

15<sup>th</sup> Edition

# Understanding Computers

Today and Tomorrow

Comprehensive

## Chapter 3

## Storage

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*updated by*  
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# Learning Objectives

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

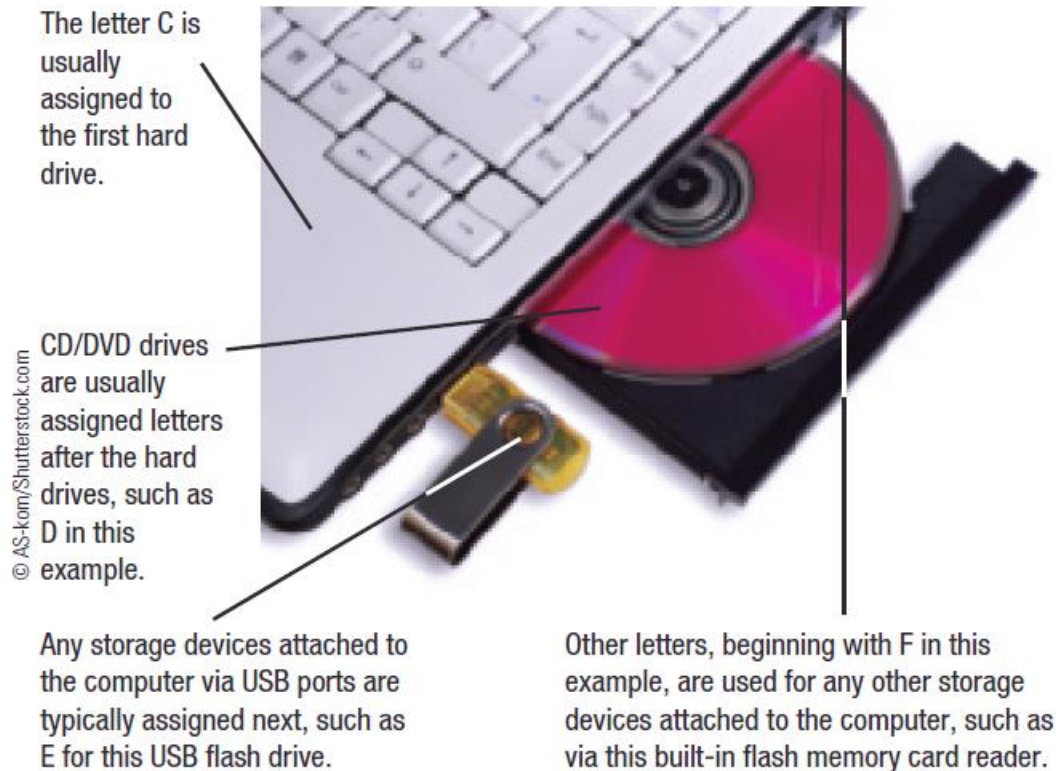
- This chapter covers:
  - The characteristics common among all storage systems
  - The primary storage for most personal computers—the hard drive
  - How optical discs work and the various types that are available today
  - Flash memory storage systems
  - Network and cloud storage, smart cards, holographic storage, and storage systems used with large computer systems
  - Storage alternatives for a typical personal computer



# Storage System Characteristics

- 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

- Volatility
  - Storage media are nonvolatile
- Random vs. Sequential Access
  - Random access (direct access) allows data to be retrieved from any location on the storage medium
  - Virtually all 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

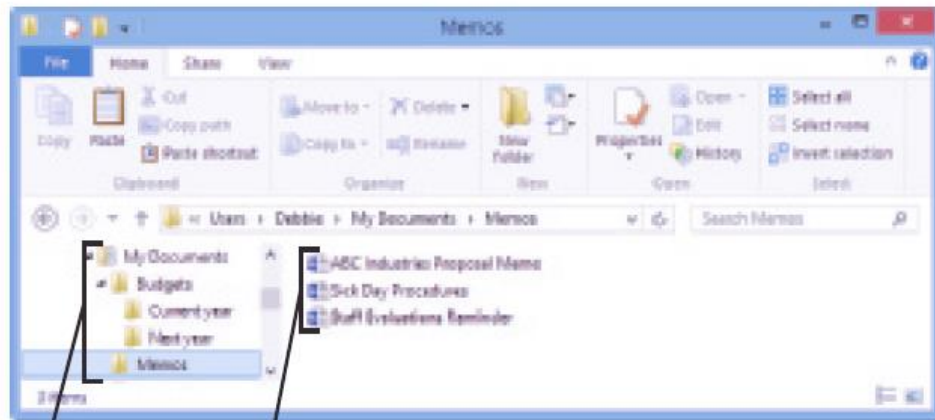
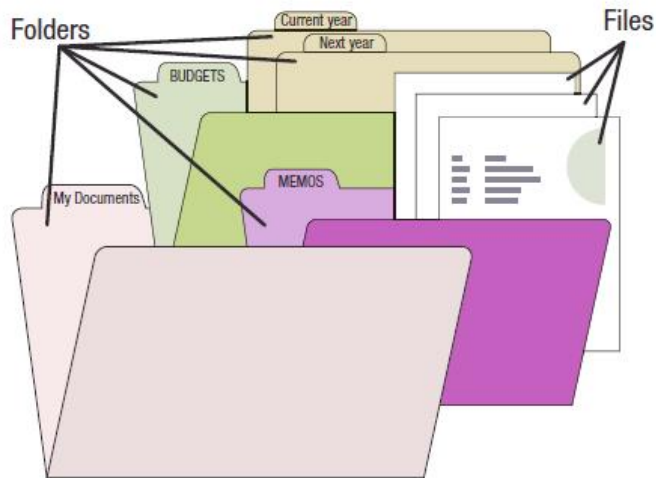


# Storage System Characteristics

- 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



Folders; the Memos folder is selected. Files in the Memos folder.

