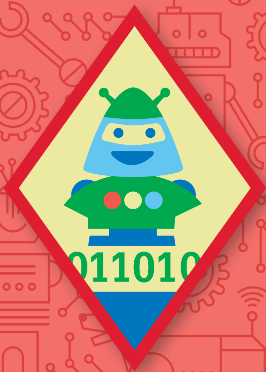
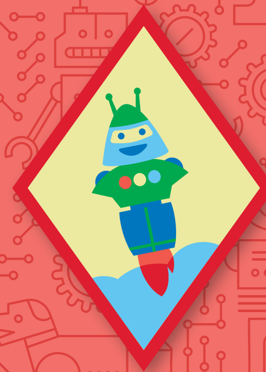




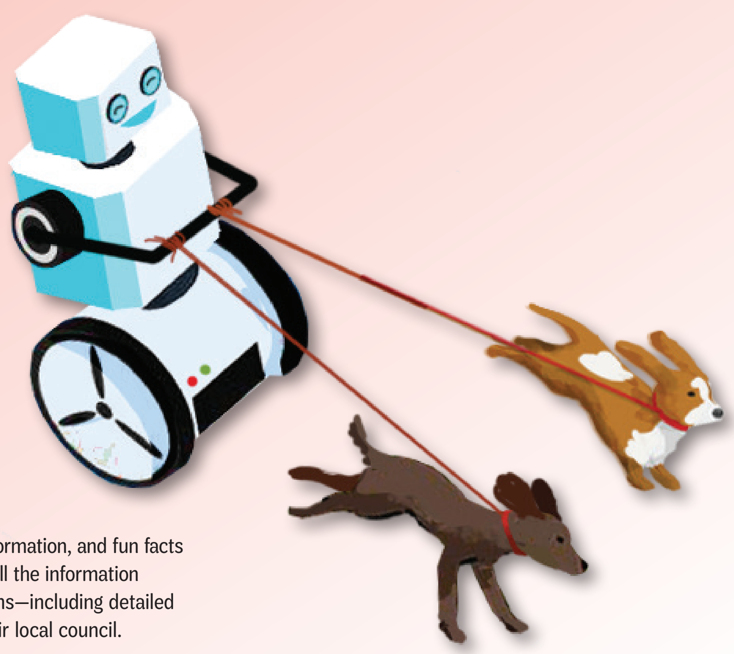
Cadette Robotics

Develop your robotics skills by earning these three badges!

Badge 1:
Programming Robots

Badge 2:
Designing Robots

Badge 3:
Showcasing Robots



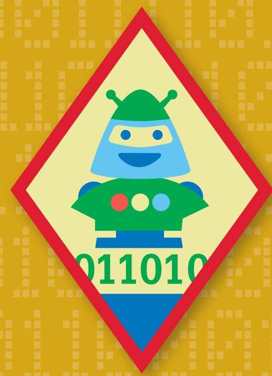
This Robotics badge booklet for girls provides the badge requirements, information, and fun facts about robotics for all three Cadette robotics badges. It does not include all the information needed to complete the badges. Volunteers may access full meeting plans—including detailed activity instructions—on the Volunteer Toolkit (VTK) or by contacting their local council.

Welcome to the world of robots!

When you've earned these three badges, you'll know how robots are built and programmed, how to design and build your own model robot, and how to share what you've created with others.

Robots can already vacuum floors and deliver snacks to offices on their own. Someday soon, robotic taxis will drive us where we want to go without humans to steer them.

What else will robots be used for in the future? If you can't wait to find out, you might want to explore the fast-growing field of robotics. From engineering to programming to digital arts to psychology, developing robots lets you draw from talents in a wide range of areas. Maybe someday you can help invent what our future looks like!



Badge 1: Programming Robots

Robots are machines that can detect what's going on around them and use that information to decide how they'll interact with the physical world. To help you understand how robots work, learn about the parts that make up a robot. Get started with electronics by making a simple sensor, something robots use to function without human operators. Then practice coding robots using important programming concepts like functions and loops.

Steps

1. **Learn about robots**
2. **Build a robot part: simple sensors**
3. **Make a box model robot with sensors**
4. **Learn about programming**
5. **Write a program for a robot**

Purpose

When I've earned this badge, I'll understand how robots work and how to control them.

STEP
1 Learn about robots

Robots are all around us. But what makes a robot different than other kinds of electrical devices? Many scientists use the Sense-Think-Act definition. It says that a robot can perform three functions that make it stand out from ordinary machines. They are:

Sense: A robot has sensors that give it information about the physical environment, the "real" world around it.

Think: The input from the robot's sensors controls the robot's movement and actions. This control is usually carried out by electronic circuits or computer programming, either onboard or remotely. Sometimes it is built into the robot's physical design. This is called a "programmable body" or "smart body."

Act: A robot usually has some way to move or affect the world around it. This can include legs, wheels, helicopter rotors, fans, arms, grippers, lights, and speakers.

Robot model based on DaVinci's sketches

Courtesy NASA/JPL-Caltech

A robot needs five main parts:

- **Sensors** send information about the environment to the robot.
- The parts that help it to think are its **controllers**. They process information from the sensors and decide how to react.
- The parts that help a robot act are its **housing**, **actuators**, and **effectors**. Housing is the robot's body. Actuators are the power system of the robot. Effectors are the parts of the robot that can move around.

