Science Ch. 21

Technology

Biography

PTOLEMY

Ptolemy was a Greek astronomer who lived in Egypt in the second century A.D. He wondered why the planets moved as they did. Each planet seemed to move eastward against the star-studded sky. But sometimes the planet backed up and moved westward for a few months. Then it would continue moving east again.

Ptolemy developed a model to explain the planets' motion. His model included the accepted idea that Earth was the center of the universe. Earth didn't move. The Moon, Sun, and planets revolved around Earth, each in its own orbit. Beyond the farthest planet were all the stars, also revolving around Earth.

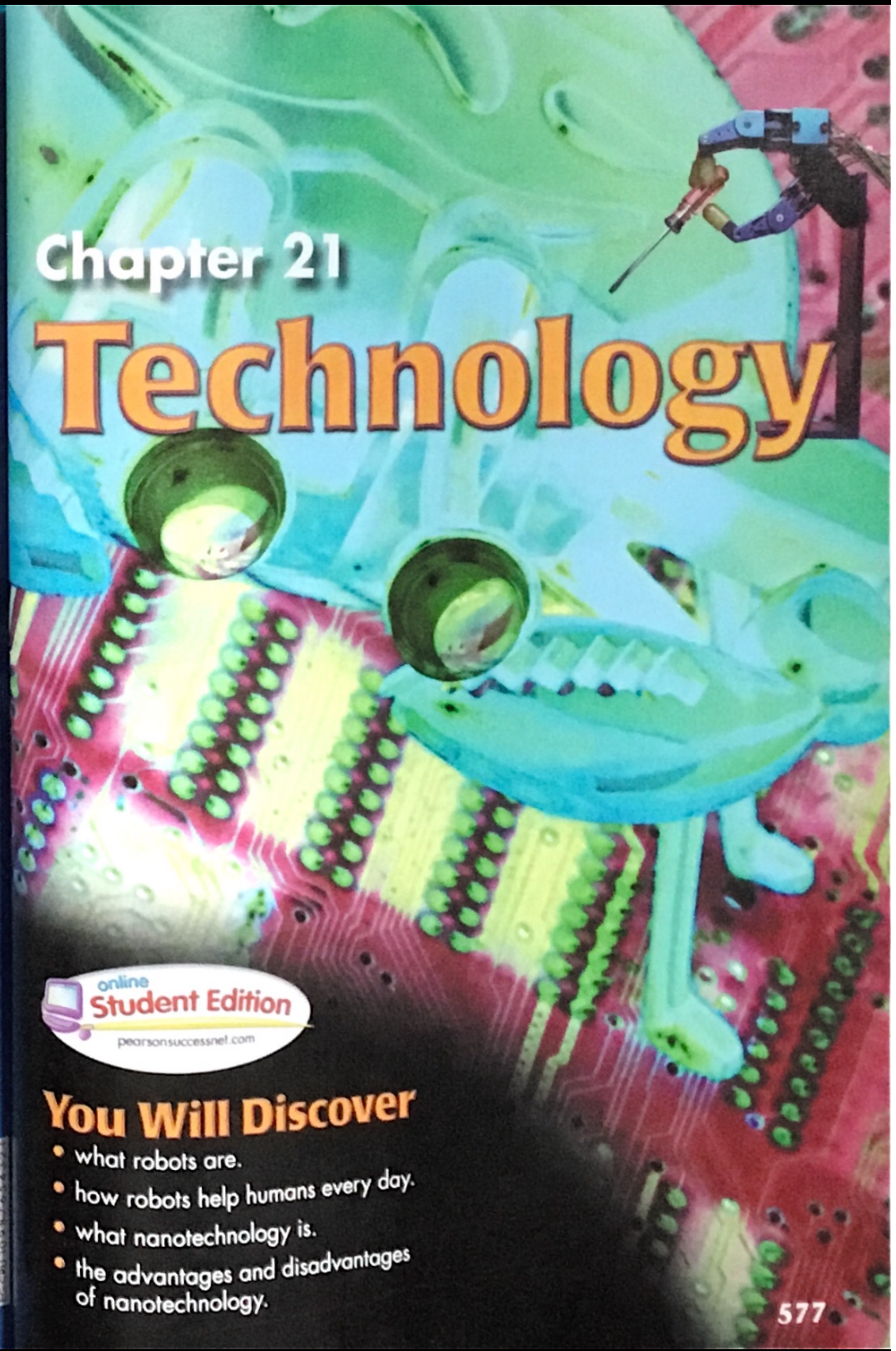
Ptolemy said that each planet made smaller orbits as it traveled along its larger orbit. You can show this motion by making small curlicues, or spirals, with your finger as you move your hand through the air. Ptolemy's model explained almost all of the motions in the sky. The Sun and Moon moved across the sky because they were revolving around Earth. This idea made so much sense that it went unchallenged for 13 centuries.

Ptolemy's model

Today we know that the planets move around the Sun, and they don't move in a curlicue fashion. But Ptolemy was a good scientist—he used knowledge available at the time to develop a model that explained his observations. He also gave future scientists something to build upon.

Lab zone **Take-Home Activity**

Make a drawing that compares Ptolemy's model of the solar system to the current model of the solar system.



Chapter 21

Technology

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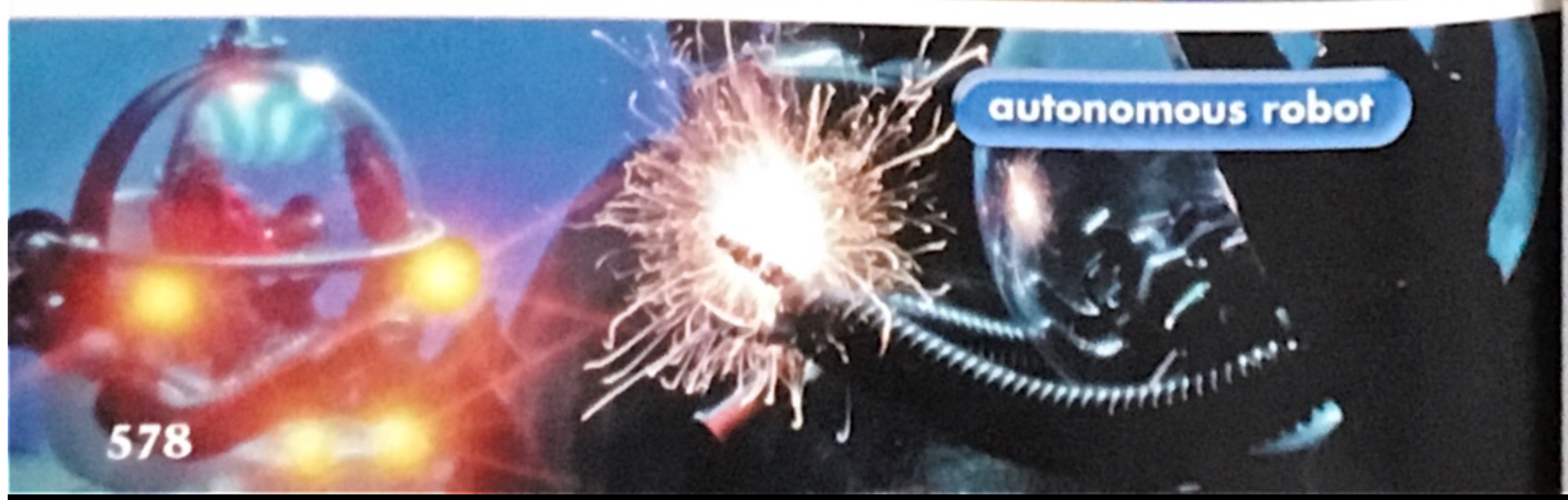
You Will Discover

- what robots are.
- how robots help humans every day.
- what nanotechnology is.
- the advantages and disadvantages of nanotechnology.

Build Background

How can robots help us now and in the future?