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**FIGURE 3-2**

## Organizing data.

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





# Storage System Characteristics

- 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



Courtesy Apricorn

**FIGURE 3-3**  
**Encrypted hard drives.** The data stored on this external hard drive is accessed via 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.

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.

Courtesy of Hitachi Global Storage Technologies; Courtesy Western Digital

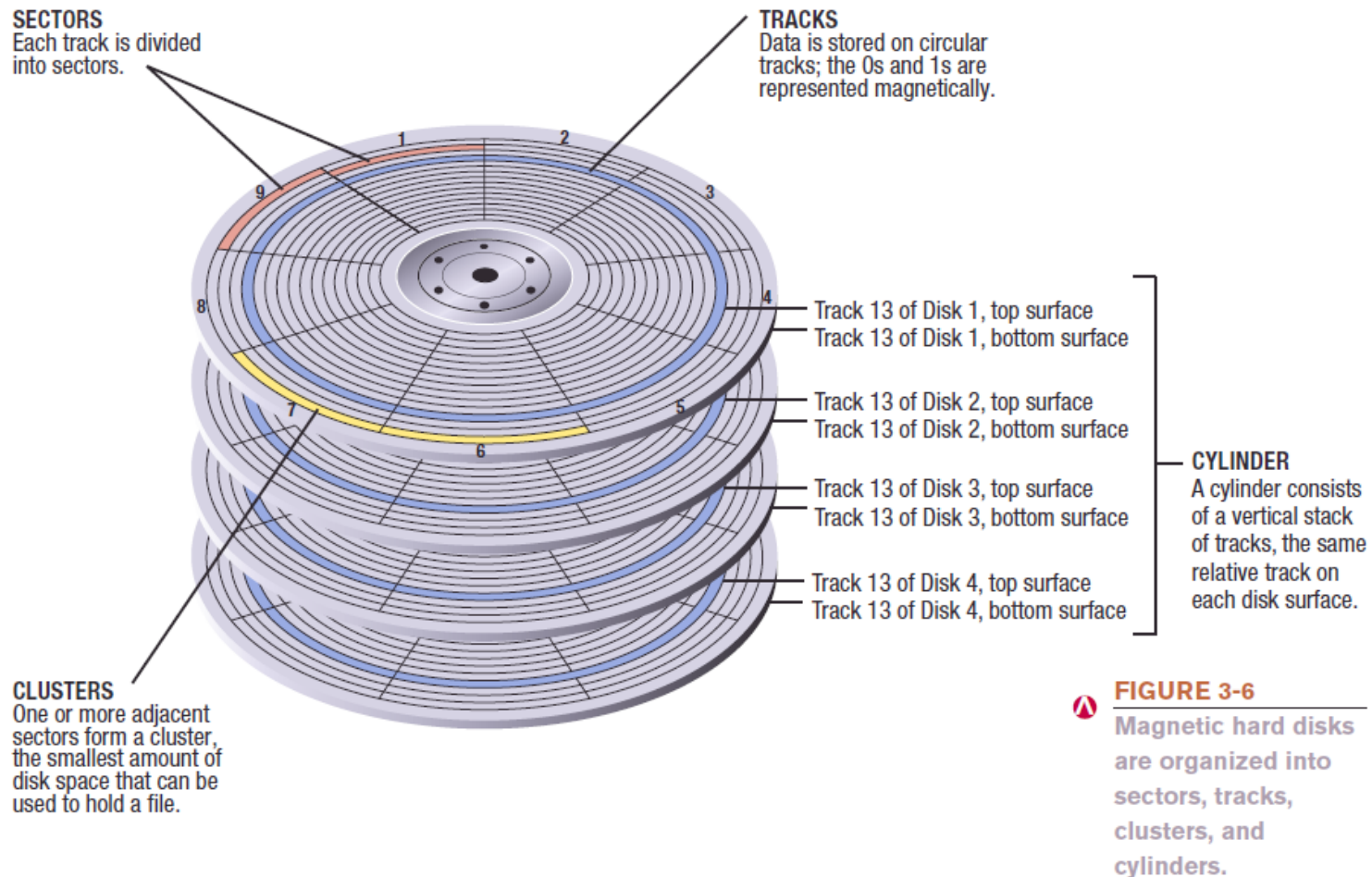
**FIGURE 3-5**  
Magnetic hard  
drives.



# Hard Drives

- 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







# How It Works Box

## More Storage for Your Tablet

- Media tablets often have 64 GB of storage
- To extend storage, can transfer content to and from PCs
- Easier is to use a wireless hard drive
- Need the appropriate app



# 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).





# Inside the Industry Box

## Data Recovery Experts

- Can recover data from damaged storage devices
- Can be used when devices are physically damaged or just stop working
- Back up to prevent data loss



Courtesy of DriveSavers Data Recovery [www.drivesavers.com](http://www.drivesavers.com)

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



# Internal and External Hard Drives

- Internal hard drives
  - Permanent storage devices located inside the system unit
  - Removed only if a problem develops
- 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

# Internal and External Hard Drives



Courtesy Western Digital

## **FULL-SIZED EXTERNAL HARD DRIVES**

Are about the size of a 5 by 7-inch picture frame, but thicker; this drive contains two magnetic hard drives, which hold 6 TB total.



Courtesy Western Digital

## **PORTABLE HARD DRIVES (MAGNETIC)**

Are about the size of a 3 by 5-inch index card, but thicker; this drive holds 2 TB.



Courtesy Transcend Information USA

## **PORTABLE HARD DRIVES (SSD)**

Are about the size of a credit card, but thicker; this drive holds 256 GB.

**FIGURE 3-8**

External hard drives.

