of having physically molded pits, most recordable optical discs have a recording layer containing organic light-sensitive dye embedded between the disc's plastic and reflective layers. One exception to this is the BD-R disc, which has a recording layer consisting of inorganic material. When data is written to a recordable disc, the recording laser inside the recordable optical drive burns the dye (for CD and DVD discs) or melts and combines the inorganic material (for BD-R discs), creating nonreflective areas that function as pits. In either case, the marks are permanent, so data on the disc cannot be erased or rewritten.

Recordable CDs are commonly used for backing up files, sending large files to others, and creating custom music CDs (for example, from MP3 files legally downloaded from the Internet or from songs located on a music album purchased on CD). DVD-Rs can be used for similar purposes when more storage space is needed, such as for backing up large files and for storing home movies, digital photos, and other multimedia files. BD-R discs can be used when an even greater amount of storage is needed, such as very large backups or high-definition multimedia files.

### Rewritable Optical Discs: CD-RW, DVD-RW, DVD+RW, and BD-RE Discs

*Rewritable optical discs* can be written to, erased, and overwritten just like magnetic hard disks. The most common types of rewritable optical discs are **CD-RW**, **DVD-RW**, **DVD+RW**, and **BD-RE discs**; BD-RE discs are also available as dual-layer discs (*BD-RE DL discs*). The capacities of rewritable discs are the same as their read-only and recordable counterparts. An additional, but not widely used, rewritable DVD format is *DVD-RAM*. DVD-RAM and DVD-RAM DL discs are supported by *DVD-RAM drives*, as well as by some DVD and BD drives.

To write to, erase, or overwrite rewritable optical discs, *phase change* technology is used. With this technology, the rewritable disc is coated with layers of a special metal alloy compound that can have two different appearances after it has been heated and then cooled, depending on the heating and cooling process used. With one process, the material *crystallizes* and that area of the disc is reflective. With another process, the area cools to a nonreflective *amorphous* state. Before any data is written to a rewritable optical disc, the disc is completely reflective. To write data to the disc, the recording laser heats the metal alloy in the appropriate locations on the spiral track and then uses the appropriate cooling process to create either the nonreflective areas (pits) or the reflective areas (lands). To erase the disc, the appropriate heating and cooling process is used to change the areas to be erased back to their original reflective state.

Rewritable optical discs are used for many of the same purposes as recordable optical discs. However, they are particularly appropriate for situations in which data written to the optical disc can be erased at a later time so the disc can be reused (such as for transferring large files from one computer to another or temporarily storing TV shows recorded on your computer that you will later watch using your living room TV and DVD player).

**FIGURE 3-15**  
Recordable CDs and DVDs.



**CD-R DISCS**  
Hold 650 MB.



**DVD+R DL DISCS**  
Hold 8.5 GB.

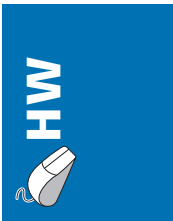


**BD-R DL DISCS**  
Hold 50 GB.

Courtesy Verbatim America LLC

Courtesy Memorex Products, Inc.

Courtesy of Sony Electronics Inc.



>**DVD-R/DVD+R discs**. Recordable DVDs. >**BD-R disc**. A recordable Blu-ray Disc. >**CD-RW disc**. A rewritable CD. >**DVD-RW/DVD+RW discs**. Rewritable DVDs. >**BD-RE disc**. A rewritable Blu-ray Disc.

## TREND

**IronKey: The World's Most Secure USB Flash Drive**

Today, the security of data being carried on portable devices, such as USB flash drives, is extremely important and the use of encrypted portable devices is a growing trend. For individuals, business employees, or government employees who need today's most secure USB flash drive, *IronKey* (see the accompanying illustration) might just be the answer.

Available in three versions (Basic, Personal, and Enterprise) and in capacities ranging from 1 GB to 32 GB, IronKey uses always-on, hardware-based encryption to protect all data written to the device. The encryption is enabled by an onboard *Cryptochip* that securely stores the encryption keys generated when the device is initialized and the user password is selected. There is also an internal counter to protect against password guessing attacks by an unauthorized individual trying to access the device. After 10 incorrect password attempts, the device self-destructs and erases all data and encryption keys stored on the device. The Personal and Enterprise versions contain additional features, such as a secure version of the Firefox browser that can be used for anonymous Web browsing (so no browsing data is stored on the local computer—just on the

IronKey drive) and the ability to store and use other portable applications on the device.

IronKey has received security validation for use by the U.S. and Canadian governments and is approved to carry classified government data. Overkill for personal use? Perhaps. But for anyone carrying sensitive data from computer to computer, highly secure USB flash drives like the IronKey can't be beat for security and convenience.



Courtesy IronKey

## FLASH MEMORY STORAGE SYSTEMS

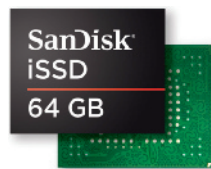
**FIGURE 3-16**  
**Embedded flash memory.**

As previously discussed, **flash memory** is a chip-based storage medium that represents data using electrons. It is used in a variety of storage systems, such as the SSDs and hybrid hard drives already discussed and the additional storage systems discussed next. For a look at what is billed as the world's most secure USB flash drive—*IronKey*—see the Trend box.



Courtesy of Dell

**PORTABLE TABLET**  
 Contains 16 GB of embedded flash memory.



Courtesy of SanDisk Corporation

**EMBEDDED FLASH MEMORY**

**Embedded Flash Memory**

**Embedded flash memory** refers to flash memory chips embedded into products. Because flash memory media are physically very small, they are increasingly being embedded directly into a variety of consumer products—such as portable digital media players, digital cameras, handheld gaming devices, GPS devices, mobile phones, and even sunglasses and wristwatches—to provide built-in data storage. Flash memory is also increasingly being integrated into mobile devices, such as small tablet computers and smartphones. While embedded flash memory can take the form of small SSDs or memory cards, it is increasingly being implemented with small stand-alone chips, such as the one shown in Figure 3-16.

- > **Flash memory.** Nonvolatile memory chips that can be used for storage by the computer or user; can be built into a computer or a storage medium.
- > **Embedded flash memory.** Flash memory chips embedded into products, such as consumer devices.

## Flash Memory Cards and Readers

One of the most common types of flash memory media is the **flash memory card**—a small card containing one or more flash memory chips, a controller chip, other electrical components, and metal contacts to connect the card to the device or reader with which it is being used. Flash memory cards are available in a variety of formats, such as *CompactFlash (CF)*, *Secure Digital (SD)*, *Secure Digital High Capacity (SDHC)*, *Secure Digital Extended Capacity (SDXC)*, *MultiMedia Card (MMC)*, *xD Picture Card (xD)*, and *Memory Stick (MS)* (see Figure 3-17). These formats are not interchangeable, so the type of flash memory card used with a device is determined by the type of flash media card that device can accept. Flash memory cards are the most common type of storage media for digital cameras, portable digital media players, mobile phones, and other portable devices. In fact, there is at least one mobile phone charger on the market that backs up all photos, contact information, and other data located on the phone to an SD card located in the charger while the phone is charging so that data can be recovered if the phone is ever lost. Flash memory cards can also be used to store data for a personal computer, as needed, as well as to transfer data from a portable device to a computer. Consequently, most desktop and notebook computers today come with a *flash memory card reader* capable of reading flash memory cards; an external flash memory card reader (see Figure 3-17) that typically connects via a USB port can be used if a built-in reader is not available. The capacity of flash memory cards is continually growing and is up to 2 GB for standard cards and 32 GB for high-capacity cards; the even higher capacity extended capacity cards are expected to reach capacities of 2 TB by 2014.

One of the most widely used types of flash memory media—Secure Digital (SD)—is available in different physical sizes, as well as in different capacities. For instance, standard-sized SD cards are often used in digital cameras and computers; the smaller *miniSD* and *microSD* (about one-half and one-quarter the size of a standard SD card, respectively, as shown in Figure 3-17) are designed to be used with mobile phones and other mobile devices. When more storage space is needed, higher capacity *miniSDHC* and *microSDHC* cards can be used.

