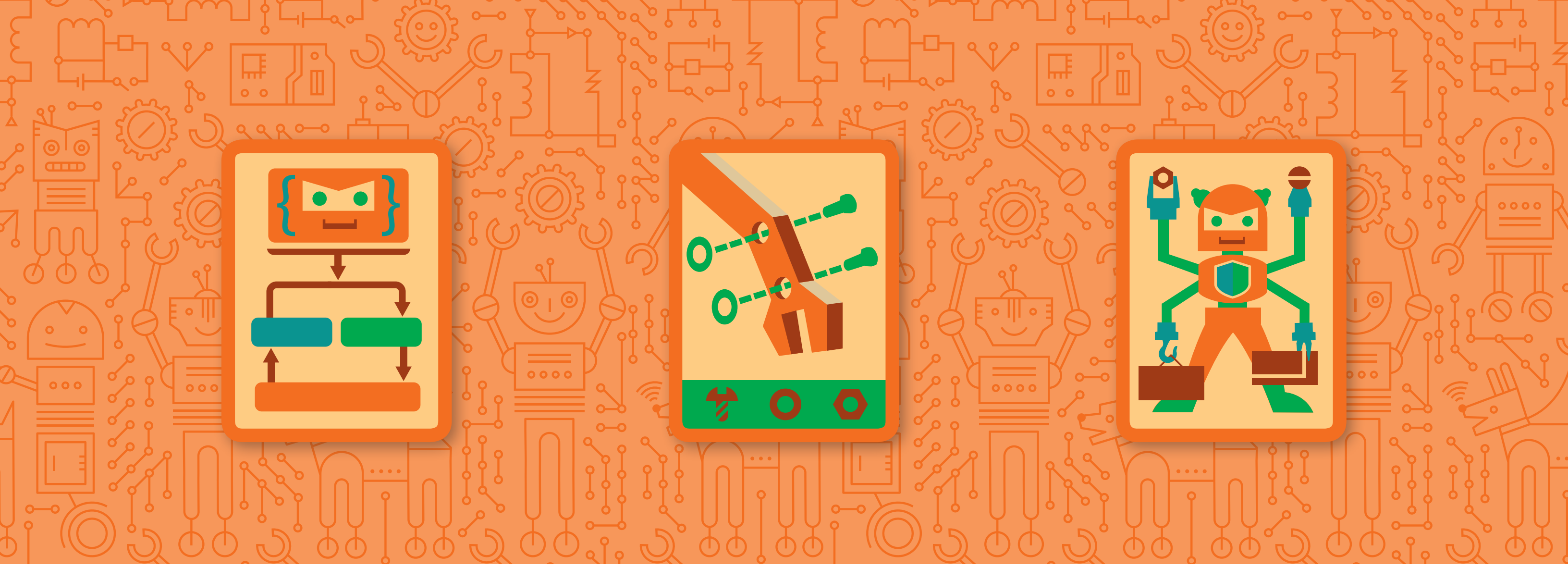


Senior Robotics

Develop your robotics skills by earning these three badges!

Badge 1:
Programming Robots

Badge 2:
Designing Robots

Badge 3:
Showcasing Robots

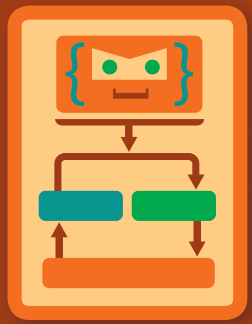
This Robotics badge booklet for girls provides the badge requirements, information, and fun facts about robotics for all three Senior robotics badges. It does not include all the information needed to complete the badges. Volunteers may access full meeting plans—including detailed activity instructions—on 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.

More and more, robots and robotic technology are popping up around our homes, our communities, and the workplace. And when you understand how robots work, you'll be better prepared to make the most of them!

Find out what you can do with robotics right now and how you can get more involved in the future. Maybe you'll be part of the next big robotics revolution!



Badge 1: Programming Robots

Robots are all around us. In fact, robots are starting to take over many jobs once done by humans, from vacuuming floors to driving delivery trucks. And robotics technology is now used in the devices we use everyday, from smartphones that can tell us the nearest pizza place to fitness wristbands that tell us how many steps we took today. To understand more about how robots work, explore the parts and systems that make up a robot, and then learn about different ways to control a robot, including computer programming.

Steps

1. **Learn about robots**
2. **Build a robot part: robot arm**
3. **Learn how robot systems work together**
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.