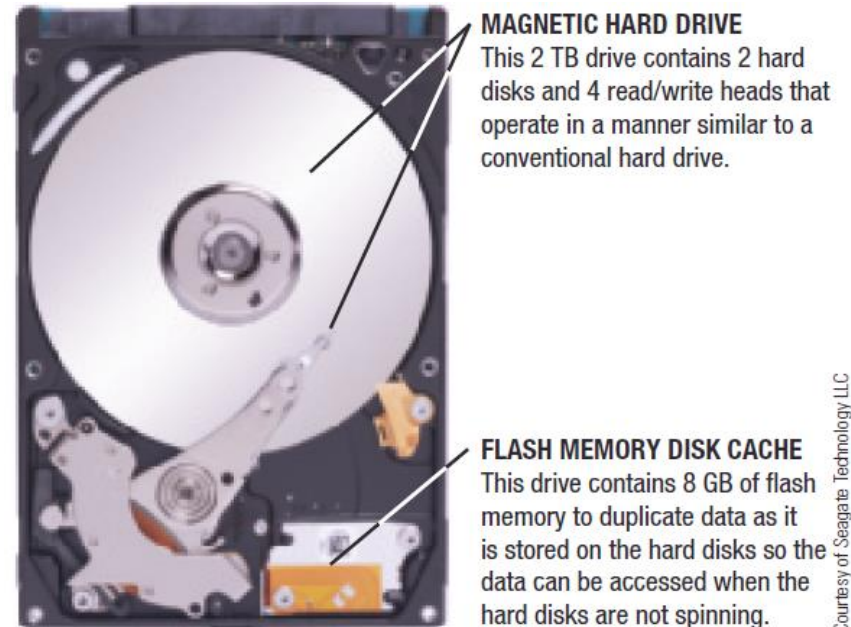


# Hard Drive Speed, Disk Caching, and Hybrid Hard Drives

- 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
  - Typically consist of memory chips on a circuit board inside the hard drive case

# Hard Drive Speed, Disk Caching, and Hybrid 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



Courtesy of Seagate Technology LLC

**FIGURE 3-9**

## Hybrid hard drives.

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



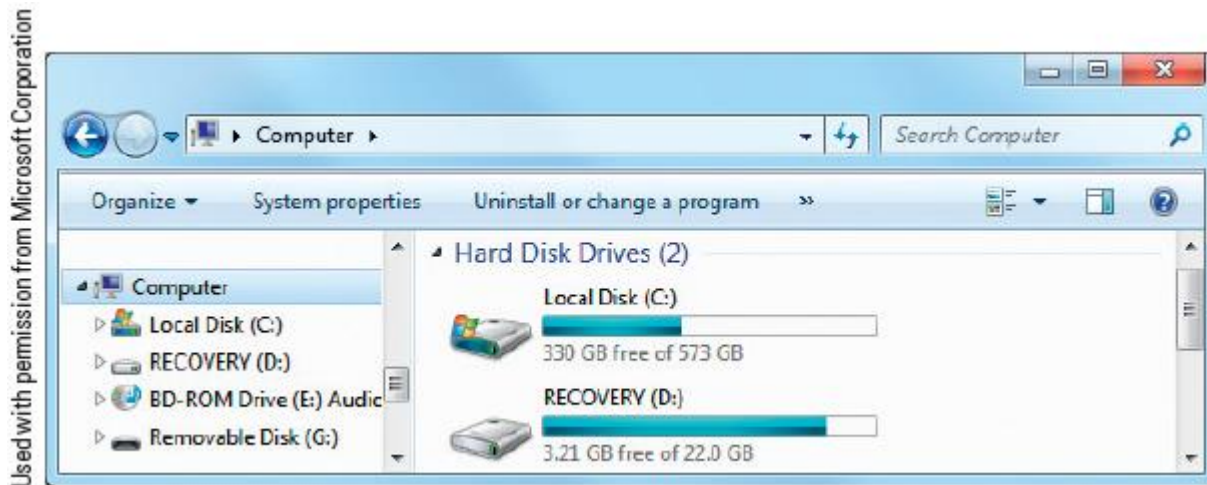
# Hard Drive Partitioning and File Systems

- 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
  - Increases efficiency (smaller drives use smaller clusters)
- Partitions used to create:
  - A recovery partition
  - A new logical drive for data
  - A dual boot system



# Hard Drive Partitioning and File Systems

- File system
  - Determines the partition size, 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 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

1. Of the following three options, the storage media that would likely 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 Discs and Drives

