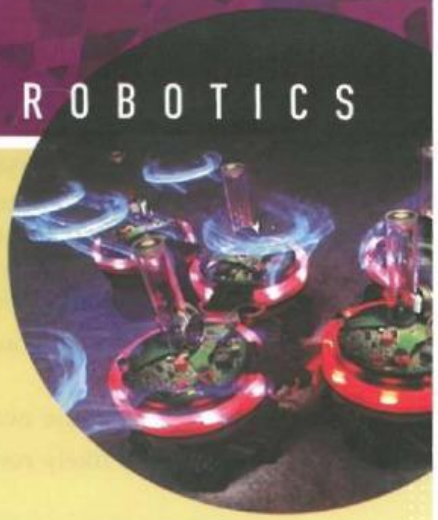
UNIT 9

ROBOTICS

Modeling Nature



In this unit, you will

- read about how the field of robotics is using models in nature to create machines.
- review analyzing criteria.
- increase your understanding of the target academic words for this unit.

READING SKILLS Analyzing Advantages and Disadvantages; Identifying Ethics and Values

Self-Assessment

Think about how well you know each target word, and check (✓) the appropriate column. I have...

TARGET WORDS	never seen the word before	seen the word but am not sure what it means	seen the word and understand what it means	used the word, but am not sure if correctly	used the word confidently in *either* speaking *or* writing	used the word confidently in *both* speaking *and* writing
AWL						
bulk						
capacity						
code						
comprise						
consist						
document						
furthermore						
illustrate						
method						
notion						
proceed						
project						
schedule						
shift						

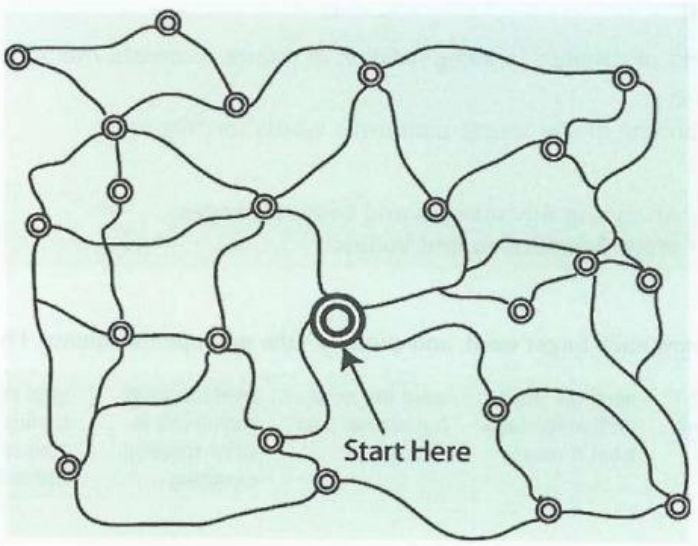
Oxford 3000™ keywords

Outside the Reading What do you know about robotics?
Watch the video on the student website to find out more.

Before You Read

Read these questions. Discuss your answers in small groups.

1. Imagine that you are a traveling salesperson and you have to travel to the towns represented on the map below. You want to find the shortest route that will take you to every town once. What strategy would you use to decide on a route? Here are some possibilities you might consider.
   - Find a route where you do not retrace your steps and assume it is good enough.
   - Always travel to the nearest town that you have not visited yet.
   - Measure each likely route.



2. Whatever method you used to find an acceptable route, you had the advantage of being able to look ahead. What strategy would you use if you had to ask directions in each town, and thus could only see one town ahead? What question(s) would you ask?
3. Science fiction stories often have "android" robot characters who serve as coworkers, advisers, and trusted friends. Would you take advice from a robot? Could a robot become your friend?

MORE WORDS YOU'LL NEED

allocate: distribute something for a particular purpose in an organized way
empathize: understand or share another person's feelings or experiences
logistical: relating to the detailed organization of a complex operation that involves a lot of people and equipment
optimize: make the best use of something; use something in an efficient or perfect way

Read

Biologists have learned a lot about the behavior of ants. This knowledge, it turns out, has surprising implications for robot design, as can be seen in these two articles from a science website.