Invent an imaginary robot that uses these five parts. How do the parts work together? How does the robot sense, think, and act?

Robots in History

The first robots were mechanical people or animals that moved automatically using windup springs and weighted gears and levers.

1464

Leonardo DaVinci designed a mechanical knight in 1464 when he was 12 years old.

1941

The word "robotics" first appeared in the science fiction book *I, Robot* by Isaac Asimov in 1941.

2004

NASA's robotic rovers Spirit and Opportunity landed on Mars in 2004. Although they were only expected to last a few weeks, they continued working for many years. Spirit keep going until 2010, and in 2018, Opportunity was still sending pictures and information back to Earth.

2018

In 2018, a robot created by two MIT students solved a Rubik's Cube in 0.38 seconds, a new world record.

WORDS TO KNOW

An **actuator** takes energy (from a battery or other source) and uses it to power a robot's movement. Examples include an electric motor or hydraulic pump.

An **algorithm** is a set of step-by-step instructions to carry out a task. A computer program is a type of algorithm.

Artificial intelligence or **AI** is a type of computer program that acts as if it can think like a human. For example, AI programs are used in devices that can answer questions and hold conversations with people in ordinary language.

Autonomous robots work some or all of the time without human control. They can make decisions based on their programming and input from the environment.

Binary is a way of presenting information using only two symbols. In math, a binary system consists of the numbers 0 and 1.

A **bug** is a problem in a computer program. To get rid of the problem, you **debug** the program.

A **circuit** is a path for electricity to travel along. Most circuits are designed as loops with a switch that can open and close the circuit, like a drawbridge. A circuit must be closed for electricity to flow.

Coding means writing a computer program, which is also known as code.

A **command** is one step in a computer program.

A **computer program** is a set of instructions that tells the machine what to do.

A **conditional statement** in a computer program tells the computer to make a choice between two or more actions. It is usually written in the form IF-THEN-ELSE. IF a certain condition is true, THEN the computer will take one action. If it is false, the computer will take the other action. For a loop, the statement might be REPEAT UNTIL a condition is true.

Conductive materials are substances that carry electricity easily, like metal.

Data is information that a computer can understand.

Documentation means keeping a record as you create your design, from idea to completion. It can include written descriptions, drawings, photos, and videos. Documentation lets you create instructions to share with others or prove that you are the inventor of a new idea.

An **effector** is a part on a robot that can move around. Examples include robot arms or legs.

A **function** is like a mini-program within another program. It's a series of commands that is given a name. When you "call" the function's name in a program, those commands are carried out at that point.

Housing refers to a robot's body.

Insulating materials don't carry electricity easily. They are used to cover conductive materials and keep electricity from leaving the circuit.

A **loop** is a computer programming shortcut that tells the computer to go back and repeat a series of commands.

A **programmable body** is a way of controlling how a robot moves by changing its physical design.

Pseudocode means writing out a computer program in everyday language. It is used as a quick way to plan out a computer program without translating it into a programming language.

A **robot** is a machine that can perform three kinds of tasks: sense, think, and act.

A **roboticist** is a scientist who works on robots and related technology.

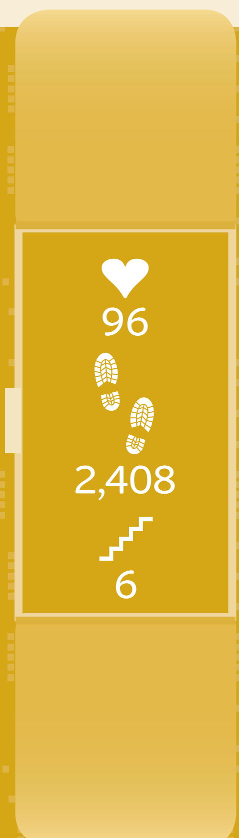
Robotics is the branch of technology that deals with designing, building, and using robots.

A **sensor** is an electronic component that transmits information to the robot about its environment.

The **uncanny valley** is the point at which an artificial life form that looks almost real appears more threatening than friendly.

Smart Wearables

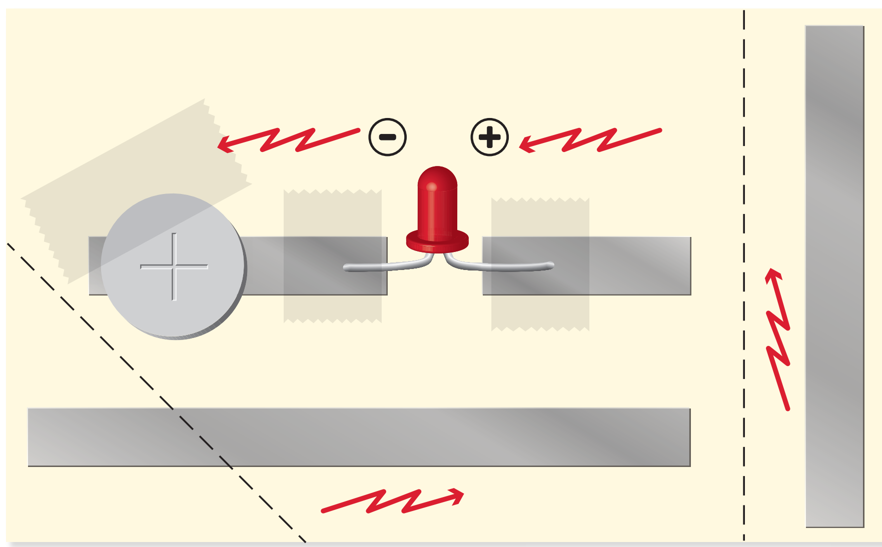
Sensors aren't just for robots. Smart wearables—such as sports bracelets that keep track of how far you've run—use sensors to gather information. They send the information to built-in or remote computers for analysis, just like robots do. Other smart wearables include glasses that identify faces or places, earrings that monitor your heart rate and body temperature, and smart shoes that vibrate to tell you when to turn right or left.

