

## **Chapter 3:**

# **Storage Media and Devices**

# Learning Objectives

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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.

# Overview

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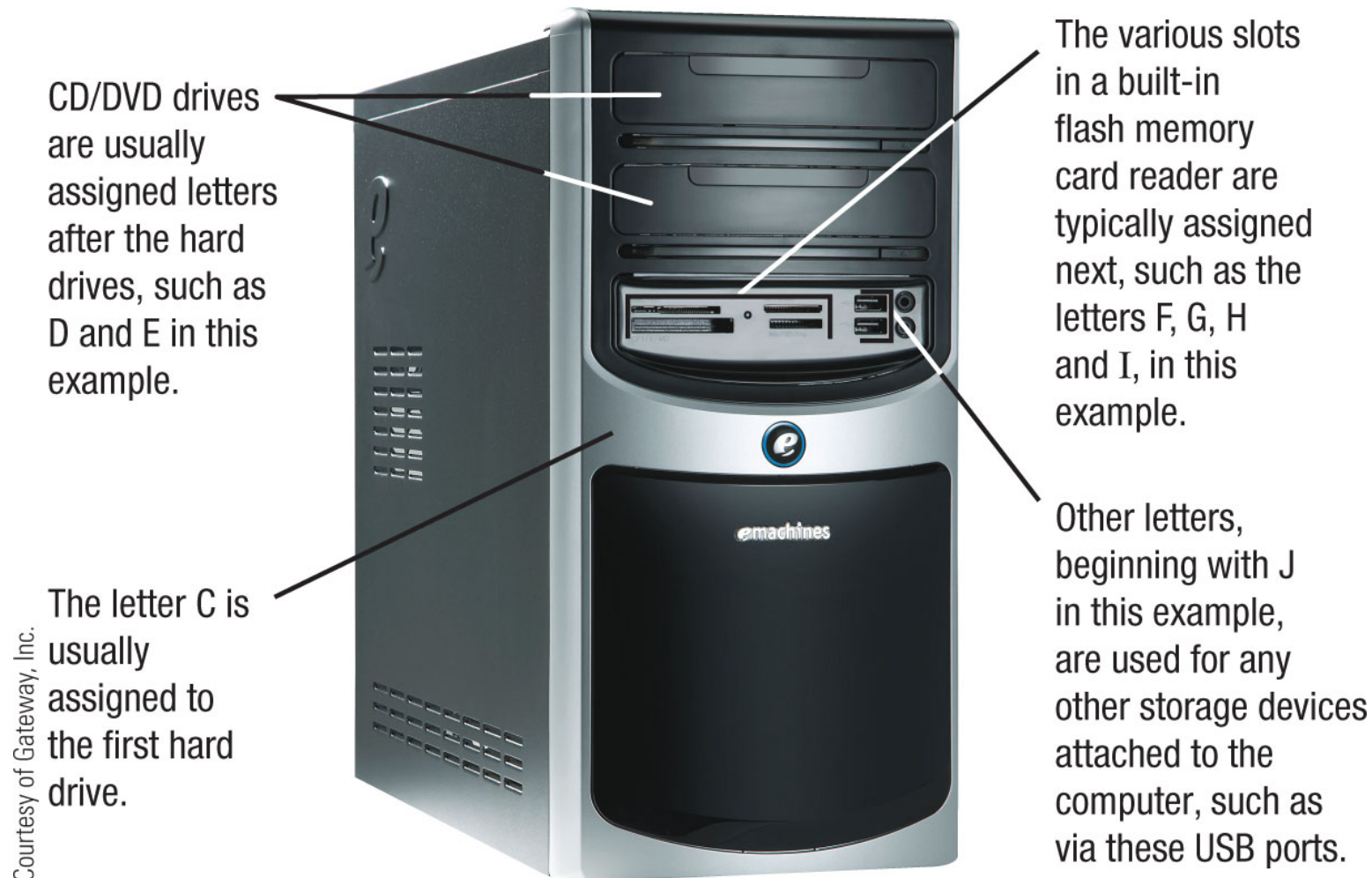
1. Examine the characteristics common among all storage systems.
2. Discuss the primary storage for most personal computers—the hard drive.
3. Discuss how optical discs work and the various types that are available today.
4. Discuss flash memory storage systems.
5. Discuss network and online/cloud storage, smart cards, holographic storage, and storage systems used with large computer systems.
6. Evaluate storage alternatives for a typical personal computer.

# Storage System Characteristics

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- Storage Media and Storage Devices
  - Medium
    - Hardware where data is stored
    - DVD disc, flash memory card, etc.
  - Device
    - DVD drive, flash memory card reader, etc.
    - Medium is inserted into device to be used
  - Can be internal, external, or remote
  - Storage devices are typically identified by letter

# Storage System Characteristics



**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.

# Storage System Characteristics

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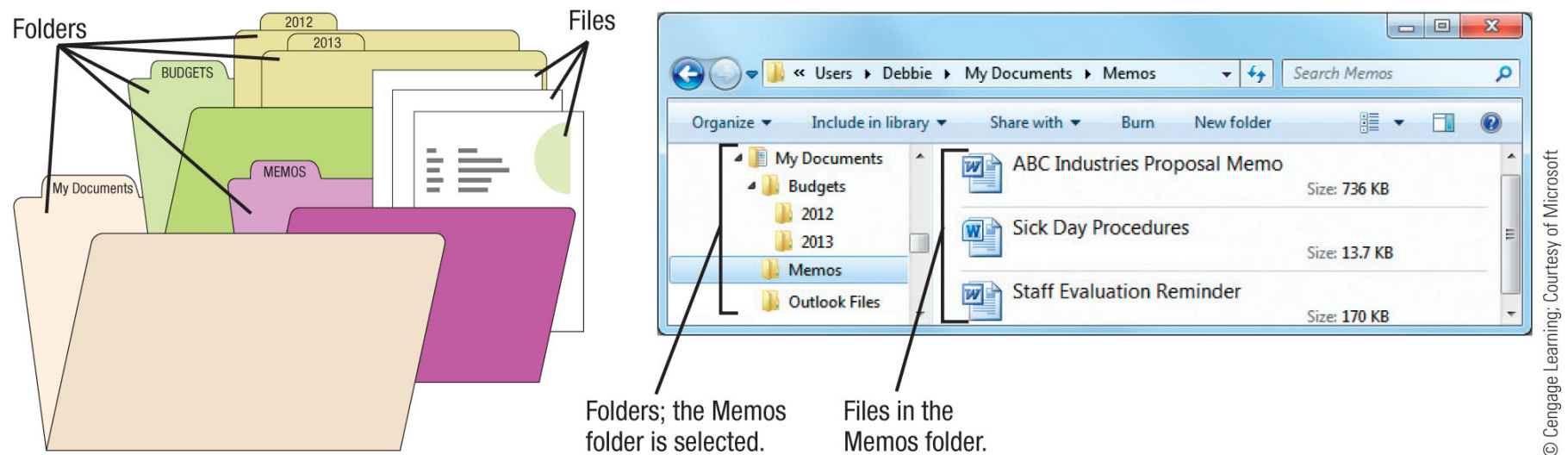
- Volatility
  - Storage devices are nonvolatile
- Random vs. Sequential Access
  - Random access (direct access) allows data to be retrieved from any location on the storage medium
  - Most storage devices use random access
  - Sequential access means retrieval of data can occur only in the order in which it was physically stored on the storage medium
    - Magnetic tape drive

# Storage System Characteristics

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- Logical vs. Physical Representation
  - File
    - Anything stored on a storage medium, such as a program, document, digital image, or song
  - Filename
    - Name given to a file by the user
  - Folder
    - Named place on a storage medium into which files can be stored

# Storage System Characteristics



**FIGURE 3-2**

## Organizing data.

Folders are used to organize related items on a storage medium.



