VISUALIZING TECHNOLOGY

Debra Geoghan

Ninth Edition

COMPLETE

VISUALIZING TECHNOLOGY

Ninth Edition

Debra Geoghan

Bucks County Community College

Pearson

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Brief Contents

Contents

CHAPTER 3
File Management 112

CHAPTER 11

Databases 548

CHAPTER 12

Program Development 598

About the Author

Amy McDermottHeart and Soul Portraits

Debra is a professor of computer and information science at Bucks County Community College, teaching computer classes ranging from basic computer literacy to cybercrime, computer forensics, and networking. She has certifications from Microsoft, CompTIA, Apple, and others. Deb has taught at the college level since 1996 and also spent 11 years in the high school classroom. She holds a B.S. in Secondary Science Education from Temple University and an M.A. in Computer Science Education from Arcadia University. Throughout her teaching career Deb has worked with educators to integrate technology across the curriculum. At Bucks she serves on many technology committees, presents technology workshops for Bucks faculty, and serves as the STEM Department coordinator. Deb is an avid user of technology, which has earned her the nickname “gadget lady.”

Dedication

This project would not have been possible without the help and support of many people. I cannot express how grateful I am to all of you. Thank you.

My team at Pearson—Jenifer, Cheryl, Stephanie, and everyone else: you have been amazing, helping to bring my vision to reality and teaching me so much along the way.

My colleagues and students at Bucks County Community College: for your suggestions and encouragement throughout this process. You inspire me every day.

And most importantly—my family. My husband and sons for your patience, help, and love—even when it meant taking a photo "right this minute," or reading a chapter when you wanted to be doing something else, or missing me while I was away. And the rest of my family and friends who agreed to let me use their photos throughout the book. I couldn't have done this without your love and support.

And finally my dad—who taught me to love technology and not be afraid to try new things. I miss you and love you, Daddy.

COMPLETE

VISUALIZING TECHNOLOGY

Ninth Edition

Visualizing Technology is always current and always engaging! With the highly visual design, students won't find pages of long paragraphs. Instead, they'll find a text written the way they are hardwired to think, with smaller sections of text that use images creatively for easier understanding and chapters that are organized as web articles with catchy headlines.

Visualizing Technology 9e continues to provide a hands-on approach to learning computer concepts, where students learn a little and then apply what they are learning in a project, through a simulation, or by watching a Viz Clip video to dive deeper. Each chapter has two *How-To* projects, focused on *Digital Literacy* and *Essential Job Skills*, so that students are gaining the skills needed for professional and personal success. Within the etext, students are engaged through interactive surveys, currency updates, videos, IT Simulations, interactives, fun study tools, and flashcards with immediate feedback. With the *Technology in the News* feature, you can keep your class current every week. And with the *Think About It* videos, students are encouraged to think critically about the impact of technology, beyond the convenience factors!

The optimal way to experience *Visualizing Technology* is with MyLab IT. All of the instruction, practice, review, and assessment resources are in one place, allowing you to arrange your course from an instructional perspective that gives students a consistent, measurable learning experience from chapter to chapter.

What's New?

- All content and images updated for currency
- **Better-than-ever Pearson etext** provides an interactive, accessible learning experience with a variety of videos, interactivities, and IT simulations to engage students
- ***Technology in the News* widget** within the etext keeps the course content up to date with weekly updates provided at the beginning of each chapter!
- **IT Simulations** provide an in-depth chapter scenario that students work through in an active learning environment and complete with a brief quiz to demonstrate understanding. Newly redesigned for a more engaging and easier-to-use learning experience. Now includes a "presentation mode" so instructors can walk through the simulation in class or with students.
- New and updated quizzes
- ***Think About It* videos** that challenge students to think beyond the convenience of technology to its true impact on society

- **New and expanded** content coverage, including:
  eSports
  High-performance computing
  Quantum computing
  Immersive technologies
  Bubbles and echo chambers
  Contact tracing
  IoT hacks
- **New and updated *Viz Clip* videos** that explore challenging topics in a "YouTube"-style approach
- **Digital Competency Badge** updated to reflect current MyLab IT content that students earn to demonstrate understanding of the core digital literacy areas of living online and computer fundamentals

What's New for Technology

- ***New Sequential Learning Module Functionality*** allows instructors to set up course activities in a sequence that students have to complete them in to ensure effective learning.
- ***Think About It*** videos encourage students to think critically about technology
- ***Redesigned IT Simulations*** for a more engaging and easier-to-use learning experience that helps students actively demonstrate understanding. Now includes a "presentation mode" so instructors can walk through the simulation in class or with students.
- ***Technology in the News*** currency updates within the etext keep the course content up to date with weekly updates provided at the beginning of each chapter!

The Program

To maximize student results, we recommend using *Visualizing Technology* with MyLab IT, the teaching and learning platform that empowers you to reach every student. By combining trusted author content with digital tools and a flexible platform, MyLab IT personalizes the learning experience and will help your students learn and retain key course concepts while developing skills that future employers are seeking in their candidates.

With MyLab IT for *Visualizing Technology,* students have access to all of the instruction, practice, review, and assessment resources in one place. To set up your course, you use a selection of activities from the content library, or you can use the new *ready-to-go learning module* functionality that allows you to assign activities in the order you want students to complete them, providing a consistent, measurable learning experience from chapter to chapter.

And with the interactive etext, students are engaged in the content through videos, IT Simulations, fun study tools, and flashcards with immediate feedback. In addition, they'll have access to current events with the new *Technology in the News* currency updates and be able to expand their critical thinking abilities with the new *Think About It* videos that encourage students to think critically about the impact of technology, beyond the convenience factors!

Solving Teaching and Learning Challenges

Each chapter has a consistent approach to instruction, hands-on practice with the *Application Projects Digital Literacy and Essential Job Skills* projects, and engagement through the videos and interactive demonstration of understanding with the *IT Simulations*.

With this approach students are engaged in active learning, skill development, and challenged to think critically about the impact of technology.

Developing Employability Skills

Digital literacy is a top required skill in today's job market! Developing these skills involves conceptual as well as hands-on learning. With *Visualizing Technology,* students get both—they learn the fundamentals of computers and have opportunities to apply what they are learning in real-world projects and simulations. Using MyLab IT and *Visualizing Technology,* students can learn, practice, and demonstrate their digital literacy.

- High-demand Office Skills are evaluated in the auto-graded Microsoft Office Application projects in each chapter.
- Essential Employability Skills are taught and practiced in the Digital Literacy and Essential Job Skills projects in each chapter helping prepare students for today's work environment.

Employability Skills Matrix (ESM)

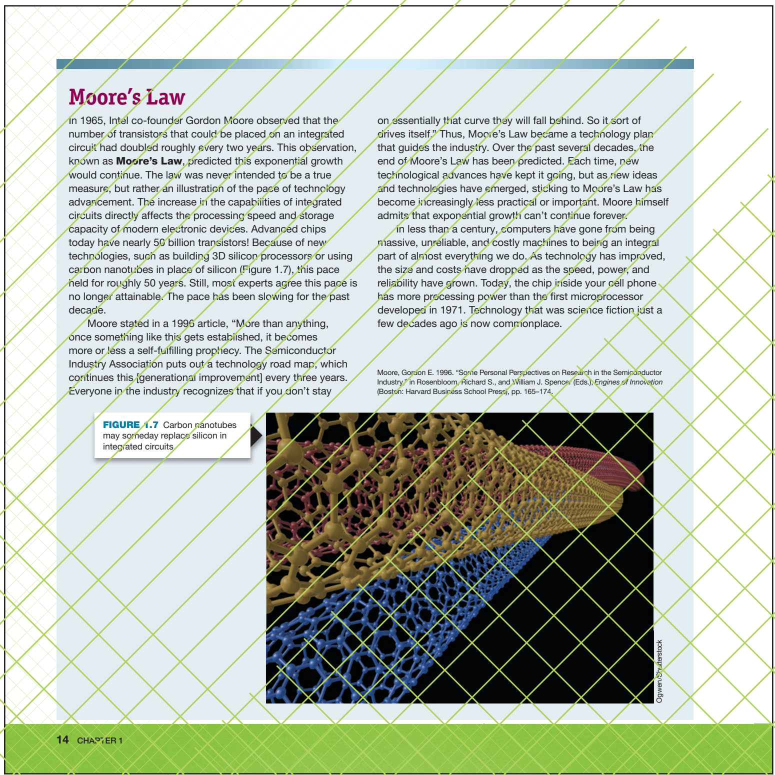
	Think About It & Critical Thinking	How To	Essential Job Skills	Digital Literacy	Ethical Dilemma	Application Projects	Do It Yourself	Collaboration
Critical Thinking	x	x			x		x	
Communication			x	x	x			x
Collaboration			x					**x**
Knowledge Application and Analysis		x	x	x			x	
Social Responsibility	x				x			

Applied Learning Opportunities Throughout

MyLab IT with *Visualizing Technology* provides students many ways to apply what they are learning with IT Simulations, Think About It videos, Check Your Understanding quizzes, Chapter quizzes, and more. And when using the etext, students have more opportunities with fun study tools and currency updates.

Real-World Projects

The projects in *Visualizing Technology* help students learn skills they'll need in the workforce and everyday life.



Moore's Law

In 1965, Intel co-founder Gordon Moore observed that the number of transistors that could be placed on an integrated circuit had doubled roughly every two years. This observation, known as **Moore's Law**, predicted this exponential growth would continue. The law was never intended to be a true measure, but rather an illustration of the pace of technology advancement. The increase in the capabilities of integrated circuits directly affects the processing speed and storage capacity of modern electronic devices. Advanced chips today have nearly 50 billion transistors! Because of new technologies, such as building 3D silicon processors or using carbon nanotubes in place of silicon (Figure 1.7), this pace held for roughly 50 years. Still, most experts agree this pace is no longer attainable. The pace has been slowing for the past decade.

Moore stated in a 1996 article, "More than anything, once something like this gets established, it becomes more or less a self-fulfilling prophecy. The Semiconductor Industry Association puts out a technology road map, which continues this [generational improvement] every three years. Everyone in the industry recognizes that if you don't stay on essentially that curve they will fall behind. So it sort of drives itself." Thus, Moore's Law became a technology plan that guides the industry. Over the past several decades, the end of Moore's Law has been predicted. Each time, new technological advances have kept it going, but as new ideas and technologies have emerged, sticking to Moore's Law has become increasingly less practical or important. Moore himself admits that exponential growth can't continue forever.

In less than a century, computers have gone from being massive, unreliable, and costly machines to being an integral part of almost everything we do. As technology has improved, the size and costs have dropped as the speed, power, and reliability have grown. Today, the chip inside your cell phone has more processing power than the first microprocessor developed in 1971. Technology that was science fiction just a few decades ago is now commonplace.

Moore, Gordon E. 1996. "Some Personal Perspectives on Research in the Semiconductor Industry," in Rosenbloom, Richard S., and William J. Spencer (Eds.), *Engines of Innovation* (Boston: Harvard Business School Press), pp. 165–174.