The Swarm Bots Are Coming

ANT ALGORITHMS GET DOWN TO BUSINESS

Ants are simple creatures, yet they can perform complicated tasks. They create highways leading to food, organize the distribution of larvae[1] in the anthill, form cemeteries by clustering dead ants, build living bridges to cross gaps in their way, and assign and **shift** tasks as needed without any centralized control. Thus, ants provide an excellent **illustration** of how simple devices can achieve complex results.

Boil down ant behavior and what do you get? A new set of business tools known as ant algorithms: basic behaviors that can be programmed into a large number of independent software agents to solve human problems.

Consider the way ants forage. When an ant comes across food, it returns to the nest, leaving a scent trail. Other ants follow the trail, find the goods, and carry them back to the nest, reinforcing the path with their own scent, which attracts still more ants. Shorter routes get more traffic, so the scent becomes stronger along these, while it dies away on longer, lesser-used ones. Using this **method**, ants follow the shortest paths between their nest and nearby food sources.

This route-finding capability is remarkably handy. Colonies of simulated ants laying down digital scent trails can find the best way to send delivery trucks through city streets or data packets through communication networks. More generally, ant algorithms can be used to find minimum-cost solutions to a variety of logistical problems in distribution and **scheduling**. Unilever uses them to allocate storage tanks, chemical mixers, and packaging facilities. Southwest Airlines uses them to optimize its cargo operations. Numerous consulting houses, such as the Swiss firm AntOptima, have embraced them as an indispensable tool.

Swarm bots helping each other up a step.

But logistics are just the beginning. Ant algorithms are also being used to control a class of robots called swarm bots. Typically, a swarm bot is a collection of simple robots (s-bots) that self-organize according to algorithms inspired by the bridge-building and task-allocation activities of ants. For example, if an s-bot encounters an object too heavy or **bulky** to carry on its own, other s-bots will grasp either the object or other s-bots until they get it under control. Two or more can link up to cross a gap that exceeds a single s-bot's stride. With this ability to temporarily mass together or spread out, a swarm bot's form

[1] Insects go through three stages of development: egg, larva, and pupa (pl. = larvae and pupae).

depends on its surroundings and the job it's doing. Such devices might prove helpful in activities like search-and-rescue and planetary exploration.

The ability to swarm, adapt, and optimize—all the skills implied by ant behavior—makes ant algorithms a crucial technology for the information age, especially as everyday objects become ever smarter. The rules that insects live by turn out to be perfectly suited to the high-tech anthill.

Social Robots

A ROBOT DESIGNER WOULD LIKE TO INTRODUCE YOU TO SOME OF HIS FRIENDS

Science fiction stories have long imagined a world populated with robots. In *The Jetsons,* a family-oriented cartoon from television's early days, Rosie the robot was a helpful, middle-aged servant. The Jetson family loved her so much that they could never bring themselves to replace her with a newer model. In more dystopian[1] stories, robots are heartless machines of chilling efficiency. In the film *Minority Report* (2002), spider-like robots swarm an apartment building systematically looking for a fugitive[2] wanted by the police. A mother calmly reassures her terrified child that the robots are not looking for her. The scene, both touching and frightening, makes us wonder if robots will be our enemies or our friends.

Zeno, a robot creation by David Hanson

Dr. David Hanson, a robot designer, thinks robots can be our friends, maybe even our best friends, but not if they look and act like spiders. To make robots more acceptable to humans, he is working on a long-term **project** to develop affordable "robots with character." He wants robots that empathize with you—that is, robots that understand you and build a relationship. To do this, robots must be able to see your face, differentiate you from others, and understand your moods. **Furthermore**, these sociable robots must be able to make appropriate facial expressions. They must look similar to humans.

Several of Hanson's robots are incredibly lifelike. His Albert Humo robot **consists** of a head, which he developed, and a walking robot body made at the Korean Advanced Institute of Science and Technology. The head looks just like the famous physicist Albert Einstein and has amazingly realistic facial expressions. But more importantly, it makes these expressions in response to how people around it behave. In a demonstration at the Technology Entertainment Design (TED) Conference in Long Beach, California in 2009, Hanson's robot smiled and frowned in response to Hanson's facial expressions.