# Storage System Characteristics

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- Logical file representation
  - Individuals view a document stored as one complete unit in a particular folder on a particular drive
- Physical file representation
  - Computers access a particular document stored on a storage medium using its physical location or locations
- Types of Storage Technology Used
  - Magnetic (conventional hard drives)
  - Optical (optical discs)
  - Electrons (flash memory media)

# Hard Drives

- Hard Drive
  - Used to store most programs and data
  - Can be internal or external
  - Can be encrypted
- Magnetic Hard Drives
  - One or more permanently sealed metal magnetic disks with an access mechanism and read/write heads
  - Read/write heads magnetize particles to represent the data's 0s and 1s



Courtesy of Apricorn

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

# 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.

## **ACCESS MECHANISM**

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

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

Courtesy of Hitachi Global Storage Technologies; Courtesy Western Digital

# Hard Drives

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- Hard disks are divided into
  - Tracks
    - Concentric path on disk where data is recorded
  - Sectors
    - A small piece of the track
  - Clusters
    - One or more sectors; smallest addressable area of a disk
  - Cylinders
    - Collection of tracks located in the same location on a set of hard disk surfaces

# Hard Drives

## SECTORS

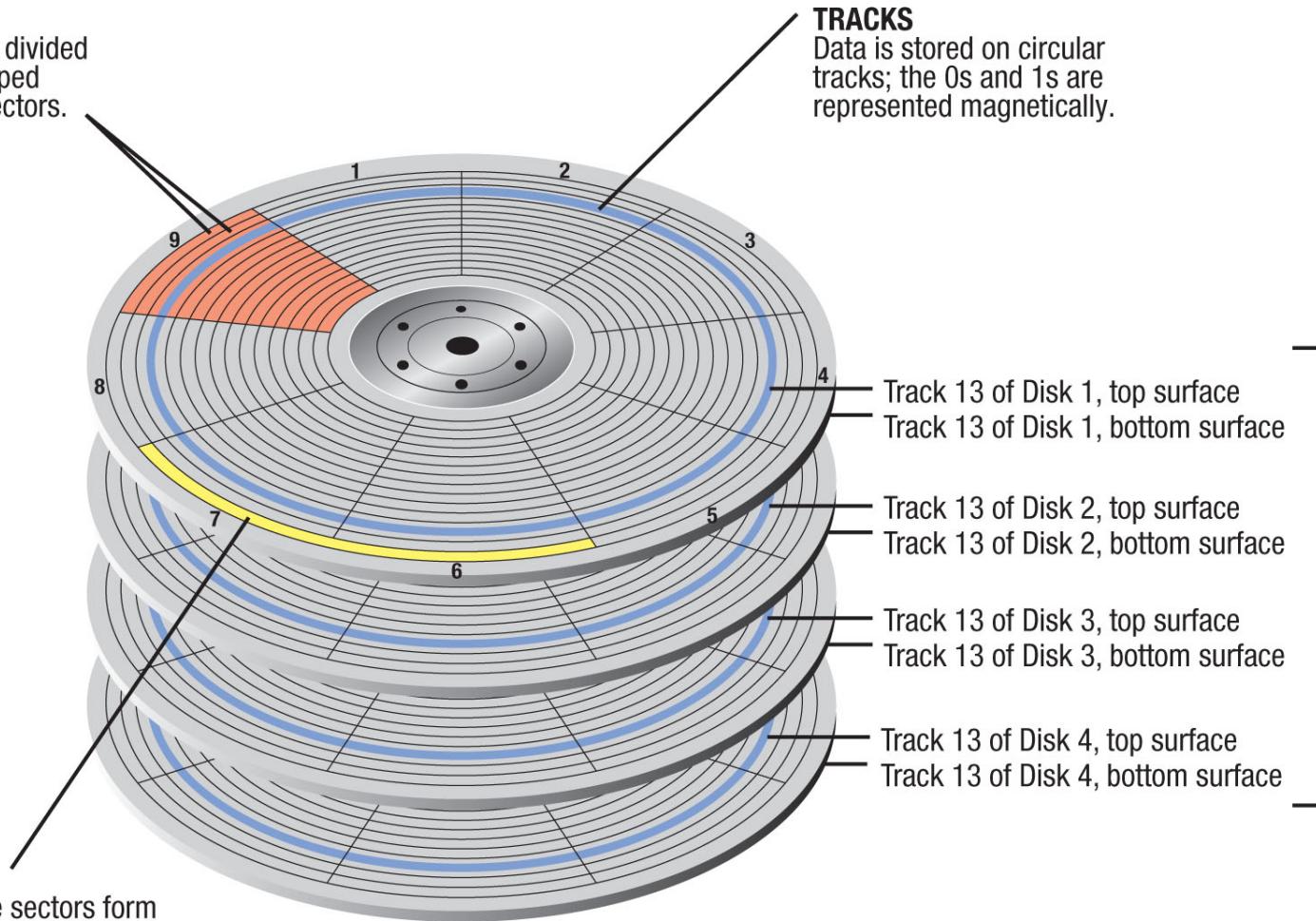
Each disk is divided into pie-shaped groups of sectors.

## TRACKS

Data is stored on circular tracks; the 0s and 1s are represented magnetically.

## CLUSTERS

One or more sectors form a cluster, the smallest storage area on a disk.



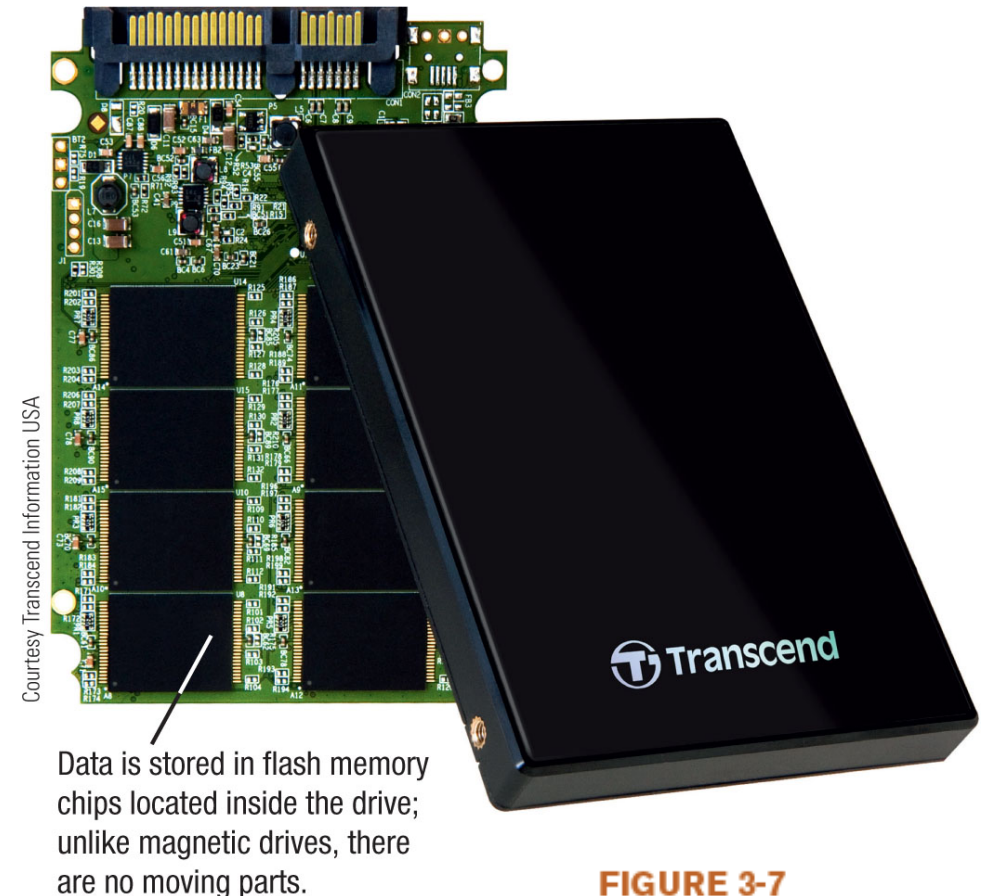
## CYLINDER

A cylinder consists of a vertical stack of tracks, the same relative track on each disk surface.