Chapter 21 Vocabulary

robot page 583

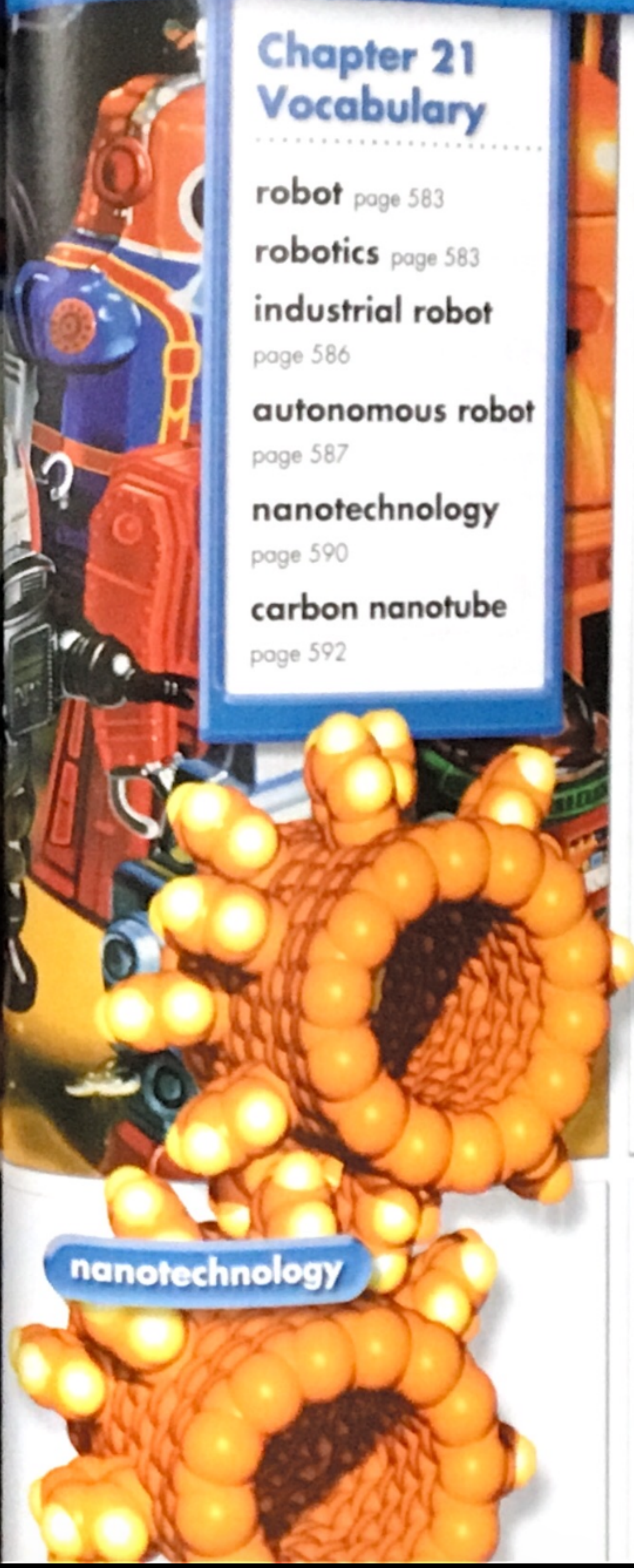
robotics page 583

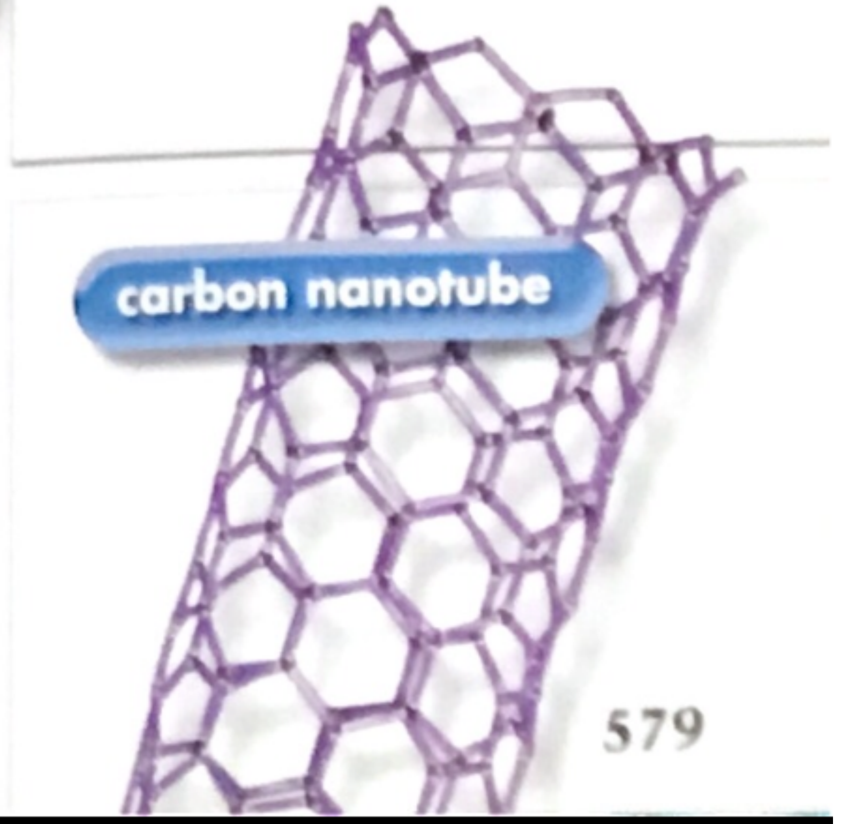
industrial robot page 586

autonomous robot page 587

nanotechnology page 590

carbon nanotube page 592





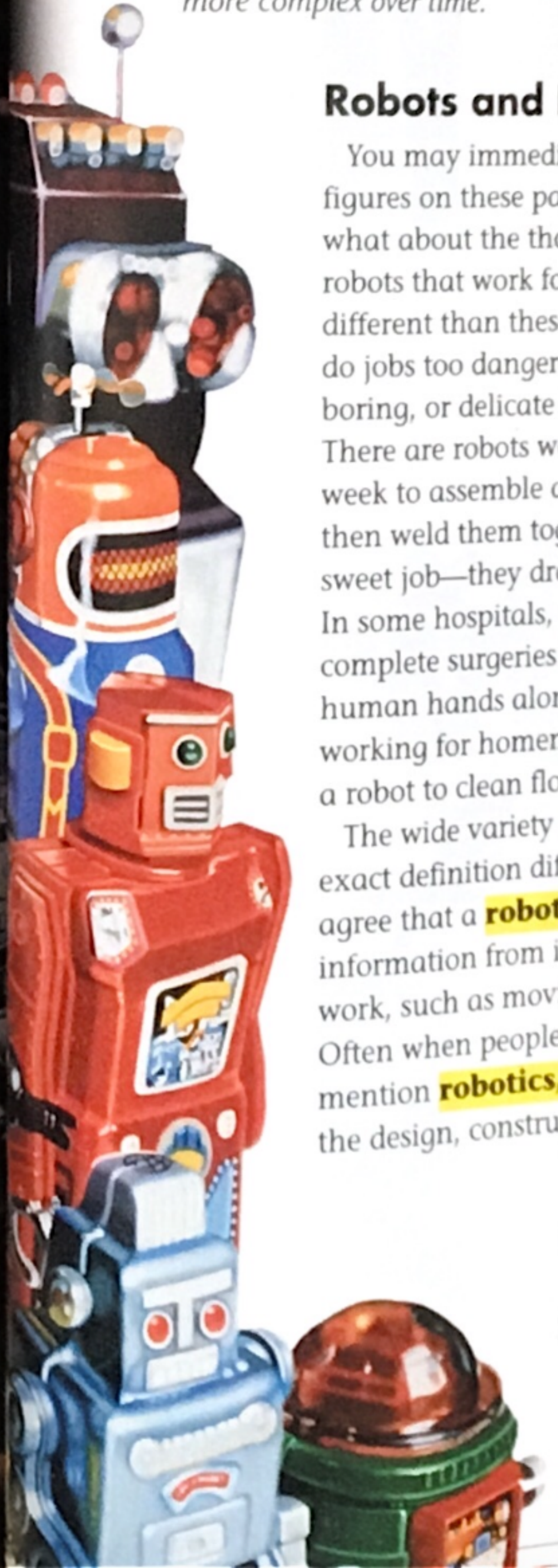
You Are There!

You stare in amazement. You had no idea that there could be so many different robots! Some are so tiny that they can fit in the palm of your hand. Others are tall—almost as tall as you are. Yet all look like humans in some way. Each has its own style of legs, arms, and head. Do all robots look like this?

Lesson 1

What is a robot?

A robot is a machine that is able to get information from its surroundings and do physical work. Today robots are used in industry and medicine, for exploration, and at home. Robots have become more complex over time.



Robots and Robotics

You may immediately recognize the figures on these pages as robots, but what about the thousands of other robots that work for us? Many look far different than these robots. Often they do jobs too dangerous, repetitive, boring, or delicate for humans to do. There are robots working 24 hours, 7 days a week to assemble automobile body panels and then weld them together. Other robots have a real sweet job—they draw chocolate stripes on cookies. In some hospitals, robot hands help human doctors complete surgeries too precise and sensitive for human hands alone. And what about robots working for homemakers? Homemakers can use a robot to clean floors or mow lawns.

The wide variety of robots makes forming an exact definition difficult. However, most scientists agree that a **robot** is a machine that is able to get information from its surroundings and do physical work, such as moving or manipulating objects. Often when people talk about robots, they also mention **robotics,** the technology dealing with the design, construction, and operation of robots.

1. **✓ Checkpoint** What two requirements must a machine meet to be a robot?
2. **Main Idea and Details** Give three details to support this statement: Robots can help humans perform tasks more efficiently.

Robot Development

Say the word *robot,* and most people think of the robots they have seen on television or in movies. For decades, these imaginary machines shaped our ideas about what robots should look like and what they should be able to do. Long before we had the technology needed to build robots, the fictional robots inspired us. They produced interest in designing and building real robots, pushing us to see how far our imagination and creativity could take us.

Although the term *robot* is less than 100 years old, people have dreamed about robots and how they might be used for thousands of years. In ancient Greece, Aristotle thought that one day machines might do work for humans by obeying directions. Two thousand years later, we find robots working in nearly every aspect of our lives.

In addition to our imagination, robot development has depended in large part on the development of other technologies, such as computers. As computer systems became more capable, computers smaller, sensors more sensitive, and computer programs more precise, robots have become able to do more complex tasks.