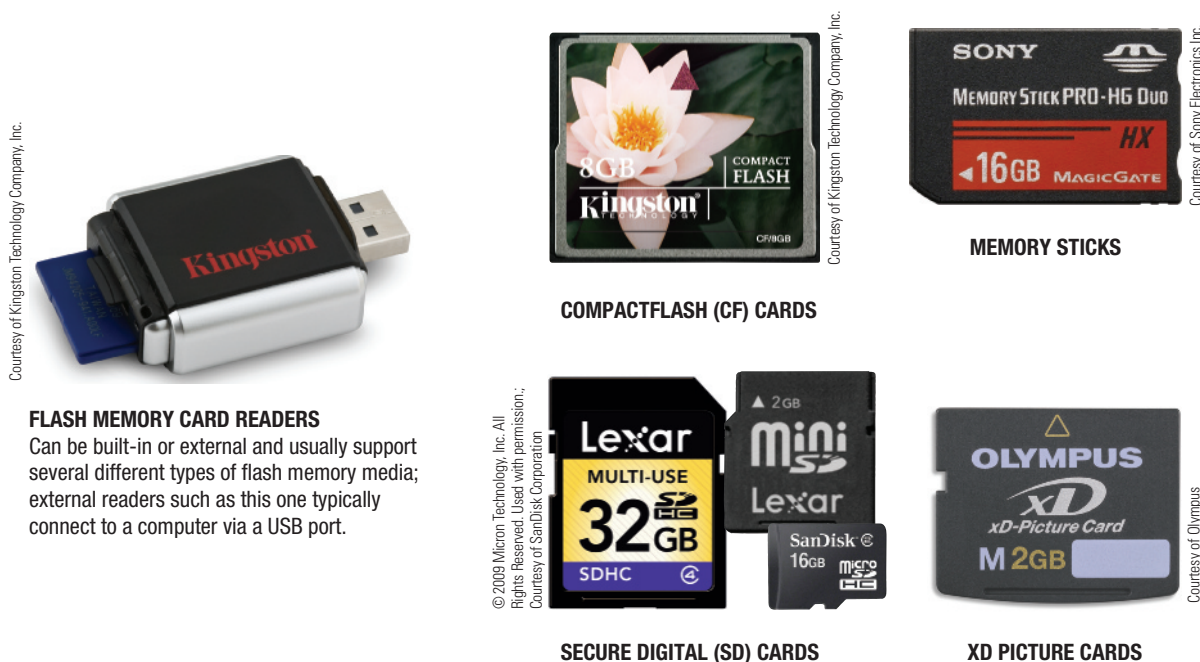
### TIP

Flash memory cards can be inserted into a reader only one way and must go in the proper slot, so be sure to check the slot type and look for the directional tips often printed on the card before inserting a card into a flash memory reader.

### TIP

The speed of SDHC cards are beginning to use class ratings to indicate their speed, such as *Class 4* cards and *Class 10* cards that have a minimum data transfer rate of 4 MB/second and 10 MB/second, respectively.

**FIGURE 3-17**  
Flash memory cards. Shown here are some of the most widely used types of flash memory cards and a multcard reader.



### FLASH MEMORY CARD READERS

Can be built-in or external and usually support several different types of flash memory media; external readers such as this one typically connect to a computer via a USB port.

COMPACTFLASH (CF) CARDS

MEMORY STICKS

SECURE DIGITAL (SD) CARDS

XD PICTURE CARDS

>**Flash memory card.** A small, rectangular flash memory medium, such as a CompactFlash (CF) or Secure Digital (SD) card; often used with digital cameras and other portable devices.

MMC cards and memory sticks are also available in mobile sizes; adapters can be used with mobile-sized flash memory cards in order to use them in a full-sized memory card reader.

While general-purpose flash memory cards can be used for most applications, there are also flash memory cards designed for specific uses. For instance, *professional flash memory cards* designed for professional photographers are faster and more durable than consumer cards; *gaming flash memory cards* are specifically designed for gaming consoles and devices, such as the Nintendo Wii or Sony PSP; *HD flash memory cards* are designed for capturing and transferring high-definition video; and *netbook flash memory cards* are designed to be used to expand the storage capabilities of a netbook computer. There are even Wi-Fi-enabled flash memory cards that can wirelessly upload digital photos taken with a camera using that card for storage, as discussed in the Technology and You box in Chapter 7.

Typically, flash memory media are purchased blank, but some flash-memory-based software (such as games, encyclopedias, and language translators) is available. A relatively new option for portable music is *slotMusic*—music albums that come stored on microSD cards. These cards can be used with any phone or portable digital media player that has a microSD slot and they typically contain extra storage space to add additional files as desired. Movies are also beginning to be delivered via flash memory media, such as microSD cards and USB flash drives. These new options for portable multimedia are geared toward individuals who would like access to this content via a mobile phone, hotel room television, netbook, or other device often used while on the go that has a flash memory card slot or a USB port.

## Go FURTHER EXPLORATION

Go to the Chapter 3 page of the **UC14 CourseMate** for links to information about flash memory media and storage systems.

**FIGURE 3-18**  
USB flash drives.



Pakinyusichai/Shutterstock.com

CONVENTIONAL DRIVE



Courtesy CustomUSB.com

CUSTOM CONVENTIONAL DRIVE



Courtesy CustomUSB.com

CUSTOM WRISTBAND DRIVE



Courtesy CustomUSB.com

CUSTOM WALLET DRIVE

USB flash drives (sometimes called *USB flash memory drives*, *thumb drives*, or *jump drives*) consist of flash memory media integrated into a self-contained unit that connects to a computer or other device via a standard USB port and is powered via the USB port. USB flash drives are designed to be very small and very portable. In order to appeal to a wide variety of users, USB flash drives are available in a range of sizes, colors, and appearances—including those designed to be attached to backpacks or worn on a lanyard around the neck; those built into pens, necklaces, wristbands, or wristwatches; those thin enough to fit easily into a wallet; and those made into custom shapes for promotional or novelty purposes (see Figure 3-18). In fact, a growing trend with promotion USB flash drives is completely custom-shaped drives made out of rubber, metal, plastic, or wood (such as the chess-piece drive shown in Figure 3-18). When the USB flash drive is built into a consumer product (such as a watch, sunglasses, or a Swiss Army knife), a retractable cord is often used to connect the device to a computer when needed. Because they are becoming

> **USB flash drive.** A small storage device that plugs into a USB port and contains flash memory media.

## TECHNOLOGY AND YOU

### Thumb Drive PCs

We all know that USB flash drives are a great way to transport documents from one location to another, but what about using one to take a personalized computer with you wherever you go? It's possible and easy to do with the use of *portable applications* (also called *portable apps*)—computer programs that are designed to be used with portable devices like USB flash drives. When the device is plugged into the USB port of any computer, you have access to the software and personal data (including your browser bookmarks, calendar, e-mail and instant messaging contacts, and more) stored on that device, just as you would on your own computer. And when you unplug the device, none of your personal data is left behind because all programs are run directly from the USB flash drive. Many portable applications (such as the PortableApps suite shown in the accompanying illustration) are free and include all the basics you might want in a single package. For instance, PortableApps includes a menu structure, antivirus program, Web browser, e-mail program, calendar program, the OpenOffice.org office suite, and more. To set up a USB flash drive as a portable computer, you need to perform the following steps:

1. Download your desired portable applications (such as the PortableApps suite) to your desktop or notebook computer.
2. Plug in your USB flash drive and run the portable apps installation program, using your USB flash drive as the destination folder.
3. Open a file management program such as Windows Explorer, double-click your USB flash drive, and then launch your portable apps software to test it.

4. Download and install any additional portable apps you would like to use (it is a good idea to include an antivirus program to try to prevent the USB flash drive from becoming infected with a computer virus).