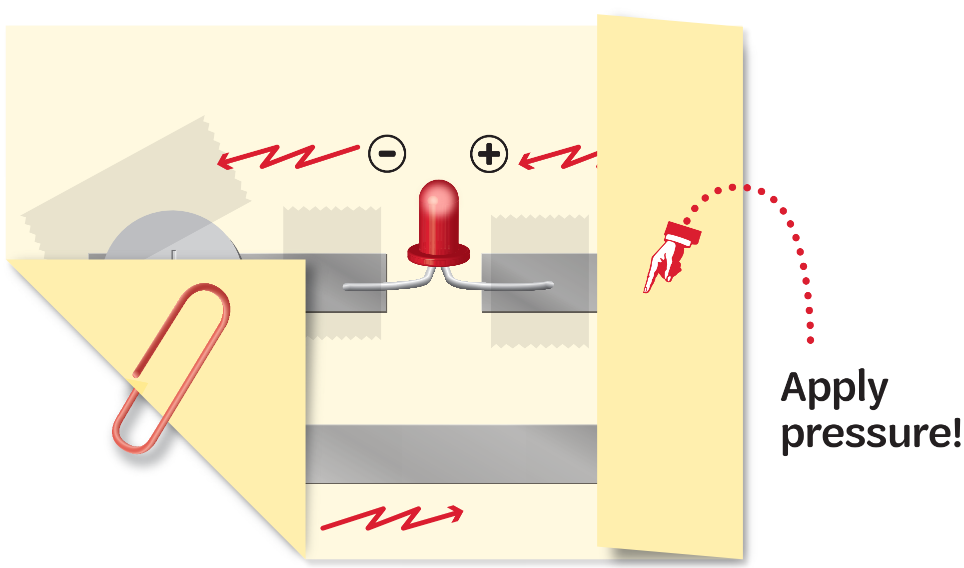


STEP

2 Build a robot part: simple sensors

On a robot, sensors take information about the outside world and translate it into high or low levels of electricity. The simplest kind of sensor acts like a switch that only turns on if the conditions are right. More advanced sensors tell robots where they are, what direction they're facing, and whether they're tilted right or left, up or down. Environmental sensors report on brightness, dampness, temperature, and air quality. And proximity sensors let robots know who or what is near. All this information helps the robot make decisions on its own—without a human telling it what to do every minute. Learn how robots use sensors by making a basic pressure sensor that can tell a robot whether it is touching something.





SENSOR SAVVY THINGS TO KNOW

A circuit is a path for electricity to flow. It is made of conductive material, a substance that carries electricity easily. It is surrounded by insulating material that doesn't carry electricity.

A sensor is basically an on-off switch for an electrical circuit. The right conditions cause electricity to flow in the circuit and send a signal to a computer or other kind of electronic controller. A computer program then tells the computer what to do.

For electricity to flow in a circuit, there needs to be a place for it to go. Usually a circuit is designed in a loop, so that the electrical energy flows around and around.

A battery (or other power source) has a positive (+) end where the electricity comes out and a negative (-) end where it goes back in. For electricity to flow, the circuit must be connected to both ends of the battery.

For electricity to flow, a circuit must be closed. If a circuit is connected to both ends of a battery, but there is an opening anywhere in the circuit, nothing happens. This is called an open circuit.

A switch or sensor controls the flow of electricity by opening and closing the circuit. It's like a drawbridge over the gap in the circuit. When the drawbridge is down, electricity can travel around the circuit. When it is up, or open, no electricity flows.

Some sensors can let higher or lower amounts of electricity flow, like the dimmer switch on a light. These kinds of sensors give variable readings, such as high or low air pressure.

Electrical components also have positive and negative ends. Some components, like LEDs, will only work if the positive and negative ends are connected in the same direction as the battery (that is, positive to positive and negative to negative).

On an LED, the longer wire, or lead, is positive. There is also a flat spot on the edge of the LED bulb. The wire on that side is negative.