# Hard Drives

- Solid State Drives (SSDs)
  - Use flash memory technology
  - Use less power and have no moving parts
  - Particularly appropriate for portable computers and mobile devices



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

# Hard Drives

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- Internal and External Hard Drives
  - Internal hard drives
    - Permanent storage devices located inside the system unit
    - Removed only if a problem develops
  - Full-size external hard drives
    - Commonly used to transport large amounts of data from one computer to another
    - Portable external hard drives are smaller and easier to transport
    - Most connect with a USB connection although some may be wireless

# Hard Drives



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.  
holds 256 GB.



Courtesy Transcend Information USA

## EXPRESSCARD HARD DRIVES

Fit into an ExpressCard slot; this drive holds 32 GB.

**FIGURE 3-8**

External hard drives.



# Hard Drives

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- Hard Drive Speed, Disk Caching, and Hybrid Hard Drives
  - Disk access time
    - Total time that it takes for a hard drive to read or write data
    - Consists of seek time, rotational delay, and data movement time
      - SSDs don't require seek time or rotational delays
  - Disk cache
    - Memory used in conjunction with a magnetic hard drive to improve system performance
    - Can be a dedicated part of RAM or memory chips on a circuit board inside the hard drive case

# Hard Drives

- Hybrid hard drive
  - Combination of flash memory and magnetic hard drive
  - Uses flash memory for cache
  - Allows encryption to be built into the drive



## **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.

**FIGURE 3-9**

### **Hybrid hard drives.**

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

Courtesy of Seagate Technology LLC

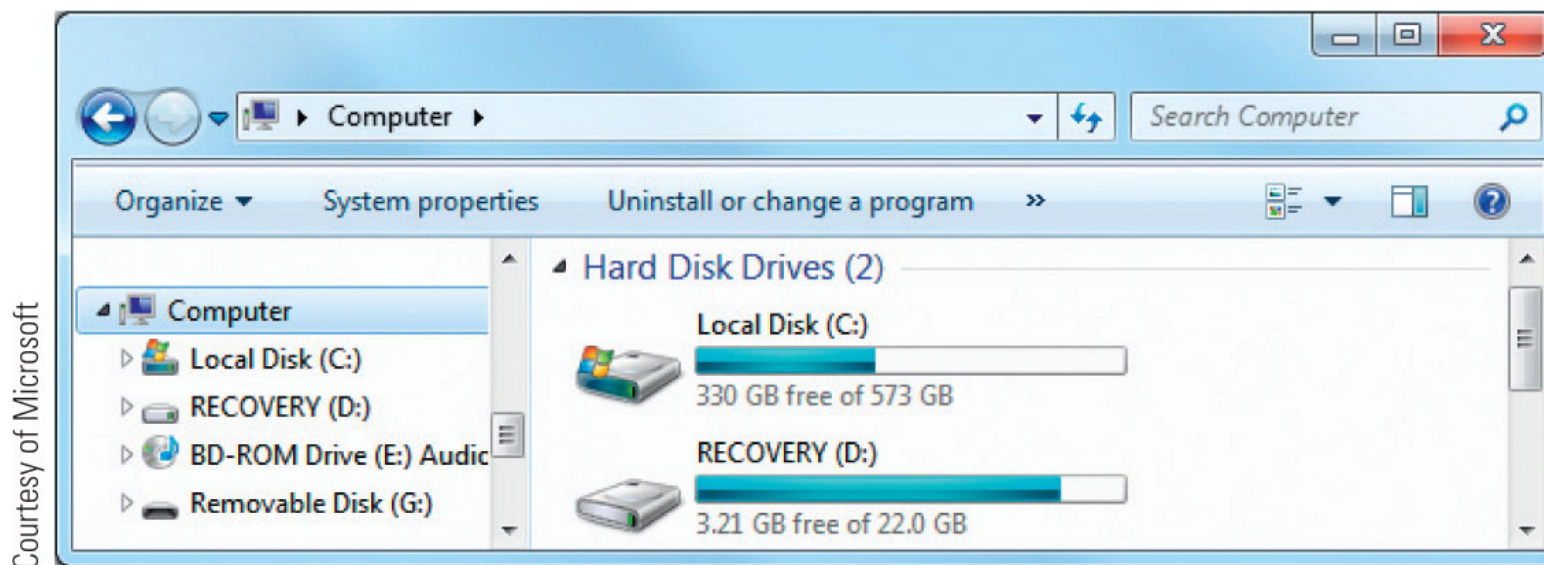
# Hard Drives

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- Hard Drive Partitioning and File Systems
  - Partitioning
    - Divides the physical capacity of a single drive logically into separate areas, called partitions
    - Partitions function as independent hard drives
    - Referred to as logical drives
    - Increase efficiency (smaller drives use smaller clusters)
  - Partitions used to
    - Create a recovery partition
    - Create a new logical drive for data
    - Create a dual boot system

# Hard Drives

- File system
  - Determines the cluster size, maximum drive size, and maximum file size
    - FAT, FAT32, and NTFS



**FIGURE 3-10**

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

# Hard Drives

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- Hard Drive Interface Standards
  - Determine how a drive connects to the computer
  - Common standards
    - Parallel ATA (PATA) - older, slower standard
    - Serial ATA (SATA)
    - eSATA
    - SCSI and the newer serial attached SCSI (SAS)
    - Fibre Channel
    - Fibre Channel over Ethernet (FCoE)
    - Internet SCSI (iSCSI)

# Quick Quiz

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1. Of the following three options, the storage media that would hold the most data is a(n) \_\_\_\_\_.
  - a. internal hard drive
  - b. USB flash memory drive
  - c. portable hard drive
2. True or False: Hard drives typically contain more than one metal hard disk.
3. The circular rings on a magnetic disk on which data is stored are called \_\_\_\_\_.

*Answers:*

*1) a; 2) True; 3) tracks*

# Optical Disks and Drives

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- Optical Disc Characteristics
  - A type of storage read from and written to using laser beams
  - Today's standard for software delivery
  - Divided into sectors like magnetic discs but use a single spiral track (groove)
  - Have a relatively large capacity and are durable
  - Used for backup purposes and for storing and transporting music, photos, video, etc.