FIGURE 1.7 Carbon nanotubes may someday replace silicon in integrated circuits

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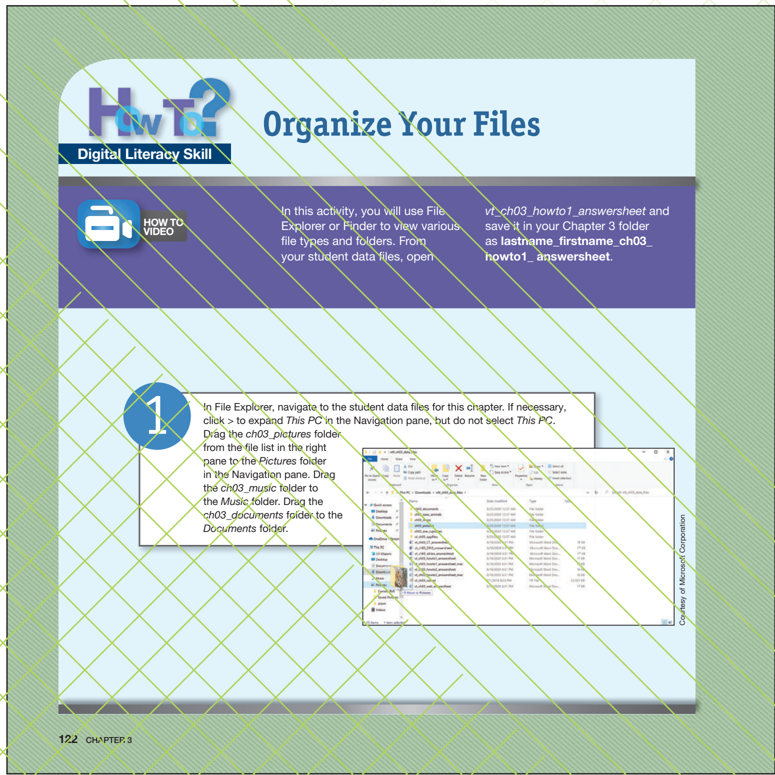
14 CHAPTER 1

Digital Literacy Skills

Hands-on projects that apply fundamental digital skills to allow students to demonstrate understanding.



How To? Digital Literacy Skill

Organize Your Files

HOW TO VIDEO

In this activity, you will use File Explorer or Finder to view various file types and folders. From your student data files, open *vt_ch03_howto1_answersheet* and save it in your Chapter 3 folder as **lastname_firstname_ch03_howto1_ answersheet**.

1 In File Explorer, navigate to the student data files for this chapter. If necessary, click > to expand *This PC* in the Navigation pane, but do not select *This PC*. Drag the *ch03_pictures* folder from the file list in the right pane to the *Pictures* folder in the Navigation pane. Drag the *ch03_music* folder to the *Music* folder. Drag the *ch03_documents* folder to the *Documents* folder.

Courtesy of Microsoft Corporation

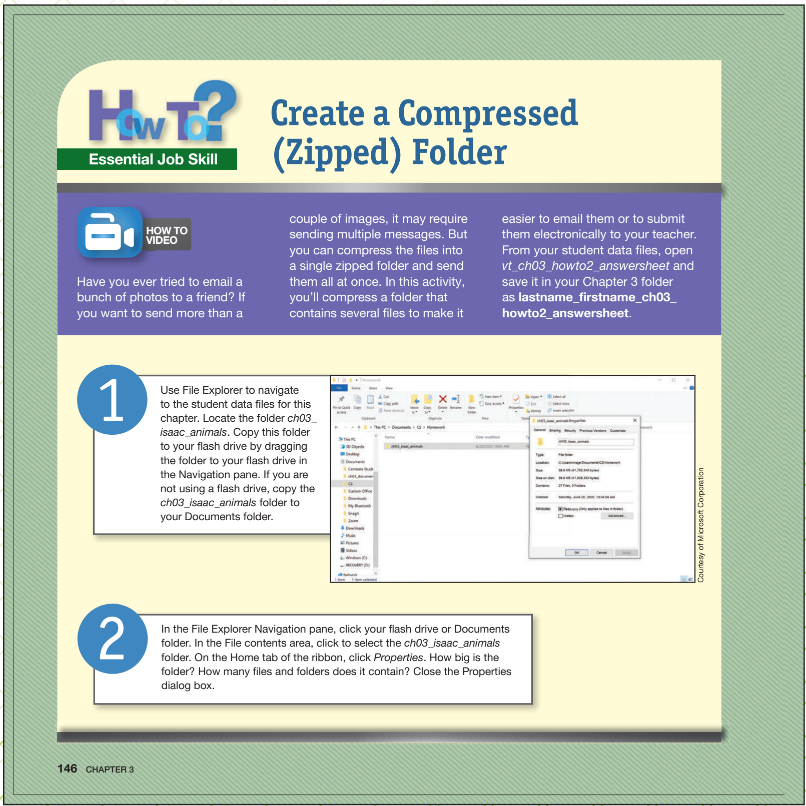
122 CHAPTER 3

Essential Job Skills

Engage students in demonstrating their skills with technology applications and tools they will use in their work lives.

Application Projects

Require students to use one of the Microsoft 365 Applications to solve a business problem and demonstrate their ability to use the application.



How To? Essential Job Skill

Create a Compressed (Zipped) Folder

HOW TO VIDEO

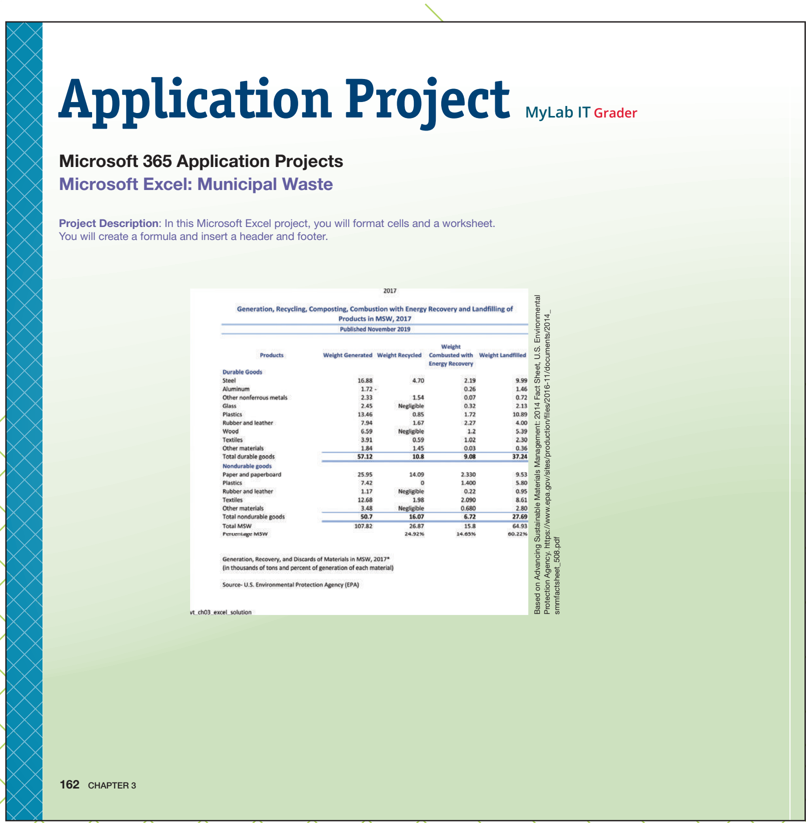
Have you ever tried to email a bunch of photos to a friend? If you want to send more than a couple of images, it may require sending multiple messages. But you can compress the files into a single zipped folder and send them all at once. In this activity, you'll compress a folder that contains several files to make it easier to email them or to submit them electronically to your teacher. From your student data files, open *vt_ch03_howto2_answersheet* and save it in your Chapter 3 folder as **lastname_firstname_ch03_howto2_answersheet**.

1. Use File Explorer to navigate to the student data files for this chapter. Locate the folder *ch03_isaac_animals*. Copy this folder to your flash drive by dragging the folder to your flash drive in the Navigation pane. If you are not using a flash drive, copy the *ch03_isaac_animals* folder to your Documents folder.

Courtesy of Microsoft Corporation

2. In the File Explorer Navigation pane, click your flash drive or Documents folder. In the File contents area, click to select the *ch03_isaac_animals* folder. On the Home tab of the ribbon, click *Properties*. How big is the folder? How many files and folders does it contain? Close the Properties dialog box.

146 CHAPTER 3



Application Project

MyLab IT Grader

Microsoft 365 Application Projects

Microsoft Excel: Municipal Waste

Project Description: In this Microsoft Excel project, you will format cells and a worksheet. You will create a formula and insert a header and footer.

2017

Generation, Recycling, Composting, Combustion with Energy Recovery and Landfilling of Products in MSW, 2017

Published November 2019

Products	Weight Generated	Weight Recycled	Weight Combusted with Energy Recovery	Weight Landfilled
Durable Goods				
Steel	16.88	4.70	2.19	9.99
Aluminum	1.72 -		0.26	1.46
Other nonferrous metals	2.33	1.54	0.07	0.72
Glass	2.45	Negligible	0.32	2.13
Plastics	13.46	0.85	1.72	10.89
Rubber and leather	7.94	1.67	2.27	4.00
Wood	6.59	Negligible	1.2	5.39
Textiles	3.91	0.59	1.02	2.30
Other materials	1.84	1.45	0.03	0.36
Total durable goods	**57.12**	**10.8**	**9.08**	**37.24**
Nondurable goods				
Paper and paperboard	25.95	14.09	2.330	9.53
Plastics	7.42	0	1.400	5.80
Rubber and leather	1.17	Negligible	0.22	0.95
Textiles	12.68	1.98	2.090	8.61
Other materials	3.48	Negligible	0.680	2.80
Total nondurable goods	**50.7**	**16.07**	**6.72**	**27.69**
Total MSW	107.82	26.87	15.8	64.93
Percentage MSW		24.92%	14.65%	60.22%

Generation, Recovery, and Discards of Materials in MSW, 2017*
(in thousands of tons and percent of generation of each material)

Source- U.S. Environmental Protection Agency (EPA)

vt_ch03_excel_solution

Based on Advancing Sustainable Materials Management: 2014 Fact Sheet, U.S. Environmental Protection Agency, https://www.epa.gov/sites/production/files/2016-11/documents/2014_smmfactsheet_508.pdf

162 CHAPTER 3

After working through the content in the book and MyLab IT, students have the opportunity to earn a Digital Competency badge that demonstrates their understanding of essential computer technology. Being digitally literate is a must-have employability skill, and with this badge students can stand out to potential employers by sharing the badge through LinkedIn and other social media.

Instructor Teaching Resources

This program comes with the following teaching resources.

Supplements available to instructors at www.pearsonhighered.com/geoghan	Features of the Supplement
Accessible PowerPoint Presentation	PowerPoints meet accessibility standards for students with disabilities. Features include but are not limited to: • Keyboard and Screen Reader access • Alternative text for images • High color contrast between background and foreground colors
End-of-Chapter Answer Key	Answers to all end-of-chapter questions
Image Library	Every image in the book
Instructor Chapter Guide	• Content Instruction • Student Preparation and Review • Active Learning Options • Chapter Assessment • End-of-Chapter Exercises • Currency Topics • Soft Skills and Team Work • Instructor Resources
Objectives Mapping	Outline of the objectives in every chapter
Solutions Files and Annotated Solution Files	• Solutions to all projects • Solutions with helpful annotations and callouts
Student Data Files	Student files to complete projects
Syllabus Template	Sample syllabus for help in setting up your course
Test Bank	1,000 multiple-choice, true/false, short-answer, and matching questions with these annotations: • Difficulty level (1 for straight recall, 2 for some analysis, 3 for complex analysis) • Objective, which provides location in the text
Computerized TestGen	TestGen allows instructors to: • Customize, save, and generate classroom tests • Edit, add, or delete questions from the Test Item Files • Analyze test results • Organize a database of tests and student results.
Transition Guide	Detailed explanation of changes between the previous and current edition

Yuganov Konstantin/Shutterstock

CHAPTER 1

What Is a Computer?

Julien Tromeur/123RF

In This Chapter

VIZ INTRO

If you've gone grocery shopping, put gas in your car, watched a weather report on TV, or used a microwave oven, then you've interacted with a computer. Most of us use computers every day, often without realizing it. Computers have become so commonplace that we don't even consider them computers. In this chapter, we discuss what a computer is and look at the development of computers in the past few centuries. After reading this chapter, you will recognize the different types of computing devices and their impact on everyday life.