To use your thumb drive computer, plug it into the USB port of any computer—many portable apps will launch automatically and display a main menu, such as the one shown in the accompanying illustration. Portable apps can also be installed on an iPod or other portable digital media player (instead of a USB flash drive) if you prefer to use that device as your portable computer.



so widely used, additional hardware related to USB flash drives are becoming available, such as *USB duplicator systems* used by educators to copy assignments or other materials to and from a large collection of USB flash drives at one time.

To read from or write to a USB flash drive, you just plug it into a USB port. If the USB flash drive is being used with a computer, it is assigned a drive letter by the computer, just like any other type of attached drive, and files can be read from or written to the USB flash drive until it is unplugged from the USB port. The capacity of most USB flash drives today ranges from 2 GB to 256 GB. USB flash drive use has become commonplace for individuals, students, and employees to transport files from one computer to another, as well as to quickly back up important files. For a look at how you can carry your personal computer with you on a USB flash drive, see the Technology and You box.

### VIDEO PODCAST



Go to the Chapter 3 page of the **UC14 CourseMate** to download or listen to the “How To: Use Portable Applications with a USB Flash Drive” video podcast.

## ASK THE EXPERT

Courtesy of Kingston Technology Company, Inc.



**Mark Tekunoff**, Senior Technology Manager,  
Kingston Technology

**Is it better to copy a file from a USB flash drive to a hard drive for extensive editing instead of working directly with (and repeatedly saving) the document on the USB flash drive?**

Flash drives use two different types of memory and can typically support 10,000 or 100,000 writes. If you take into consideration that USB flash drives have a feature called *wear leveling* to make sure that no single data location gets used over and over, the typical USB flash drive can last 7 to 10 years.

For performance, however, it's always better to process work on the hard drive. Of course, a consumer can use the USB flash drive to save or process data too, it will just be a little slower.

In addition to providing basic data storage and data portability, USB flash drives can provide additional capabilities. For instance, they can be used to lock a computer and to issue Web site passwords; they can also include *biometric features*—such as a built-in fingerprint reader—to allow only authorized individuals access to the data stored on the USB flash drive or to the computer with which the USB flash drive is being used.

## OTHER TYPES OF STORAGE SYSTEMS

Other types of storage systems used with personal and business computers today include *remote storage*, *smart cards*, and *holographic storage*. There are also storage systems and technologies designed for large computer systems. These systems are discussed next.

### Network Storage and Online/Cloud Storage Systems

**Remote storage** refers to using a storage device that is not connected directly to the user's computer; instead, the device is accessed through a local network or through the Internet. Using a remote storage device via a local network (referred to as *network storage*) works in much the same way as using *local storage* (the storage devices and media that are directly attached to the user's computer). To read data from or write data to a remote storage device (such as a hard drive in another computer being accessed via a network), the user just selects it (see Figure 3-19) and then performs the necessary tasks in the normal fashion. Network storage is common in businesses; it is also used by individuals with home networks for backup purposes or to share files with another computer in the home.

Because of the vast amount of data shared and made available over networks today, network storage has become increasingly important. Two common types of network storage used today are **network attached storage (NAS)** devices and **storage area networks (SANs)**. NAS devices are high-performance storage systems that are connected individually to a network to provide storage for the computers connected to that network. They can be large storage systems designed for a large business, or smaller NAS devices designed for a home or small business (such as the one in Figure 3-19). A growing trend, in fact, is home NAS devices designed to store multimedia data (such as downloaded music, recorded TV shows, and downloaded movies) to be distributed over a home entertainment network. NAS devices typically connect to the network via a wired networking connection, although some use a wireless networking connection; networking is explained in detail in Chapter 7.

A storage area network (SAN) also provides storage for a network, but it consists of a separate network of hard drives or other storage devices, which is connected to the main network. The primary difference between network attached storage and a storage

### ONLINE VIDEO

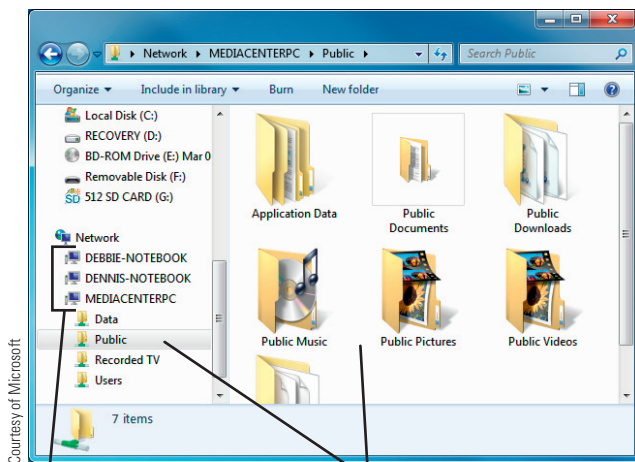


Go to the Chapter 3 page of the **UC14 CourseMate** to watch the "A Look at Network Storage" video clip.

### TIP

If the router used to connect devices to your home network includes a USB port, you can create a NAS by plugging a USB storage device (such as an external hard drive) directly into the router.

> **Remote storage.** A storage device that is not directly connected to the computer being used, such as one accessed through a local network or the Internet. > **Network attached storage (NAS).** A high-performance storage device individually connected to a network to provide storage for computers on that network. > **Storage area network (SAN).** A network of hard drives or other storage devices that provide storage for a network of computers.



Courtesy of Microsoft

Computers on this network.

Items in the Public folder on the computer called MEDIACENTERPC.

### SHARED FOLDERS

Shared folders on network computers appear and are accessed in a manner similar to local folders.



Image courtesy of Iomega an EMC company

### NETWORK ATTACHED STORAGE (NAS) DEVICES

This NAS device holds 4 TB of data and provides storage for all computers on the network.

**FIGURE 3-19**  
Network storage.

area network is how the storage devices interface with the network—that is, whether the storage devices act as individual network nodes, just like computers, printers, and other devices on the network (NAS), or whether they are located in a completely separate network of storage devices that is accessible to the main network (SAN). However, in terms of functionality, the distinction between NAS and SANs is blurring, since they both provide storage services to the network. Typically, both NAS and SAN systems are scalable, so new devices can be added as more storage is needed, and devices can be added or removed without disrupting the network.

Remote storage devices accessed via the Internet are often referred to as **online storage** or **cloud storage**. While these terms are often used interchangeably, some view cloud storage as a specific type of online storage that can be accessed on demand by various Web applications. Most online applications (such as Google Docs, the Flickr photo sharing service, and social networking sites like Facebook, for instance) provide online storage for these services. There are also sites whose primary

## ASK THE EXPERT



Image courtesy of Iomega an EMC company

**Bill Hansen**, Program Manager, Consumer Storage Products, Iomega Corporation

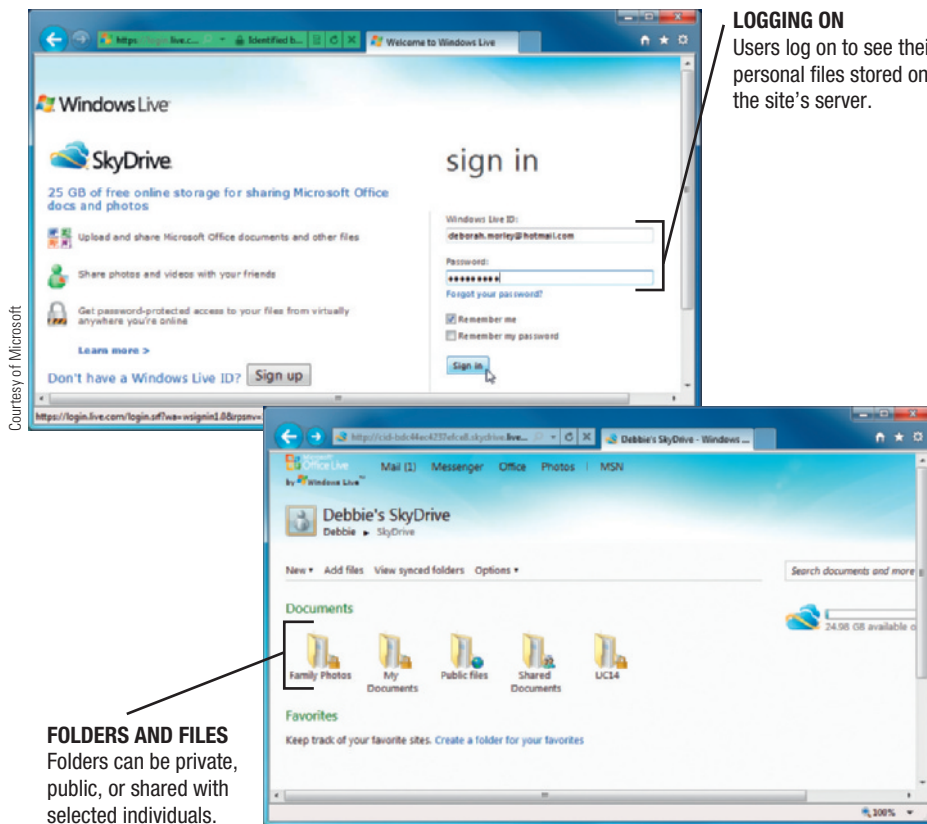
### Do home networks today need network hard drives?