Robot designers work to increase a robot's ability to solve problems. The goal is to design a robot that can survey its environment, analyze data, make a judgment, and then take appropriate action. In turn, improved robot design opens new technologies. For example, a robot capable of moving a mere 0.0000001 centimeter at a time will allow us to manufacture a single molecule, one atom at a time.

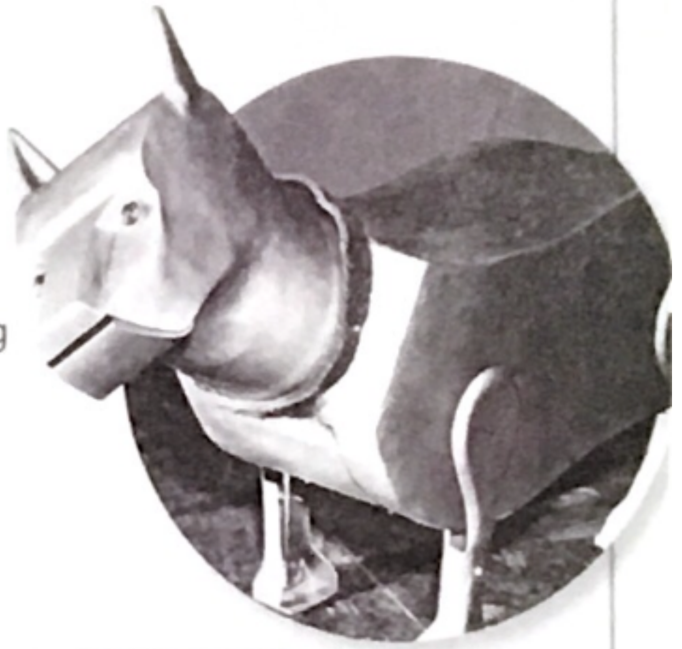
1. **Checkpoint** Compare and contrast Capek's 1921 robot shown on the timeline with the 2000 robots.
2. **Art in Science** Draw a robot you would like to have in your home. Show what task you would want it to do. Then trade drawings with a partner. Evaluate your partner's robot design.

~270 B.C. Greek engineer Ctesibus builds organs and water clocks with movable figures.

1739 Jacques Vaucanson, a French engineer, creates an automatic duck that can drink, eat, and perform other functions.

1801 Joseph-Marie Jacquard, a French weaver, invents a method of controlling looms using cards with holes punched in them.

1921 Czech playwright Karel Capek introduces the word *robot* in the play *Rossum's Universal Robots*. *Robot* comes from the Czech word *robota*, meaning "drudgery."



1939–1940 A mechanical man and dog appear at the New York World's Fair.

1951 The first remote-operated, jointed arm handles radioactive materials for the Atomic Energy Commission.

1961 The first industrial robot begins work in an automobile factory.

1970 Shakey, the first mobile robot with vision, figures out how to move around obstacles.

1985 The first robot-aided surgery is performed.

1994 Dante II, a six-legged walking robot, explores Mt. Spurr volcano in Alaska and collects samples of volcanic gases.

1997 NASA's *Pathfinder* lands on Mars and sends the *Sojourner* rover to explore the Martian landscape.

2000 The latest robots that resemble humans appear. They can perform tasks much like humans, including climbing stairs.

2001 The *Space Station Remote Manipulator System (SSRMS)* begins to complete assembly of the International Space Station.

2002 Researchers develop a robotic assistant for the elderly.

2004 NASA Mars rovers *Spirit* and *Opportunity* land on the red planet.

Robots in Industry

The elbow of this welding robot allows the welding torch to be handled in almost the same ways in which a human would handle it.

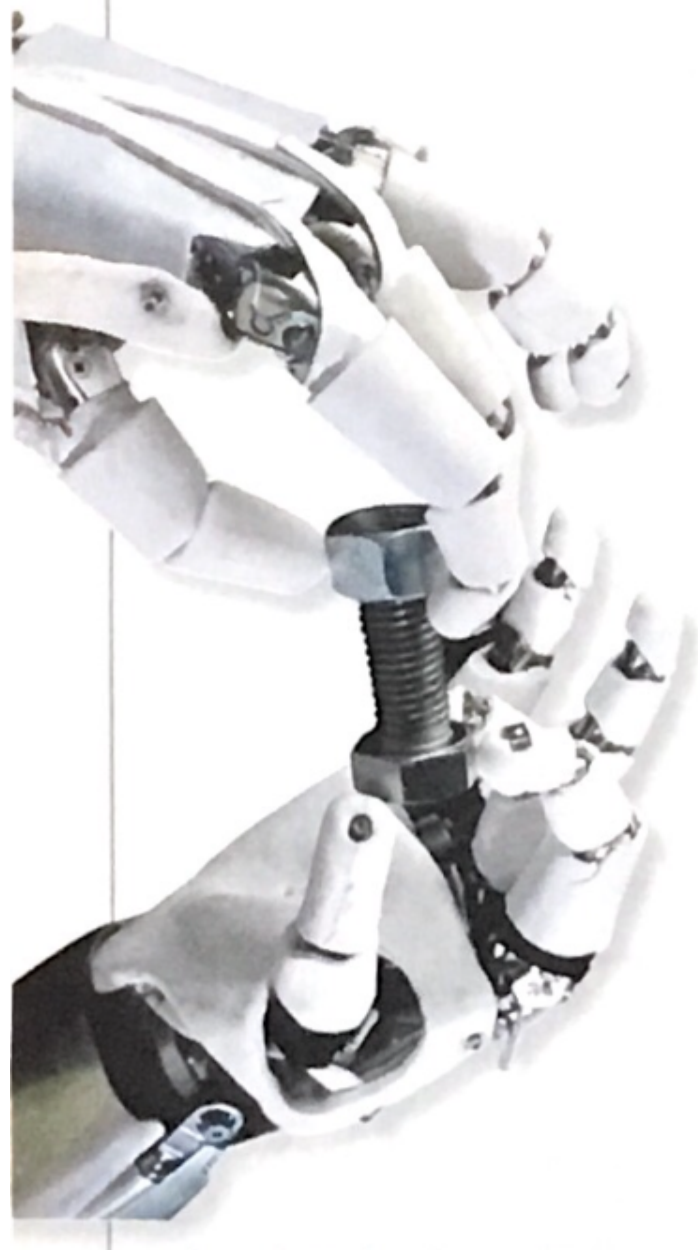
Nearly 90 percent of today's robots work in factories, more than half of them in automobile factories. Robot arms weld, paint, iron, assemble, pack, inspect, and test manufactured parts. An automatically controlled **industrial robot** can handle several products or items at a time and can be programmed to complete several different tasks.

The most common kind of industrial robot is the robotic arm, which is controlled by a computer. Many industrial robots have "joints" that are very similar to a human arm. You can see in the picture below that a robotic arm has a shoulder, elbow and forearm. A human arm can pivot in seven different ways. This kind of robotic arm can pivot in six different ways.

Different parts attached to the robotic arm enable it to perform specific tasks. For example, the robotic hands shown to the right can be attached to a robotic arm to turn a screwdriver or a bolt. Other attachments might be drills, spray painters, or welding tools.

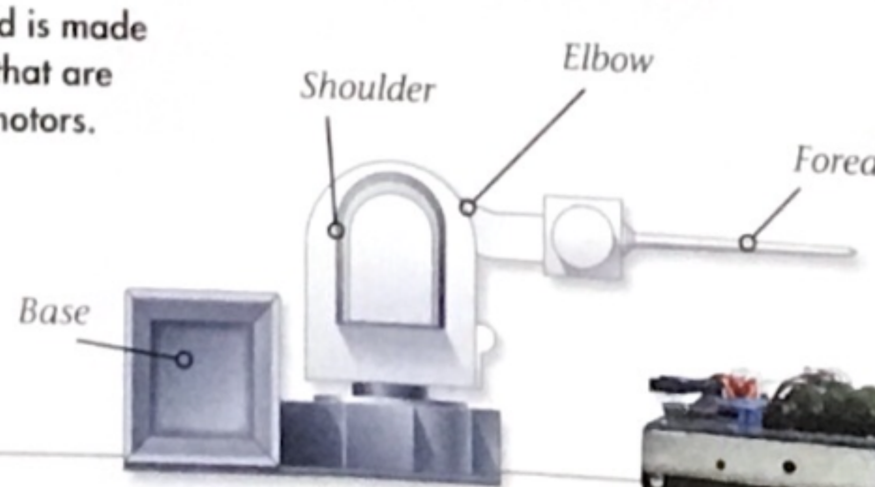
A robot assigned to weld has three arm movements and three wrist movements. It also has position sensors, making it possible to "teach" the robot how to weld. A human operator leads the robot through the motions necessary to weld a specific location. Sensors on the robot's joints record the twists, turns, and other motions. The robot's computer saves the information, allowing the robot arm to repeat the motions exactly.