Objectives

1. **Explain the Functions of a Computer**
2. **Describe the Evolution of Computer Hardware**
3. **Describe How Computers Represent Data Using Binary Code**
4. **List the Various Types and Characteristics of Personal Computers**
5. **Give Examples of Other Computing Devices**
6. **List the Various Types and Characteristics of Multiuser Computers**
7. **Explain Ubiquitous Computing and Convergence**

Running Project

In this project, you'll explore computers used in everyday life. Look for instructions as you complete each article. For most articles, there is a series of questions for you to research. At the end of the chapter, you'll submit your responses to the issues raised.

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What Does a Computer Do?

Objective 1

Explain the Functions of a Computer

A **computer** is a programmable machine that converts raw **data** into useful **information**. Raw data includes numbers, words, pictures, or sounds that represent facts about people, events, things, or ideas. A toaster can never be anything more than a toaster—it has one function—but a computer can be a calculator, a media center, a communications center, a classroom, and much more. The ability to change its programming distinguishes a computer from any other machine.

Necessity Is the Mother of Invention

The original computers were people, not machines. The technical and scientific advancements of the Industrial Revolution at the end of the 19th century led to a growing need for this type of calculated information and the development of the first mechanical computers. In the late 19th and early 20th centuries, Harvard University hired women as computers to compare star positions. These women are credited with many astronomical discoveries. In the 1930s, NASA hired hundreds of women as computers. The 2016 book and movie based on the book *Hidden Figures* tell the story of a group of these women and their contributions to the Mercury space program. Dorothy Vaughan was the first African American manager at NASA and taught herself and many other computers to program the new IBM systems in FORTRAN. Mary Jackson became one of the first black female aeronautical engineers. In 2020, NASA named its headquarters in Washington, DC, for Mary Jackson. Mathematician Katherine Johnson worked on projects from Alan Shepard's May 1961 mission Freedom 7 to the Space Shuttle and missions to Mars. The Katherine G. Johnson Computational Research Facility at the Langley Research Center is named in her honor.

agsandrew/Shutterstock

In the early 19th century, mathematician Charles Babbage designed a machine called an **Analytical Engine**. This mechanical computer could be programmed using **punch cards**—stiff pieces of paper that convey information by the presence or absence of holes (Figure 1.1). Punch cards were developed by Joseph Marie Jacquard as part of the Jacquard loom to manufacture textiles with intricate patterns. The Analytical Engine would have been the first mechanical computer, but the technology didn't exist at the time to build it. In his 1864 book *Passages from the Life of a Philosopher*, Babbage wrote, "The whole of the development and operations of analysis are now capable of being executed by machinery. As soon as an Analytical Engine exists, it will necessarily guide the future course of science." In 2011, a group of researchers at London's Science Museum began a project to build Babbage's computer. As of spring 2020, the group had created a database that digitized and cataloged Babbage manuscripts and notes, but building the steam-powered model has not begun.

Mathematician Ada Lovelace, a contemporary of Babbage, wrote a program for the Analytical Engine to calculate a series of Bernoulli numbers—a sequence of rational numbers used in number theory. Because of her efforts, many consider her the first computer programmer. Lovelace never tested the program because there were no machines capable of running it; however, when tested on a computer today, her program yields the correct mathematical results. In 1979, the Ada computer language was named in her honor.

In 1936, mathematician Alan Turing wrote a paper titled *On Computable Numbers*, in which he introduced the concept of machines that could perform mathematical computations—later called **Turing machines**. In 1950, he developed the **Turing test**, which tests a machine's ability to display intelligent behavior. It took 64 years for the first computers to pass the Turing test in 2014. Many consider Alan Turing to be the father of computer science and **artificial intelligence (AI)**—the branch of science concerned with making computers behave like humans. Alan Turing was the subject of the 2014 movie *The Imitation Game.* Today, AI applications include game playing, speech recognition, smart appliances, medical and engineering research, weather forecasting, robots and automation, credit card fraud detection, self-driving vehicles, and the list goes on. AI systems are helping humans solve problems in areas that range from entertainment to saving lives.

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FIGURE 1.1 Punch cards carried commands to a computer.

FIGURE 1.2 The information processing cycle converts data collected from a customer order form into information used to fulfill the order.

The Information Processing Cycle

Computers convert data into information by using the **information processing cycle (IPC)**. The four steps of the IPC are input, processing, storage, and output. Raw data entered into the system during the input stage is processed or manipulated to create useful information. The information is stored for later retrieval and then returned to the user in the output stage. Figure 1.2 shows a general analogy of how this works. In this example, a customer is ordering an item online. The data collected from the customer is input. The input is temporarily stored in the system until it can be processed. During processing, the data is used to evaluate the customer order. The output is sent to the employee to pick, pack, and ship the order.

It was nearly a century after Babbage designed his Analytical Engine until the first working mechanical computers were built. From that point, it took only about 40 years to go from those first-generation machines to the current fourth-generation systems.

Running Project

Many developments of the Industrial Revolution, such as the Jacquard loom, helped pave the way for modern computers. Use the Internet to find out how the following people also contributed: George Boole, Vannevar Bush, Nikola Tesla, and Gottfried Wilhelm Leibniz.

4 Things You Need to Know

- Computers are programmable machines.
- The four steps of the information processing cycle are input, processing, storage, and output.
- The IPC converts raw data into useful information.
- Artificial intelligence is the science of making computers behave like humans.

Key Terms

Analytical Engine

artificial intelligence (AI)

computer

data

information

information processing cycle (IPC)

punch card

Turing machine

Turing test

How To?

Digital Literacy Skill

Capture a Screenshot of Your Desktop

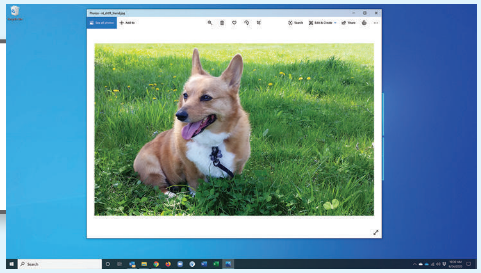
HOW TO VIDEO

A useful skill is creating screenshots of your desktop. For example, it helps provide directions on how to do something or for keeping a record of an error message that appears on your screen. Windows includes several ways to capture a screenshot. You can save your screenshots, email them, paste them into documents, and annotate and highlight them. In this Activity, you will use the Snipping Tool to capture a screenshot. Macs include the Screenshot or Grab tool.

The Windows Snipping Tool can capture four types of snips: Free-form, Rectangular, Window, or Full-screen. The Mac Screenshot tool can capture three types of images: Selected Portion, Selected Window, or Entire Screen. Screenshot can also record the screen to video.

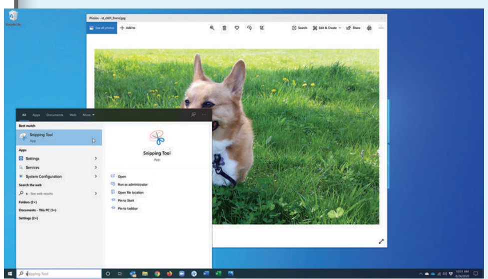
From your student data files, open the *vt_ch01_howto1_answersheet* file and save the file as **lastname_firstname_ch01_howto1_answersheet**.

1. From your student data files, right-click the file *vt_ch01_friend*, point to *Open with*, and then click *Photos*. Do not maximize the Photos window.



Debra Geoghan; Courtesy of Microsoft Corporation

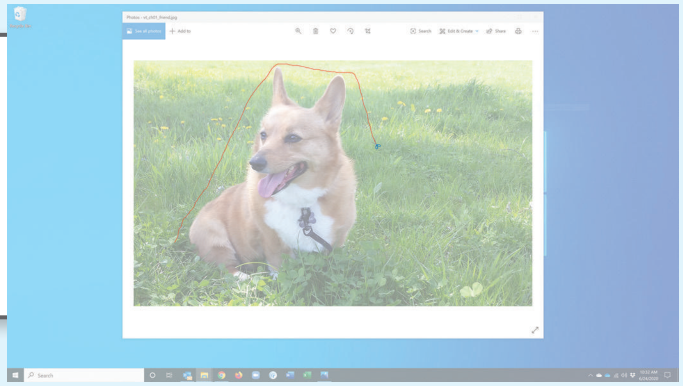
2. In the Windows search box on the taskbar, type **snip** and then, in the Search results, click *Snipping Tool*. The Snipping Tool may include information about Snip & Sketch, an alternate screen capture tool included with Windows. If the Snipping Tool is not available on your system, you can use Snip & Sketch to complete this activity.



Debra Geoghan; Courtesy of Microsoft Corporation

3

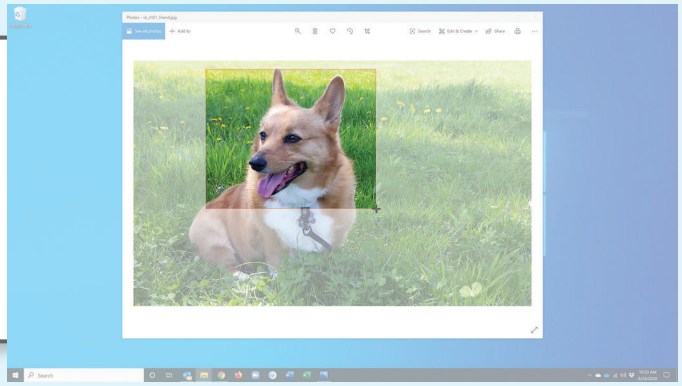
In the Snipping Tool window, click the drop-down arrow next to *Mode* and click *Free-form Snip*. Drag the mouse to draw a line around the dog's head with the Snipping Tool scissors. Click the *Copy* icon on the toolbar. Switch to your answer sheet and paste the snip under *Free-form Snip*. You can resize the image to fit your answer sheet.



Debra Geoghan; Courtesy of Microsoft Corporation

4

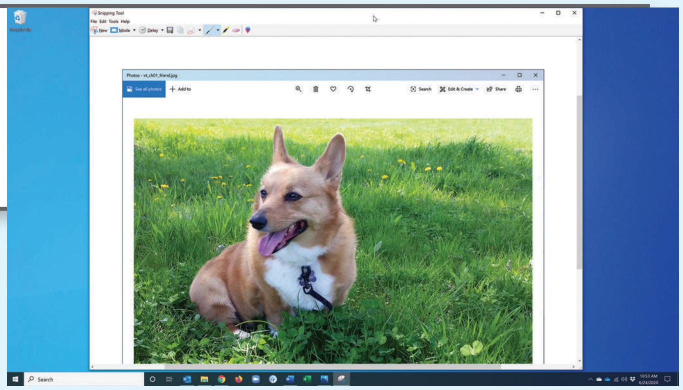
Return to your image. In the Snipping Tool window, click *New*. Click the drop-down arrow next to *Mode* and click *Rectangular Snip*. Drag the box around the dog and release the mouse button. Click the *Copy* icon on the toolbar. Paste the rectangular snip into your document under *Rectangular Snip*.



Debra Geoghan; Courtesy of Microsoft Corporation

5

Use the same procedure to capture a Window Snip of the dog and paste in your document. In a paragraph, describe the difference between the snips you took. Save the file and submit it as directed by your instructor.



Debra Geoghan; Courtesy of Microsoft Corporation

MAC

If you are using a Mac:

1. From your student data files, double-click the file *vt_ch01_friend* to open it in Preview.
2. From Launchpad, click the *Other* folder, and then open Screenshot. If Screenshot is not available on your system, open Grab.
3. From the Screenshot toolbar, click *Capture Selected Portion*. Click *Options*, and click *Clipboard*. Drag the box around the dog's head and click *Capture*. The capture is saved to the clipboard (memory) of your computer. Switch to your answer sheet and paste the capture under Selected Portion. Use the same procedure to capture a window and screen and paste both in your document. In a paragraph, describe the difference between the screenshots you took. Save the file and submit it as directed by your instructor.