Definitely! Just as the Internet has changed the way we communicate, network hard drives are changing the way we share information in the home. By plugging a network hard drive into your home network, you can share files and folders easily with anyone on that network—no more walking a CD or USB flash drive around to every computer like in the past. Today's network hard drives are simple to set up and use, and they are designed to allow you to access and share your music, pictures, videos, or other files easily with the other devices on your home network. You can also use a network hard drive as a backup target for all of your computers. In a nutshell, network hard drives greatly enhance the ability to share and store your valuable digital files at home.

> **Online storage.** Remote storage devices accessed via the Internet; also called **cloud storage**.







**FIGURE 3-20**  
**Online storage.** This site provides 25 GB of free storage.



### VIDEO PODCAST

Go to the Chapter 3 page of the **UC14 CourseMate** to download or listen to the “How To: Sync iTunes with Amazon Cloud Player” video podcast.

objective is to allow users to store documents online, such as *Box* or Windows Live *SkyDrive*. Typically, online/cloud storage sites are password protected (see Figure 3-20) and allow users to specify uploaded files as private files or as shared files that designated individuals can access.

The ability to store documents online (or “in the cloud”) is growing in importance as more and more applications are becoming Web based and as individuals increasingly want access to their files from anywhere with any Internet-enabled device, such as a portable computer or mobile phone. Online storage is also increasingly being used for backup purposes—some online storage sites have an automatic backup option that uploads the files in designated folders on your computer to your online account at regular specified intervals, as long as your computer is connected to the Internet. Many Web sites providing online storage to individuals offer the service for free (for instance, SkyDrive gives each indi-

vidual 25 GB of free storage space); others charge a small fee, such as \$10 per month for 50 GB of storage space.

Business cloud storage services are also available, such as those offered in conjunction with cloud computing services that allow subscribers to access a flexible amount of both storage and computing power as needed on demand. For instance, *Amazon Simple Storage Service (Amazon S3)*—one of the leaders in *enterprise cloud storage*—charges a monthly fee per GB of storage used plus a fee based on the amount of data transferred that month. This service can be used alone or in conjunction with Amazon’s cloud computing service, *Amazon Elastic Compute Cloud (Amazon EC2)*. In addition to these *public cloud storage services*, businesses can also create *private storage clouds* designed to service just that particular business.

### Smart Cards

A **smart card** is a credit card-sized piece of plastic that contains computer circuitry and components—typically a processor, memory, and storage (see Figure 3-21). Smart cards today store a relatively small amount of data (typically 64 KB or less) that can be used for payment or identification purposes. For example, a smart card can store a prepaid amount of *digital cash*, which can be used for purchases at a smart card-enabled vending machine or computer—the amount of cash available on the card is reduced each time the card is used. Smart cards are also commonly used worldwide for national and student ID cards, credit and debit cards, and cards that store identification data for accessing facilities or computer networks. Although these applications have used conventional *magnetic stripe* technology in the past,

> **Smart card.** A credit card-sized piece of plastic containing a chip and other circuitry that can store data.

the processor integrated into a smart card can perform computations—such as to authenticate the card and encrypt the data on the card to protect its integrity and secure it against unauthorized access—and can allow data to be added to the card or modified on the card as needed. The increased capabilities of smart cards has also allowed for new applications, such as storing biometric data (fingerprint characteristics, for instance) and other identifying data needed to accelerate airport security and to link patients to the *electronic health records* increasingly being used by hospitals.

To use a smart card, it must either be inserted into a *smart card reader* (if it is the type of card that requires contact) or placed close to a smart card reader (if it is a *contactless* card) built into or attached to a computer, keyboard, vending machine, or other device (refer again to Figure 3-21). Once a smart card has been verified by the card reader, the transaction—such as making a purchase or unlocking a door—can be completed. For an even higher level of security, some smart cards today store biometric data in the card and use that data to ensure the authenticity of the card's user before authorizing the smart card transaction (biometrics, encryption, and other security procedures are discussed in more detail in Chapter 9). An emerging trend is the use of *mobile smart cards*—smart microSD cards that are designed to add smart card capabilities to any computer or mobile device that contains a microSD slot.

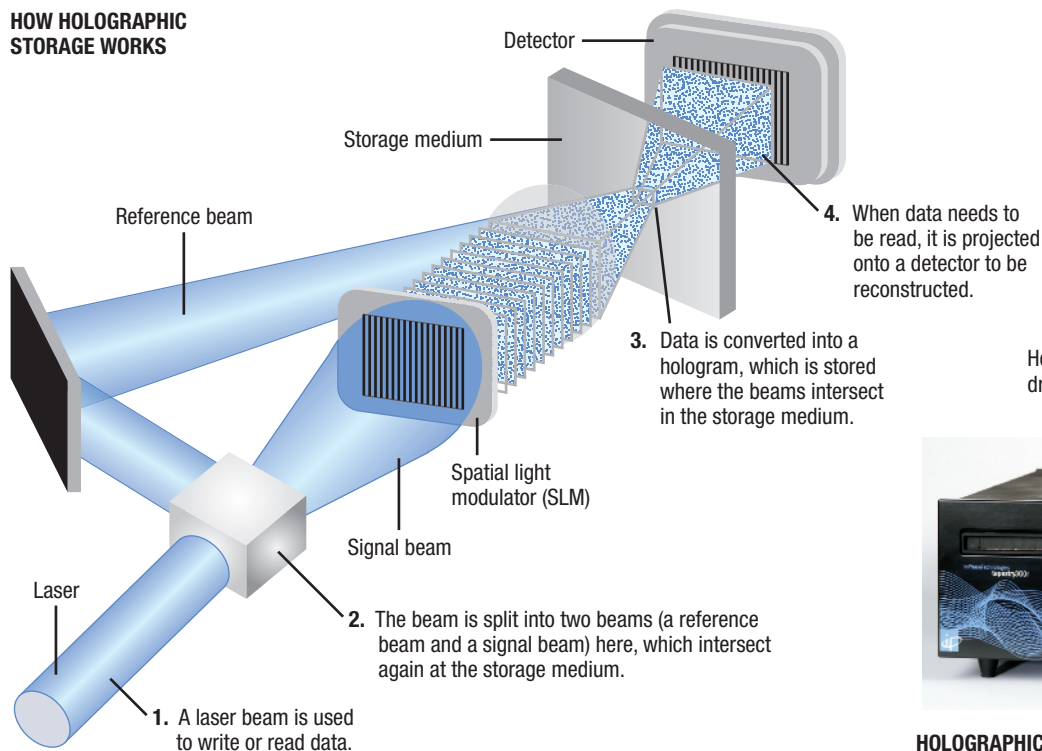
## Holographic Storage

**Holographic storage** is a type of three-dimensional (3D) storage system that, after many years of research and development, is now just about a reality. *Holographic drives* typically connect to a computer via a serial attached SCSI (SAS) or Fibre Channel interface. To record data onto a *holographic disc* or *holographic cartridge*, the holographic drive splits



**FIGURE 3-21** Smart cards. Smart cards can be used to log on to computers and networks, access facilities, pay for goods and services, and so forth.