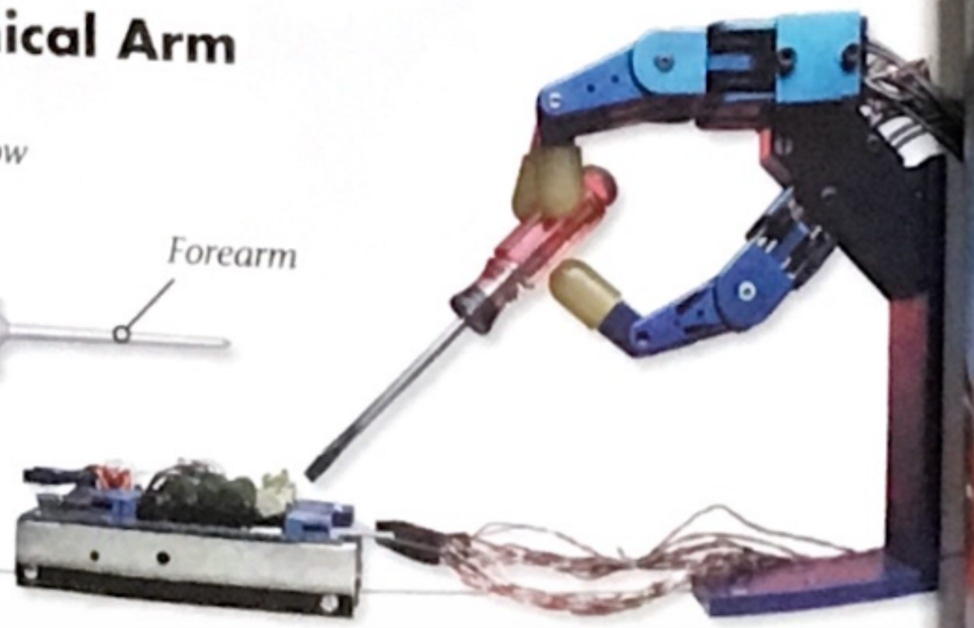
Similar directions guide robots to place silicon chips onto circuit boards and then solder them. In fact, the same type of information can direct a robot to pick up a delicate muffin from one moving conveyor belt, turn the muffin in the right direction, and finally place it in a box on a second moving conveyor belt.



This robotic hand is made of metal pieces that are moved by tiny motors.

A Mechanical Arm





Exploring with Robots

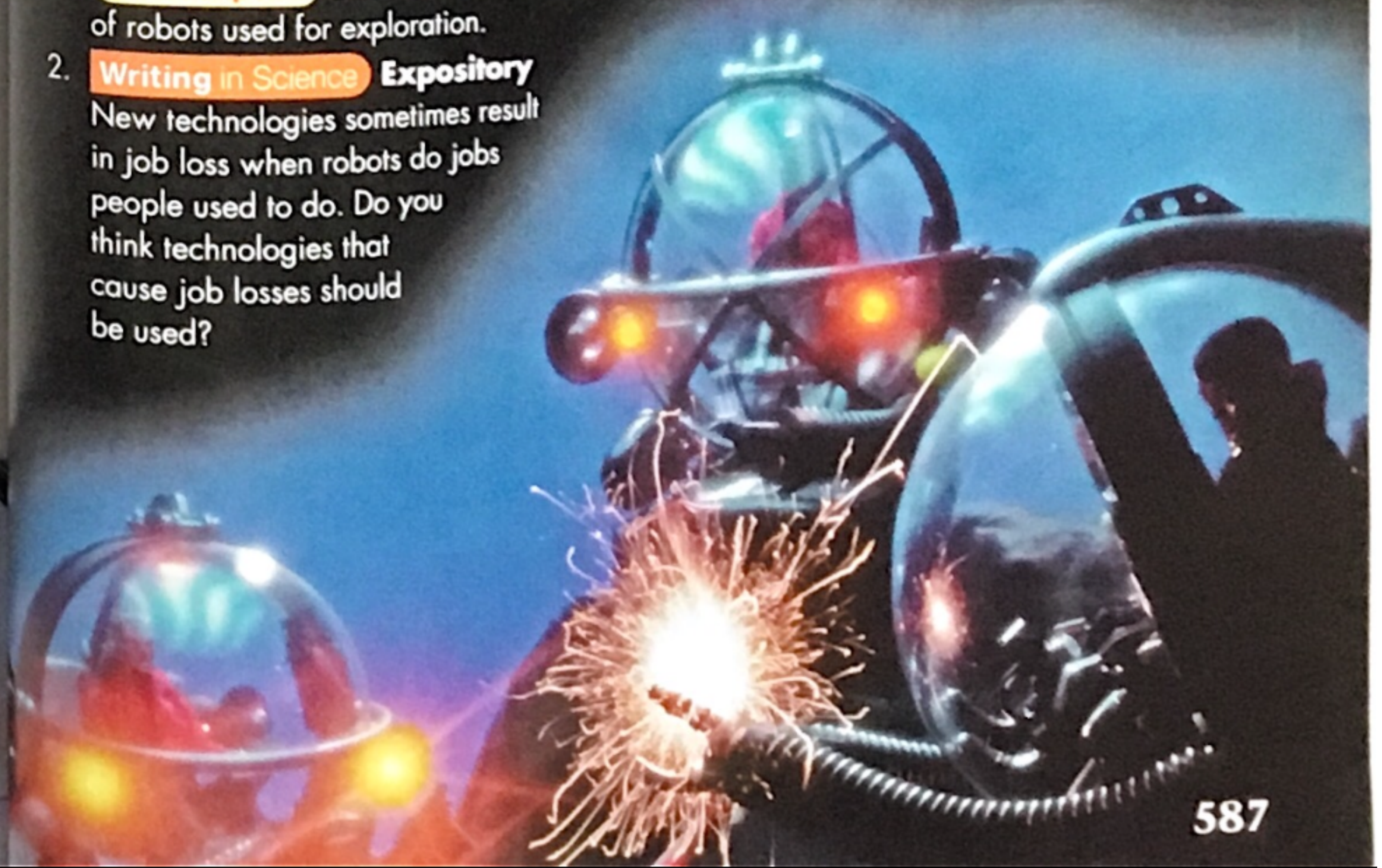
While industry leads the way in robot use, many robots work in exploration. Robots that are used to explore can be placed into one of two categories. One category includes the remotely operated vehicle (ROV or rover). NASA's Mars missions have used rovers *Sojourner*, *Spirit*, and *Opportunity*. A human operator decided in which direction and how fast each rover should move. The operator then sent signals to the rover describing each move to make.

NASA's Personal Satellite Assistant, or PSA

Rovers search sewers, pipes, collapsed mineshafts, and heating and cooling ducts—places humans cannot go. Rovers investigate and defuse bombs and examine areas contaminated by radioactive materials—jobs far too dangerous for humans.

The second category of exploring robot is an **autonomous robot**. This type of robot acts without direct supervision. It can "decide" whether to travel over a rock or around it. One autonomous robot being developed at NASA is the Personal Satellite Assistant, or PSA. The robot is about the size of a softball. It has sensors for monitoring conditions in a spacecraft, such as the amounts of oxygen, carbon dioxide, and other gases. It can monitor the amount of bacterial growth in the spacecraft too. Sensors also keep tabs on air temperature and air pressure. The camera can be used to video conference. Navigation sensors and other parts enable the robot to move by itself throughout the spacecraft. According to NASA, the robots will function as another set of "eyes, ears, and nose" for the crew.

1. ✓ **Checkpoint** Describe two kinds of robots used for exploration.
2. **Writing in Science** **Expository** New technologies sometimes result in job loss when robots do jobs people used to do. Do you think technologies that cause job losses should be used?



Robots in Medicine

Sending robots to explore space and other locations led to another robot function—using them to routinely travel between locations. Hospitals employ these messenger robots to carry supplies, equipment, and medications from one location to another.

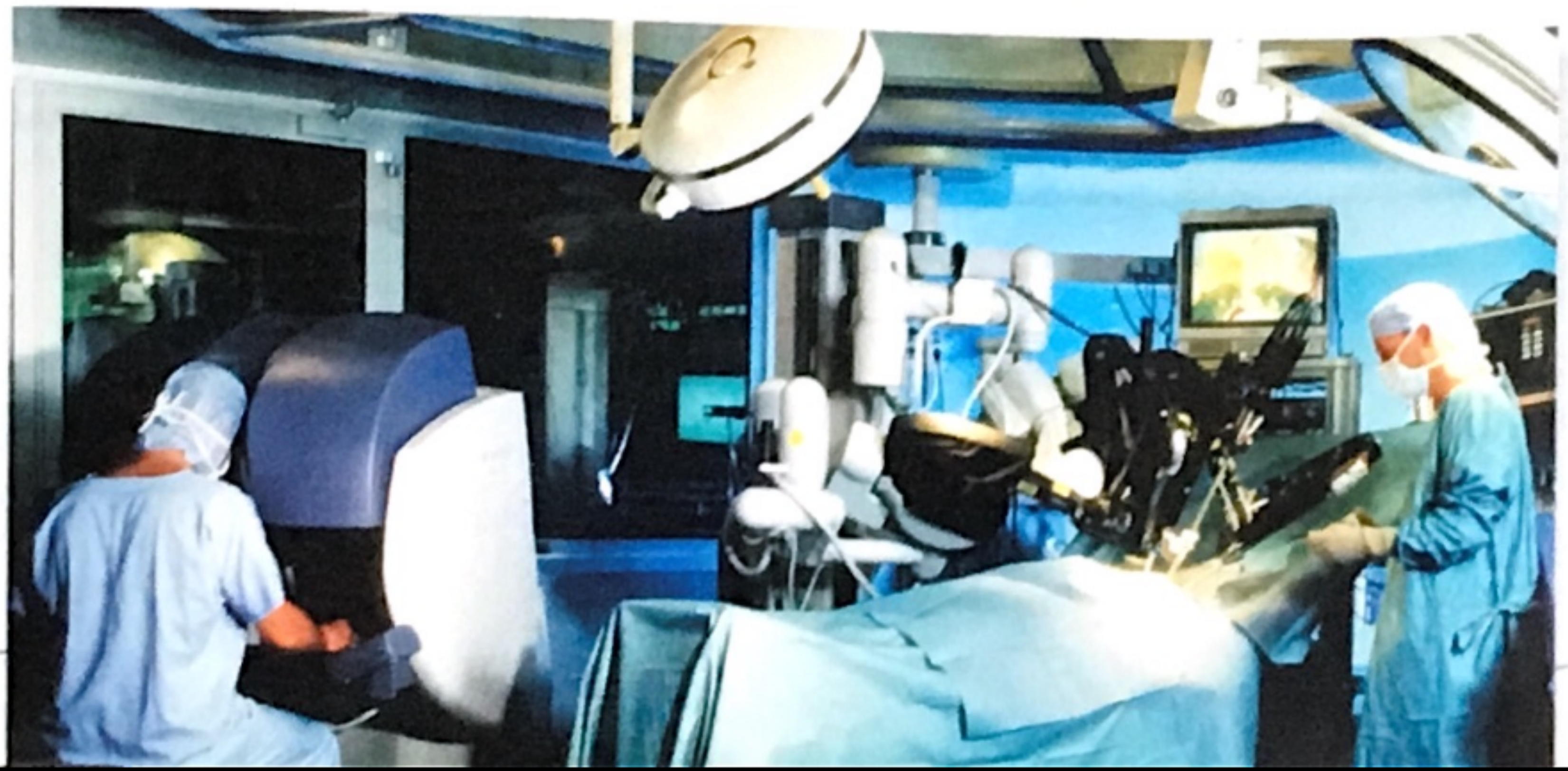
The hands of the surgical robot are capable of more precise movements than a human surgeon's hands.