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A Brief History of Computers

Objective 2

Describe the Evolution of Computer Hardware

In this article, we look at the evolution of computers in the past century—from the massive first-generation machines of the 1930s and 1940s to the modern fourth-generation devices—and how Moore's Law has predicted the exponential growth of technology.

History of Computers

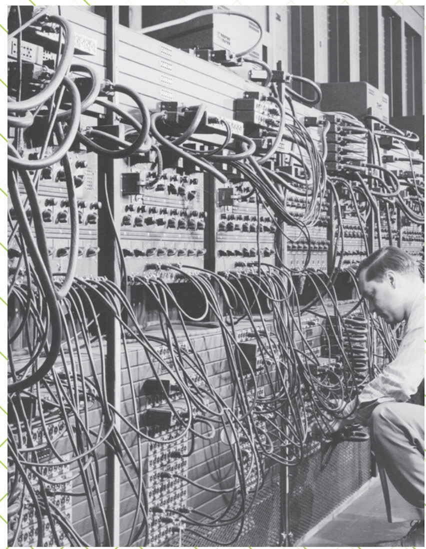
Computers have come a long way since Babbage and Turing. Between the mid-19th and mid-20th centuries, the Industrial Revolution gave way to the Information Age. Since that time, the pace of technology has grown faster than ever before.

FIRST-GENERATION COMPUTERS

During the 1930s and 1940s, several electromechanical and electronic computers were built. These first-generation computers were massive in size and used vacuum tubes and manual switches to process data. **Vacuum tubes**, which resemble incandescent light bulbs, give off a lot of heat and are notoriously unreliable. The **Electronic Numerical Integrator and Computer (ENIAC)**, built at the University of Pennsylvania between 1943 and 1946, is considered the first working, digital, general-purpose computer (Figure 1.3). ENIAC used about 18,000 vacuum tubes, weighed almost 30 tons, and occupied about 1,800 square feet. Created initially to calculate artillery firing tables, ENIAC wasn't completed until after the war ended and was reprogrammed to solve a range of other problems, such as atomic energy calculations, weather predictions, and wind-tunnel design. The programming was done by manipulating switches and took six programmers several days to complete.

The Harvard Mark I, also known as the IBM Automatic Sequence Controlled Calculator, was a general-purpose digital calculator used by the U.S. Navy toward the end of World War II. It was 51 feet long and 8 feet tall. Grace Hopper worked on the Mark I and was one of the first computer programmers. During her 42-year Navy career, Hopper helped develop the first compiled programming languages, which converted human language into computer commands. She earned the rank of rear admiral. Hopper is sometimes credited with coining the term *bug* to refer to a glitch in a computer program, but her contributions are much more impressive.

Important first-generation computers include the Z1 and Z3 built in Germany; the Colossus machines in the United Kingdom; and the Atanasoff–Berry Computer (ABC), the Harvard Mark 1, ENIAC, and UNIVAC in the United States (Table 1.1).



Pictorial Press Ltd/Alamy Stock Photo

FIGURE 1.3 ENIAC was the first working, digital, general-purpose computer.

TABLE 1.1 Important First-Generation Computers

Date	Computer	Origin	Creator	Description
1936–1941	Z1–Z3	Germany	Konrad Zuse	The Z1 through Z3 were mechanical, programmable computers. Working in isolation in Germany, Konrad Zuse didn't receive the support of the Nazi government, and his machines were destroyed during the war.
1942	Atanasoff–Berry Computer (ABC)	United States	Professor John Atanasoff and graduate student Clifford Berry at Iowa State College	The ABC was never fully functional, but Atanasoff won a patent dispute against John Mauchly (ENIAC), and Atanasoff was declared the inventor of the electronic digital computer.
1944	Colossus	United Kingdom	Tommy Flowers	Used by code breakers to translate encrypted German messages, these computers were destroyed after the war and kept secret until the 1970s.
1944	Harvard Mark 1	United States	Designed by Howard Aiken and programmed by Grace Hopper at Harvard University	The U.S. Navy used the Mark 1 for gunnery and ballistic calculations until 1959.
1946	ENIAC	United States	J. Presper Eckert and John Mauchly at the University of Pennsylvania	ENIAC was the first working, digital, general-purpose computer.
1951	UNIVAC	United States	Eckert/Mauchly	The world's first commercially available computer, UNIVAC, was famous for predicting the outcome of the 1952 presidential election.

SECOND-GENERATION COMPUTERS

Invented in 1947, **transistors**—tiny electronic switches that replaced vacuum tubes—enabled second-generation computers in the 1950s and 1960s to be more powerful, smaller, more reliable, and reprogrammed in far less time than first-generation computers. Figure 1.4 illustrates the difference between the size of a vacuum tube and a transistor.

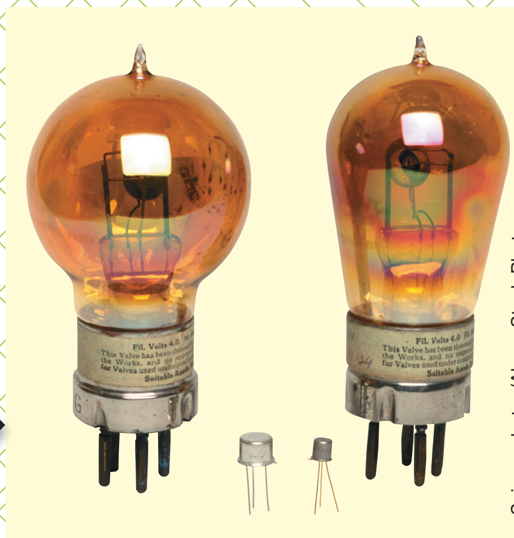
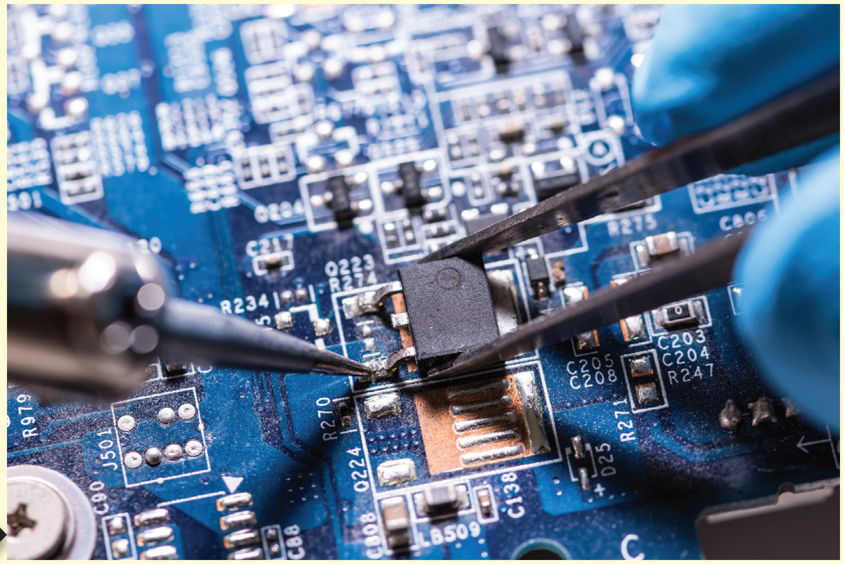


FIGURE 1.4 The vacuum tube and the transistor.

Sciencephotos/Alamy Stock Photo

THIRD-GENERATION COMPUTERS

The 1960s saw the development of **integrated circuits**—chips that contain large numbers of tiny transistors fabricated into a semiconducting material called silicon (Figure 1.5). Third-generation computers used multiple integrated circuits to process data. They were even smaller, faster, and more reliable than their predecessors, although there was much overlap between second- and third-generation technologies in the 1960s. The Apollo Guidance Computer, used in the moon landing missions, was designed using transistors, but over time, the design was modified to use integrated circuits instead. The 2000 Nobel Prize in physics was awarded for the invention of the integrated circuit.

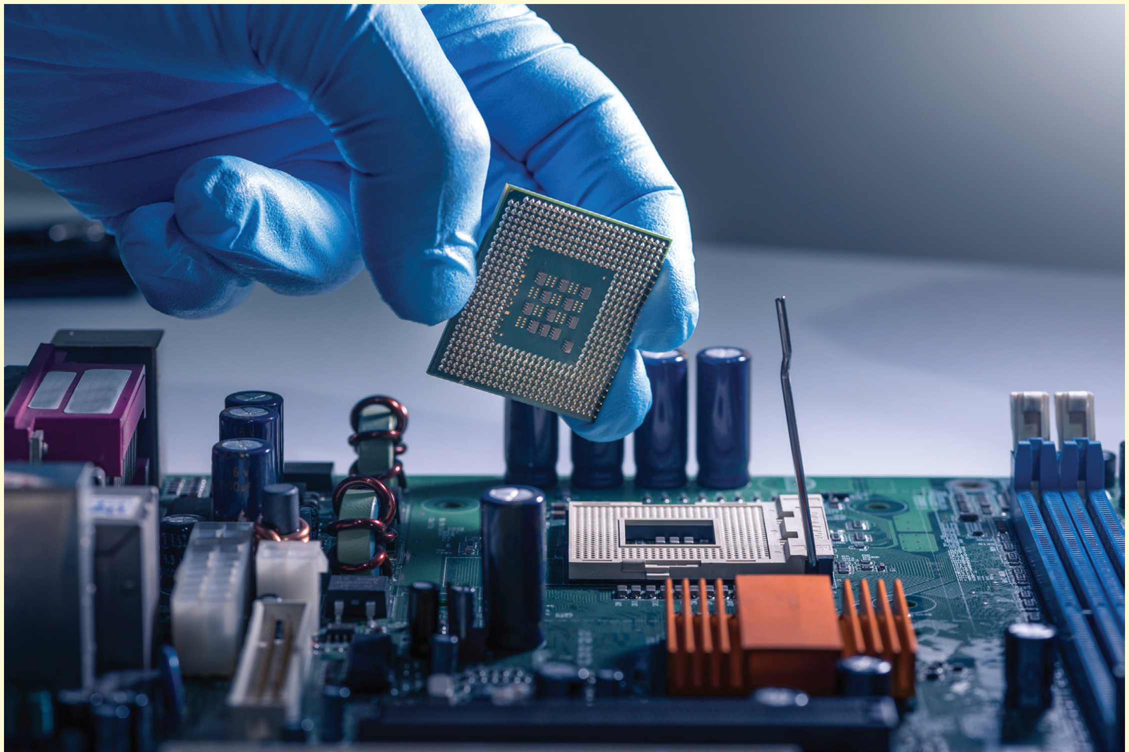


Preechar Bowonkitwanchai/Shutterstock

FIGURE 1.5 Integrated circuits on a circuit board.

FOURTH-GENERATION COMPUTERS

The integrated circuit made the development of the microprocessor possible in the 1970s. A **microprocessor** is a complex integrated circuit that contains processing circuitry. The **central processing unit (CPU)** is the primary microprocessor in the computer. It behaves like the brain of the computer, controls all functions performed by other components, and processes all the commands it receives (Figure 1.6). Other microprocessors that can be found in a computer control the network (NPU), graphics (GPU), or audio (APU) processing. The first microprocessor was developed in 1971 and was as powerful as ENIAC. Today's fourth-generation personal computers use microprocessors. Microprocessors are found in everything from alarm clocks to automobiles to refrigerators.



Preechar Bowonkitwanchai/Shutterstock

FIGURE 1.6 Fourth-generation computers use microprocessors.