> **Holographic storage.** An emerging type of storage technology that uses multiple blue laser beams to store data in three dimensions.

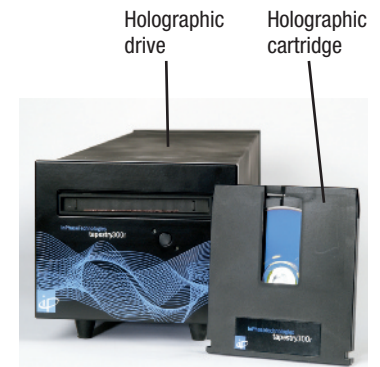
**HOW HOLOGRAPHIC STORAGE WORKS**

**FIGURE 3-22**  
**Holographic storage.** Holographic drives store up to one million bits of data in a single flash of light.

the light from a blue laser beam into two beams (a *reference beam* whose angle determines the address used to store data at that particular location on the storage medium and a *signal beam* that contains the data). The signal beam passes through a device called a *spatial light modulator (SLM)*, which translates the data's 0s and 1s into a *hologram*—a three-dimensional representation of data in the form of a checkerboard pattern of light and dark pixels—at the intersection of the reference beam and signal beam. The two beams intersect within the recording medium to store the hologram at that location (see Figure 3-22) by changing the optical density of the medium.

Over one million bits of data can be stored at one time in a single flash of light, so data access in holographic storage systems can be very fast. And, because the hologram goes through the entire thickness of the medium, in three dimensions, much more data can be stored on a holographic disc or cartridge than on a CD, DVD, or BD of the same physical size. In fact, hundreds of holograms can be stored in an overlapping manner in the same area of the medium—a different reference beam angle or position is used for each hologram so it can be uniquely stored and retrieved when needed. To read data, the reference beam projects the hologram containing the requested data onto a *detector* that reads the entire data page at one time. Holographic storage systems will initially use removable recordable holographic cartridges that hold 300 GB per cartridge; 1.6 TB cartridges, as well as drives that can hold multiple cartridges for increased storage capacity, are expected in the near future.

Since initial holographic data storage systems will be read-only, they are particularly suited to applications in which large amounts of data need to be stored or retrieved quickly, but rarely changed, such as for data archiving of e-mail and other business data, medical records, movies and TV shows, and data recorded by military sensors. Rewritable holographic drives and media are currently in the development stage and are expected to be available in the near future. In addition to storage capacity and fast access, holographic storage has a longer media life and uses much less energy than magnetic or optical storage systems.



**HOLOGRAPHIC DRIVES AND CARTRIDGES**

### Storage Systems for Large Computer Systems

Businesses and other organizations have tremendous storage needs. In addition to regular business data storage (such as employee files, customer and order data, business

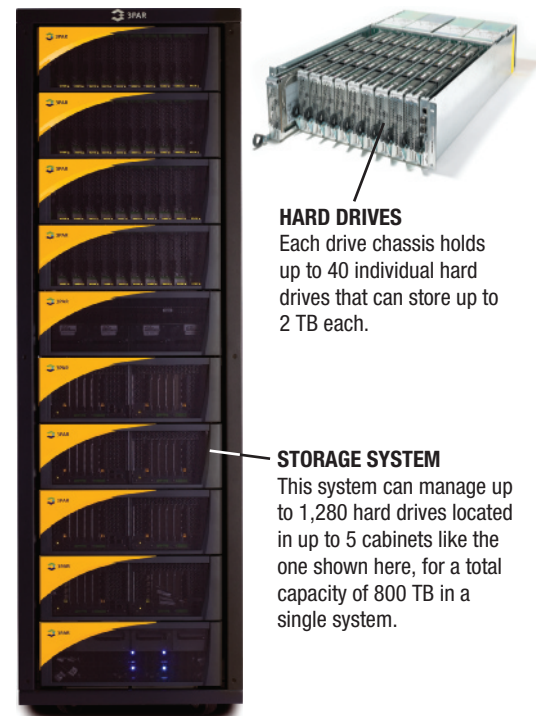
documents, and Web site content), new regulations are continually increasing the types of and amounts of data that many businesses need to archive. For instance, the *Health Insurance Portability and Accountability Act (HIPAA)* requires healthcare providers to archive huge amounts of medical data, and the *Sarbanes-Oxley Act* requires certain accounting records and work papers to be archived for five years. In addition, a recent *e-discovery* federal mandate requires businesses to locate and provide to the courts in a timely manner any document stored electronically (such as e-mail messages, text messages, and text documents) that is needed for evidence in civil litigation involving their companies. All of these requirements mean that business storage needs are growing exponentially—one forecast predicts that digital storage needs will increase by 50% annually through 2014—and the documents must be stored in a manner in which they can be readily retrieved as needed.

Storage for large computer systems (such as those containing mainframe computers and midrange servers) utilizes much of the same storage hardware, standards, and principles as those used with personal computers, but on a much larger scale. However, instead of finding a single magnetic or SSD hard drive installed within the system unit, you are most likely to find a large storage system (sometimes called a *storage server*)—a separate piece of hardware containing multiple high-speed hard drives—connected to the computer system or network. Large storage systems typically contain drawers of hard drives for a large total capacity. For instance, the storage system shown in Figure 3-23 can include up to 1,280 hard drives for a total capacity of 800 TB. These types of storage systems—also referred to as *enterprise storage systems*—typically use fast Fibre Channel or iSCSI connections and are *scalable*, meaning that more hard drives can be added as needed up to the maximum system capacity. In addition to being used as stand-alone storage for large computer systems, large storage systems may also be used in network attached storage (NAS), storage area network (SAN), and *RAID (redundant arrays of independent disks)* systems. Most large storage systems are based on magnetic hard disks, although SSD and *magnetic tape storage systems* are also possible. RAID and magnetic tape systems are discussed next.

## RAID

**RAID (redundant arrays of independent disks)** is a method of storing data on two or more hard drives that work together. Although RAID can be used to increase performance, it is most often used to protect critical data on a large storage system. Because RAID usually involves recording redundant (duplicate) copies of stored data, the copies can be used, when necessary, to reconstruct lost data. This helps to increase the *fault tolerance*—the ability to recover from an unexpected hardware or software failure, such as a system crash—of a storage system.

There are several different RAID designs or levels that use different combinations of RAID techniques. For example, *RAID 0* uses *disk striping*, which spreads files over two or more hard drives (see the leftmost part of Figure 3-24). Although striping improves performance since multiple hard drives can be accessed at one time to store or retrieve data, it does not provide fault tolerance. Another common RAID technique is *disk mirroring*, in which data is written to two duplicate hard drives simultaneously (see the rightmost part of Figure 3-24). The objective of disk mirroring is to increase fault tolerance—if one of the hard drives fails, the system can instantly switch to the other hard drive without any loss of



**HARD DRIVES**  
Each drive chassis holds up to 40 individual hard drives that can store up to 2 TB each.

**STORAGE SYSTEM**  
This system can manage up to 1,280 hard drives located in up to 5 cabinets like the one shown here, for a total capacity of 800 TB in a single system.

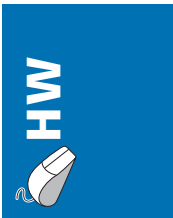
**FIGURE 3-23**  
**Large storage systems.** Large storage systems are usually scalable so additional hard drives can be added as needed.