A Short History of Robots

1940s

In the 1940s, science fiction writer Isaac Asimov came up with the idea of Three Laws of Robotics to prevent a robot uprising. In his stories, the laws were programmed into every robot. They said: a robot must never harm a human, must always obey a human's orders, and always protect itself if it can without breaking the first two laws.

1967

MIT professor Seymour Papert created a simple computer language in 1967 called Logo to teach children coding by programming "turtle" robots to move around a grid. Papert's ideas led to the development of the LEGO® Mindstorms robotics kit in 1998.

2015

According to The International Federation of Robotics, in 2015 more than three million domestic robots were cleaning floors, mowing lawns, and cleaning swimming pools in homes around the world. That number was expected to rise to 30 million within a few years.

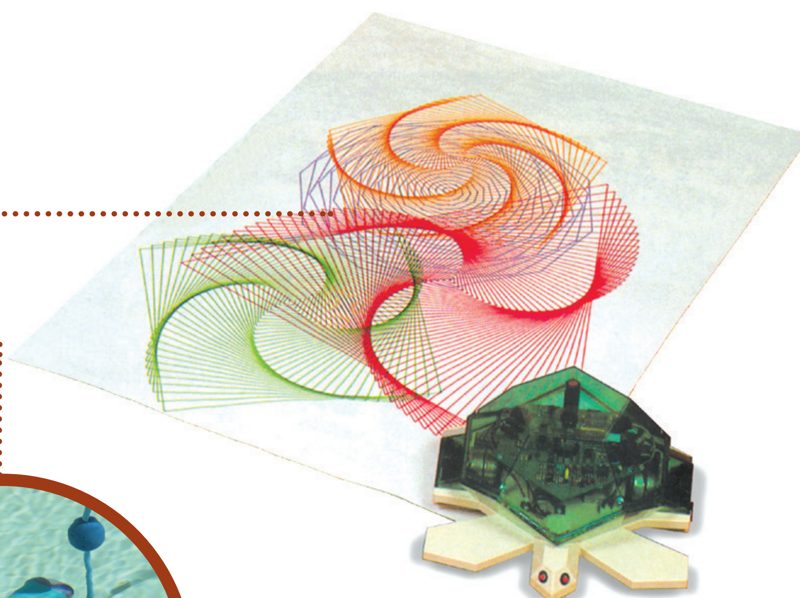
STEP 1 Learn about robots

Robots are machines that can detect what's going on around them and use that information to decide how they will interact with the physical world. That's what makes them different from ordinary appliances, which need a human to turn them on and run them.