Moore's Law

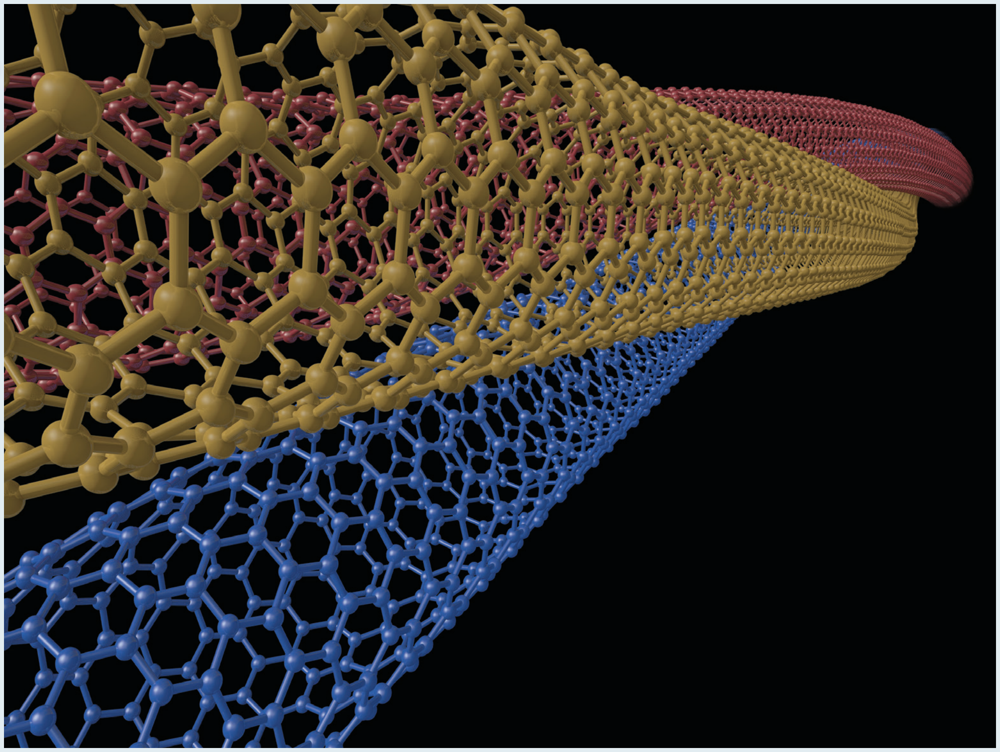
In 1965, Intel co-founder Gordon Moore observed that the number of transistors that could be placed on an integrated circuit had doubled roughly every two years. This observation, known as **Moore's Law**, predicted this exponential growth would continue. The law was never intended to be a true measure, but rather an illustration of the pace of technology advancement. The increase in the capabilities of integrated circuits directly affects the processing speed and storage capacity of modern electronic devices. Advanced chips today have nearly 50 billion transistors! Because of new technologies, such as building 3D silicon processors or using carbon nanotubes in place of silicon (Figure 1.7), this pace held for roughly 50 years. Still, most experts agree this pace is no longer attainable. The pace has been slowing for the past decade.

Moore stated in a 1996 article, "More than anything, once something like this gets established, it becomes more or less a self-fulfilling prophecy. The Semiconductor Industry Association puts out a technology road map, which continues this [generational improvement] every three years. Everyone in the industry recognizes that if you don't stay on essentially that curve they will fall behind. So it sort of drives itself." Thus, Moore's Law became a technology plan that guides the industry. Over the past several decades, the end of Moore's Law has been predicted. Each time, new technological advances have kept it going, but as new ideas and technologies have emerged, sticking to Moore's Law has become increasingly less practical or important. Moore himself admits that exponential growth can't continue forever.

In less than a century, computers have gone from being massive, unreliable, and costly machines to being an integral part of almost everything we do. As technology has improved, the size and costs have dropped as the speed, power, and reliability have grown. Today, the chip inside your cell phone has more processing power than the first microprocessor developed in 1971. Technology that was science fiction just a few decades ago is now commonplace.

Moore, Gordon E. 1996. "Some Personal Perspectives on Research in the Semiconductor Industry," in Rosenbloom, Richard S., and William J. Spencer (Eds.), *Engines of Innovation* (Boston: Harvard Business School Press), pp. 165–174.

FIGURE 1.7 Carbon nanotubes may someday replace silicon in integrated circuits.



ogwen/Shutterstock

GREEN COMPUTING

Smart Homes

The efficient and eco-friendly use of computers and other electronics is called **green computing**. Smart homes and smart appliances help save energy and, as a result, are good for both the environment and your pocketbook.

Smart homes use home automation to control lighting, heating and cooling, security, entertainment, and appliances. Such a system can be programmed to turn various components on and off at set times to maximize energy efficiency. So, the heat can turn up, and the house can be warm right before you get home from work while not wasting the energy to keep it warm all day while you're away. If you're away on vacation or have to work late, you can remotely activate a smart home by phone or over the Internet. Some utility companies offer lower rates during off-peak hours, so programming your dishwasher and other appliances to run during those times can save you money and help energy utility companies manage the power grid, potentially reducing the need for new power plants.

Can't make your home a smart home overnight? No worries! You can take some small steps without investing in an entire smart home system. Try installing a programmable thermostat, putting lights on timers or motion sensors, and running appliances during off-peak hours.

Smart appliances can monitor signals from the power company transmitted over the **smart grid**—a network for delivering electricity to consumers that includes communication technology to manage electricity distribution efficiently. When the electric grid system is stressed, smart appliances can react by reducing power consumption. Although these advances are called smart home technology, the same technologies are also found in commercial buildings.

zhu difeng/Shutterstock

Running Project

Use the Internet to look up current microprocessors. What companies produce them? Visit computer.howstuffworks.com/microprocessor.htm and read the article. How many transistors were included in the first home computer processor? What was the name of the processor, and when was it introduced?

5 Things You Need to Know

- First-generation computers used vacuum tubes.
- Second-generation computers used transistors.
- Third-generation computers used integrated circuits (chips).
- Fourth-generation computers use microprocessors.
- Moore's Law states that the number of transistors that can be placed on an integrated circuit doubles roughly every two years—in the past decade, it has ranged from 18 months to five years.

Key Terms

central processing unit (CPU)

Electronic Numerical Integrator and Computer (ENIAC)

green computing

integrated circuit

microprocessor

Moore's Law

smart appliance

smart grid

smart home

transistor

vacuum tube

Nicole Lienemann/Shutterstock

Bits and Bytes

Objective 3

Describe How Computers Represent Data Using Binary Code

VIZ CLIP

Bits and Bytes

Humans have ten digits—our fingers!—which is why the most commonly used number system is the decimal, or base 10, number system. Computers have switches, not fingers, and use the **binary number system**, also referred to as **base 2**, a number system that has only two digits—0 and 1. All information entered into a computer system must be converted into binary digits.

Binary Code

Computers do not speak English, Spanish, Chinese, or any other human language, so how does a computer interpret what a human inputs? On a typewriter, when you press the *A* key, you get an A on the page. Computers only understand 0s and 1s, so when you press the *A* key on a computer keyboard, it must somehow be converted to 0s and 1s. Digital data is represented using a **binary code**. A binary code represents digital data as a series of 0s and 1s that can be understood by a computer.

Binary code works like a bank of light switches. If there is only a single light switch in a room, there are two possible states: The light can either be on or off. This code works in situations with only two possibilities, such as yes/no or coffee/tea, but it fails when there are more than two choices, such as vanilla/chocolate/strawberry. Adding another switch—or bit—increases the possible combinations by a factor of two, which equals four possibilities. A third switch, or bit, gives us eight possibilities, and so on (Table 1.2). A **bit**, short for binary digit, is the smallest unit of digital data. Eight bits equal a **byte**, which gives us 256 possibilities. A byte represents a single character in modern computer systems. For example, when you press the *A* key, the binary code 01000001 (65 in decimal) is sent to the computer.

American Standard Code for Information Interchange (ASCII) was developed in the 1960s using a 7-bit system that represented 128 characters. It included English alphabet symbols in both uppercase and lowercase, numbers 0 through 9, punctuation, and a few special characters. It was later expanded to an 8-bit extended set with 256 characters, but ASCII needed to be adapted for other languages, and many extended sets were developed. The most common extended ASCII set is **Unicode**. Unicode is the standard on the Internet and includes codes for most of the world's written languages, mathematical systems, and special characters. It has codes for about 100,000 characters. The first 256 characters are the same in both ASCII and Unicode; however, the characters in the last rows in Table 1.3 include Latin, Greek, and Cyrillic symbols, which are represented only in Unicode.

TABLE 1.2 A Binary Code Using Eight Switches, or Bits, Has 256 Different Possible Combinations

Number of Bits (Switches)	Possibilities	Power of Two
1	2	2^1
2	4	2^2
3	8	2^3
4	16	2^4
5	32	2^5
6	64	2^6
7	128	2^7
8	256	2^8

TABLE 1.3 ASCII and Unicode Representations

Character	ASCII (in Decimal)	Unicode (in Decimal)	Binary Code
#	35	35	00100011
$	36	36	00100100
0	48	48	00110000
1	49	49	00110001
A	65	65	10000001
B	66	66	1000010
a	97	97	1100001
b	98	98	1100010
œ		339	
ŕ		341	
α		945	

Quantum Computing

Unlike current computers that use bits having only two states, **quantum computers** use the quantum properties of superposition and entanglement to create multiple states using **qubits**, or **quantum bits**—the basic units of quantum information. This exponentially increases the processing power over current computers. Superposition can be visualized as a spinning coin—it is neither heads nor tails—until it stops spinning. Billions of dollars have been invested in the development of quantum computers. There are several working models, but we are still years away from functional quantum computers. Quantum computers will help us solve problems that even our most advanced supercomputers do not have the computing power to solve. They will simulate chemical reactions and financial markets, improve weather forecasting and AI advances, break encryption, develop new drugs, and help find cures. The possibilities are endless—if they work. The quantum computers that currently exist are highly sensitive and prone to errors, essential to help develop better quantum computers, but not really useful for anything else.

Patpitchaya/Shutterstock

Measuring Data

Bits (b) are used to measure data transfer rates such as an Internet connection, and bytes (B) are used to measure file size and storage capacity. The decimal prefixes—powers of ten—of *kilo, mega, giga, tera, peta*, and so on, are added to the base unit (*bit* or *byte*) to indicate larger values. Binary prefixes—powers of two—*kibi, mebi*, and *gibi* are used for random-access memory (RAM). A megabyte (MB) is equal to 1,000,000 bytes, and a mebibyte (MiB) is equal to 1,048,576 bytes, a slightly larger value. Tables 1.4 and1.5 compare the two systems.

A megabyte (MB) is equal to 1 million bytes—the equivalent of about 500–800 pages of plain text. The size of a single picture taken with a digital camera can be 24 megabytes or more. A gigabyte is equal to 1,000 megabytes; most storage is measured in gigabytes and terabytes. A terabyte equals 1,000 gigabytes. As the commonly used types of digital files have changed from plain text to images, music, and video, the file sizes have become larger, and the need for storage has grown. Fundamentally, however, all files are still just 0s and 1s.