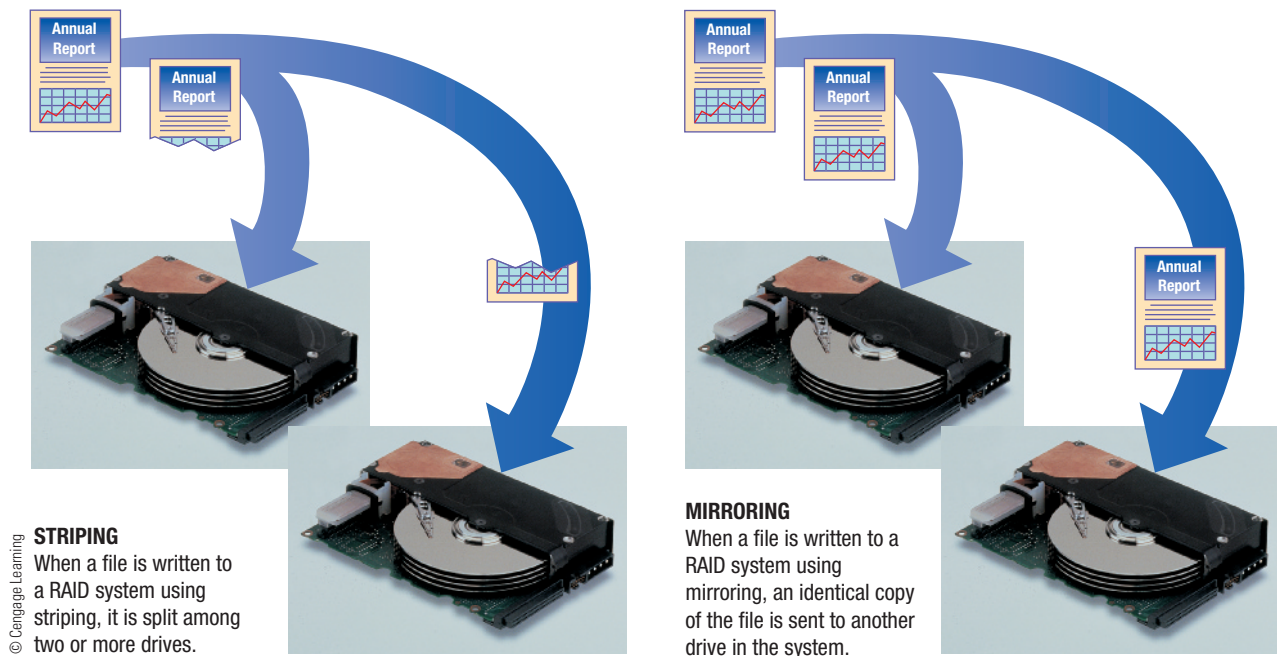
## ONLINE VIDEO



Go to the Chapter 3 page of the **UC14 CourseMate** to watch the “Understanding NAS and RAID” video clip.

**>RAID (redundant arrays of independent disks).** A storage method that uses several hard drives working together, typically to increase performance and/or fault tolerance.





**FIGURE 3-24**  
**RAID.** Two primary RAID techniques are striping and mirroring.

data or service. *RAID 1* uses disk mirroring. Levels beyond RAID 1 use some combination of disk striping and disk mirroring, with different types of error correction provisions.

One disadvantage of RAID in the past is the difficulty traditionally involved with setting up and maintaining the system. New storage systems—such as *Drobo* storage systems (see Figure 3-25)—eliminate this concern. Drobo devices connect to an individual computer or a network similar to an external hard drive (such as via a USB, FireWire, eSATA, iSCSI, or Ethernet connection) and have up to 12 empty drive bays into which hard drives can be inserted for a total storage capacity of up to 36 TB. Like many RAID systems, Drobo systems offer continuous data redundancy, but they are much easier to use than conventional RAID systems and no special skills are needed to manage, repair, or upgrade them. For instance, hard drives just slide in and out of Drobo devices and drives can be swapped in order to replace a bad hard drive or to increase capacity, even while the devices are being used. When a drive is replaced, the system automatically copies data as needed to the new hard drive to restore the system back to its configuration before the hard drive failed or was removed. The new hard drives don't have to match the others—they can be different types, speeds, capacities, and brands. In addition, Drobo has additional features (called *thin provisioning* and *automatic tiering*) that allow applications more control over the storage system than usual. This



**FIGURE 3-25**  
**A Drobo storage system.**

flexibility and ease of use makes the Drobo systems particularly appropriate for individuals and small businesses that need the security of data redundancy but have no IT personnel to assign to a RAID system.

### Magnetic Tape Systems

**Magnetic tape** consists of plastic tape coated with a magnetizable substance that represents the bits and bytes of digital data, similar to magnetic hard disks. Although magnetic tape is no longer used for everyday storage applications because of its sequential-access

> **Magnetic tape.** Storage media consisting of plastic tape with a magnetizable surface that stores data as a series of magnetic spots; typically comes as a cartridge.

property, it is still used today for business data archiving and backup. One advantage of magnetic tape is its low cost per terabyte.

Most computer tapes today are in the form of *cartridge tapes*, such as the one shown in Figure 3-26. Computer tapes are read by *tape drives*, which can be either an internal or an external piece of hardware. Tape drives contain one or more read/write heads over which the tape passes to allow the tape drive to read or write data. Cartridge tapes are available in a variety of sizes and formats; tape sizes and formats generally are not interchangeable. Tape cartridge capacity varies widely, from 500 MB to more than 1 TB per cartridge. When an even larger capacity is required, *tape libraries*—devices that contain multiple tape drives—can be used to boost storage capacity up to 10 PB.



Courtesy of Iomega

**FIGURE 3-26**  
This magnetic tape cartridge holds 80 GB.

## EVALUATING YOUR STORAGE ALTERNATIVES

Storage alternatives are often compared by weighing a number of product characteristics and cost factors. Some of these product characteristics include speed, compatibility, storage capacity, convenience, and the portability of the media. Keep in mind that each storage alternative normally involves trade-offs. For instance, most systems with removable media are slower than those with fixed media, and external drives are typically slower than internal ones. Although cost is a factor when comparing similar devices, it is often not the most compelling reason to choose a particular technology. For instance, although USB flash drives are relatively expensive per GB compared to optical discs and external hard drives, many users find them essential for transferring files between work and home or for taking presentations or other files with them as they travel. For drives that use a USB interface, the type of USB port is also significant. For example, storage devices that connect via a USB port adhering to the original USB 1.0 standard transfer data at up to 12 Mbps—USB 2.0 devices are about 40 times faster and USB 3.0 devices are about 10 times as fast as USB 2.0 devices.

With so many different storage alternatives available, it is a good idea to research which devices and media are most appropriate for your personal situation. In general, most computer users today need a hard drive (for storing programs and data), some type of recordable or rewritable optical drive (for installing programs, backing up files, and sharing files with others), and a flash memory card reader (for transferring photos, music, and other content between portable devices and the computer). Users who plan to transfer music, digital photos, and other multimedia data on a regular basis between devices—such as a computer, digital camera, mobile phone, and printer—will want to select and use the flash memory media that are compatible with the devices they are using. They will also need to obtain the necessary adapter for their computer if it does not include a compatible built-in flash memory reader. Virtually all computer users today will also need at least one convenient free USB port to be used to connect external hard drives, USB flash drives, and other USB-based storage hardware, as well as USB devices that contain storage media, such as digital cameras and portable digital media players. Several convenient USB ports are even better, though a USB hub can be used to connect multiple devices to a single USB port, if needed.

Mobile device users have fewer options for storage alternatives, so users should consider the available options when selecting a mobile device to ensure it can perform the functions the user deems necessary, such as the ability to back up data and contacts in the cloud or on a medium the user can access with another device, the ability to transfer photos and other data to a computer or printer, and so forth. As mentioned in the chapter, there are specific storage devices designed for mobile devices. One example, a backup and charging system for the iPhone and iPod Touch, is shown in Figure 3-27. This device automatically backs up contacts and photos onto an SD card whenever the iPhone or iPod is placed into the charger so this data can be transferred to a new iPhone or iPod Touch if the mobile device is lost or stolen.



Image courtesy of Iomega an EMC company

**FIGURE 3-27**  
Backup/charging system for iPhone and iPod Touch.

### TIP

Since most netbooks don't come with an optical drive, users of these netbooks may want to also obtain an external DVD drive to use when needed.

## SUMMARY

### Chapter Objective 1:

Name several general characteristics of storage systems.

### Chapter Objective 2:

Describe the two most common types of hard drives and what they are used for today.