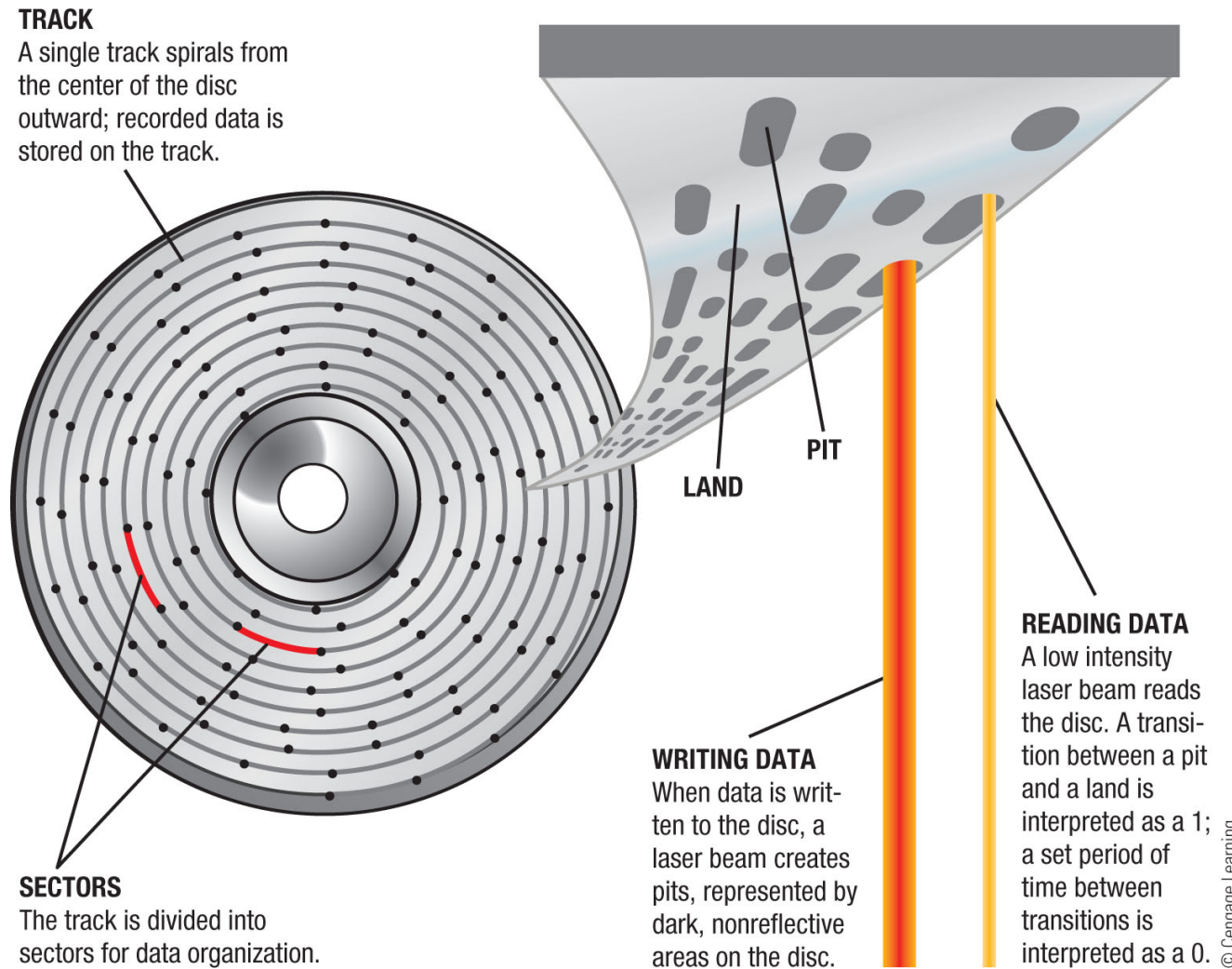
# Optical Discs and Drives

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- Representing Data on an Optical Disc
  - Read-only optical disc
    - Surface of disc is molded or stamped
  - Recordable or rewritable disc
    - Optical drive is used and the reflectivity of the disc is changed using a laser to represent the data
  - Data is stored in 0s and 1s
    - Pits and lands are used to represent 1s and 0s
    - The transition between a pit and a land represents a 1; no transition represents a 0  
(The pits and lands themselves do not directly represent the zeros and ones)



# Optical Discs and Drives



**FIGURE 3-11**  
How recorded optical discs work.

# Optical Discs and Drives

## – Optical Drives

- Three categories of discs: CD, DVD, or Blu-Ray Disc (BD)
- Can be read-only, recordable, or rewritable
- Almost always downward compatible
- Can support single or dual layer discs
- Recording data onto disc is called burning
- Can be internal or external drives
  - External drives typically USB

**FIGURE 3-12**

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



Image courtesy of Iomega an EMC company

# Optical Discs and Drives

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- Optical Disc Shapes, Sizes, and Capacities
  - Standard size is 120-mm (about 4.7 inches)
    - Mini discs are smaller—80-mm
  - Theoretically can be made into various shapes—  
hearts, triangles, irregular shapes, or a hockey-  
rink shape
    - Patent battle exists about changing optical disc  
shapes
    - None of these different shapes are currently  
available

# Optical Discs and Drives

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- Major advantage is their large capacity
  - CD discs are normally single layer and hold 650 or 700 MB
  - DVD discs hold 4.7 GB (single-layer) or 8.5 GB (dual-layer)
  - BD discs hold 25 GB (single-layer) or 50 GB (dual-layer)
  - Discs can also be double-sided
  - Researchers continually work to increase the capacity of optical discs

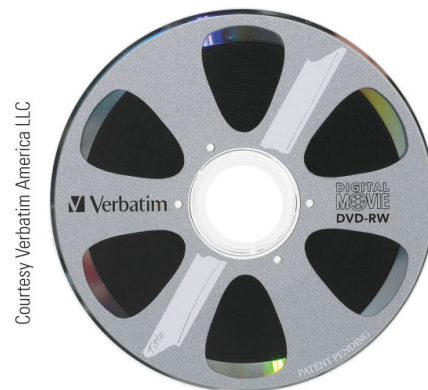
# Optical Discs and Drives

**FIGURE 3-13**

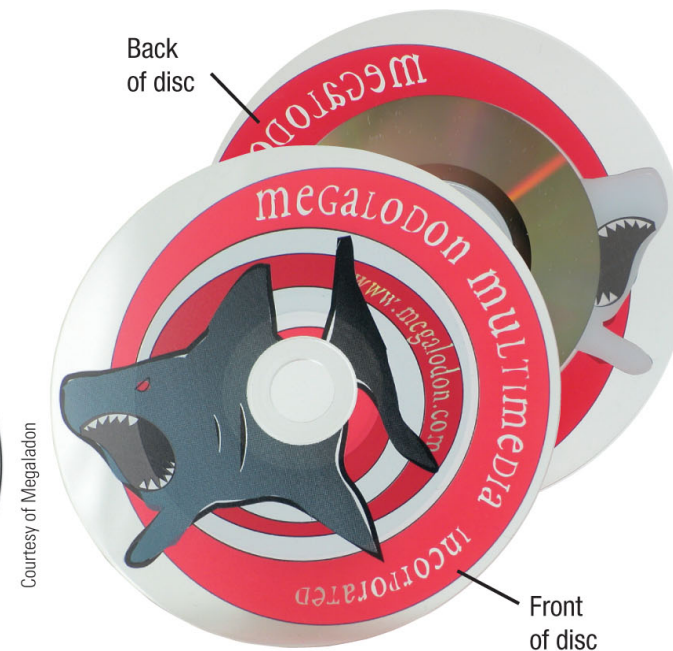
Optical discs are available in a variety of sizes, appearances, and capacities.