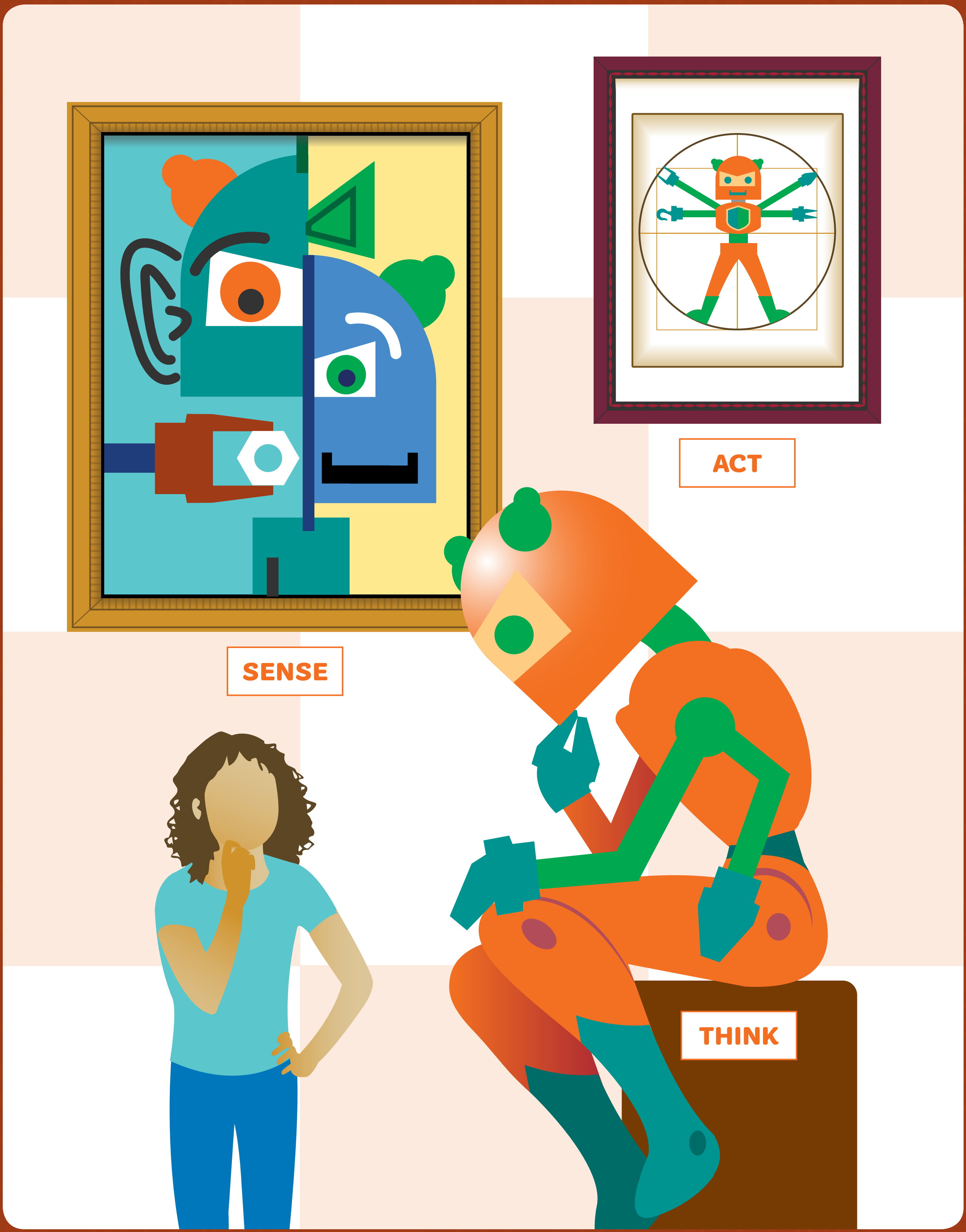
Scientists call this the Sense-Think-Act definition because a robot can usually perform three functions:

> **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.

Think about the many challenges a robot could be programmed to solve. What features and parts would the robot need to sense, think, and act?



The Valiant Turtle Robot, first used in the 1980s, is programmed using Logo to move and draw with a pen.


SENSE
ACT
THINK

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.

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.

Biomimicry means using animals, humans, or other living things as models for a robot's design.

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

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

The **Design Thinking Process** is a method used to create good, useful products. The steps include defining a need, designing and building a prototype, testing it, and then making improvements by repeating the process.

Degrees of freedom are the number of directions a robot part can move.

Documentation refers to keeping a record in words and pictures of designing and building a project.

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

Housing refers to a robot's body.

In a **hydraulic system**, liquid under high pressure is pushed back and forth. When you push in a controller on one side, a piston on the other side is pushed out. When you pull the controller out, the piston moves back in.

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

Iterate means to repeat something over again.

Locomotion is the ability to move from one place to another.

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

Open source designs are made public so that anyone can study, modify, and make their own versions of them.

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 **prototype** is a rough model used for visualizing and testing a design.