### Chapter Objective 3:

Discuss the various types of optical discs available today and how they differ from each other.

## STORAGE SYSTEMS CHARACTERISTICS

*Storage systems* make it possible to save programs, data, and processing results for later use. They provide nonvolatile storage, so when the power is shut off, the data stored on the storage medium remains intact. All storage systems involve two physical parts: a **storage device** (such as a DVD drive) and a **storage medium** (such as a DVD disc). Data is often stored *magnetically* or *optically* on storage media, and storage media are read by the appropriate types of drive. Drives can be *internal*, *external*, or *remote*. Drives are typically assigned letters by the computer; these letters are used to identify the drive.

*Sequential access* allows a computer system to retrieve the records in a file only in the same order in which they are physically stored. *Random access* (also called *direct access*) allows the system to retrieve records in any order. In either case, **files** (sometimes called *documents*) stored on a storage medium are given a **filename** and can be organized into **folders**. This is referred to as *logical file representation*. *Physical file representation* refers to how the files are physically stored on the storage medium by the computer.

## HARD DRIVES

**Hard drives** are used in most computers to store programs and data. Conventional hard drives are **magnetic hard drives**; a newer type of hard drive that uses flash memory instead of magnetic disks is the **solid-state drive (SSD)**. Hard drives can be *internal* or *external*; external hard drives can be full-sized or portable. **Hybrid hard drives** are a combination of a magnetic hard drive and an SSD, containing a large amount of flash memory that is used in conjunction with magnetic hard disks to provide increased performance while reducing power consumption.

Magnetic hard drives contain metal hard disks that are organized into concentric **tracks** encoded with magnetized spots representing 0s and 1s. **Sector** boundaries divide a magnetic disk surface into pie-shaped pieces. A **cluster**, which is the smallest amount of disk space that can be allocated to hold a file, contains one or more sectors. All tracks in the same position on all surfaces of all disks in a hard drive form a **cylinder**. A separate *read/write head* that corresponds to each disk surface is used to read and write data. Hard drives can be divided into multiple *partitions* (logical drives) for efficiency or to facilitate multiple users or operating systems. Solid-state drives (SSDs) are increasingly used for portable computers because they are more shock-resistant and energy-efficient.

The total time it takes for a magnetic hard drive to read from or write to disks is called **disk access time**. A **disk cache** strategy, in which the computer transfers additional data to memory whenever disk content is retrieved, can help to speed up access time. Hard drives can connect to a computer using one of several standards, such as *serial ATA (SATA)*, *parallel ATA (PATA)*, *serial attached SCSI (SAS)*, *eSATA*, *Fibre Channel*, *FireWire*, or *USB*.

## OPTICAL DISCS AND DRIVES

**Optical discs**, such as **CD discs**, **DVD discs**, and **Blu-ray Discs (BDs)**, store data *optically* using laser beams, and they can store data much more densely than magnetic disks. They are divided into tracks and sectors like magnetic disks, but they use a single spiral track instead of concentric tracks. Data is represented by *pits* and *lands* permanently formed on the surface of the disk. Optical discs are available in a wide variety of sizes, shapes, and capacities and are read by **optical drives**, such as *CD* or *DVD drives*. **CD-ROM discs** come with data already stored on the disc. CD-ROM discs cannot be erased or overwritten—they are

*read-only*. **DVD-ROM discs** are similar to CD-ROM discs, but they hold much more data (at least 4.7 GB instead of 650 MB). High-capacity read-only optical discs designed for high-definition content are **BD-ROM discs**. *Recordable discs* (**CD-R**, **DVD-R/DVD+R**, and **BD-R discs**, for example) and *rewritable disks* (**CD-RW**, **DVD-RW/DVD+RW**, and **BD-RE discs**, for instance) can all be written to, but only rewritable discs can be erased and rewritten to, similar to a hard drive. Recordable CDs and DVDs store data by burning permanent marks onto the disc, similar to CD-ROM and DVD-ROM discs; rewritable discs typically use *phase change* technology to temporarily change the reflectivity of the disc to represent 1s and 0s.

## FLASH MEMORY STORAGE SYSTEMS

**Flash memory** is used in a variety of storage systems. It can be **embedded flash memory**, which is embedded into products to provide storage capabilities, or it can take the form of *flash memory media* like *flash memory cards* and *USB flash drives*. **Flash memory cards**, one of the most common types of flash memory media, are commonly used with digital cameras, portable computers, and other portable devices, as well as with desktop computers. Flash memory cards come in a variety of formats—the most common are *CompactFlash (CF)* and *Secure Digital (SD) cards*. **USB flash drives** connect to a computer or other device via a USB port and are a convenient method of transferring files between computers. They can also provide other capabilities, such as to lock a computer or control access to the data stored on the USB flash drive.

## OTHER TYPES OF STORAGE SYSTEMS

**Remote storage** involves using a storage device that is not directly connected to your computer. One example is using a *network storage* device, such as a **network attached storage (NAS)** or **storage area network (SAN)**. Another is **online storage** or **cloud storage**, that is, storage available via the Internet. **Smart cards** contain a chip or other circuitry usually used to store data or a monetary value. **Holographic storage**, which uses multiple blue laser beams to store data in three dimensions, is an emerging option for high-speed data retrieval applications.

Storage systems for larger computers implement many of the same standards as the hard drives used with personal computers. However, instead of a single set of hard disks inside a hard drive permanently installed within a system unit, a large *storage system* is often used. **RAID (redundant arrays of independent disks)** technology can be used to increase *fault tolerance* and performance. **Magnetic tape** systems store data on plastic tape coated with a magnetizable substance. Magnetic tapes are usually enclosed in cartridges and are inserted into a *tape drive* in order to be accessed. Magnetic tape is typically used today only for backup and archival purposes.

## EVALUATING YOUR STORAGE ALTERNATIVES

Most personal computers today include a hard drive, some type of optical drive, a flash memory card reader, and multiple USB ports that can be used to connect USB-based storage devices, such as external hard drives and USB flash drives, as well as other USB hardware. The type of optical drive and any additional storage devices are often determined by weighing a number of factors, such as cost, speed, compatibility, storage capacity, removability, and convenience.

HW



### Chapter Objective 4:

Identify some flash memory storage devices and media and explain how they are used today.

### Chapter Objective 5:

List at least three other types of storage systems.

### Chapter Objective 6:

Summarize the storage alternatives for a typical personal computer.



**REVIEW ACTIVITIES****KEY TERM MATCHING**

- a. disk cache
- b. file
- c. flash memory card
- d. folder
- e. hard drive
- f. holographic storage
- g. RAID
- h. remote storage
- i. solid-state drive (SSD)
- j. storage area network (SAN)

**Instructions:** Match each key term on the left with the definition on the right that best describes it.

1. \_\_\_\_\_ A named place on a storage medium into which files can be stored to keep the files stored on that medium organized.
2. \_\_\_\_\_ A hard drive that uses flash memory media instead of metal magnetic hard disks.
3. \_\_\_\_\_ An emerging type of storage technology that uses multiple blue laser beams to store data in three dimensions.
4. \_\_\_\_\_ A small, rectangular flash memory medium, such as a CompactFlash (CF) or Secure Digital (SD) card; often used with digital cameras and other portable devices.
5. \_\_\_\_\_ A network of hard drives or other storage devices that provide storage for a network of computers.
6. \_\_\_\_\_ A storage device that is not directly connected to the computer being used, such as one accessed through a local network or the Internet.
7. \_\_\_\_\_ A storage method that uses several hard drives working together, typically to increase performance and/or fault tolerance.
8. \_\_\_\_\_ Memory used in conjunction with a magnetic hard drive to improve system performance.
9. \_\_\_\_\_ Something stored on a storage medium, such as a program, a document, or an image.
10. \_\_\_\_\_ The primary storage system for most computers; used to store most programs and data used with that computer.