STEP

3 Make a box model robot with sensors

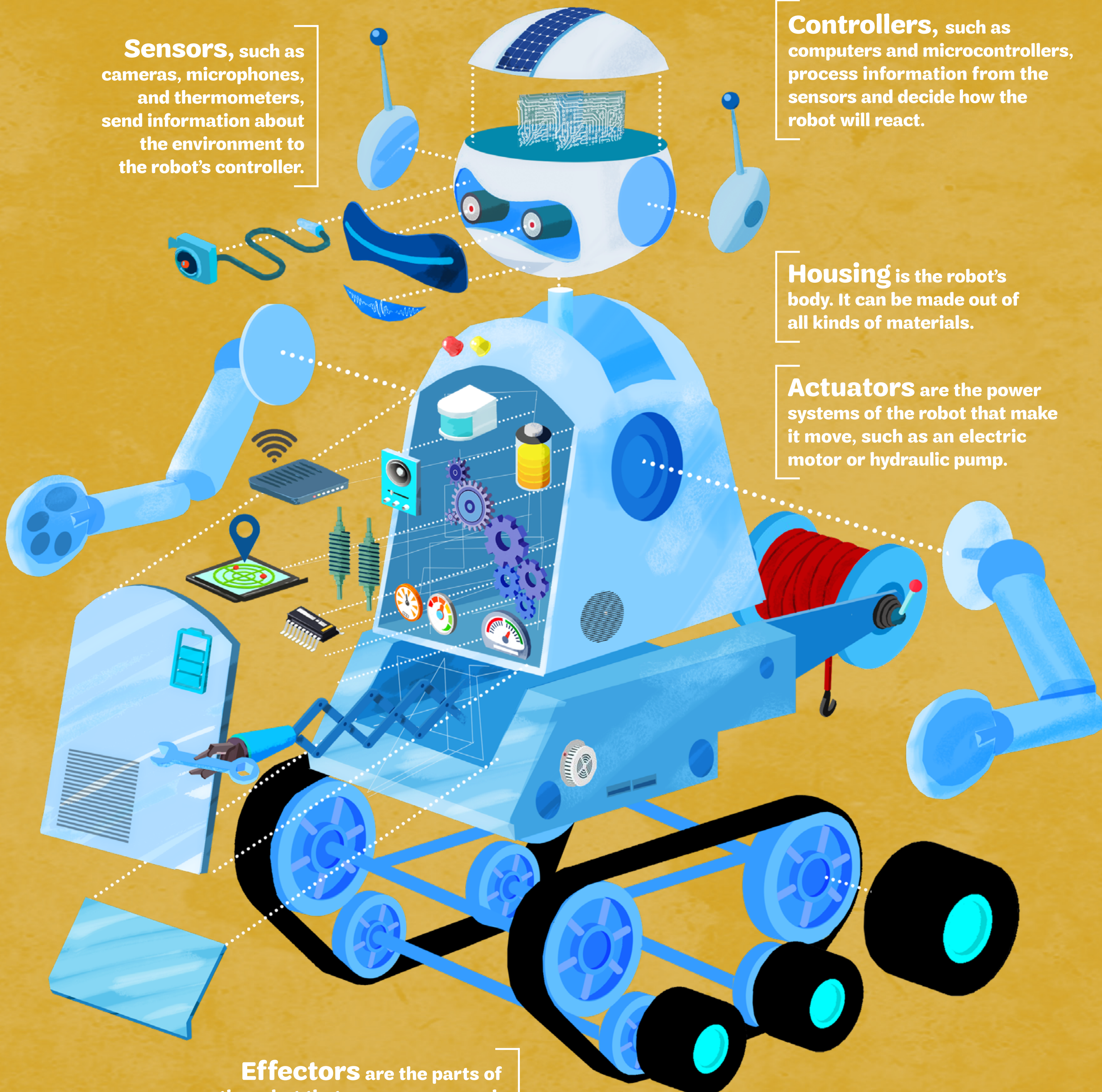
A robot's brain can be programmed to react when the sensor goes on or when it turns off. For example, a robot with a light sensor can be programmed to move toward dark areas or light areas. A simple pressure sensor, like the one in Step Two, can be used in many ways—it can tell a robot when it has bumped into something, is about to go over the edge of a step or table, or is brushing against the walls or ceiling of a tunnel. A pressure sensor can also be used as a button.

Now that you have a sensor, test it using only a cardboard box. Attach your sensors and move the box to make the sensors light up, showing how the sensors would send signals to a controller on a real robot.

Invent an imaginary robot using each of the five parts.
How do the parts work together? Why is it important for roboticists to think about how the parts work together as they start their design?

Learn About the Five Parts of a Robot

Robots can be very simple or very complicated. But in general, most robots contain five main parts:



Sensors, such as cameras, microphones, and thermometers, send information about the environment to the robot's controller.

Controllers, such as computers and microcontrollers, process information from the sensors and decide how the robot will react.

Housing is the robot's body. It can be made out of all kinds of materials.

Actuators are the power systems of the robot that make it move, such as an electric motor or hydraulic pump.

Effectors are the parts of the robot that can move around, such as arms, grippers, legs, wheels, treads, fins, and propellers.

Autonomous Versus Remote Control

Messages between a human operator and a robot can take seconds or minutes to travel back and forth, if the robot is on the other side of the globe, at the bottom of the ocean, or on another planet. As a result, most robots perform tasks automatically, but use a combination of remote control and **autonomous** or self-control to make decisions when needed.

Here's how it can work:

- The robot receives remote control instructions from its human operator about what direction to go in and what to do when it gets there.
- It handles the driving, flying, or swimming automatically.
- At the same time, it watches out for and avoids obstacles autonomously, based on input from its sensors.