Getting robots to smile at a smile took some doing. Says Hanson, "I developed a series of technologies that allowed robots to make more realistic facial expressions than previously achieved." Human facial expressions are powered by several dozen muscles. To mimic the action of these muscles, Hanson's robot faces contain 28 tiny motors covered by a spongy material he developed, called Frubber. When attached to the motors, Frubber moves and wrinkles just like human skin.

[1] *dystopian:* relating to *dystopia*—a world that has gone bad, the opposite of *utopia,* or a perfect world
[2] *fugitive:* someone wanted by the police who is running to avoid capture

The robots also need to recognize facial expressions quickly. At the Machine Perception Laboratory at the University of California at San Diego, researchers are developing technology that can detect and follow human faces. Working with that group, Hanson developed the Character Engine, software that allows the machine to recognize where people are looking, track head positions, and mimic or learn facial expressions.

And of course the robots must be able to speak and give relevant responses. Sometimes Hanson's robots give answers that seem memorized. The question "Do you think?" triggers a playful answer that reminds us that much of what humans say is predictable and does not require much thinking. Obviously, that is the programmer teasing us. But as the robot learns more about us, it uses that knowledge and information from the Internet to come up with new things to say.

By combining programming genius with movie-inspired animatronics[3], Hanson has launched an ambitious effort to make robots seem like us. Even more extreme is Professor Hiroshi Ishiguro's work at Osaka University in Japan. His animatronic "Geminoid" robots are so lifelike that many people find them "creepy." Others favor a less lifelike approach. At the Center for Robotics and Intelligent Machines at the Georgia Institute of Technology, researchers are making robots with cute, childlike faces and humanlike movements, but the machines are obviously robots. Hanson has favored this approach in designing Zeno, a smaller, doll-like robot suitable as a playmate for children.

Are friendly robots dangerous? Sherry Turkle, a psychologist at the Massachusetts Institute of Technology, thinks so. In her book, *Alone Together: Why We Expect More from Technology and Less from Each Other* (2011), she warns that robots may disappoint us and leave us lonelier if they take our attention away from human friends. Turkle's concerns may seem overstated. The same complaint, after all, could be made about books or television. But before dismissing her, are you sure you will be able to resist those big adoring robot eyes hanging on every word you say? In the end, we may be better served by scary spiders than a lovable Rosie.

[3] *animatronics:* the process of making and operating robots that move and look like real people and animals

Reading Comprehension

A. Mark each sentence as *T* (true) or *F* (false) according to the information in Reading 1. Use the dictionary to help you understand new words.

___1. Ants respond to instructions communicated from the center of the nest.

___2. As the strength of a scent trail diminishes, ants show less interest in that path.

___3. Ant algorithms are currently being used to assist in search-and-rescue operations.

___4. Robots today are being used to hunt down and identify fugitives.

___5. David Hanson's robots are capable of learning.

___6. Dr. Hanson's robots are designed for use in movies.

___7. For Hanson, cost is a factor to consider when designing robots.

B. Scan the reading to find the sentences paraphrased below. Write the line number in the blank.

___ 1. Ants show us how complex problems can be solved by tiny machines following simple instructions.

___ 2. And then there is the way that ants find and retrieve food.

___ 3. There are many amazing uses for this ability to find their way from one point to another.

___ 4. Hanson's creations have a remarkable resemblance to humans.

___ 5. Furthermore, the robots need to process and produce meaningful human language.

READING SKILL Analyzing Advantages and Disadvantages

LEARN

Reading assignments may ask you to weigh the advantages and disadvantages of an idea or plan. Reading 1, for example, might prompt these questions:

- What benefits can we gain from studying ant algorithms?
- What advantages do social robots have?
- What is one potential drawback of making robots very lifelike?
- What problems are solved by using social robots?

APPLY

A. Read these lists of potential advantages and disadvantages that might be relevant when analyzing a plan or idea. Can you think of other considerations to add to each list?

Advantages	Disadvantages
inexpensive	expensive
efficient	wasteful, inefficient
simple to understand	complicated
convenient, easy to use	takes too long to design or build
quick to install, operate, or replace	dangerous
easy to modify or expand	fragile; needs frequent replacement
safe and reliable	expensive to clean, maintain, or repair
durable	dangerous, risky
easy to clean, maintain, and repair	dirty and polluting
widely available	limited availability
_____	_____
_____	_____
_____	_____

B. Drawing on information from the readings, list advantages and disadvantages for each of these technological solutions. The readings may imply advantages and disadvantages not directly discussed.