**SELF-QUIZ**

**Instructions:** Circle **T** if the statement is true, **F** if the statement is false, or write the best answer in the space provided. **Answers for the self-quiz are located in the References and Resources Guide at the end of the book.**

1. **T F** A computer system with a C drive and a D drive must have two physical hard drives.
2. **T F** The smallest amount of space a file on a disk can take up is one cluster.
3. **T F** External hard drives typically connect via a flash memory reader.
4. **T F** A CD-R disc can be written to by the user.
5. **T F** A hybrid hard drive contains both magnetic hard disks and optical discs.
6. The drive letter that would most likely be assigned to the primary hard drive on a typical personal computer is \_\_\_\_\_.
7. Storage media are not \_\_\_\_\_, meaning they do not lose their contents when the power is shut off.
8. A single-sided, single-layer CD disc typically holds \_\_\_\_\_.
9. A(n) \_\_\_\_\_ looks similar to a credit card but contains a chip and other circuitry that can store data.
10. Secure Digital (SD) cards are one type of \_\_\_\_\_ medium.

## EXERCISES

1. Assume, for simplicity's sake, that a kilobyte is 1,000 bytes, a megabyte is 1,000,000 bytes, and a gigabyte is 1,000,000,000 bytes. You have a 500-gigabyte hard drive with the following content:

ITEM	STORAGE SPACE USED
Operating system	65 MB
Other software	1,350 MB
Digital photos and videos	1,000 MB
Other documents	85 MB

How much storage space is currently being used? \_\_\_\_\_ How much is left? \_\_\_\_\_

2. Supply the missing words to complete the following statements.
- A(n) \_\_\_\_\_ disc can hold either 25 GB or 50 GB and is designed for high-definition content, such as movies.
  - Thumb drive* is another name for a(n) \_\_\_\_\_.
  - Memory used in conjunction with a magnetic hard drive to improve system performance is called a disk \_\_\_\_\_.
3. Explain why CD-ROM discs are not erasable, but CD+RW discs are.
4. List two possible advantages and two possible disadvantages for using online storage.
5. Which types of storage media would be appropriate for someone who needed to exchange large (5 MB to 75 MB) files with another person? List at least three different types, stating why each might be the most appropriate under specific conditions.

1. There are a number of types of flash memory cards available, such as SD, CF, XD, and memory stick. Is there an advantage to having multiple standards or would it be beneficial to consumers if there was only one flash memory standard, such as just the various sizes of SD cards? Would having a single standard be less expensive and more convenient for consumers? If so, will a single standard naturally evolve or should it be mandated by the storage industry or the government? If you use multiple types of flash memory cards with your devices, would you prefer they all used the same type? Why or why not?
2. People send their digital photos over the Internet in different ways. For instance, digital photos are often e-mailed to others, posted on Facebook pages and other social networking sites, and uploaded to a server (such as one belonging to Snapfish, Walmart, or Costco) in order to order prints, enlargements, or other photo-based items. If you have ever sent photos over the Internet, were you concerned about someone other than the intended recipient intercepting or viewing your photo files? If you have ever uploaded files to a processing service for printing, did you check to see if the Web server being used was secure? Should individuals be concerned about sending their personal photos over the Internet? There are a number of advantages, but are there privacy risks, as well?

DISCUSSION  
QUESTIONS

HW



# PROJECTS

## HOT TOPICS

1. **Thumb Drive PCs** As discussed in the chapter Technology and You box, USB flash drives can be used to bring your personal software and settings with you to any computer with which you use that drive. In addition, USB flash drives can be used to securely store files, grant access to a computer, and more.

For this project, research two features that USB flash drives can provide, in addition to just data storage. For your selected features, determine what the feature does, how it works, what benefits it provides, and some examples of USB flash drives that are currently being sold that include that feature. Is there an additional cost for drives that contain this feature? If so, do you think it is worth the extra cost? Do you think the feature is beneficial? Why or why not? At the conclusion of your research, prepare a one- to two-page summary of your findings and opinions and submit it to your instructor.

## SHORT ANSWER/ RESEARCH

2. **Big Brother?** Some of the storage technology used today, such as smart cards, can help facilitate fast and secure access to locked facilities, can protect against the use of stolen credit card numbers, and, when used in conjunction with a biometric characteristic, can unequivocally identify an individual. They can also be used for employee monitoring, such as to identify the location of an employee carrying or wearing his or her smart card at any time. While some people find benefits to the applications just discussed, others worry that smart cards and other devices will be used to track our movements.

For this project, write a short essay expressing your opinion about the use of smart cards and similar technology to identify individuals for various applications. Is the convenience of smart card technology worth the possible loss of privacy? Do you think employers or the government have the right to track individuals' movements? If so, under what conditions? What are some advantages and disadvantages for the government and your employer always knowing where you are? Have you ever used a smart card or been identified with a biometric system? If so, how do you rate the experience? Submit your opinion on this issue to your instructor in the form of a one-page paper.

## HANDS ON



3. **Online/Cloud Storage** There are a number of online or cloud storage services (such as ADrive, Windows Live SkyDrive, and Box) designed to allow individuals to back up files online and share specific files with others; specialty online storage services designed for digital photo sharing include Flickr, Photobucket, and Snapfish.

For this project, visit at least one online/cloud storage site designed for backup and file exchange, and at least one site designed for digital photo sharing. You can try the sites listed above or use a search site to find alternative sites. Tour your selected sites to determine the features each service offers, the cost, the amount of storage space available, and the options for sending uploaded files to others. Do the sites password protect your files, or are they available for anyone with an Internet connection to see? What are the benefits for using these types of storage services? Can you think of any drawbacks? Would you want to use any of the storage sites you visited? Why or why not? At the conclusion of this task, prepare a short summary of your findings and submit it to your instructor.

4. **Lost and Found** Portable computers, mobile phones, USB flash drives, and other portable devices are lost all the time today. They can be dropped out of a pocket or bag, inadvertently left on a table, and so forth. If the owner has identifying information (name, phone number, or e-mail address, for instance) printed on the device, the individual who finds the device can attempt to return it to the owner. But what if there is no identifying information clearly visible on the device? Should the finder look at the contents of the device to try to determine the owner? If the device is lost in a location where there is a responsible party (such as an airplane or a restaurant), the finder can turn over the device to that authority (such as a flight attendant or manager), but is it ethical for the responsible party to look at the contents in order to identify the owner? If you lost a device, would you want someone to look at the contents to try to determine your identity? Why or why not? Is looking at the contents on a found device ever ethical? Should it be illegal?

For this project, form an opinion about the ethical ramifications of lost devices and be prepared to discuss your position (in class, via an online class discussion group, in a class chat room, or via a class blog, depending on your instructor's directions). You may also be asked to write a short paper expressing your opinion.

5. **Flash Cards** There are a wide variety of flash memory card products available today and they can be used with a variety of devices.

For this project, find at least two different examples of flash memory card products in each of the following three categories: user storage; software, music, or movie delivery; and an interface for a peripheral device. Share your findings with the class in the form of a short presentation, including the products that you found, their purpose, what devices they are intended to be used with, and their cost. Be sure to also mention any additional categories or applications using flash cards (in addition to the three categories listed here) that you found doing your research. The presentation should not exceed 10 minutes and should make use of one or more presentation aids, such as the whiteboard, handouts, overhead transparencies, or a computer-based slide presentation (your instructor may provide additional requirements). You may also be asked to submit a summary of the presentation to your instructor.

**Instructions:** Go to the Chapter 3 page of the **UC14 CourseMate** to work the following Web Activities.

6. **Interactive Activities** Work the interactive **Crossword Puzzle**, watch the **Video Podcasts** and **Online Videos**, and explore the **Further Exploration** links and the **Flashcards** associated with this chapter.
7. **Student Edition Labs** Work the following interactive **Student Edition Lab**.
- **Managing Files and Folders**
8. **Test Yourself** Review the **Online Study Guide** for this chapter, then test your knowledge of the terms and concepts covered in this chapter by completing the **Key Term Matching** and **Beat the Clock** games, and then taking the **Interactive Quiz**.

## ETHICS IN ACTION

HW



## PRESENTATION/ DEMONSTRATION

## WEB ACTIVITIES



Student Edition  
Labs