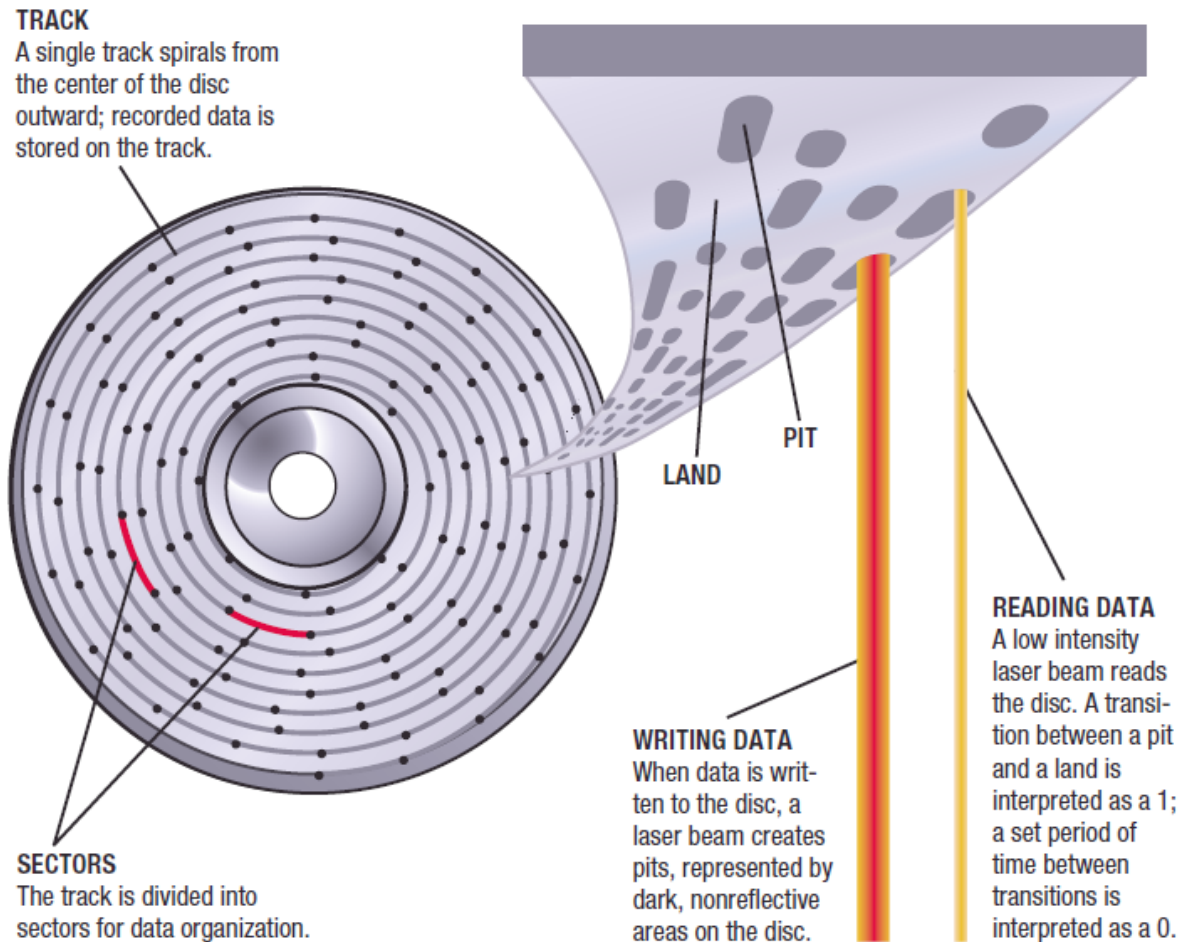
- Optical Disc Characteristics
  - A type of storage read from and written to using laser beams
  - Today's standard for software delivery
  - Divided into sectors like magnetic discs but use a single spiral track (groove)
  - Have a relatively large capacity and are durable
  - Used for backup purposes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



# Optical Discs and Drives

- 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
  - 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

# 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 connect via USB port

**FIGURE 3-12**

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





# Optical Discs and Drives

- 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

- Major advantage: 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
    - DL and XL discs
    - 4K (Ultra HD) Blu-ray Discs





# Optical Discs and Drives

TYPE OF DISC	CAPACITY	USED FOR
CD	700 MB	Audio music delivery; custom CDs containing music, photos, etc.
DVD DVD-DL	4.7 GB 8.5 GB	Movie and software delivery; custom DVDs containing videos, music, photos, etc.
BD BD-DL BDXL	25 GB 50 GB 100 GB (rewritable) or 128 GB (recordable)	Primarily movie delivery

**FIGURE 3-14**  
Summary of optical discs.



# 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 (PlayStation, Wii, Xbox, etc.)



# Recordable Optical Discs

- CD-R, DVD-R, DVD+R, BD-R Discs
  - Can be written to, but cannot be erased and reused
  - No physically molded pits
  - Most have a recording layer containing organic light-sensitive dye between disc's plastic and reflective layers
    - Except the BD-R disc, which has inorganic material
  - Used for backing up files, sending large files to others, and creating custom music CDs



# Rewritable Optical Discs

- CD-RW, DVD-RW, DVD+RW, and BD-RE 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 and recordable discs, except BDXL
  - Appropriate for transferring large files from one computer to another or temporarily storing TV shows



# Quick Quiz

1. The capacity of the typical CD disc is \_\_\_\_\_.
  - a. 50 GB
  - b. 700 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*



# Trend Box

## DNA Data Storage

- Possible data storage medium
  - Long-term, high-density encoding
- Researchers have encoded data in DNA
  - Translated into binary 0s and 1s, then to a ternary code, and then as strings of DNA's chemical bases and stored in DNA
- Biggest obstacle is cost - \$12,400/MB
- Biggest possibility: archiving







# Flash Memory Storage Systems

- Flash Memory
  - Chip-based storage medium that represents data using electrons
  - Used in SSDs and hybrid hard drives
- Embedded Flash Memory
  - Flash memory chips embedded into products, such as
    - Portable digital media players, digital cameras
    - Handheld gaming devices, GPS devices, mobile phones
    - Sunglasses and wristwatches

# Flash Memory Storage Systems



**FIGURE 3-16**

Embedded flash  
memory.





# Flash Memory Storage Systems

- Flash Memory Cards and Readers
  - Flash memory card
    - Small card containing one or more flash memory chips, a controller chip, and metal contacts to connect the card to the device or reader with which it is being used
    - Available in various formats that are not interchangeable:

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

# Flash Memory Storage Systems

Courtesy Kingston Technology Company, Inc. © 2013 Micron Technology, Inc. All Rights Reserved. Used with permission.



USB MULTI-CARD READER

Has slots for 3 types of flash memory cards here.