Solutions	Advantages	Disadvantages
ant algorithms		
robots that don't look human		
robots that look human		

Vocabulary Activities

Noun	Verb	Adjective	Adverb/Conjunction
bulk bulkiness	_____	bulky bulk	_____
_____	consist (of)	_____	_____
_____	_____	_____	furthermore
illustration illustrator	illustrate	illustrated illustrative	illustratively
method methodology	_____	methodical	methodically
project	_____*	_____	_____
schedule	schedule	scheduled scheduling	_____
shift	shift	_____	_____

*The verb *project* and its forms are treated in Unit 4.

A. Read this article on Mars mini-probes, a possible application of swarm technology. Fill in the blanks with a target word from the chart above that completes the sentence in a grammatical and meaningful way.

Various (1) _____projects_____ over the last 40 years to explore the planet Mars with robots have had mixed success. Some researchers believe it's time for us to (2) _____ our thinking away from the rolling or walking robots of the *Star Wars* films.

One alternative is to send a team of swarming robots that (3) _____ spread out like ants or bees, exploring the planet in every direction. Previous Mars rovers were too heavy and (4) _____ to explore the rugged terrain without risking destruction. A team of "swarm bots" would (5) _____ of hundreds or even thousands of tennis-ball-sized robots designed to hop,

bounce, or roll across the Martian surface. Each probe would have its own fuel cell and carry different kinds of sensors to collect scientific samples. This (6) _____ assures mission success even if most of the swarmbots are destroyed or lost.

B. **The words in bold have more than one meaning, depending on context. Read these sentences and circle the meaning that best fits the context.**

1. They **shifted** their attention to the problem of the robot's fuel supply.
   a. changed focus b. changed position
2. The **bulk** of the meeting was devoted to logistics and scheduling.
   a. majority b. large size
3. The project was under budget and ahead of **schedule.**
   a. a timeline of tasks to complete b. a table of prices or rates
4. The poll detected a significant **shift** in public opinion.
   a. a work period b. a change in attitude
5. The company buys its paper products in **bulk.**
   a. large sizes b. large, unpackaged quantities
6. You will find the cost **schedule** on an insert at the back of the catalogue.
   a. a timeline of tasks to complete b. a table of prices or rates
7. The article clearly **illustrates** why there is growing interest in swarm technology.
   a. provides pictures showing b. provides examples showing

Before You Read

Read these questions. Discuss your answers in small groups.

1. Are robots with humanlike intelligence a development that we should embrace or fear?
2. What characteristics or qualities must a machine have in order to be considered a robot?

MORE WORDS YOU'LL NEED

aspiration: a strong desire to do something; a hope or ambition
emulate: try to be like something else; design or create an artificial copy that looks and behaves the same as the original

READING 2

Read

Our ancient quest to create androids is about to destroy the boundary between humans and machines. Ray Kurzweil explains how and ponders the implications in this online article.

Robots 'R' Us

Human experience is marked by a refusal to obey our limitations. We've escaped the ground, we've escaped the planet, and now, after thousands of years of effort, our quest to build machines that emulate our own appearance, movement, and intelligence is leading us to the point where we will escape the two most fundamental confines of all: our bodies and our minds. Once this point comes—once the accelerating pace of technological change allows us to build machines that not only equal but surpass human intelligence—we'll see cyborgs (machine-enhanced humans), androids (human-robot hybrids), and other combinations beyond what we can even imagine.

Although the ancient Greeks were among the first to build machines that could emulate the intelligence and natural movements of people, these efforts flowered in the European Renaissance, which produced the first androids with lifelike movements. These included a mandolin-playing lady, constructed in 1540 by Italian inventor Gianello Torriano. In 1772 Swiss watchmaker Pierre Jacquet-Droz built a pensive child named L'Écrivain (The Writer) that could write passages with a pen. L'Écrivain's brain was a mechanical computer that was impressive for its complexity even by today's standards.