TABLE 1.4 Decimal Storage Capacity Prefixes

Decimal Prefix	Symbol	Decimal Value	
		Exponential	Numeric
		10^3	1,000
Mega	M	10^6	1,000,000
Giga	G	10^9	1,000,000,000
Tera	T	10^{12}	1,000,000,000,000
Peta	P	10^{15}	1,000,000,000,000,000
Exa	E	10^{18}	1,000,000,000,000,000,000
Zetta	Z	10^{21}	1,000,000,000,000,000,000,000
Yotta	Y	10^{24}	1,000,000,000,000,000,000,000,000

TABLE 1.5 Binary Storage Capacity Prefixes

Binary Prefix	Symbol	Binary Exponent	Decimal Value
Kibi	Ki	2^{10}	1,024
Mebi	Mi	2^{20}	1,048,576
Gibi	Gi	2^{30}	1,073,741,824
Tebi	Ti	2^{40}	1,099,511,627,776
Pebi	Pi	2^{50}	1,125,899,906,842,624
Exbi	Ei	2^{60}	1,152,921,504,606,846,976
Zebi	Zi	2^{70}	1,180,591,620,717,411,303,424
Yobi	Yi	2^{80}	1,208,925,819,614,629,174,706,176

CAREER SPOTLIGHT

JOBS

BIOINFORMATICS Computers have become integral to almost every career. Nowhere is this more evident than in the field of biology. **Bioinformatics** is the application of information technology to the area of biology. Scientists use computers to analyze data, predict how molecules will behave, and maintain and search massive databases of information. The rapid growth of biological information over the past few decades has created a demand for new technologies and people who know how to use them. This field requires at least a four-year degree. If you have a keen interest in science and technology, bioinformatics might be a good career choice for you.

Angellodeco/Shutterstock

Running Project

Use the Internet to research the usage of decimal and binary prefixes discussed in this chapter. Describe two instances when binary prefixes are more commonly used.

4 Things You Need to Know

- Computers use the binary (base 2) number system.
- ASCII and Unicode are binary code character sets.
- A bit is the smallest unit of digital information.
- A byte is equal to 8 bits and represents one character.

Key Terms

American Standard Code for Information Interchange (ASCII)
binary code
binary (base 2) number system
bioinformatics
bit
byte
quantum bit (qubit)
quantum computer
Unicode

Rawpixel.com/Shutterstock

Let's Get Personal

Objective 4

List the Various Types and Characteristics of Personal Computers

SIMULATION **What Is a Computer?**

A **personal computer (PC)** is a small microprocessor-based computer used by one person at a time. A personal computer can be a notebook, a mobile device, or a desktop. Today, the term *personal computer* usually refers to a computer running a Windows operating system; however, Mac computers and those running Linux operating systems are also personal computers.

Desktop Computers

A **desktop computer** is a personal computer that fits into a workspace, such as a desk or counter—designed to stay put. Desktops range in price from under $300 for basic personal systems to thousands of dollars for high-end machines used for video editing, gaming, and number crunching. Desktop computers offer the most speed, power, and upgradability for the lowest cost. A **workstation** is a high-end desktop computer or one that's attached to a network in a business setting.

An **all-in-one computer** is a compact desktop computer with an integrated monitor and system unit (Figure 1.8). Some all-in-ones are wall-mountable. All-in-ones save desktop real estate but may be difficult to upgrade because of their small size. They are popular in places where space is at a premium, such as emergency rooms, bank teller windows, and classrooms.

Ekaphon maneechot/Shutterstock

FIGURE 1.8 An all-in-one desktop computer with the components mounted behind the monitor is accessible in settings in which desktop space is limited.

Notebook Computers

Notebook or **laptop** computers are portable personal computers. Notebook computers can rival desktops in power and storage capacity—but can cost significantly more than a comparable desktop system. Despite the higher cost, notebooks have become more affordable and thus more popular. By 2021, notebooks are forecast to outsell desktops more than two to one. Modern notebook computers come with built-in wireless networking capabilities, webcams, and bright widescreen displays and can handle most ordinary computing tasks with ease. High-end notebooks with large screens and powerful processors are referred to as desktop replacements because many individuals now purchase this type of system instead of a traditional desktop computer.

A **convertible notebook** computer has a screen that can swivel to fold into what resembles a notepad or tablet. These computers include a touch screen or a digital pen called a **stylus** that enables you to write directly on the screen, making them useful for taking notes or drawing diagrams and for making information such as sales catalogs portable. A **two-in-one notebook** has a detachable screen that converts to a tablet, such as the Microsoft Surface shown in Figure 1.9. A **tablet** is a handheld mobile device that falls somewhere between a notebook and a smartphone. A tablet has an LCD—liquid-crystal display—screen, a long battery life, and built-in wireless connectivity. Tablets are an excellent choice for travel. A tablet may have a detachable keyboard, making it more notebook-like with the keyboard in place. Tablets come with a variety of preinstalled **mobile applications**, or **mobile apps**—programs that extend the functionality of mobile devices. Thousands of apps can be downloaded and installed to make the device even more versatile. With these apps, you can edit documents, take photographs, surf the web, send and receive email, and watch videos.

A **subnotebook** is a notebook computer that is thin and light and that has high-end processing and video capabilities. The screen on a subnotebook is typically in the range of 13–15 inches. Ultrabooks that run Windows, Chromebooks, and Apple's MacBook Air are examples of subnotebooks.

Oleksiy Maksymenko/imageBROKER/Alamy Stock Photo

FIGURE 1.9 Microsoft Surface.

Mac, PC, or Something Else?

In the personal computer market, there are three major platforms of personal computers to choose from: Macs, Chromebooks, and PCs. A computer platform includes both the hardware and software that make up the system. What's the difference between the three, and which one should you choose? Most of the configurations of computers discussed in this chapter are available in all platforms. The primary difference between them is the operating system they run. An **operating system** (OS) is software that provides the user with an interface to communicate with the hardware and software on a computer. A computer can't run without an operating system installed. Operating systems are discussed in detail in another chapter.

Apple builds **Mac** computers, which run the macOS operating system. Using a program called Boot Camp, users can also run Microsoft Windows on a Mac. Macs have a reputation for being secure, stable, and fun. They come with a variety of useful programs already installed and are very user-friendly. Macs are often used in creative businesses, such as advertising and graphic design, and are growing in popularity in the home market.

PCs are available in numerous models, configurations, and price ranges, built by many companies, including Sony, Asus, Lenovo, and Toshiba. PCs that run some version of the Windows or Linux operating systems constitute over 85 percent of the U.S. market share. Those that run Windows have the largest selection of software available.

Chromebooks are growing in popularity and are prevalent in K–12 schools. Chromebooks are subnotebooks that run the Chrome OS—a version of the Linux operating system released by Google. These notebooks work best when connected to the Internet and rely on web apps and online storage rather than traditional software. The Chromebox is a desktop computer running Chrome OS. Figure 1.10 highlights some of the features of Macs, PCs, and Chromebooks.

Personal computers have become so commonplace that roughly 80 percent of U.S. households have at least one personal computer. Since 2014, tablet sales rivaled PC sales. The type of system you choose depends on many factors, including personal preferences, the types of software you use, compatibility with school or work computers, and cost.

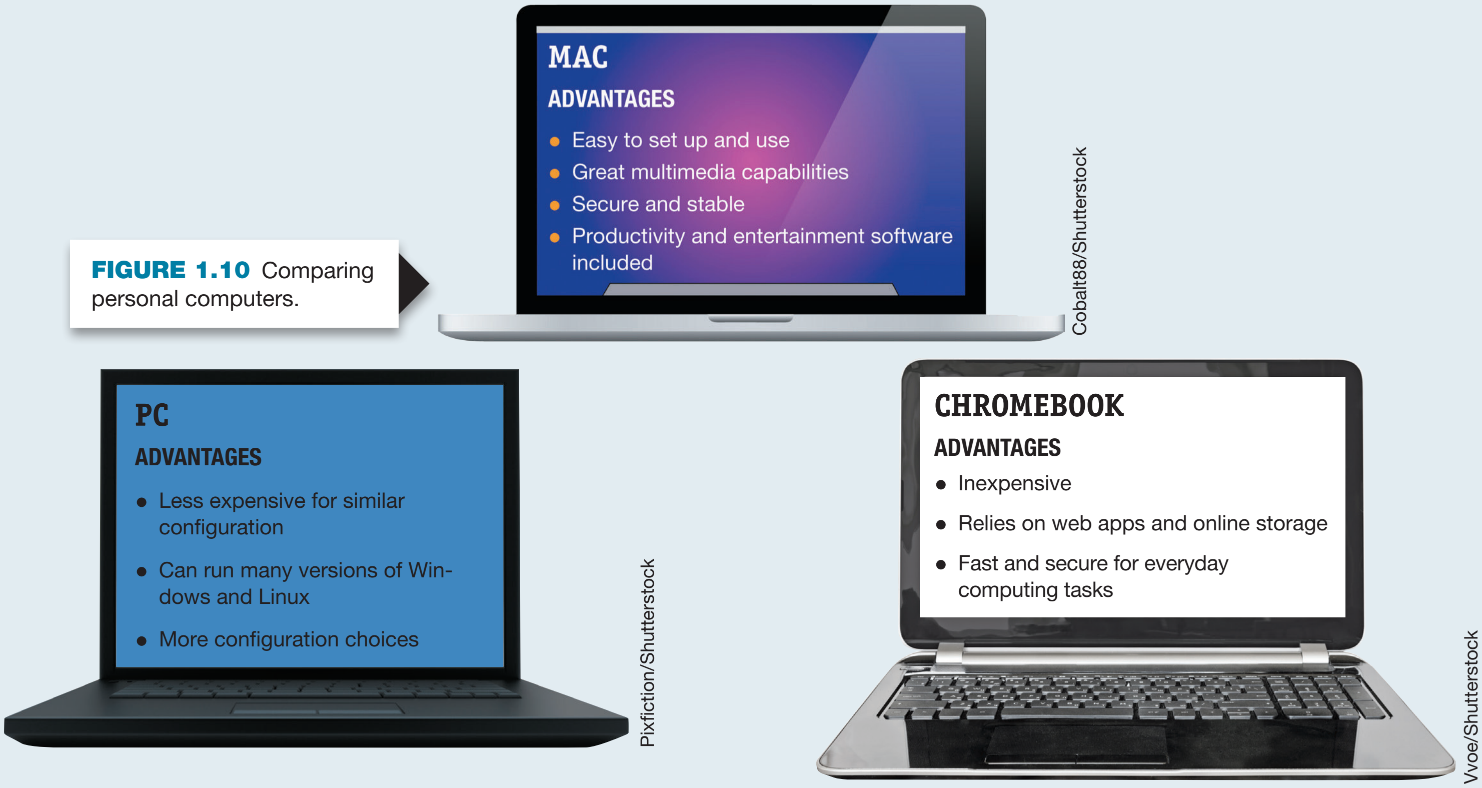


FIGURE 1.10 Comparing personal computers.

Ergonomics

An improperly set up workspace can affect your health, comfort, and productivity. **Ergonomics** is the study of the relationship between workers and their workspaces. Ergonomic design creates a work environment designed to reduce illnesses and musculoskeletal disorders. The furniture you use, the lighting in the room, and the position of your equipment all affect your work environment.

Whether you are working in class at a desktop computer, sitting on the couch playing video games, or reading a book on an e-reader at the beach, your goal should be to keep your body in a neutral body position without twisting or turning to reach or see your screen. You should not need to lean forward, and your feet should be flat on the ground or a footrest. Your monitor should be at or below eye level so you do not need to tilt your neck to see it, and the lighting should not cause glare on your screen. The keyboard and mouse should be positioned so your arms are in a relaxed position, as shown in Figure 1.11. One crucial step that many people forget is to take regular breaks to stretch and move around. Technology can help you be more ergonomic—for example, an app on the Apple Watch will remind you to stand up every 50 minutes. Following ergonomic design principles will help you work more comfortably and reduce strain on your body.