**STANDARD 120 MM (4.7 INCH) SIZED DISC**



**MINI 80 MM (3.1 INCH) SIZED DISC**



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

# Optical Discs and Drives

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- Read-Only Optical Discs: CD ROM, DVD ROM, and BD-ROM
  - Can be read from, but not written to, by the user
    - CD-ROM (compact disc read-only memory)
    - DVD-ROM (digital versatile disc read-only memory)
    - BD-ROM (Blu-Ray disc read-only memory)
  - Normally come pre-recorded
    - Software programs
    - Clip art and other graphics
    - Music
    - Movies
    - Games (UMD, Wii, Xbox, etc.)

# Optical Discs and Drives

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- Recordable Optical Discs: CD-R, DVD-R, DVD+R, BD-R Discs
  - Can be written to, but cannot be erased and reused
    - Uses phase change technology
      - Heating and cooling process is used to change the reflectivity of the disc
    - Capacities are identical to the read-only discs
    - CD-R discs - recordable CDs
    - DVD-R/DVD+R discs can be dual-layer
    - BD-R can be dual-layer
  - Used for back up, sending large files to others, creating custom music CDs, storing home movies, etc.



# Optical Discs and Drives



Courtesy Verbatim America LLC

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



Courtesy Memorex Products, Inc.

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



Courtesy of Sony Electronics Inc.

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

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



# Quick Quiz

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1. The capacity of the typical CD disc is \_\_\_\_\_.
  - a. 50 GB
  - b. 650 MB
  - c. 4.7 GB
2. True or False: A DVD-RW disc can be written to and rewritten to.
3. The tiny depressions, dark areas, or otherwise altered spots on an optical disc that are used to represent data are called \_\_\_\_.

**Answers:**

*1) b; 2) True; 3) pits*

# Flash Memory Storage Systems

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- Flash Memory
  - Non-volatile memory chips used for storage by the computer or the user
  - Used in SSDs, hybrid hard drives, and USB flash drives
- Embedded Flash Memory
  - Flash memory chips embedded into products, such as

Portable digital media players	Digital cameras	GPS devices
Handheld gaming devices	Mobile phones	Sunglasses
Wristwatches	Tablet computers	Smartphones

# Flash Memory Storage Systems



## PORTABLE TABLET

Contains 16 GB of embedded flash memory.



## EMBEDDED FLASH MEMORY

# Flash Memory Storage Systems

- Flash Memory Cards and Readers
  - Flash memory card
    - A small card containing one or more flash memory chips, controller chips, and metal contacts to connect the card to the device or reader with which it is being used
    - Available in various formats:

CompactFlash	Secure Digital (SD)	xD Picture Card
Memory Stick	Secure Digital High Capacity (SDHC)	
MultiMedia Card (MMC)	Secure Digital Extended	Capacity (SDXC)

These formats are not interchangeable

# Flash Memory Storage Systems

Courtesy of Kingston Technology Company, Inc.



## 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.



Courtesy of Kingston Technology Company, Inc.

## COMPACTFLASH (CF) CARDS



Courtesy of Sony Electronics Inc.

## MEMORY STICKS

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

© 2009 Micron Technology, Inc. All Rights Reserved. Used with permission.; Courtesy of SanDisk Corporation



## SECURE DIGITAL (SD) CARDS



Courtesy of Olympus

## XD PICTURE CARDS

# Flash Memory Storage Systems

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- General-purpose flash memory card
  - Appropriate for most applications
- Specialized flash memory cards
  - Professional flash memory cards
    - Designed for professional photographers
  - Gaming flash memory cards
    - Designed for gaming consoles
  - HD flash memory cards
    - Designed for capturing and transferring high definition video
  - Netbook flash memory cards

# Flash Memory Storage Systems

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- USB Flash Drives
  - Sometimes called flash memory drives, jump drives, or thumb drives
  - Small storage devices that plug into and are powered by a USB port and contain flash memory storage
  - Available in a range of sizes, colors, and appearances
  - May also be used to lock a computer and to issue Web site passwords
  - Can include biometric features, such as a built-in fingerprint reader



# Flash Drive Storage Systems



**CONVENTIONAL DRIVE**



**CUSTOM CONVENTIONAL DRIVE**



**CUSTOM WRISTBAND DRIVE**



**CUSTOM WALLET DRIVE**

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



# Other Types of Storage Systems

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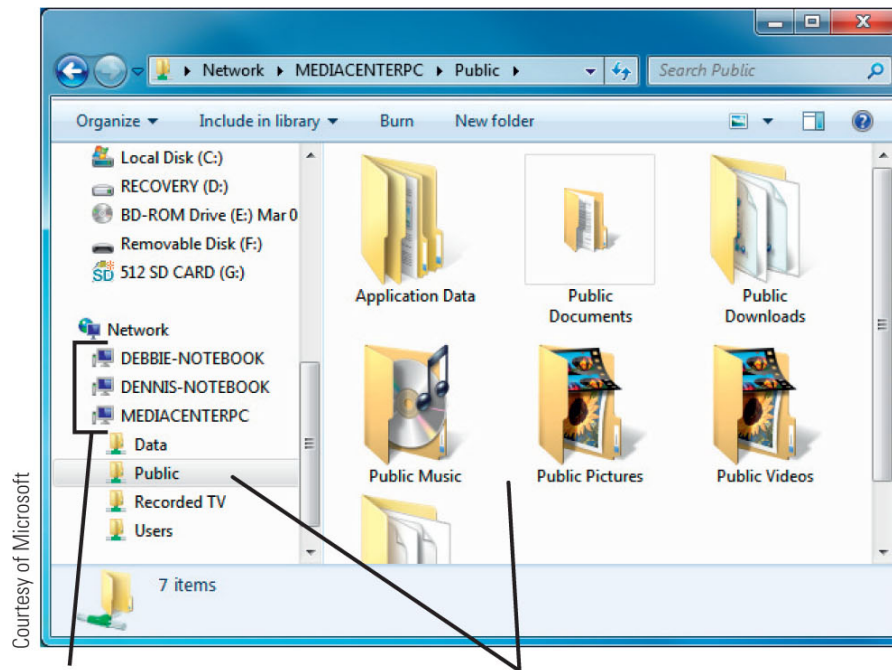
- Network Storage and Online/Cloud Storage Systems
  - Remote storage
    - Using a storage device not directly connected to the computer being used
    - Accessed through the internet or through a network
  - Network storage
    - Via a local network

# Other Types of Storage Systems

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- Network attached storage (NAS)
  - Connected directly to a network
  - High performance storage for computers connected to a network
- Storage area network (SAN)
  - Separate network of hard drives or other storage devices which are attached to the main network

# Other Types of Storage Systems



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.