Messenger robots are not the only robots in a hospital. Robotic surgeons—robotic hands moved by a human surgeon's hands—are now being used in hospitals around the world. Doctors can control the robots by mechanical devices or voice activation. In many operations, human hands cannot be as precise as robotic hands. Robot-assisted surgery results in smaller scars, less pain, and shorter hospital stays.

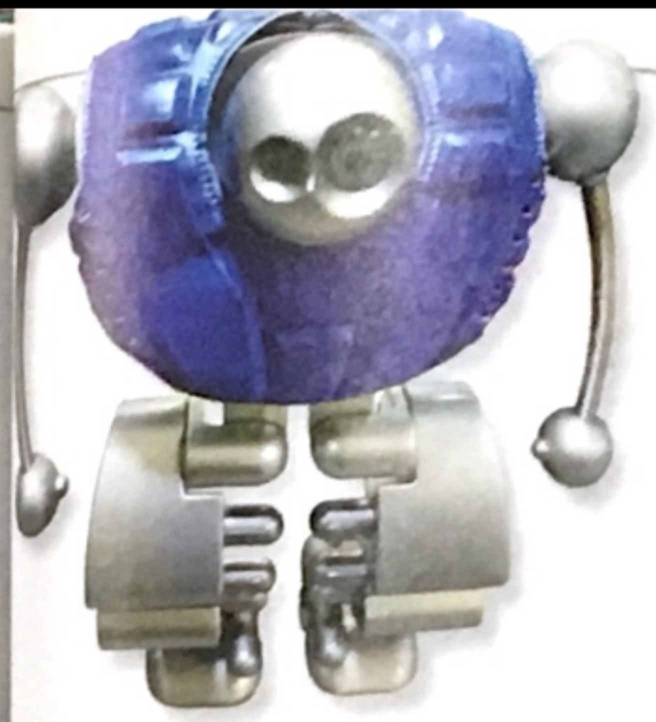
In one robotic system, the doctor sits at a control center, which is a few feet from the patient. A camera placed inside the patient sends 3-D images of the operation area and the surgical instruments to the doctor at the control center. The doctor controls the surgical instruments by moving the controls in much the same way a person moves a joystick.

In another use, robots act as patients for medical students. The robots are programmed to show a set of symptoms and then respond to treatment, including surgery and medication. Some robots are programmed to "die" if they receive improper or inadequate treatment.

Robots are tackling another problem—helping doctors check on their patients when they can't actually visit them. The robot contains a video screen on which the doctor's face appears. A video camera acts as the robot's eyes and ears. Doctors can interact with their patients via the robot using a live computer-video hookup. The goal is not to replace human doctors but instead to enable doctors to interact with their patients no matter where the doctor is.



Human hands guide the hands of a robotic surgical system during precision surgery.



Game robots, like rovers, are remote controlled. However, information gained while working and playing with these robots can help develop completely robotic players for other games or sports.

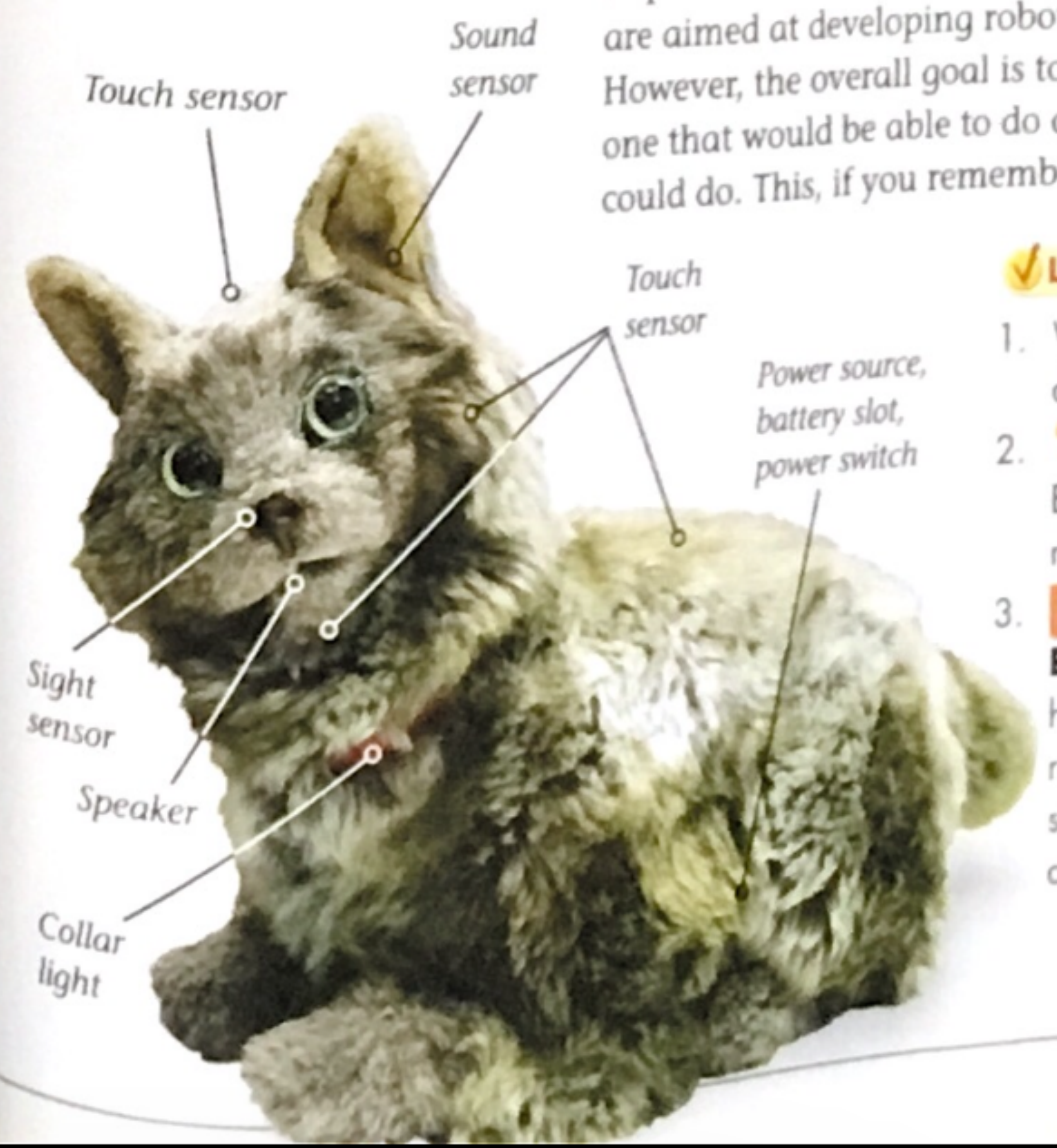
Robots at Home

You don't have to visit a factory, Mars, or a hospital to see robots in action. In your own home, you can watch popular television programs in which home-built robots challenge one another in an arena. Toy makers offer robot kits that encourage the construction of dozens of interesting robot creations. You may be familiar with the cute, furry robots and the robotic dogs that are made just for entertainment. Given the success of these robots, researchers are working on making a doll-like robot able to perform dozens of movements on its own.

Some companies want to develop a robot that will act as a household companion. This robot would be able to move about the home easily. It would be available to help with tasks, such as giving medication and taking out the garbage. Perhaps such a robot could be programmed to provide care for an elderly or less able person. It could monitor the person's time spent in the kitchen or bathroom, watching television or napping. If any actions seemed out of the ordinary, the robot would dial an emergency number and alert an attendant.