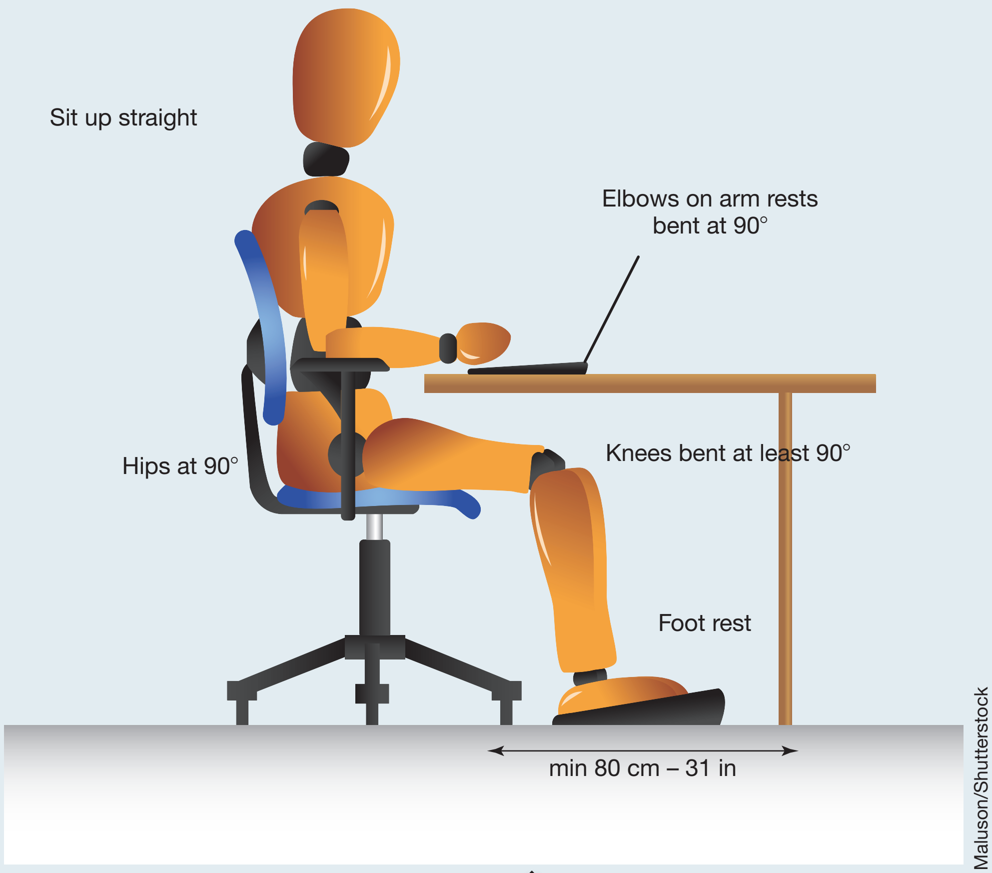


FIGURE 1.11 An ergonomic workstation.

UNIVERSAL DESIGN

Universal design principles not only help create environments that accommodate people with disabilities but also benefit those with no special needs. For example, wider doorways allow wheelchairs and walkers through and make it easier to carry merchandise and move furniture. In technology, applying universal design means designing easily accessible spaces. This term also refers to input and output devices that can be used and adjusted by everyone. Devices should be simple and intuitive to use for everyone. Universal design extends to software and website design as well.

Jaren Jai Wicklund/Shutterstock

Viz Check—In MyLab IT, take a quick quiz covering Objectives 1–4.

Running Project

It's hard to imagine a job that doesn't require a working knowledge of personal computers. Look up the term *digital literacy*. Use several different websites to get an idea of what this term means, and then write a description of digital literacy for the career that you plan to pursue.

5 Things You Need to Know

- Desktop computers give you the most bang for your buck.
- Notebook or laptop computers are portable PCs.
- Tablets fall somewhere between notebooks and smartphones and run mobile apps.
- The primary difference between a Mac, Chromebook, and PC is the operating system software.
- Ergonomics and universal design help create workspaces that are healthy and easier for users.

Key Terms

all-in-one computer

Chromebook

convertible notebook

desktop computer

ergonomics

laptop

Mac

mobile application (mobile app)

notebook

operating system (OS)

personal computer (PC)

stylus

subnotebook

tablet

two-in-one notebook

universal design

workstation

HOW TO?

Essential Job Skill

Ergonomics

HOW TO VIDEO

Computer programs and services on the web receive continuous updates and improvements, so the steps to complete this web-based activity may differ from the ones shown. You can often look at the screens and the information presented to determine how to complete the activity.

The Occupational Safety and Health Administration (OSHA) website has a computer workstation checklist. In this activity, you will use the checklist to evaluate your workspace at home or school. From your student data files, open the *vt_ch01_howto2_answersheet* file and save it as **lastname_firstname_ch01_howto2_answersheet**.

1 Open your browser and go to **www.osha.gov/SLTC/etools/computerworkstations.**

Captured from www.osha.gov/SLTC/etools/computerworkstations 6/24/20

2

Click *Good Working Positions* and read the information on this page. What does “neutral body positioning” mean, and what are the four reference postures?

Captured from www.osha.gov/SLTC/etools/computerworkstations 6/24/20

3

Click *Checklists* and click *Evaluation*. Complete the checklist to evaluate your workspace. For each question that you answer no to, click the appropriate link to read the information on how to correct the problem. How did your workstation fare? What are some areas for improvement? How could you improve your score?

Captured from www.osha.gov/SLTC/etools/computerworkstations 6/24/20

4

When you have finished the checklist, click the link to Print Checklist. If you are using Safari or Chrome, save the checklist as a PDF file. Using Edge, Internet Explorer, or Firefox, print using the Microsoft Print to PDF or Microsoft XPS Document Writer option. Save the file as **lastname_firstname_ch01_howto2_checklist**. Submit both the answer sheet and checklist files as directed by your instructor.

Mark Nazh/Shutterstock

Beyond the Desktop

Objective 5

Give Examples of Other Computing Devices

Today, the term *computer* no longer refers only to desktops used for office work. Many of us carry computers with us everywhere we go. Mobile devices have become the primary computing devices for many people.

Mobile Devices

Mobile devices are portable, handheld computers used for business and entertainment, and come in many different shapes and sizes—from tablets and smartphones to fitness monitors that you wear on your wrist. Some of these devices serve specialized functions, such as GPS navigation, while others, such as smartphones, are more general-purpose devices. Mobile devices are the fastest-growing segment of personal computers.

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SMARTPHONES AND TABLETS

Mobile devices such as smartphones and tablets combine features such as Internet and email access, digital cameras, GPS and mapping tools, and access to thousands of mobile apps. Mobile devices are useful when carrying a regular notebook computer isn't practical.

Basic mobile phones are limited to making phone calls and perhaps texting and taking photos. **Smartphones** are small computers that combine a cellular phone with such features as Internet and email access, a digital camera, mapping tools, and the ability to edit documents. You can download additional mobile applications, or mobile apps, to extend their capabilities, which makes them true convergence devices. The cellular networks offered by major carriers provide data transfer speeds that rival home connections. This improved connection speed enables you to check email, watch TV, video chat, and play online games almost anywhere. Your cellular plan may include separate charges for voice and data. Employing apps that use your data connection can quickly use up the amount of data in your plan, leading to reduced speed or extra cost. Apps can also decrease the battery life of your device. Many mobile phones use a **subscriber identity module (SIM) card** that identifies the phone and includes account information and cellular carrier. Cellular-enabled tablets use the same network as your smartphone to access the Internet. You need to purchase a data plan from your mobile carrier to use this feature.

WEARABLES AND GPS

Computers worn on the body are known as **wearables**. These hands-free computers are used for fitness tracking and health monitoring, communications, military operations, and entertainment. The Apple Watch is a general-purpose wearable computer (Figure 1.12).

Originally built by the military, the **Global Positioning System**, or **GPS**, consists of at least 24 satellites operating at all times (Figure 1.13), plus several spares. These satellites transmit signals that are picked up by a GPS receiver on the ground

Jacek Lasa/Alamy Stock Photo

FIGURE 1.12 The Apple Watch is a wearable computer.

Etelmaging/Shutterstock

FIGURE 1.13 The Global Positioning System (GPS) is a satellite-based navigation system placed into orbit by the U.S. Department of Defense.

to determine the receiver's current location, time, and velocity through the triangulation of the signals. Since the mid-1990s, GPS devices have been available for civilian use. There are scientific applications for GPS technology, such as surveying, map making, self-navigating robots, and clock synchronization. Automobiles, airplanes, and boats employ GPS for navigation and tracking. Many mobile apps use GPS for navigation, location services, and just plain fun. For example, some apps use your location to determine what information to display, such as discounts, local weather, or nearby restaurant recommendations.

Geocaching is an electronic scavenger hunt played around the world. Players, called geocachers, hide geocaches—typically small waterproof containers—and post GPS coordinates on the Internet. You can then find the geocaches using your GPS device or app on your mobile device to help you navigate. The geocaches have logbooks to sign and often small prizes. Geocachers that find a prize leave something else in return, so you never know what you will find. Check out geocaching.com to find out how to play.

Gorodenkoff/Shutterstock

Video Game Systems and Simulations

A **video game system** is a computer designed primarily to play games. The first arcade video games were released in the early 1970s, and video game systems for the home soon followed. Magnavox released its Odyssey game console in 1972. It was programmed to play 12 different games. Atari released a home version of Pong for the 1975 holiday season. Sold exclusively through Sears, Pong was the hottest gift of the year. For many people, video game systems were the first computers they had in their homes.

Competitive video game playing, or **Esports**, is a multibillion-dollar industry. Teams and individuals play for millions of dollars. Millions of fans watch live streams of matches on YouTube and Twitch. Championship matches air on ESPNs various platforms. The National Association of Collegiate Esports (NACE) has over 70 member schools.

Game consoles such as Microsoft Xbox and Sony PlayStation systems have high-end processing and graphics capabilities. These consoles can play movies and music, enable online game play, and browse the Internet. They have built-in solid-state drives for quick startup and storage. Players interact with video games using a **game controller**. In 2016, PlayStation VR was the first virtual-reality headset released for a game console. The ninth-generation consoles are the Xbox Series X (2020) and Sony's PlayStation 5 (2020). Each update brings improved hardware and better gaming experience.

Handheld video games enable you to take your games wherever you go. The popularity of smartphones and tablets has reduced this market dramatically. The Nintendo Switch (2017) is a hybrid system that allows you to connect the handheld system to a dock that turns it into a console system. During the COVID-19 pandemic in 2020, sales of the Switch surged as people looked for things to do when under stay-at-home orders.

Virtual reality (VR) is an artificial world that consists of images and sounds created by a computer that is affected by the actions of a person who is experiencing it. Wearing a VR headset is immersive—shutting out the outside world. Related to VR is **augmented reality (AR)**—an overlay of virtual content on the physical world (Figure 1.14). The virtual content does not interact with the physical world. For example, AR apps on a mobile device can overlay maps or provide details about locations and objects in the real world.

The Microsoft HoloLens is an example of a mixed reality device—a self-contained, holographic computer. With **mixed reality**, you can interact with **holograms**—3D images created by laser or another light source—in the real world. For example, you could walk around a holographic patient or a model of an entire city.

Video game systems aren't just for entertainment. In healthcare, medical students use video game simulations to learn to be better doctors, stroke patients in rehab use simulations to improve fine-motor reflexes, and surgeons use simulations to practice intricate techniques. In other applications, pilots train on flight simulators, business students solve complex problems, and biology students perform virtual dissections. Simulations enable you to immerse yourself in a situation that may not be safe or accessible otherwise.

Aleksei Gorodenkov/Alamy Stock Photo

FIGURE 1.14 An architect interacts with a mixed reality model of a city.

Running Project

Use the Internet to find out how medical students are using video game simulations. What are some of the medical schools using such systems? How are these systems used? How do professors and students feel about them? What other fields use simulators to train students?

FIND OUT MORE ...

GPS and Beyond

GPS is a U.S.-based system. Did you know that Russia has a system called GLONASS and the European system is called Galileo? Together these three systems provide global coverage, and yet there are still places on earth where GPS is inaccessible. The Defense Advanced Research Projects Agency (DARPA) is working on a new positioning system that won't use satellites at all. Use the Internet to find out how this new system will work and when it will be functional.