MICROSD-TO-SD ADAPTER



USB MICROSD READER



COMPACTFLASH (CF) CARDS

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MEMORY STICKS

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SECURE DIGITAL (SD) CARDS

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XD PICTURE CARDS

Courtesy of Olympus

**FIGURE 3-17**  
Some flash memory cards, readers, and adapters.



# Flash Memory Storage Systems

- 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



# Flash Memory Storage Systems

- USB Flash Drives
  - Sometimes called flash memory drives, jump drives, or thumb drives
  - Flash memory media integrated into a self-contained unit that plug into and is powered by a USB port
  - Designed to be very small and very portable
  - Available in a host of formats including custom shapes
  - Can be built into a consumer product
  - Can 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



Courtesy Kingston Technology Company, Inc.

CONVENTIONAL DRIVE



Courtesy CustomUSB.com

CUSTOM CONVENTIONAL DRIVE



Courtesy CustomUSB.com

CUSTOM LANYARD DRIVE



Courtesy CustomUSB.com

CUSTOM WALLET DRIVE

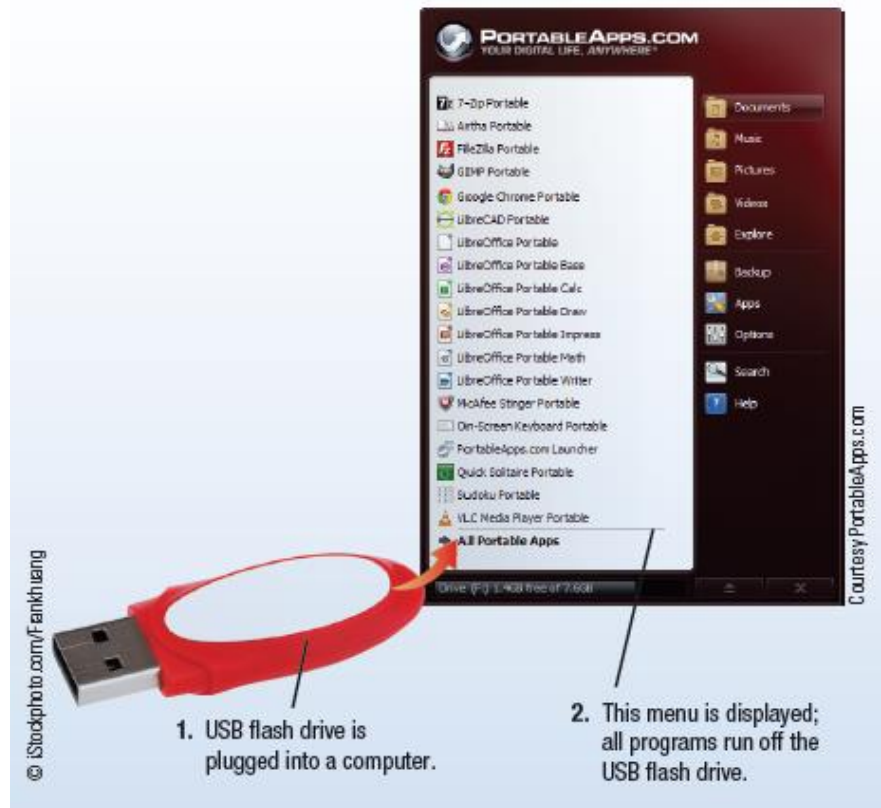
**FIGURE 3-18**  
USB flash drives.



# Technology and You Box

## Thumb Drive PCs

- Portable apps turn USB flash drives and other small devices into personal computers
- Download app and desired software to the USB flash drive
- To use, plug into a computer





# Other Types of Storage Systems

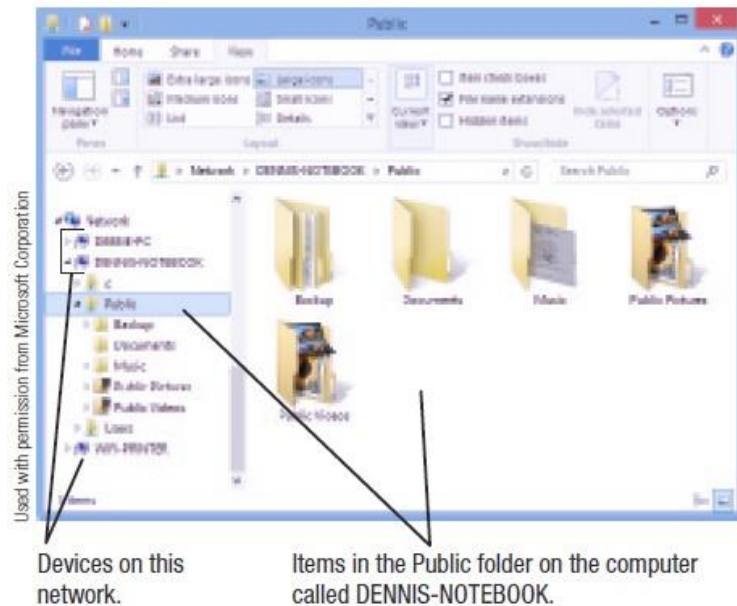
- Network Storage and Cloud Storage Systems
  - Remote storage
    - Using a storage device not directly connected to the computer being used
    - Accessed through the Internet or through a network
  - Network storage
    - Remote storage via local network



# Network and Cloud Storage Systems

- Network attached storage (NAS)
  - High performance storage systems connected individually to a network
  - Designed for small business and home use
- Storage area network (SAN)
  - Separate network of hard drives or other storage devices which are attached to the main network

# Network and Cloud Storage Systems



## SHARED FOLDERS

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



Courtesy Western Digital

## NETWORK ATTACHED STORAGE (NAS) DEVICES

This NAS device holds up to 16 TB of data and provides storage for all computers on the network.