STEP 4 Learn about programming

Computer programs are written in the form of an algorithm—a step-by-step set of instructions that tells the computer what to do. On many robots, you'll find microcontrollers or onboard computers that are programmed to analyze incoming data and use it to carry out complicated instructions. Write an algorithm to tell someone how to complete a familiar task. See if you can simplify your algorithm using loops, functions, and conditional statements.

STEP 5 Write a program for a robot

Computer programs use commands to tell the machine what to do. A command is one step in a program. A robot's programming tells it to look for input from its sensors, test it to see if it meets certain limits, and then carry out an action if it does. For instance, a program might tell a robot to move forward when light sensors detect that it is bright enough and stop if it gets dark. Each of those steps is a command. Write simulated computer code that tells a robovac how to vacuum a room and follows the sense, think, and act definition of a robot. This means that your program should tell the robot what conditions to look for and what it should do if certain conditions are met!

How to Talk to Robots

Ever wonder how robots can take commands from human operators or make decisions based on sensor readings? It works like this:

- Inside a computer are millions of switches that can either be "on" or "off." In math terms, "on" is written as 1 and "off" is written as 0. Every command can be translated into a pattern of ones and zeroes that corresponds to switches that are "on" and "off." This is known as binary, because there are only two choices.
- When a sensor is activated, electricity starts to flow through it. The amount of electricity is usually measured in units called volts. A robot's computer brain can be programmed to react differently depending on how much voltage is getting through.
- To make it easier for people to talk to computers, programming languages translate commands from binary into a code which is more like human language. Some popular languages used in robotics research and education include Java, Python, and Arduino. Beginners often use visual languages like Scratch and MakeCode. They let you drag-and-drop blocks on a computer screen instead of typing in words or abbreviations.

Now that I've earned this badge, I can give service by:

- Sharing basics about robots with younger Girl Scouts.
- Programming a robot to solve problems for other people.
- Finding problems that can be addressed with robotics and looking for ways to solve them.

I'm inspired to:

Badge 2: Designing Robots

Researchers often build robot prototypes from materials that are cheap and easy to find. They may include crafts materials, like paper and cardboard, and household materials, like rubber balloons. For this badge, come up with ideas and build a prototype of a new kind of robot that could help someone to overcome a daily obstacle.

Steps

1. **Pick a challenge**
2. **Explore possible solutions**
3. **Plan your prototype**
4. **Build a prototype**
5. **Get feedback on your robot**

Purpose

When I've earned this badge, I'll know how to design a robot and build a prototype.

Robotic Exoskeletons

In the movies, Iron Man's robotic suit gave him superhuman power and even let him fly. In real life, medical exoskeletons are being developed to help people who have weak muscles or are paralyzed. They consist of supports that users strap on or around their bodies. Sensors detect when the user wants to move, and motors help to get them going.

Exoskeletons may also help give extra strength to factory workers who have to lift heavy loads or to volunteers carrying huge backpacks full of equipment to the site of forest fires in places with no roads. The challenge is to make the exoskeletons comfortable, affordable, and easy to put on and take off.

Courtesy of fuseproject

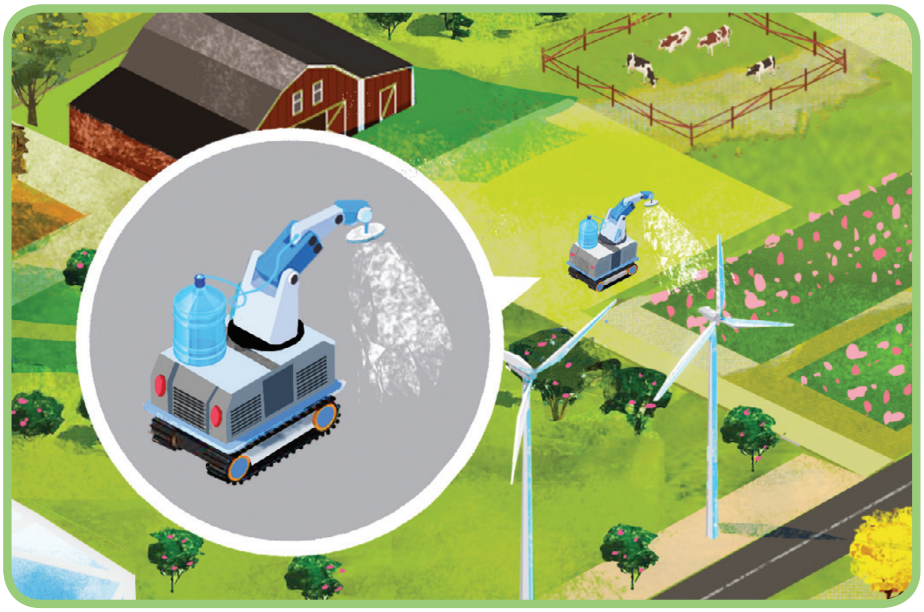
Superflex's Aura Powered Suit reinforces the elderly user's muscle power as they move, sit, and stand.

STEP 1 Pick a challenge

One way robots help people is to take the place of humans in carrying out difficult or tedious jobs. Some of these are obstacles you or people you know may face in going about everyday activities.