It's clear that robots are here to stay. Each new robot generation will perform new and more complex tasks with less hands-on direction. Large universities, research corporations, and government agencies will rely on improved technology to build these robots. Today's efforts are aimed at developing robots to perform specific tasks. However, the overall goal is to make a universal robot—one that would be able to do almost everything a human could do. This, if you remember, was Aristotle's prediction.

A Robotic Pet



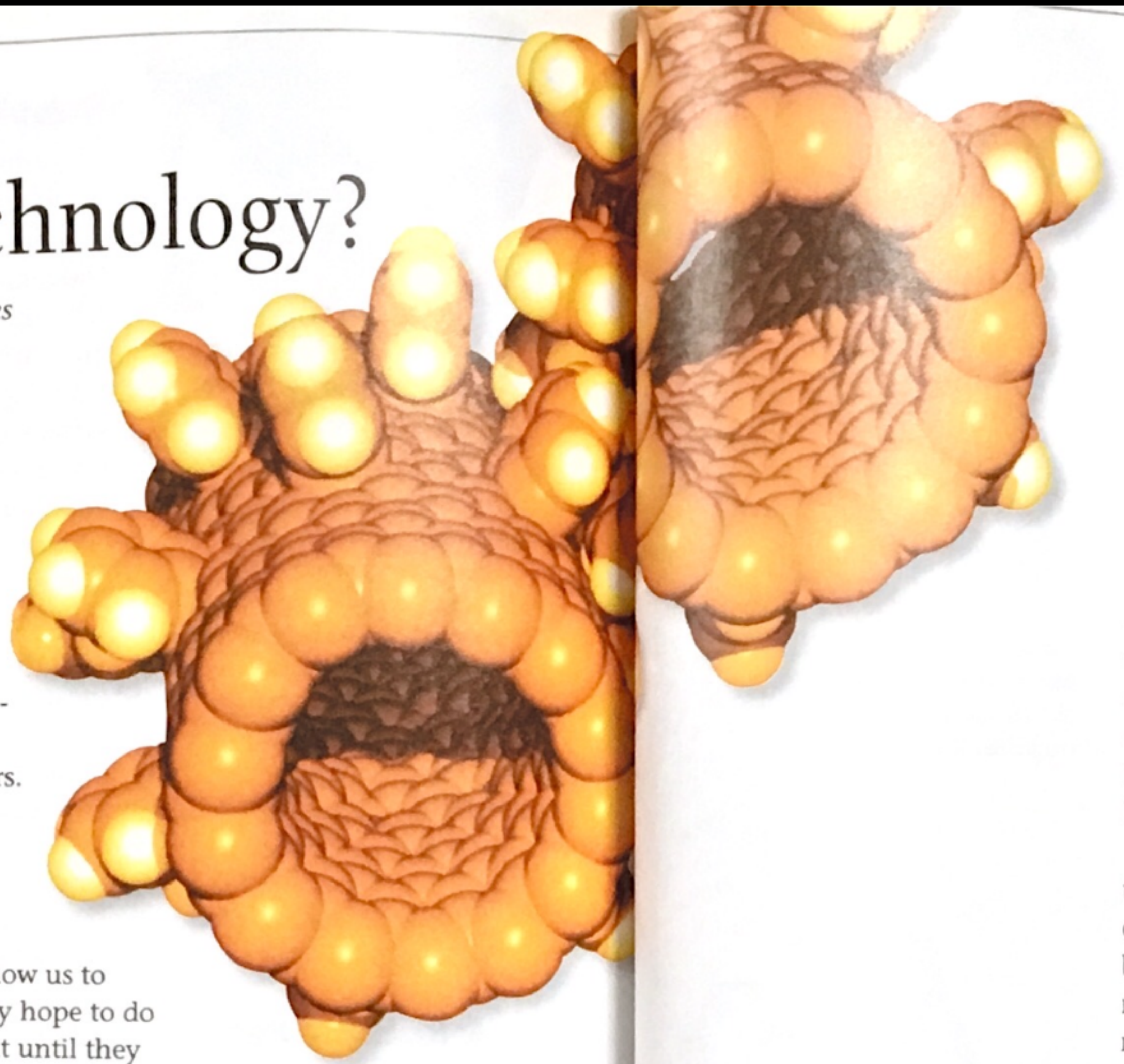
✓Lesson Checkpoint

1. What kinds of jobs do robots do that humans cannot do?
2. **Main Idea and Details** Explain how an autonomous robot solves problems.
3. **Writing in Science** **Expository** What are some human needs that you think robots could not provide solutions for? Explain your answers in a paragraph.

Lesson 2

What is nanotechnology?

Nanotechnology deals with materials and machines that are measured in nanometers.



Very, Very Small Technology

People dreamed of robots and what they might do long before they were actually developed. Sometimes scientists accidentally stumble into technologies that offer possibilities beyond our wildest dreams. One of the newest technologies, nanotechnology, seems to offer just such possibilities. **Nanotechnology** is the very small-scale technology that deals with materials and processes on a scale best measured in nanometers. A nanometer is a measure of length that is one billionth the length of a meter.

Scientists hope to build nanogears such as this.

Atom-by-Atom

Researchers claim that nanotechnology will allow us to build the materials we want, atom by atom. They hope to do this by lining atoms up in a specific arrangement until they form the desired shape. Does handling atoms one at a time sound too fantastic? As you can see in the picture below, scientists have already done it!

In addition to getting each atom in the correct location, this new technology should allow scientists to make almost any material—as long as its construction follows the laws of physics.

Two challenges must be met before nanotechnology succeeds. First, scientists have to find a way to move an atom so that it is placed precisely. Scientists know that robots can be precise, so they might look to a nano-sized robotic arm to pick and position each atom.

The second challenge scientists face is finding a way to pick and position billions and billions of atoms. If they are building something atom-by-atom, they will need a lot of robotic arms to put together nano-sized parts into larger parts. More robots will put together the larger parts into still larger parts, eventually forming a product we can actually see.

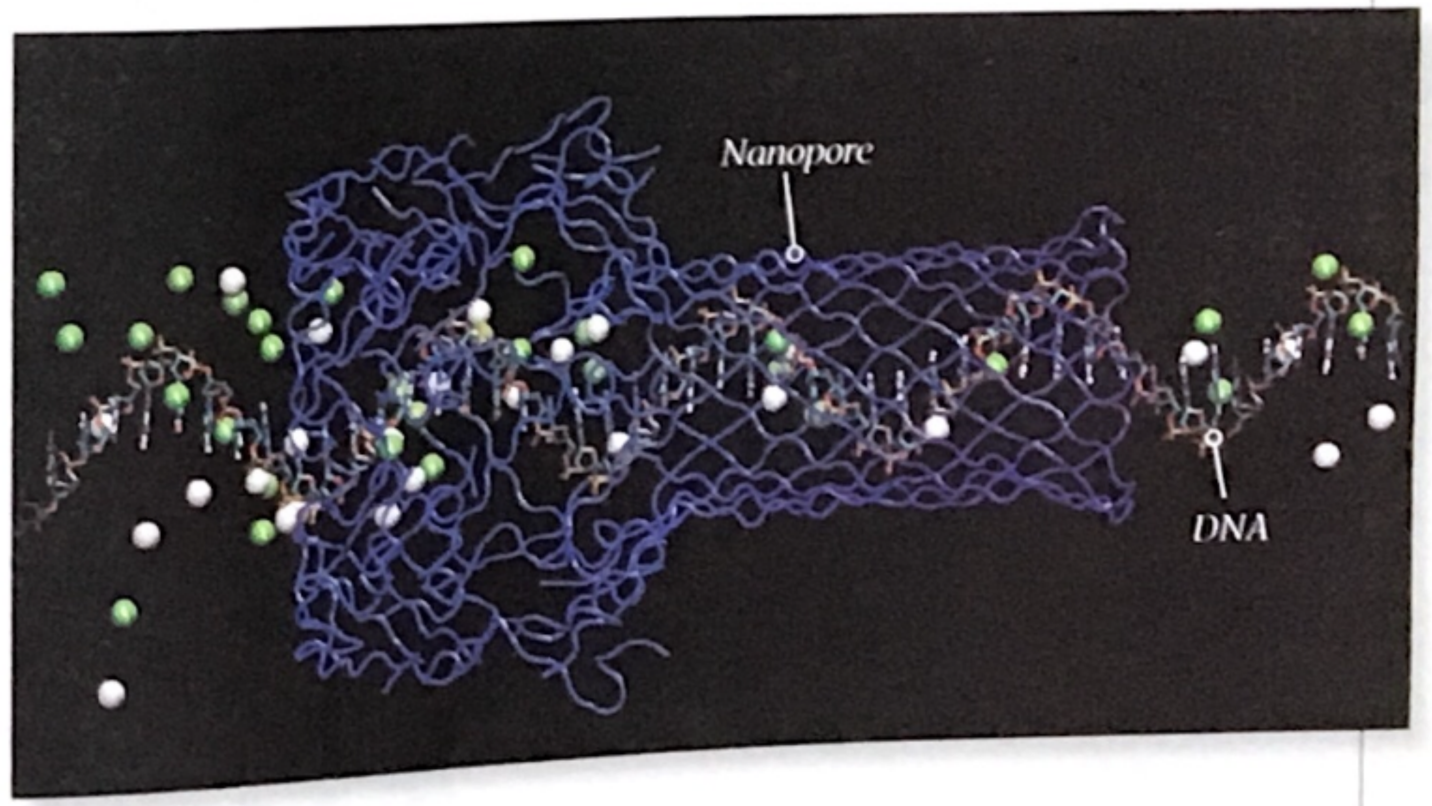
In 1990, researchers moved 35 xenon atoms, one at a time, arranging them to form letters.