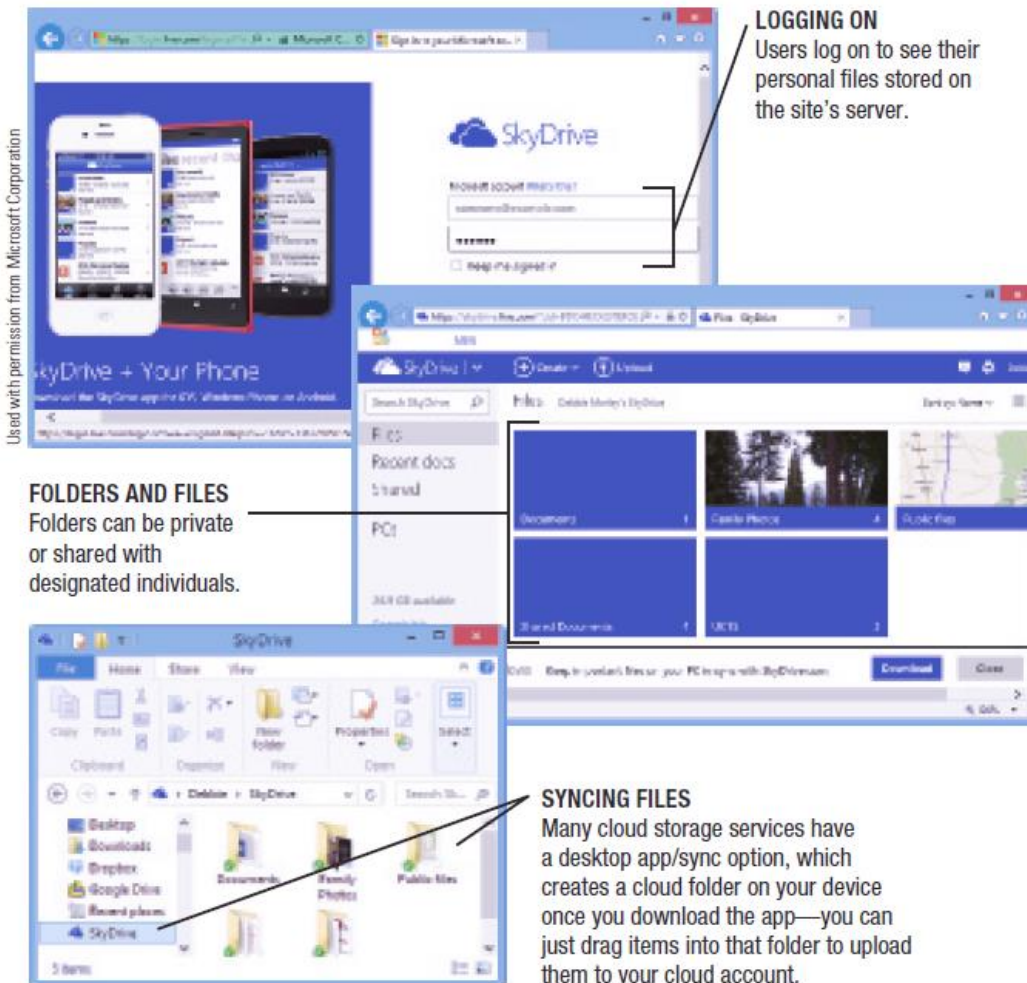
**FIGURE 3-19**  
Network storage.



# Network and Cloud Storage Systems

- Cloud storage (online storage)
  - Accessed via the Internet
    - Via Web sites (Flickr, Facebook, Google Docs, etc.)
    - Via online storage sites (Box, Dropbox, etc.)
    - Growing in importance because more and more applications are Web based
    - Increasing being used for backup purposes
    - Files can be synched between PC and cloud storage
    - Many Web sites providing online storage offer it free
    - Business cloud storage is available

# Network and Cloud Storage Systems



**FIGURE 3-20**  
**Cloud storage.** This site provides 7 GB of free storage.





# Smart Cards

- Smart Card
  - 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, door lock, vending machine, or other device
  - Some smart cards store biometric data
  - Use of mobile smart cards is an emerging trend





# Smart Cards



LOGGING ONTO A COMPUTER VIA A CONTACT SMART CARD READER



MAKING A VENDING MACHINE PURCHASE VIA A CONTACT SMART CARD READER



ACCESSING A SECURE FACILITY VIA A CONTACTLESS SMART CARD READER



PURCHASING SUBWAY ACCESS VIA A CONTACTLESS SMART CARD READER

Photos by HID Global Corporation

**FIGURE 3-21**

Common smart card applications.