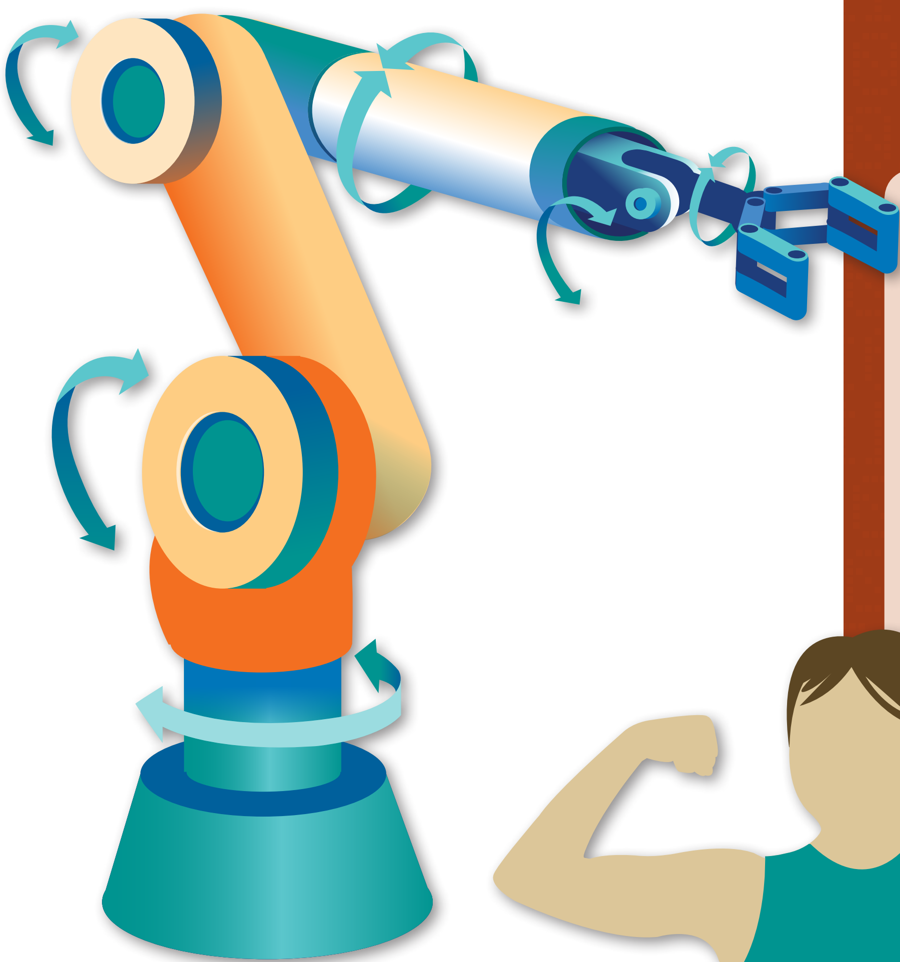
A **sensor** is an electronic component that transmits information to the robot about its environment.

A **swarm** is a group of robots that work together to complete complicated tasks, such as assembling buildings.

STEP

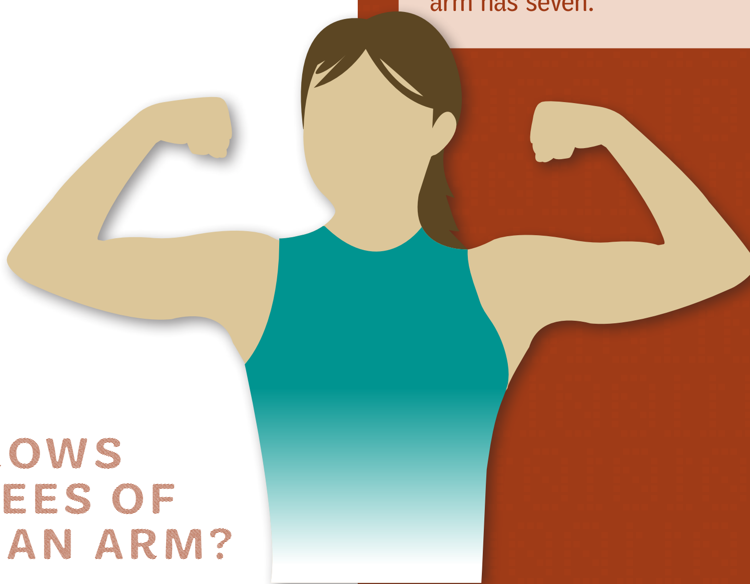
2 Build a robot part: robot arm

One of the most common types of robots consist of only an arm. In factories, robot arms are used to move heavy objects. Their power comes from hydraulic systems that push pistons open and closed with high pressure liquids. But robot arms can also make it possible to perform superhuman tasks such as delicate microscopic surgery, making them one of the most versatile types of robotic machines. Build a simple robot arm that uses hydraulic systems and is made of everyday materials. Once you understand how the system works, see if you can add a robot gripper that you can use to pick something up!

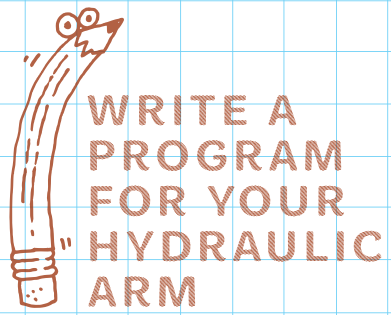


Degrees of Freedom

The more joints on a robot arm, the more ways it can bend or turn. The number of directions a part can move are called its “degrees of freedom.” A robot arm typically has six degrees of freedom. A human arm has seven.