Nanotechnology Applications

Scientists have not yet been able to build many things atom-by-atom. But they have had success changing some existing materials. Researchers have found that they can change certain molecules, called nanopores, to meet their needs. For example, nanopore material can act like a sponge, absorbing mercury or lead from polluted water supplies.

Nanoshells may be the future's best way to fight cancer. Nanoshells are about 120 nanometers in size—that's 1,500 times smaller than a human hair. The shells are injected into a tumor. Then the tumor area is heated. Temperatures inside the tumor become high enough to damage the cancer cells. But they don't damage normal cells in the same area. Nanoshells may be used to deliver cancer drugs to specific parts of the body. Many cancer drugs are harmful not to just cancer cells, but to normal body cells as well. Using nanoshells would limit the body's exposure to harmful substances in the drugs.

Another medical application involves nanocrystals that give off specific colors of light. Researchers can tag chromosomes with these crystals. When the patient's blood sample is exposed to a specific type of light, the nanocrystals glow in response. Researchers can use results from the process to get information about a person's susceptibility to lung cancer.



Scientists are developing procedures to use nanopores to sequence DNA.

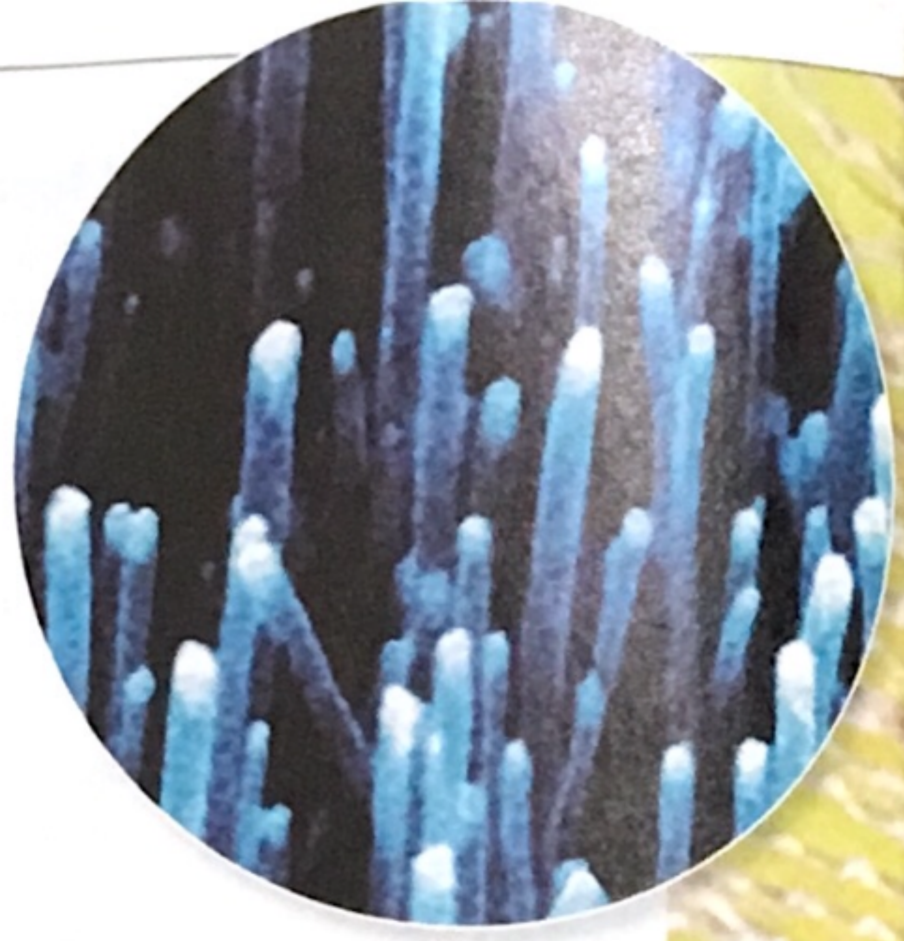
1. ✓Checkpoint What is nanotechnology?
2. Describe two applications of nanotechnology.

Carbon Nanotubes

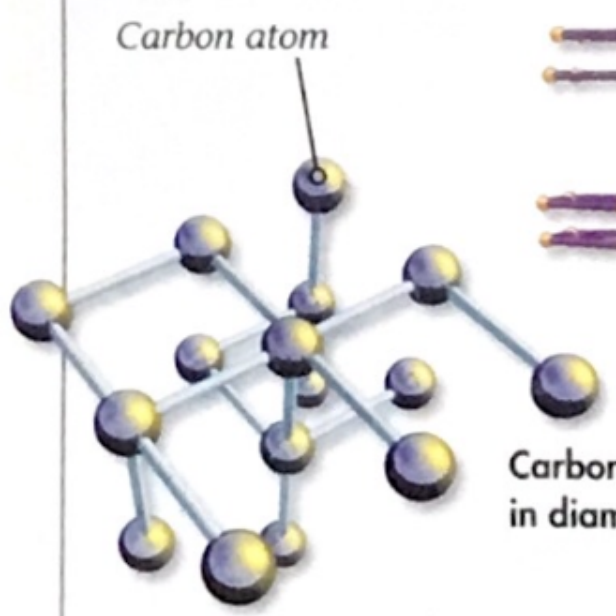
For hundreds of years people have known that the element carbon exists in three different forms—diamond, graphite, and "amorphous" carbon. In 1985, scientists discovered a fourth form of carbon with individual molecules that are made up of 60 carbon atoms. These molecules are called buckyballs. Study the pictures below to compare the arrangement of atoms in these forms of carbon.

Then in 1991, researchers found a fifth type of carbon molecule. In this molecule, carbon atoms in six-sided rings arrange themselves in the shape of a tube. The size of the molecule is about a nanometer. This form of carbon is called a **carbon nanotube.**

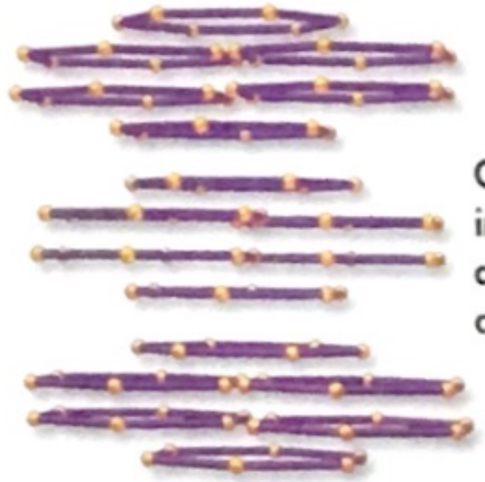
The properties of diamonds are very different from those of graphite. Recent studies show that carbon nanotubes have properties that are different from both graphite or diamond. For example, carbon nanotubes are exceptionally stiff and can be one hundred times tougher than steel at one-sixth the weight.



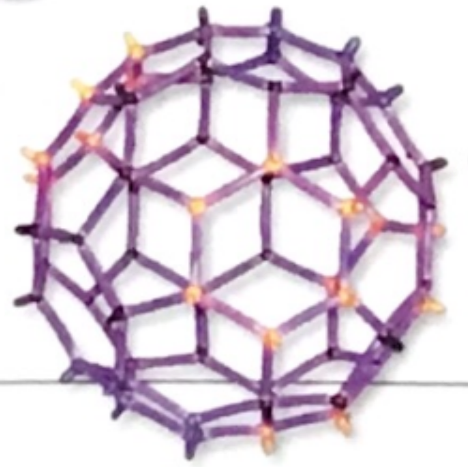
The carbon nanotubes shown growing in the picture above have been magnified 295 times.