Such inventions led scientists and philosophers to speculate that the human brain itself was just an elaborate automaton. Around 1700, Wilhelm Leibniz wrote, "What if these theories are really true, and we were magically shrunk and put into someone's brain while he was thinking. We would see all the pumps, pistons, gears, and levers working away, and we would be able to **document** their workings completely, in mechanical terms, thereby completely describing the thought processes of the brain. But that description would nowhere contain any mention of thought! It would **consist** of nothing but descriptions of pumps, pistons, levers!"

Leibniz was on to something. There are indeed pumps, pistons, and levers inside our brain—we now recognize them as neurotransmitters, ion channels,[1] and the other molecular components of the neural machinery. And although we don't yet fully understand the details of how these little machines create thought, our ignorance won't last much longer.

The word "robot" originated almost a century ago. Czech dramatist Karel Čapek first used the term in his 1921 play *R.U.R.* (for "Rossum's Universal Robots"), creating it from the Czech word "robota," meaning obligatory work. In the play, he describes the invention of intelligent biomechanical machines intended as servants for their human creators. While lacking charm and goodwill, his robots brought together all the elements of machine intelligence: vision, touch sensitivity, pattern recognition, decision-making, world knowledge, fine motor coordination, and even a measure of common sense.

[1] *ion channels:* chemicals that send electrical signals between brain cells and proteins that help control the flow of electrical energy

Čapek intended his intelligent machines to be evil in their perfect rationality and scornful of human frailty. These robots ultimately rise up against their masters and destroy all humankind, a dystopian **notion** that has been echoed in much science fiction since.

The specter[2] of machine intelligence enslaving its creators has continued to impress itself on the public consciousness. But more significantly, Čapek's robots introduced the idea of the robot as an imitation or substitute for a human being. The idea has been reinforced throughout the 20th century, as androids engaged the popular imagination in fiction and film, from Rosie (in the 1960s cartoon *The Jetsons*) to C-3PO and the Terminator.[3]

The first generation of modern robots was, however, a far cry from these anthropomorphic[4] visions, and most robot builders have made no attempt to mimic humans. The Unimate, a popular assembly-line robot from the 1960s, was capable only of moving its one arm in several directions and opening and closing its gripper. Today, there are more than two million Roomba robots scurrying around, performing a task (vacuuming) that used to be done by humans, but they look more like fast turtles than housekeepers. Most robots will continue to be utilitarian devices designed to carry out specific tasks. But when we think of the word "robot," Čapek's century-old concept of machines made in our own image still dominates our imagination and inspires our goals.

The aspiration to build human-level androids can be regarded as the ultimate challenge in artificial intelligence. To do it, we need to understand not just human cognition but also our physical skills—this is, after all, a critical part of what the brain does. Coordinating intention with movement in a complex environment is largely the responsibility of the cerebellum, which **comprises** more than half the neurons in the brain. And the body itself represents much of our complexity: There is more information in the human genome[5], which describes the human body, than in the design of the brain.

We are making tremendous strides toward being able to understand how the brain works. The performance/price ratio and **capacity** of every type of information technology is doubling about every year. I call this pervasive phenomenon the law of accelerating returns. Our grasp of biology is **proceeding** at an accelerating pace, exponentially[6] increasing every year. Indeed, we are augmenting and recreating nearly every organ and system in the human body: hearts and pancreases, joints and muscles.

The same progression applies to our knowledge of the human brain. The three-dimensional resolution[7] of brain scans has been exponentially increasing, with the amount of data that scientists are gathering on the brain similarly increasing every year. And they are showing that this information can be understood by converting it into models and simulations of brain regions, some two dozen of which have already been completed.

If we are to recreate the powers of the human brain, we first need to understand how complex it is. There are 100 billion neurons, each with thousands of connections and each connection containing about 1,000 neural pathways. I've estimated the amount of information required to characterize the state of a mature brain at thousands of trillions of bytes: a lot of complexity.

But the design of the brain is a billion times as simple as this. How do we know? The design of the human brain—and body—is stored in the genome, and the genome doesn't contain that much information. Since we know the genome's structure, we can compress its information to an amount smaller than the **code** for a word processing program.