Here are some ways robots help people every day:

- **Assistive technology**—Robotic limbs help people who are missing arms or legs. Exoskeletons help people who have weak or paralyzed muscles to move around.
- **Home care aides**—Companion robots keep elderly people company and record their vital signs like temperature and blood pressure.
- **Education**—Telepresence mobile robot cams let students go to class remotely.
- **Household**—Robot vacuums, pool cleaners, and mowers do chores that people find boring.



- **Farming**—Dairy farm robots can milk cows all day long. Hydroponic farms, where plants are grown in water instead of soil, have self-regulating systems that control the light and temperature in the greenhouse and automatically release nutrients into the water as plants need it.
- **Search and rescue**—Shockproof robots go into disaster areas to look for survivors.

Think about ways that robots can help people in their daily lives—what problem could you solve with a new robot design?

STEP

2 Explore possible solutions

One of the most important things roboticists, engineers, and scientists do when they work on a new project is to keep a record, which is known as documentation.

When you work on a project, the notes and pictures taken along the way help you to go back and see where mistakes might have happened.

When your project is done, you can share your documentation so others can repeat or improve upon your design.

And if you decide to patent a new design, your documentation will help you prove that you were the one who invented it!

Now that you have defined the challenge, write down all the ideas you have for how a robot might help solve the problem. Test each of the ideas by acting out how the robot would work and choose one idea to prototype.

Things to think about:

- **How does your robot get around? For example, it might have wheels, legs, treads, or be able to fly.**
- **What kinds of sensors will it need? For example, it might need sensors for touch, light, location, or speed.**
- **Does it need grippers, claws, or other tools to move things around in the outside world?**
- **What types of material is it made of? Are they light or heavy, big or small, hard or soft?**
- **How does it interact with people? Does it need to be compliant (safe to use around people)? Do people need to feel comfortable talking to it?**
- **What does it look like?**

The Design Thinking Process

The Design Thinking Process is a series of steps that help you to identify and work through problems as you develop your robot. Here is a typical series of steps in the Design Thinking Process:

- Pick a challenge/define a problem.
- Research the problem.
- Brainstorm possible solutions and choose a solution to test.
- Design and build a prototype.
- Test the prototype.
- Iterate as needed.
- Share your project.

Biomimetic Robots and the Uncanny Valley

When robots borrow designs from animals, plants, or other living things, they can work more efficiently. This is called biomimicry.

The SpotMini robot dog, built by Boston Dynamics, looks and moves very much like a real dog. But it has one important difference—in place of a head, it has cameras and sensors built into its chest.

Some versions also have a mechanical arm where a head would normally go. The arm allows the robot dog to turn door knobs, load dishes into a dishwasher, and perform other useful tasks.

However, for many people, the SpotMini falls into the **uncanny valley**—the point at which an artificial life form looks more creepy than cute.

STEP 3

Plan your prototype

A prototype is a model that lets you design and test your robot idea (or some part of it) to see how well it works.

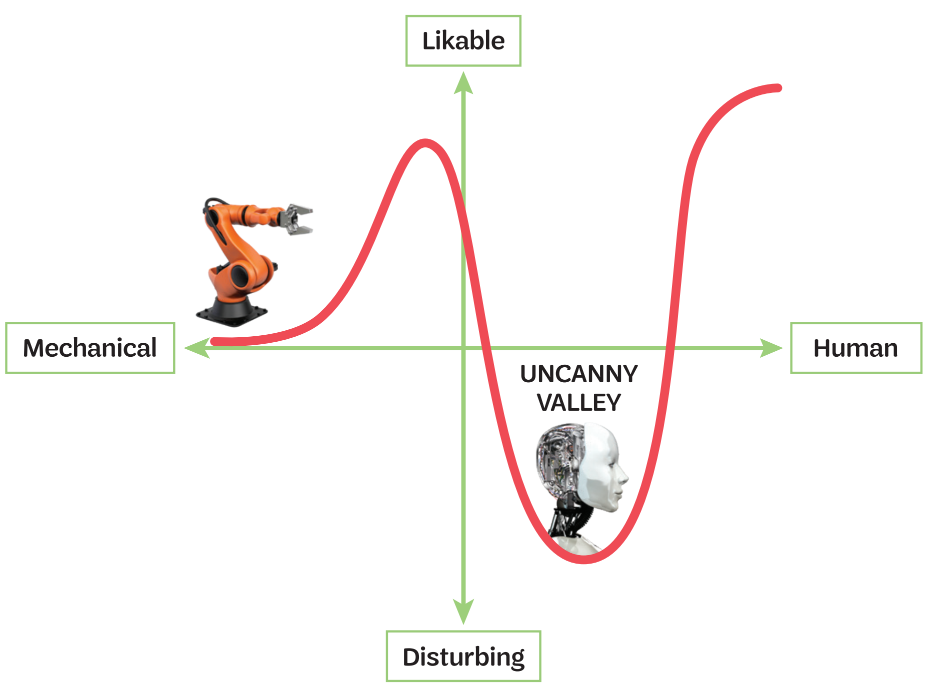
Think of it as a rough sketch in physical form. It doesn't have to be high tech or expensive. In fact, most projects go through several iterations and multiple prototypes, hopefully improving them each time. That means materials that are easy and quick to work with are best.