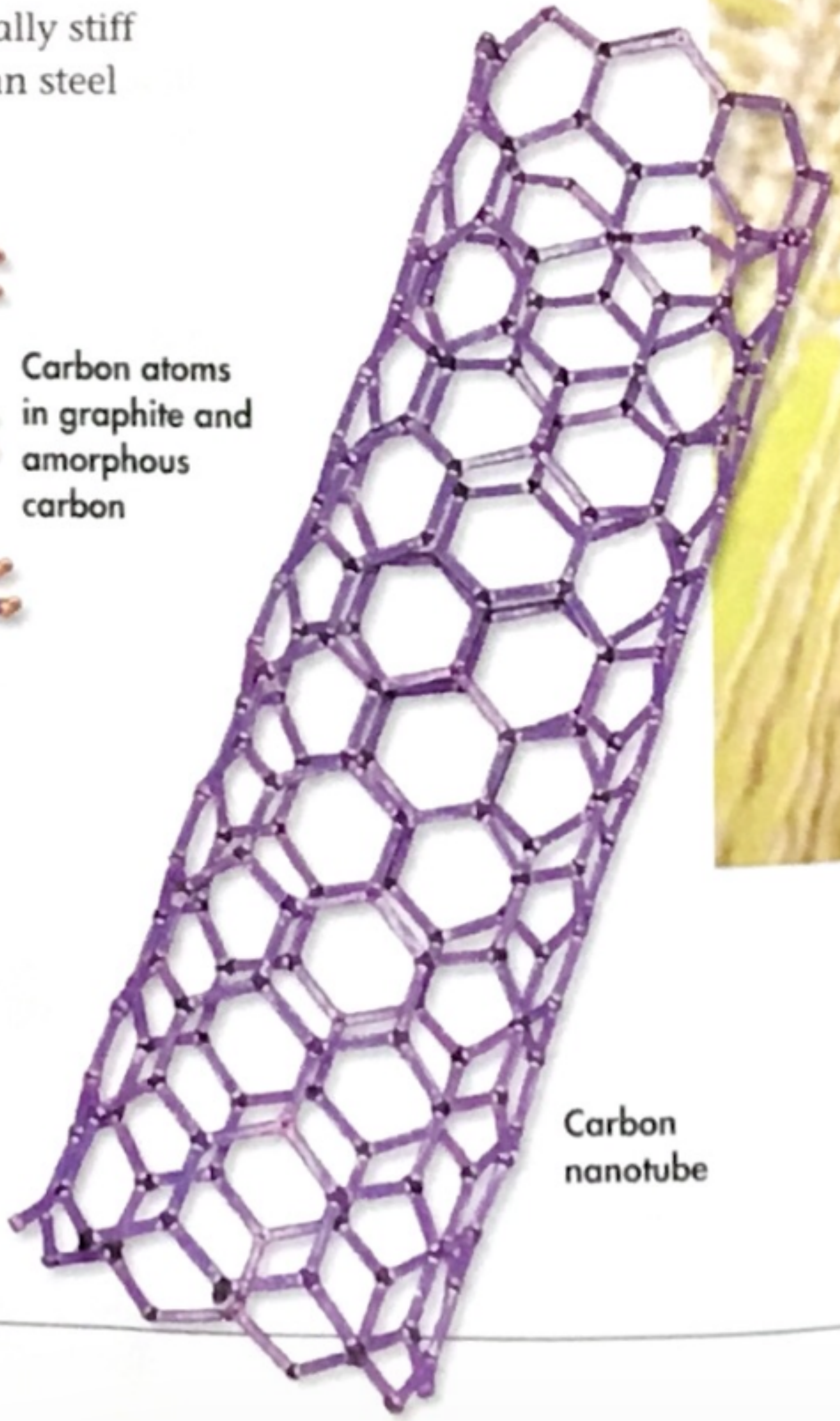
Carbon atoms in diamond



Carbon atoms in graphite and amorphous carbon



Carbon atoms in a buckyball



Carbon nanotube

Fibers of carbon nanotubes (black in swatch above) can be woven into fabrics that can store energy, receive radio signals, or act as sensors. These fabrics can track the body movements of athletes, dancers, and soldiers who wear them.

The carbon nanotube's electrical properties are astounding. Merely twisting a carbon nanotube can change it from an electrical conductor as efficient as copper to a less efficient conductor similar to silicon. In addition, carbon nanotubes conduct heat better than silicon. Silicon is used in making computers and transistors for electronic equipment. These properties of nanotubes lead researchers to think that it may be possible to produce ultra-small transistors and other electrical devices. These devices might be ten times smaller than those in use today.

Benefits and Risks

At this time, nanotechnology promises enormous benefits—from custom-designed materials to ultra-small computers. But what are the risks? As scientists take advantage of custom molecules, they will need to find out whether the molecules will harm the environment. Ultra-small computers will help design better microphones, cameras, and tracking devices. But people will have to decide how to use these inventions for their own security without giving up privacy. Also, society will need to decide how to use nanotechnology to bring better health care, agricultural practices, and manufacturing knowledge to our own country and others.

✓ Lesson Checkpoint

1. Name two risks associated with nanotechnology.
2. **Math in Science** What is the size of a nanometer in terms of a centimeter?
3. **Writing in Science** **Persuasive** Write a letter to the editor of your local newspaper explaining whether you think the public ought to have a say in how nanotechnology is used. Explain why.

Math in Science

The Mathematics of NANOTECHNOLOGY

You have been learning about nanotechnology, which involves technological developments on a very small scale. The prefix *nano* means "one billionth." So, a nanometer (nm) equals one billionth of a meter, or one millionth of a millimeter. Look at the size of 1 millimeter on a metric ruler. A nanometer is one millionth of that size!

The chart below gives the exponential form of very small numbers.

Word Form	Standard Form	Exponential Form
1 thousandth	0.001	10^{-3}
1 ten-thousandth	0.0001	10^{-4}
1 hundred-thousandth	0.00001	10^{-5}
1 millionth	0.000001	10^{-6}
1 ten-millionth	0.0000001	10^{-7}
1 hundred-millionth	0.00000001	10^{-8}
1 billionth	0.000000001	10^{-9}

Here's another way to think of the size of a nanometer. A millimeter is one thousandth of a meter (0.001 m); a micrometer is one thousandth of a millimeter (0.001 mm) and a nanometer is one thousandth of a micrometer (0.001 μm).

$$0.001 \times 0.001 \times 0.001 = 0.000000001$$
$$10^{-3} \times 10^{-3} \times 10^{-3} = 10^{-9}$$

In nanotechnology, it is important that tiny robots, called nanorobots, be able to make copies of themselves repeatedly. This is called exponential assembly.

For example, in one process starting with one nanorobot, each nanorobot makes three copies of itself in a day and then stops working. How many nanorobots will be made on Day 4?

The number of nanorobots will increase by powers of 3.

Day	0	1	2	3	4
Power of 3	3^0	3^1	3^2	3^3	3^4
Number	1	3	9	27	81

Use what you've learned to answer each question.

1. You have read that a nanoshell is about 120 nanometers in size. Write this measure in meters, using standard form. Show how you found your answer.
2. A process starts with one nanorobot that makes three copies of itself in a day and then stops working. How many nanorobots will be made on Day 8? Day 10? Copy and extend the chart above to help you find your answer.
3. In the first step of one assembly process, a great number of very small parts are assembled into larger parts. Then these parts are assembled into larger parts, and the step is repeated over and over. If the size of the parts doubles for each step, how many steps would be needed to go from a part that is 1 nanometer in size to a part that is at least 1 millimeter in size? Use a calculator or copy and continue the chart until you find the answer. (Remember: 1 mm = 1,000,000 nm)

Step	0	1	2	3	4
Power of 2	2^0	2^1	2^2	2^3	2^4
Number	1	2	4	8	16

Lab zone Take-Home Activity

Use library resources to find more information about nanotechnology. Make a poster or write a story about the possible benefits of nanotechnology in the future. Use your imagination together with the facts you have found.

Chapter 21 Review and Test Prep

Use Vocabulary

autonomous robot (p. 587)	**nanotechnology** (p. 590)
carbon nanotube (p. 592)	**robot** (p. 583)
industrial robot (p. 586)	**robotics** (p. 583)

Use the term from the list above that best completes each sentence.

1. The technology dealing with robots is called ________.

2. A machine able to get information from its surroundings and do physical work is a(n) ________.

3. A robot that can act without direct human supervision is a(n) ________.

4. If a robot is automatically controlled, can handle several products at once, and can be programmed to complete several different tasks, it is a(n) ________.

5. The technology that deals with the materials and processes in terms of one-billionth of a meter is ________.

6. The most recently discovered form of carbon with properties far different from those of diamonds and graphite is a(n) ________.

Explaining Concepts

7. Explain why robots are better at some jobs than human workers are.

8. What must a true robot be able to do without human direction?

9. What problems must scientists solve before nanotechnology can provide the benefits it seems to promise?

10. Explain how technology such as computers has influenced the development of robots.

11. Describe the structure of a buckyball.

12. How are Mars rovers *Spirit* and *Opportunity* different from autonomous robots?

Process Skills

13. Forming Questions and Hypotheses What question do you have about robots that could be answered by doing an experiment? Write your question as a statement that can be tested by an experiment.

14. Infer Why might a surgeon suggest that the operation you need is best performed with the aid of a robot?

Main Idea and Details

15. Make a graphic organizer like the one shown below. Fill in details about the main idea.

Robots can perform human tasks.

Detail | Detail | Detail

Test Prep

Choose the letter that best completes the statement or answers the question.

16. Today most robots work in
- Ⓐ hospitals.
- Ⓑ space exploration.
- Ⓒ industry.
- Ⓓ home entertainment.

17. Carbon atoms arranged in six-sided rings to form tubes are
- Ⓕ buckyballs.
- Ⓖ graphite.
- Ⓗ carbon nanotubes.
- Ⓘ diamonds.

18. Which is a property of carbon nanotubes that might make it possible for them to replace silicon in electronic equipment?
- Ⓐ They're poor conductors of heat.
- Ⓑ They glow when hit by a light.
- Ⓒ They can change from an efficient electrical conductor to a poor one.
- Ⓓ They can assemble themselves.

19. Explain why the answer you chose for Question 17 is best. For each of the answers you did not choose, give a reason why it is not the best choice.

20. Writing in Science **Narrative** Write a short story in which a robot is a hero because it saved people from one of the dangers of nanotechnology.