4 Things You Need to Know

- Smartphones and tablets are handheld mobile devices.
- GPS is a satellite-based navigation system.
- Wearables are computers worn on the body.
- Today's video game consoles are systems with high-end graphics and processing.

Key Terms

augmented reality (AR)

Esports

game controller

geocaching

Global Positioning System (GPS)

hologram

mixed reality

mobile device

smartphone

subscriber identity module (SIM) card

video game system

virtual reality (VR)

wearable

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Computing on a Large Scale

Objective 6

List the Various Types and Characteristics of Multiuser Computers

Multiuser computers are systems that allow multiple simultaneous users to connect to them. The advantages of multiuser systems include centralized resources and security. Multiuser computers are more powerful than personal computers.

Servers

Server computers provide services, such as Internet access, email, or file and print services, to client systems such as your home or office computer. A **client** is a device that connects to or requests services from a server. Servers range in size and cost from minimal servers costing a few hundred dollars to massive enterprise servers costing hundreds of thousands of dollars (Figure 1.15).

Small and midrange servers that users connect to via personal computers can perform complex calculations, store customer information and transactions, or host an email system for an organization. They can support hundreds of simultaneous users and are scalable, allowing for growth as a company's needs change.

Horoscope/Shutterstock

FIGURE 1.15 In multiuser systems, multiple simultaneous users connect to a server computer.

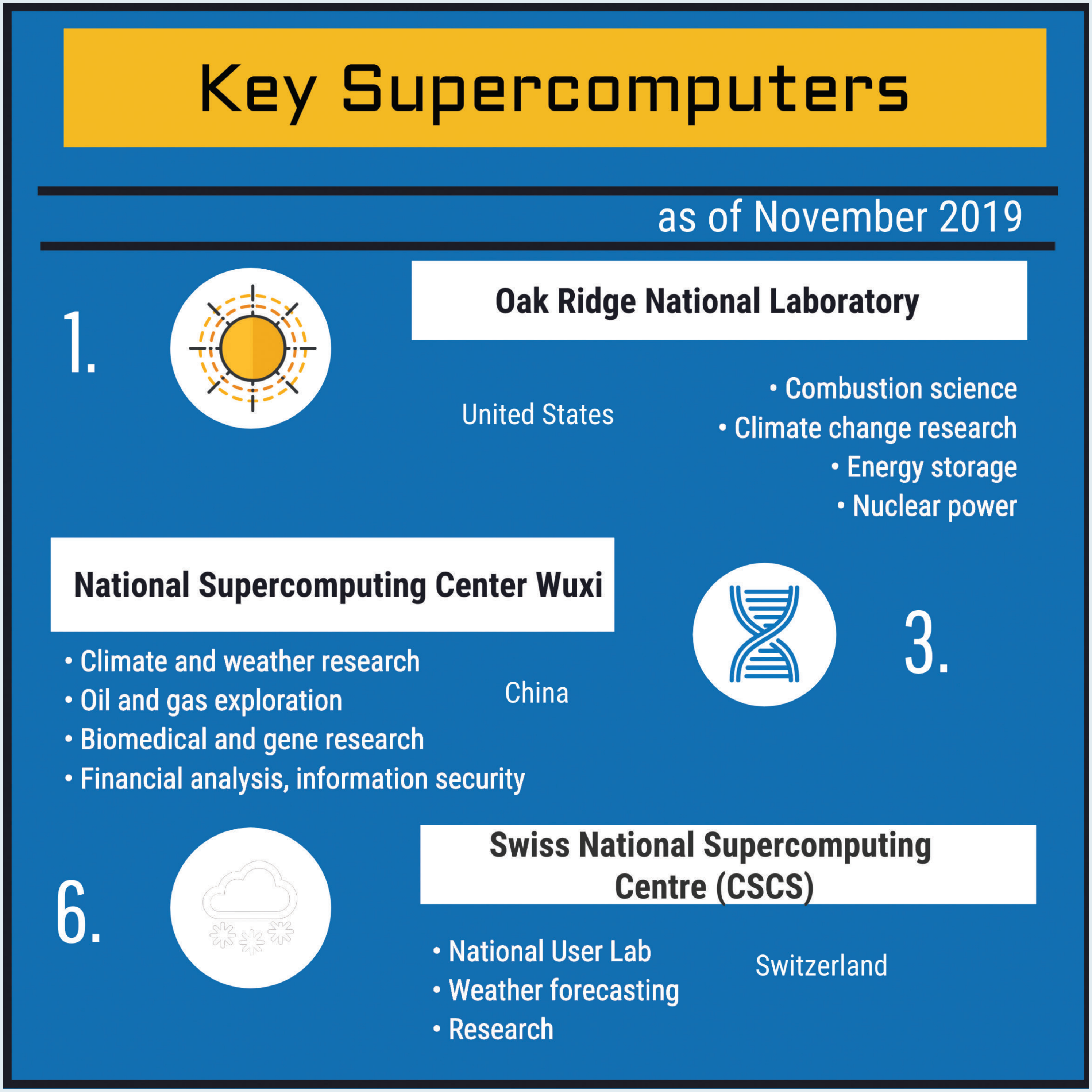
Mainframes are large computers that can perform millions of transactions in a day. Mainframe computers have largely been replaced by **enterprise servers**, and the terms are sometimes used interchangeably (Figure 1.16). These systems allow thousands of users to utilize the system concurrently. These are used by businesses that have massive amounts of data or transactions to process, such as banks and insurance companies.

scanrail/123RF

FIGURE 1.16 Enterprise servers can allow thousands of simultaneous users and perform millions of transactions every day.

Supercomputers

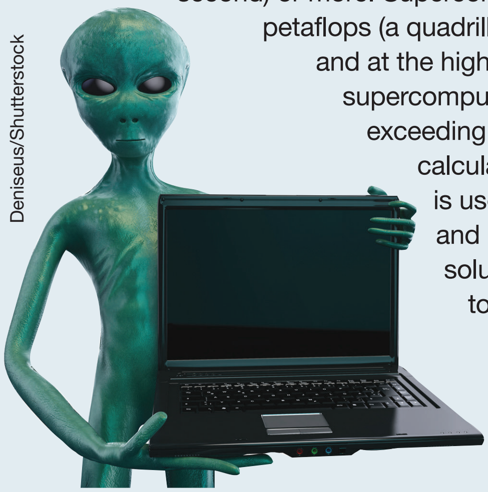
Supercomputers are very expensive computer systems designed to perform a limited number of tasks as quickly as possible. They perform complex mathematical calculations, such as those used in weather forecasting and medical research. A supercomputer can consist of a single computer with multiple processors or can be a group of computers that work together. The world's top supercomputers are found at major universities and research institutes around the world. Figure 1.17 provides a sampling from the listing of the top 500 supercomputers from **top500.org**.



Debra Geoghan

FIGURE 1.17 Important supercomputers as of November 2019, from top500.org.

Distributed and Grid Computing



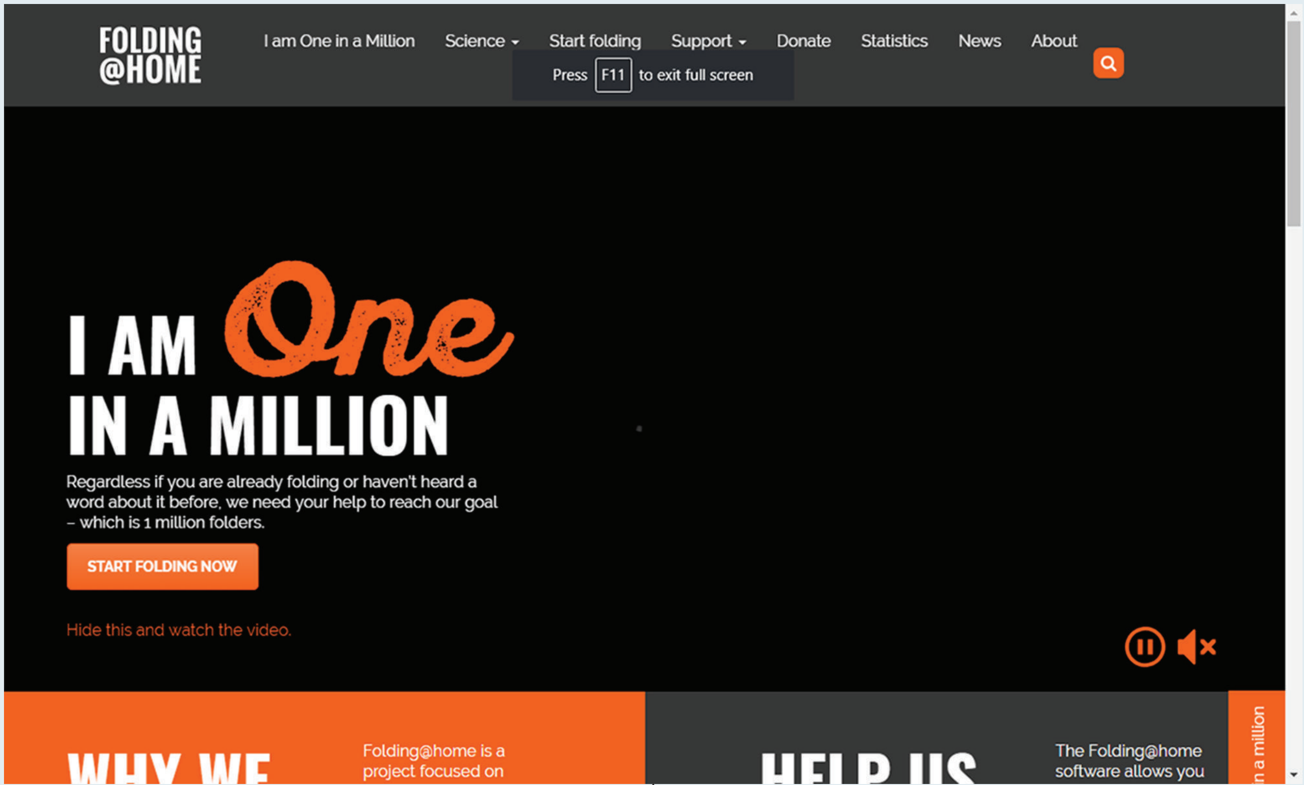
Deniseus/Shutterstock

High-performance computing (HPC) systems use parallel processing and function at a teraflop (a trillion calculations per second) or more. Supercomputers can exceed petaflops (a quadrillion calculations per second), and at the highest end, the newest supercomputers hit the exascale range, exceeding an exaflop (a billion billion calculations per second). HPC is used to research, model, and simulate problems to find solutions. HPS has been used to model the COVID-19 pandemic in the search for treatments and vaccines.

Supercomputers are HPC systems. On a smaller scale, HPC systems can be distributed clusters of multiprocessor computers—referred to as nodes—working together to solve problems that one system is not powerful enough to solve on its own. The cost of an HPC cluster, which typically consists of 16 to 64 computers, is much lower than that of a supercomputer, making HPC affordable for small and medium-sized businesses and research institutions.

Distributed computing distributes the processing of a task across a group of computers. Distributed computing using a group of computers in one location is called **grid computing**. On a much larger scale, **volunteer computing** projects harness the idle processing power of hundreds or thousands of personal computers. At **boinc.berkeley.edu**, a volunteer can choose from a variety of projects to join. Volunteer computing project websites have active communities where volunteers can talk to scientists and each other.

A volunteer interested in astronomy might join SETI@home. One of the first volunteer computing projects, SETI@home



"Folding Home." Pande Lab & Stanford.edu. Stanford University Web. http://folding.stanford.edu/. Reprinted with permission.

FIGURE 1.18 The Folding@home website.