## NETWORK ATTACHED STORAGE (NAS) DEVICES

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

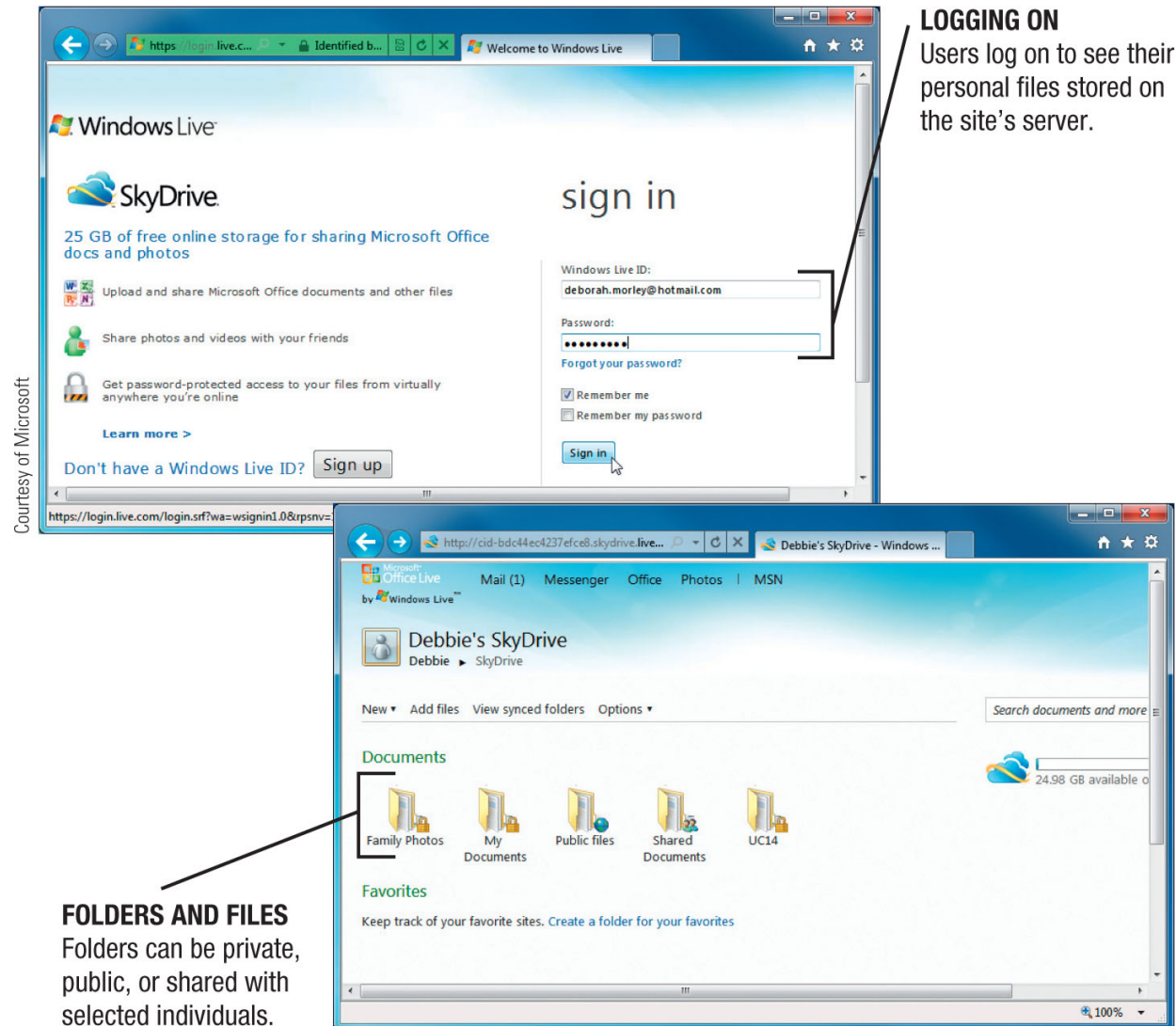
**FIGURE 3-19**  
Network storage.

# Other Types of Storage Systems

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- Online storage or cloud storage
  - Accessed via the Internet
    - Via Web sites (Flickr, Facebook, Google Docs, etc.)
    - Via online storage sites (Box.net, SkyDrive, etc.)
    - Growing in importance because more and more applications are web-based
    - Increasing being used for back up purposes
    - Many web sites providing online storage offer it free

# Other Types of Storage Systems



**FIGURE 3-20**

**Online storage.** This site provides 25 GB of free storage.

# Other Types of Storage Systems

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## – Smart Cards

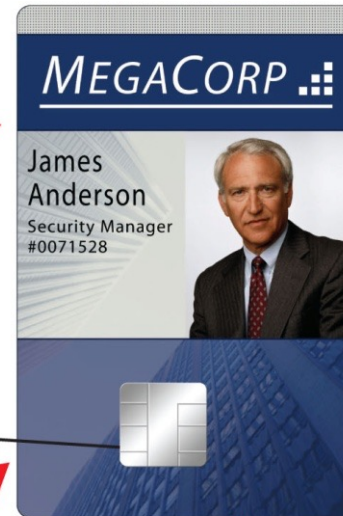
- Credit card-sized piece of plastic that contains some computer circuitry (processor, memory, and storage)
- Stores small amount of data (about 64 KB or less)
- Commonly used to store prepaid amounts of digital cash or personal information
- Smart card readers are built into or attached to a computer, keyboard, vending machine, or other device
- Some smart cards store biometric data
- Can be used in conjunction with encryption and other security technologies