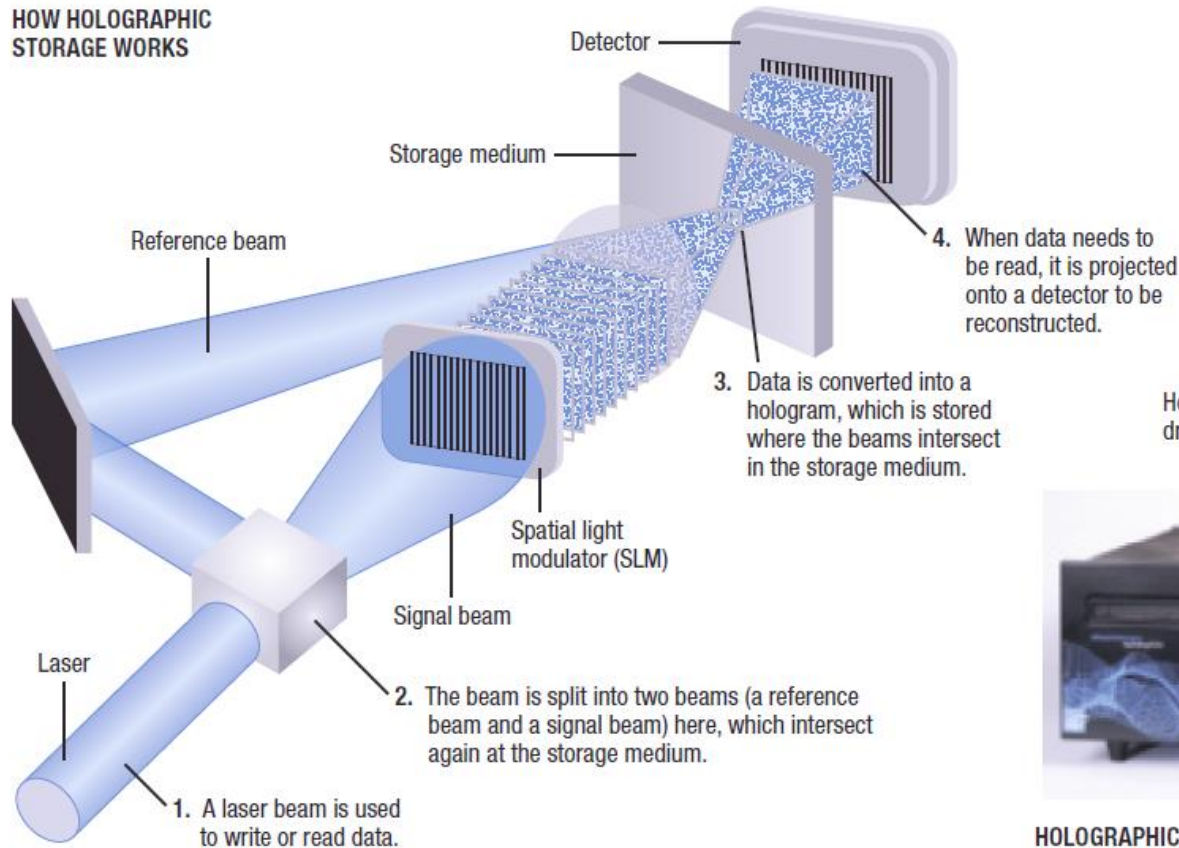


# Holographic Storage

- Holographic storage
  - Holographic drives connect to a computer via a serial attached SCSI (SAS) or Fibre Channel interface
  - Uses multiple blue laser beams to store data in three dimensions
    - Reference beam and signal beam
  - Suited to applications in which large amounts of data need to be stored or retrieved quickly but rarely changed
    - Archiving business data, medical records, TV shows, sensor data , etc.

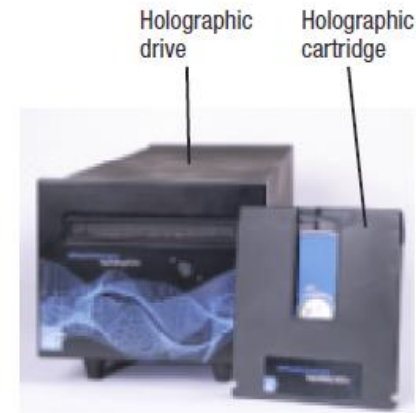
# Holographic Storage

## HOW HOLOGRAPHIC STORAGE WORKS



**FIGURE 3-22**

**Holographic storage.** Holographic drives store more than one million bits of data in a single flash of light.



Courtesy of Signal Lake

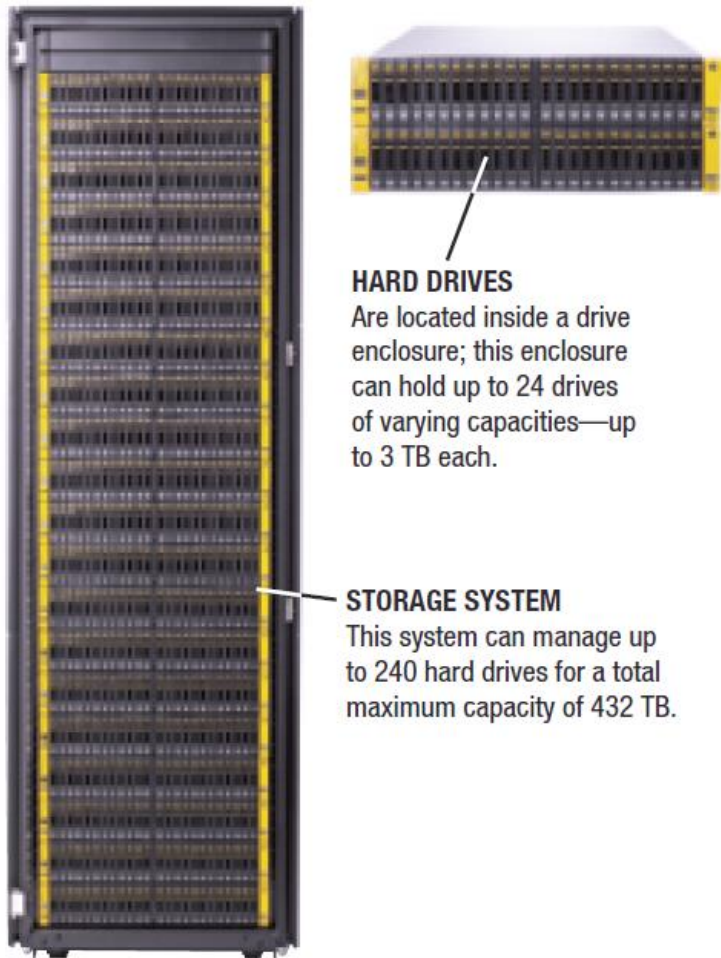
**HOLOGRAPHIC DRIVES AND CARTRIDGES**



# Storage Systems for Large Computer Systems

- Business storage needs are growing exponentially
  - Digital data produced is expected to double every two years through 2020
- Storage server
  - Hardware device containing multiple high-speed hard drives connected to the computer system or network
  - Most are based on magnetic hard discs

# Storage Systems for Large Computer Systems



## **HARD DRIVES**

Are located inside a drive enclosure; this enclosure can hold up to 24 drives of varying capacities—up to 3 TB each.