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[2] *specter:* a haunting image
[3] *C-3PO was a robot from the* Star Wars *films; the Terminator was a robot from the* Terminator *films*
[4] *anthropomorphic:* attributing human characteristics to an object
[5] *human genome:* all of the chemical sequences **encoded** in human DNA
[6] *exponentially:* an extremely rapid increase
[7] *resolution:* degree of clarity of an image

My point is not that the brain is simple, but that the design is at a level of complexity that we can fathom[8] and manage. And by applying the law of accelerating returns to the problem of analyzing the brain's complexity, we can reasonably forecast that there will be exhaustive models and simulations of all several hundred regions of the human brain within about 20 years.

Once we understand how the mind operates, we will be able to program detailed descriptions of these principles into inexpensive computers, which, by the late 2020s, will be thousands of times as powerful as the human brain. So we will have both the hardware and software to achieve human-level intelligence in a machine by 2029. We will also by then be able to construct fully humanlike androids at exquisite levels of detail and send blood-cell-size robots into our bodies and brains to keep us healthy from inside and to augment our intellect. By the time we succeed in building such machines, we will have become part machine ourselves. We will, in other words, finally transcend what we have so long thought of as the ultimate limitations: our bodies and minds.

[8] *fathom:* comprehend

Reading Comprehension

A. Mark each sentence as *T* (true) or *F* (false) according to the information in Reading 2. Use the dictionary to help you understand new words.

___ 1. Ray Kurzweil sees advanced cyborg and android robots as inevitable.

___ 2. Karel Čapek saw robots as a threat to humans.

___ 3. According to Kurzweil, we have trouble seeing utilitarian devices as being true robots.

___ 4. As our technological capabilities increase, technology becomes more and more expensive.

___ 5. Kurzweil believes we have underestimated the complexity of the human brain.

___ 6. The actual structure of the brain is less complex than the code for some computer programs.

___ 7. According to Kurzweil, we will not only create machines with superhuman intelligence, but we will also enhance our own intelligence.

B. Scan the article for the answers to these questions. First think about the key word you will scan for. Use any annotations or highlighting you have done to help you. Compare answers with a partner.

1. What are cyborgs and androids?

   Cyborgs are androids are types of human or human-like robots.

2. What was L'Écrivain and when was it built?
3. Who was the philosopher who speculated that the brain was a mechanical system?
4. Where was Karel Čapek from?
5. About how many neurons are there in the human brain?
6. About how long did Kurzweil think it would take to create an "exhaustive model" of the human brain at the time he wrote this article?
7. If Kurzweil is correct, when can we expect to see a machine with human level intelligence?

READING SKILL Identifying Ethics and Values

LEARN

In weighing advantages and disadvantages, we also consider ethics, values, and morals. Will an idea or plan promote things we like or value? Will it discourage things we dislike or fear?

APPLY

A. Here are some ethical and moral considerations. Can you think of others to add to the lists?

Things we want to . . .

encourage, promote, or increase		discourage, prevent, or decrease	
good health	justice	violence	vanity
wealth	self-control	crime	laziness
freedom	trust	fatigue	dishonesty
free time/recreation	loyalty	disease	self-centeredness
taking responsibility	generosity	pain	rudeness
fairness	friendliness	poverty	irresponsible behavior
learning	politeness/civility	favoritism	immoral behavior
security	cooperation	injustice	environmental damage
beauty	bravery	greed	loss of traditions
knowledge	_____	narcissism	_____
amusement and fun	_____	decay and ugliness	_____
new experiences	_____	jealousy	_____

B. Sometimes writers will imply what ethical concerns or values are important to them. Each statement on the left describes one feature of a trend, development, or behavior. Match each statement to a desire or fear listed on the right.

___ 1. Research shows that few people can truly function well on less than eight hours of sleep a night.	a. It promotes curiosity and wonder.
___ 2. Google Books offers free publicity and a new avenue for sales.	b. It encourages irresponsible financial decision-making.
___ 3. Economic bubbles make people believe that they are richer than they are.	c. It encourages favoritism and unfairness.
___ 4. Students from rural areas will be penalized.	d. It damages health.
___ 5. A mission to Mars will increase children's interest in science and exploration.	e. It increases popularity and profits.

C. **Read this comment on Kurzweil's ideas. Then, in a small group, discuss the questions that follow.**

Ray Kurzweil, the author of "Robots 'R' Us," has some controversial views about the future of humans. He feels that advances in biochemistry, neurology, and computer science will allow us to redesign our bodies and our minds in ways that will make us more intelligent and perhaps immortal. Kurzweil is generally optimistic about these developments. Others may see such developments as a serious threat to our values.