# Other Types of Storage Systems



USING A SMART CARD TO LOG ON TO A COMPUTER



Smart card circuitry

A SMART CARD



USING A SMART CARD TO ACCESS A SECURE FACILITY



USING A SMART CARD TO PAY FOR A VENDING MACHINE PURCHASE

Photo by HID Global Corporation

**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.



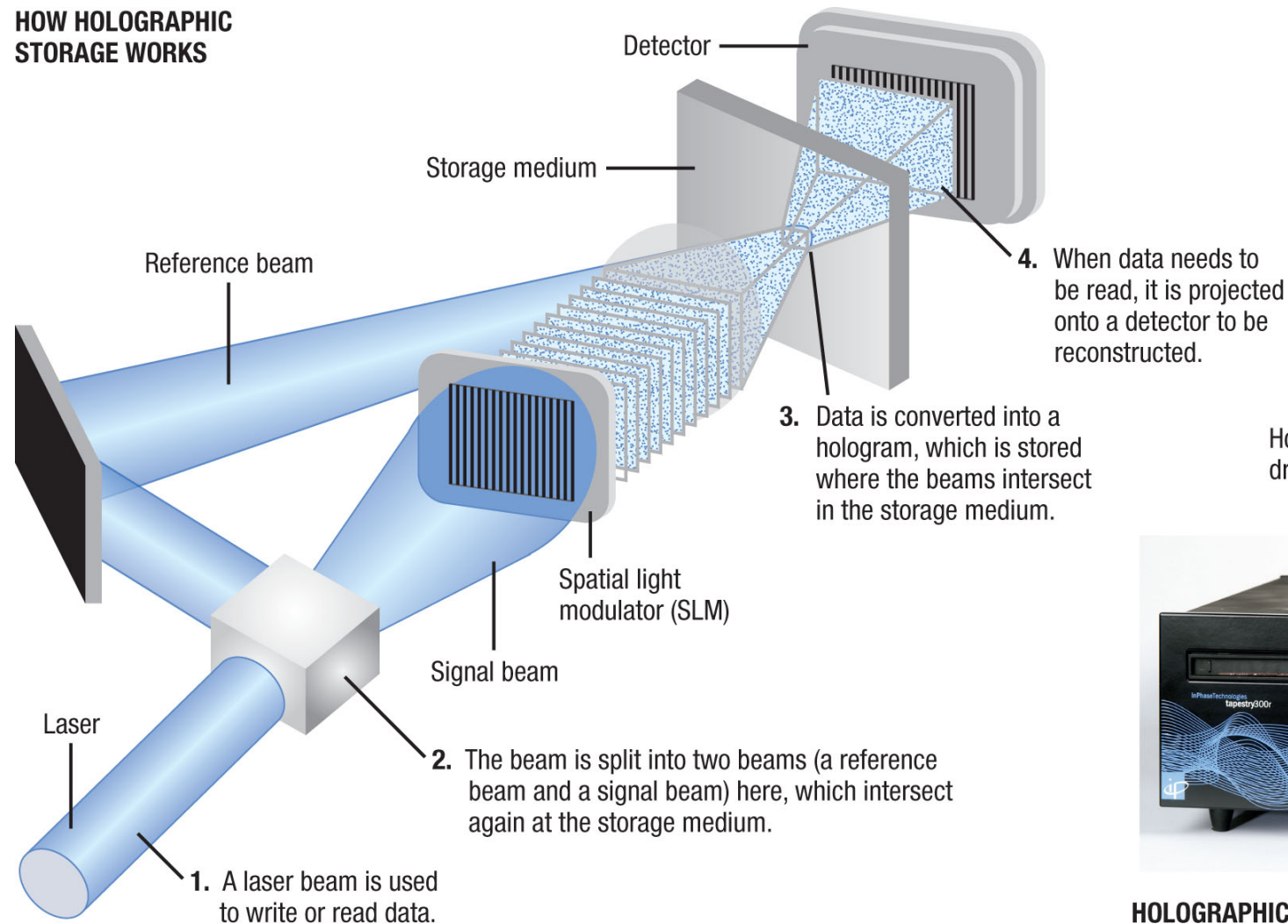
# Other Types of Storage Systems

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- Holographic storage
  - Emerging type of 3D storage technology
  - Uses multiple blue laser beams to store data in three dimensions
    - Reference beam
    - Signal beam
  - Possible applications
    - High-speed digital libraries
    - Image processing for medical, video, and military purposes
    - Any other applications in which **data needs to be stored or retrieved quickly in large quantities but rarely changed**

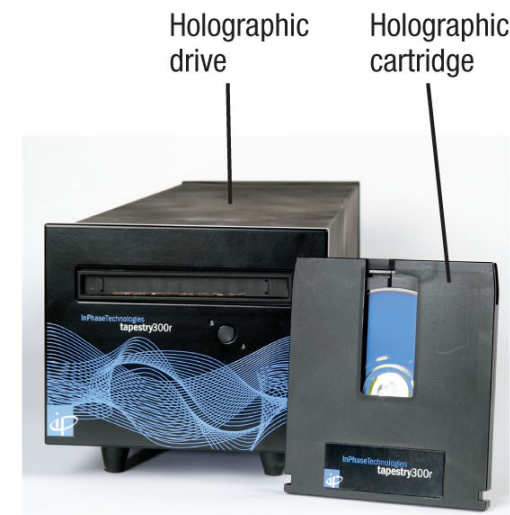
# Other Types of Storage Systems

## 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.



Courtesy of Signal Lake

**HOLOGRAPHIC DRIVES AND CARTRIDGES**

# Other Types of Storage Systems

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- Storage Systems for Large Computer Systems
  - Storage server
    - Hardware device containing multiple high-speed hard drives connected to the computer system or network
    - Most are based on magnetic hard discs
  - Businesses have to store tremendous amounts of data
    - Storage needs will increase 50% annually through 2014
    - Business data
    - Employee and customer data
    - E-discovery data

# Other Types of Storage Systems

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- RAID (redundant arrays of independent discs)
  - Method of storing data on two or more hard drives that work together to do the job of a larger drive
  - Mostly used to protect critical data on large storage systems
  - Usually involves recording redundant copies of stored data
  - Helps to increase fault tolerance

# Other Types of Storage Systems

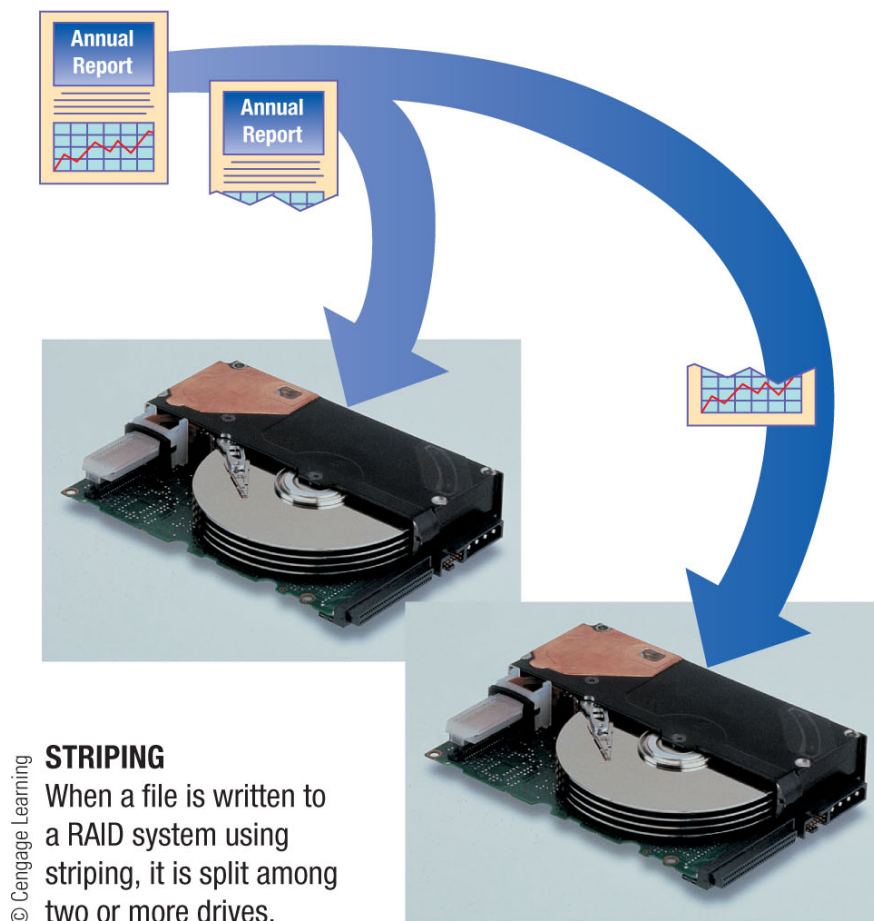
- Different levels of RAID:
  - RAID 0 = disk striping (spread files over two or more hard drives)
  - RAID 1 = disk mirroring (duplicate copy)
  - Other level use a combination of striping and mirroring
- Drobo system
  - New RAID storage system
  - Much easier to use than previous
  - Offers continuous data redundancy