## **STORAGE SYSTEM**

This system can manage up to 240 hard drives for a total maximum capacity of 432 TB.

Courtesy Hewlett-Packard Development Company, L.P.

## **FIGURE 3-23**

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



# Storage Systems for Large Computer Systems

- 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



# Storage Systems for Large Computer Systems

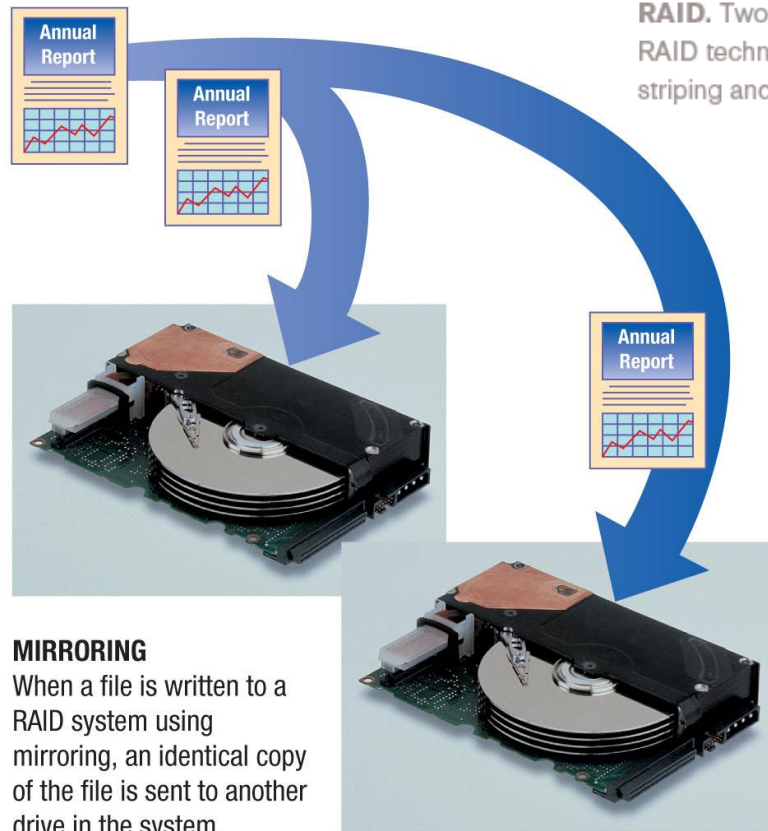
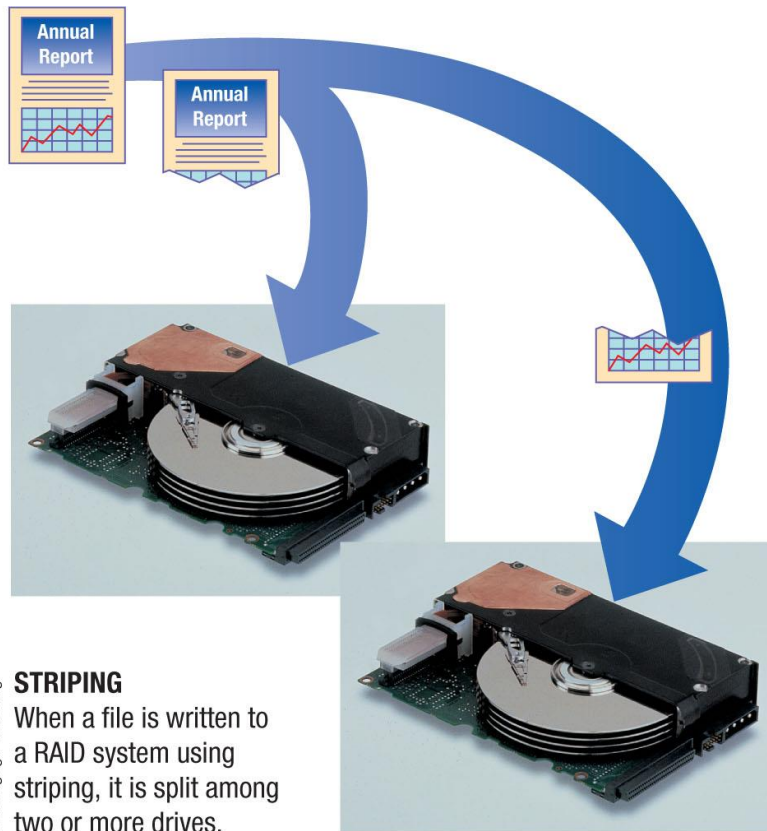
- Different levels of RAID:
  - RAID 0 = disk striping (spread files over two or more hard drives)
  - RAID 1 = disk mirroring (duplicate copy)
  - Other level use a combination or striping and mirroring
- Drobo system
  - New RAID storage system
  - Much easier to use than previous systems
  - Offers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



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



# Storage Systems for Large Computer Systems



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



# Magnetic Tape Systems

- Magnetic Tape
  - Plastic tape coated with a magnetizable substance that represents the bits and bytes of digital data
  - Primarily used for backup and archival purposes
  - Sequential access only
  - Low cost per terabyte
  - Most tapes today are in the form of cartridge tapes



**FIGURE 3-26**

This magnetic tape cartridge holds 80 GB.

Courtesy Imation



# Evaluating Your Storage Alternatives

- 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 ports



# Quick Quiz

1. An online photo sharing site is an example of \_\_\_\_\_.
  - a. RAID
  - b. cloud 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*