1. What value is there in being able to redesign ourselves?
2. What values may be threatened by such a change?

REVIEW A SKILL **Analyzing Criteria** (See p. 117)

In Unit 8, you studied how to use criteria to make decisions. Look through the readings in this unit for criteria that we could use to decide if a robot seems human. Then add other criteria the readings may have overlooked. Which criteria seem most important?

The robot should make appropriate facial expressions.

Vocabulary Activities

Noun	Verb	Adjective	Adverb/Conjunction
capacity	incapacitate	incapacitated	_____
code	encode decode	coded	_____
_____	comprise	_____	_____
document documentation documentary	document	(well-)documented	_____
notion	_____	notional	notionally
procedure proceedings proceeds	proceed (to)	procedural	procedurally

A. **Fill in the blank with a target word from the chart above that completes the sentence in a grammatical and meaningful way.**

In many early science fiction stories, a scientist creates a robot and then the robot (1) _____ to kill its creator. But science fiction writer Isaac Asimov disagreed with this idea. His (2) _____ was that a robot could be "sympathetic and noble." In 1940, Asimov and science fiction writer and editor John W. Campbell conceived the Three Laws of Robotics:

- A robot may not injure a human being or, through inaction, allow a human being to come to harm.
- A robot must obey orders given it by human beings except where such orders would conflict with the First Law.
- A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

Three of the nine stories that (3)_____ Asimov's *I, Robot* anthology mention these laws, and many of the robots in his later novels and stories follow this (4)_____ of behavior.

The laws are not contained in any formal, written (5)_____ that a thinking robot could refer to and quote. Instead, the laws are (6) _____ mathematically into the robot's programming and operate much like the natural instinct that directs human beings to protect their own children.

For Asimov, this is analogous to safety features and strict operating (7) _____ that are part of all tools and machines. But will this built-in ethical code work if machines can think for themselves? If robots develop the (8) _____ for conscious thought, is it possible that they will they choose to ignore the three laws?

B. **The words in bold have more than one meaning, depending on context. Read these sentences and circle the meaning that best fits the context.**

1. The library's **capacity** is inadequate for the number of books in the collection.
   a. power to do something b. amount of physical space
2. The Three Laws of Robotics are a **code** of conduct devised by Isaac Asimov.
   a. a secret system of letters or numbers b. a set of principles
3. This **notion** was first expressed in a short story by Asimov.
   a. an idea or opinion b. an impulse or desire
4. He had a sudden **notion** to call an old friend of his.
   a. an idea or opinion b. an impulse or desire
5. The scientist recorded his theories in a **code** that we are just now beginning to understand.
   a. a set of principles b. a secret system of letters or numbers
6. Although I don't agree with him, I'm impressed by his intellectual **capacity**.
   a. power to do something b. amount of physical space

Collocations Chart			
Verb	**Adjective**	**Noun**	**Prepositional phrase**
_____	_____	*bulk*	of the money, work, estate, operation, information
have	intellectual, limited, reduced, full, large, excess, creative, maximum, limitless, enormous	*capacity*	for sth
_____	strict, moral, criminal, genetic, secret	*code*	of conduct, behavior, ethics, practice
_____	(well-)*documented*	evidence, case, report, account, history, example, occurrences	_____
have	strange, peculiar, vague, clear, false, commonplace, everyday, popular, complex	*notion*	_____
adopt, follow, use, establish	simple, complex, complicated, standard, proper, correct, scientific	*procedure*	_____
set up, carry out, fund, initiate	large, ambitious, worthwhile, important, joint, special	*project*	_____
_____	decided, definite, mental	*shift*	in emphasis, attitude, policy, perception from (sth) to (sth)
shift	_____	gears, blame, burden, emphasis, cost, perspective	_____

C. **The chart above shows some of the more predictable collocations, or word partners, for selected target vocabulary. Using the chart, complete these sentences with the correct form of an appropriate word.**

1. Many universities have a strict _____ of behavior regarding plagiarism and the use of other people's intellectual property.
2. According to Ray Kurzweil, in the next 10 to 20 years, the intellectual and creative _____ of computers will greatly exceed that of the human brain.