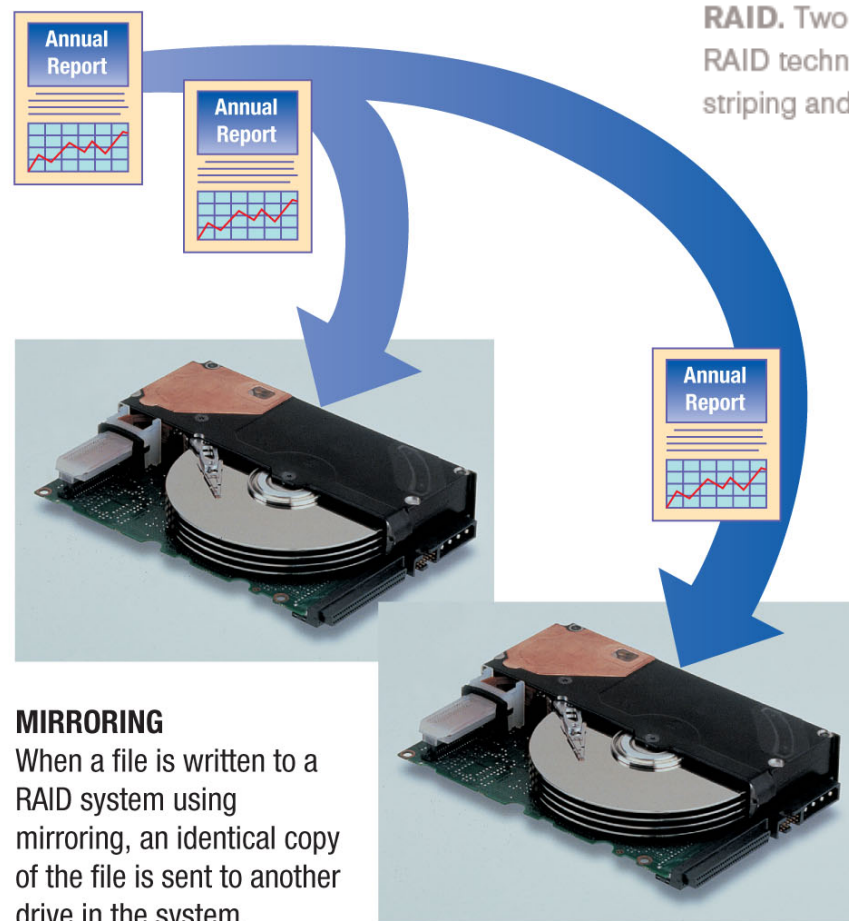
**FIGURE 3-25**

A Drobo storage system.

# Other Types of Storage Systems



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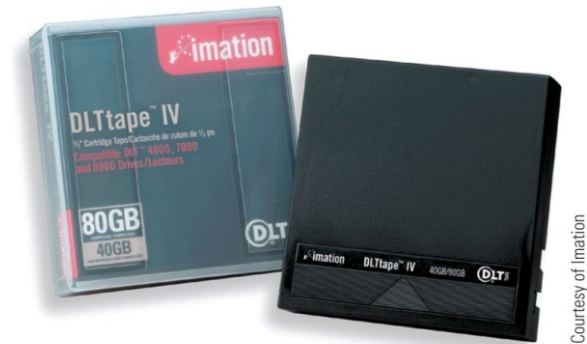


**FIGURE 3-24**  
RAID. Two primary RAID techniques are striping and mirroring.

# Other Types of Storage Systems

## – Magnetic Tape Systems

- Plastic tape with a magnetizable surface that stores data as a series of magnetic spots
- Primarily used for backup and archival purposes
- Sequential access only
- Low cost per megabyte
- Most tapes today are in the form of cartridge tapes





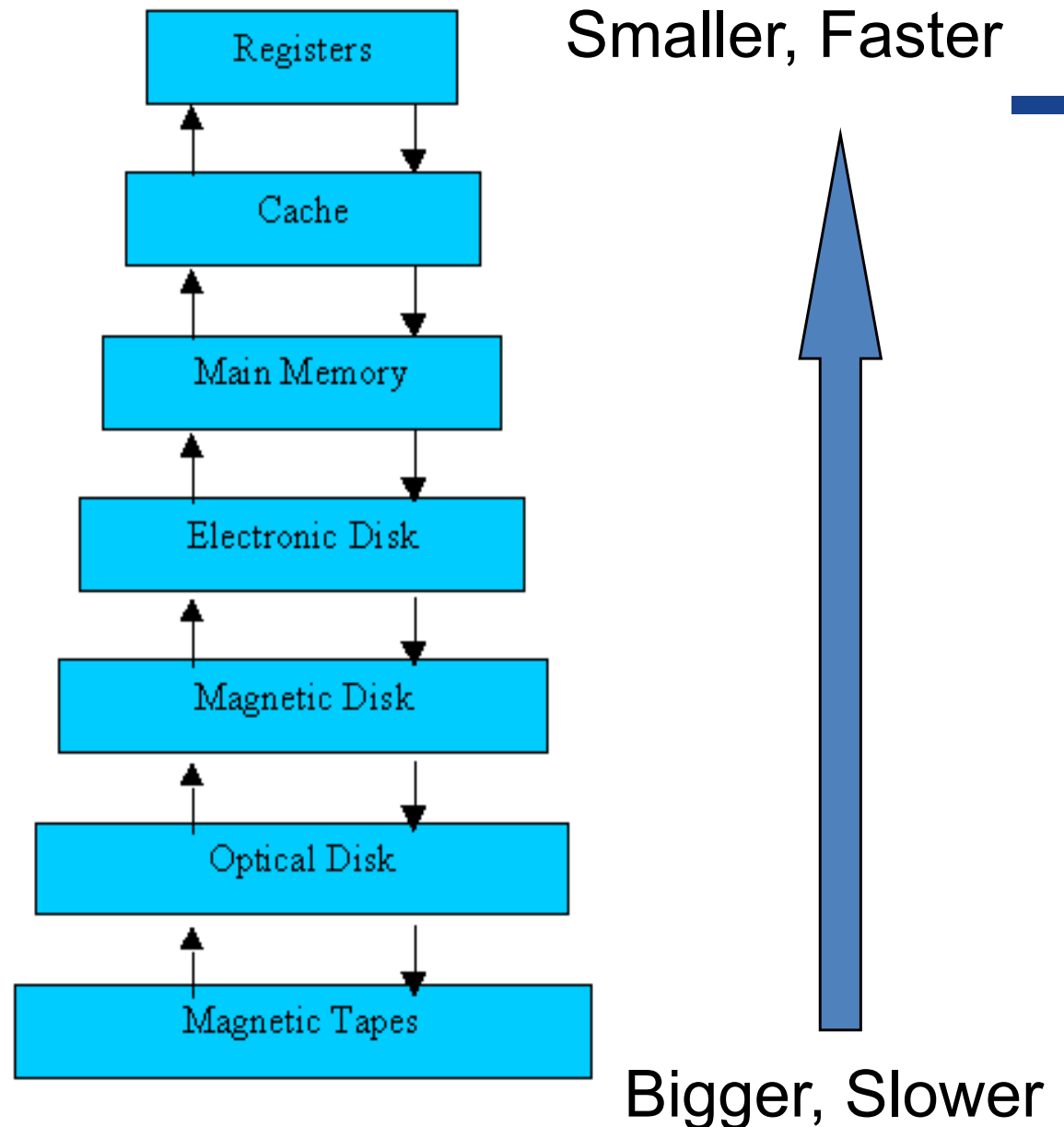
# Evaluating Your Storage Alternatives

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- Product Characteristics to Consider:
  - Speed
  - Compatibility
  - Storage capacity
  - Convenience
  - Portability
- Most Users Require:
  - Hard drive
  - Recordable or rewritable optical drive
  - Flash memory card reader
  - USB port(s)

# The Storage Hierarchy

- Main memory (RAM) for currently used data.
- Disk for the main database (secondary storage).
- Tapes for archiving older versions of the data (tertiary storage).



# Quick Quiz

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1. An online photo sharing site is an example of \_\_\_\_\_.
  - a. RAID
  - b. remote storage
  - c. holographic storage
2. True or False: Flash memory storage systems are called solid-state storage systems because they are nonvolatile.
3. A type of sequential storage that sometimes used today for backup purposes is \_\_\_\_\_.

*Answers:*

*1) b; 2) False; 3) magnetic tape*