Engineers will sometimes use toy building sets, such as LEGO® bricks, for their prototypes. They may also custom design parts using laser cut cardboard or 3D-printed plastic models. For your prototype, you can use any tools and materials you have available. To start, create a build plan. Think about how you'll demonstrate how your robot, or some part of it, works.

As you're planning, keep these thing in mind:

- **Deadline—**How much time do have to produce a working model? Keep track of time and materials and make sure all the parts come together on schedule.
- **Documentation—**How will you make a record of your project? You can take notes, make drawings, or shoot photos and video.
- **Packaging—**Work on making your robot look appealing to the people who will be using it.

Uncanny Valley—Likable or Disturbing?



STEP

4 Build a prototype

A prototype lets you visualize and test your design. When designing and building robot prototypes, researchers often start by testing one part, such as a robotic gripper.

Once that's working, they may test their gripper on different kinds of robot arms. Then on the next version, they may add programming to control the gears, levers, and motors.

As you build your prototype, don't worry if it doesn't work like the real thing—you may not be able to add motors, electronic sensors, or controllers to your prototype, but you can show where they should go on the finished robot.


Kamigami™ robot

Using only cardboard templates and an app to program, Kamigami™ robots can be designed to move, do tricks and compete against one another.

STEP

5 Get feedback on your robot

Getting feedback on a project is an important part of the Design Thinking Process. Engineers and roboticists usually share their work with their peers and coworkers. They will also seek out experts with more experience to make suggestions.

And don't forget to get feedback from the people who will be using your design! They are the ones who can really tell you whether your idea is successful. When your prototype is ready, share it for feedback and use what you learn to improve your design.

Robot Research Using Everyday Stuff

Robots are often made with the latest high-tech materials—but scientists can and do make prototypes out of anything they have lying around.

A team from Cornell University and the University of Chicago created an early version of a vacuum-activated robot gripper by filling a party balloon with coffee grounds.

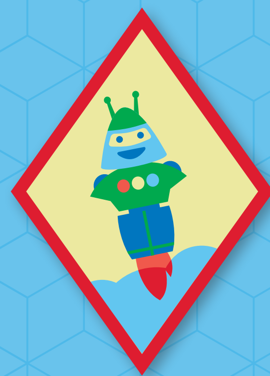
In San Francisco, the company Otherlab prototyped its inflatable robots with rubber bicycle tubes.

And graduate students from Stanford University turned early prototypes of laser-cut cardboard insects into a popular toy robot for kids called Kamigami.™

Now that I've earned this badge, I can give service by:

- Creating a robotics workshop for younger girls.
- Learning more about cool new robots and letting people know about them.
- Creating a presentation about the many ways robots can help solve everyday problems and sharing it with others.

I'm inspired to:



Badge 3: Showcasing Robots

After engineers build a working version of their robots, they release them to the public. They may enter them into challenges and competitions or market them through a website or crowd-funding campaign. Now that you've built your robot prototype, it's time to share your design with others and explore a future in robotics.

Steps

1. **Learn about robotics events and organizations**
2. **Create a presentation about your robot**
3. **Present your robot pitch to others for feedback**
4. **Find out about robotics opportunities for teens**
5. **See robot makers and robots in action**

Purpose

When I've earned this badge, I'll know how to share my robot designs with the world.

STEP

1 Learn about robotics events and organizations

You can see and participate in robotics events around the country.

Here are some places to check out:

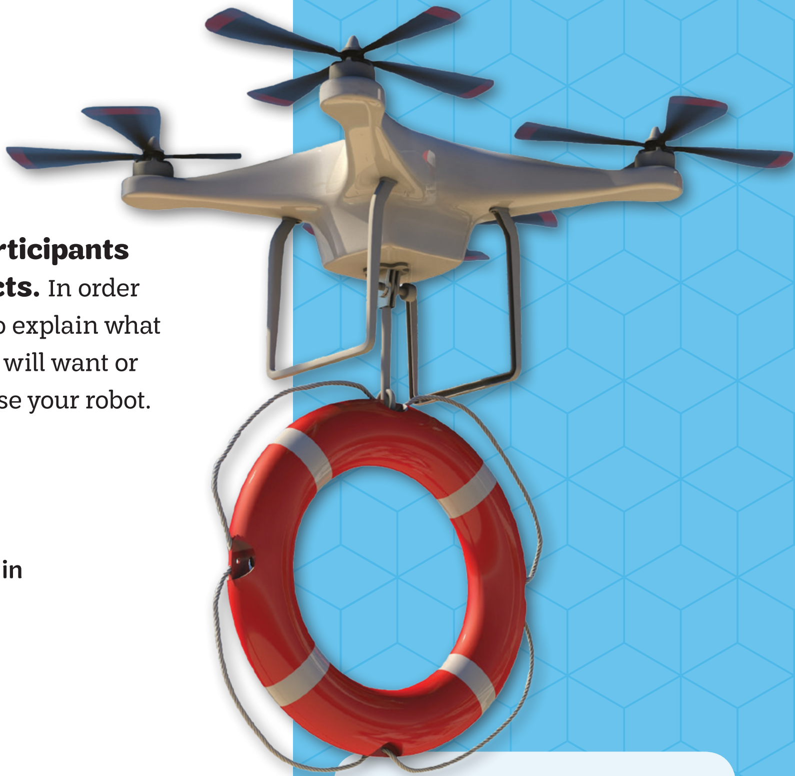
- **Middle, high school, and college robotics competitions—**In robotics competitions, teams build robots according to official regulations and face off against robots from other teams as they complete a series of tasks while preventing their opponents from finishing first. Other kinds of science competitions accept robotics projects as well. Many are held by nationwide organizations at local, regional, and national levels for a variety of ages. For example, you might have heard of FIRST or VEX robotics competitions.
- **Maker Faires, maker expos, and state and county fairs—**Maker Faires and other kinds of maker expos are free to exhibitors and often feature robotics areas. They are frequently hosted at schools, libraries, and museums. Although they are noncompetitive, some events award ribbons to exhibitors in different categories. State and county fairs sometimes feature robotics among other maker, engineering, and handicraft exhibits as well.
- **Science festivals—**Science festivals are locally produced events that may include engineering and robotics. There are also major national events like the USA Science Festival in Washington, DC, and the World Science Festival in New York City.

FIRST Robotics Competition

Thousands of teams from around the world, including Girl Scout teams, take part in the FIRST Robotics competition every year. In 2010, a team of 11- to-13-year-old Girl Scouts called the Flying Monkeys won a $20,000 FIRST LEGO League Global Innovation Award from the X Prize Foundation for their invention, the BOB-1. Made from moldable plastic and Velcro, the BOB-1 allowed a little girl who was born without fingers to hold a pencil. The team also won a patent application for the device, which cost less than $10 to build.

Girl Scouts at a robotics competition

STEP 2 Create a presentation about your robot



Many student robotics competitions require participants to make short presentations about their projects. In order to let people know about your robot, you have to be able to explain what it does, how it works, and why it is something that people will want or need. Create a presentation that you could use to showcase your robot.

You might include important information like:

- The robot's name
- The kind of environment it is designed to operate in
- What it's designed to do
- How it senses, thinks, acts
- What makes it special or unique

STEP 3 Present your robot pitch to others for feedback

Giving and receiving feedback in a helpful way is an important skill to develop. As you listen to others present, ask useful questions that will get someone talking about their robot. For example, you could ask, “What is the purpose of this robot?” or “How well does it meet its goal?” Be sure to point out what you like about a design as well as make suggestions for improvements.

Flying Robot Lifeguards

In 2018, a lifeguard in Australia saved two teenagers with the help of a robotic drone he was testing out. In just over a minute, the lifeguard spotted the boys struggling against ocean waves with the minicopter’s camera. He instructed the drone to drop an inflatable device nearby so the teens could float back to shore. More advanced models of the rescue drone also use AI to analyze images from its camera and identify sharks.

STEP
4 Find out about robotics opportunities for teens

People involved in developing and using robots come from a wide range of backgrounds. There are a few universities that offer undergraduate (bachelor's) degrees in robotics, but in most cases students earn their undergraduate degree in another area, and then go on to study robotics in graduate school. And sometimes people work in the field of robotics after studying subjects that seem totally unrelated. How could a musician use robotics? What about a mathematician? Brainstorm how robotics can be incorporated into interests you have and things you already like to do.

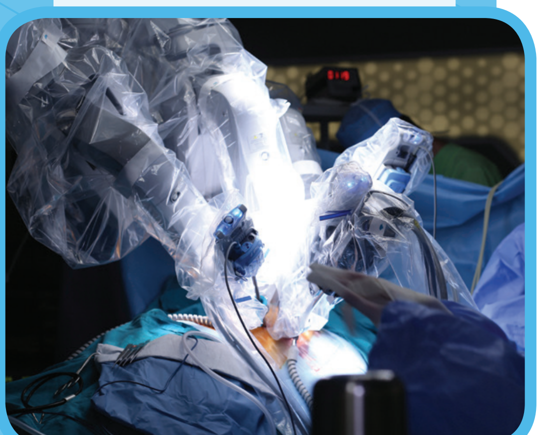
STEP
5 See robot makers and robots in action

There may be robots used in places around your community or nearby. Some of the places you can observe robots and meet robot builders and technicians include:

- Hospitals and surgery centers
- College and university robotics, engineering, or computer science departments
- Factories and warehouses using industrial robots
- Robotics and engineering companies
- Farms using milking robots and drones
- Science museums
- Science education companies and camps
- Makerspaces
- Robot hobby clubs or organizations
- Robotics events

Medical Robots

You may find robots at work in the most unlikely places —including hospitals and surgery centers. The DaVinci Surgical System is a robot that helps doctors by translating their movements to tiny, more flexible instruments. Surgeons can perform delicate operations more quickly and accurately. And because it works on a smaller area of the patient, recovery is shorter and easier as well. In the future, surgical robots might allow doctors to operate on patients far away as well as right next to them.



Now that I've earned this badge, I can give service by:

- Presenting my robot prototype to students in my school or to other Girl Scouts to get them interested in robotics.
- Volunteering to help with robotics classes at my local community center or elementary school.
- Organizing or joining a robotics team that enters competitions or pursuing a challenge of my own choosing.

I'm inspired to:

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