CAN YOU DRAW ARROWS SHOWING THE DEGREES OF FREEDOM OF A HUMAN ARM?

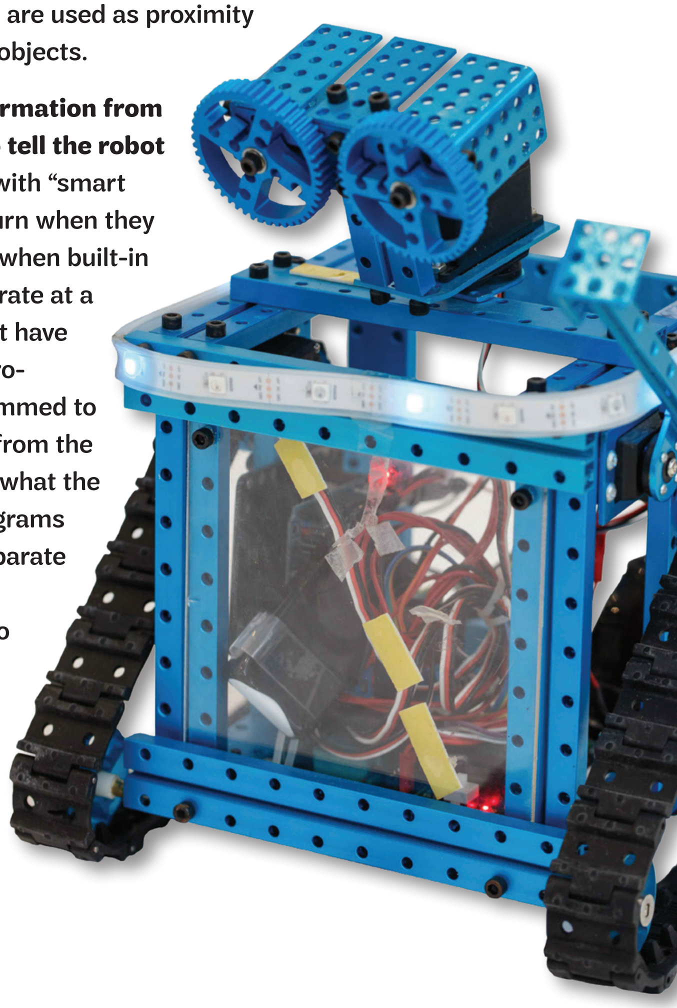


STEP

3 Learn how robot systems work together

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

- **The robot's *housing* is its body.** It can be made of anything from metal and plastic to inflatable vinyl, lightweight cardboard, or soft silicone rubber.
- **The robot is powered by its *actuators*.** The actuators take energy supplied to the robot and convert it into physical motion. They include motors that spin and pistons that go back and forth. The energy can come from sources including batteries, solar panels, air pumps, or hydraulic systems.
- **The parts of a robot that move around are called its *effectors*.** Legs, wheels, treads, arms, grippers, and propellers are all types of effectors.
- ***Sensors* transmit information about the environment to the robot.** They include touch or pressure sensors, light sensors and cameras, microphones (audio sensors), thermometers (temperature sensors), and tilt sensors. GPS and accelerometers measure speed and direction. Radar and sensors that measure infrared, microwave, and electromagnetic radiation are used as proximity sensors to detect nearby objects.
- ***Controllers* take the information from the sensors and use it to tell the robot how to respond.** Robots with "smart bodies" are designed to turn when they bump into an obstacle or when built-in motors cause them to vibrate at a certain speed. Robots that have electronic circuits or micro-controllers can be programmed to process electrical inputs from the robot's sensors to decide what the robot should do next. Programs can also be written on separate computers or even smart phones and transmitted to the robot wirelessly.



This robot has treads for effectors and housing made of plastic and metal.

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. For a robot, the instructions are based on information, or input, about conditions in the physical world. A flowchart is a diagram that shows an algorithm as a kind of map. Decisions are shown as questions. Each response, or output, leads to a different path.

To learn about programming robots, choose a familiar task and write down instructions for how you carry it out in the form of a flowchart.

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. If you need to repeat a set of steps in a computer program, you can use a shortcut, such as a loop or a function:

- **A loop tells the program to go back and repeat a series of commands.**
- **A function is a series of commands that is given a name. It is like a mini-program within the main program. When you "call" the name of the function, those steps are carried out at that point.**

Pseudocode uses commands in regular human language. Use your flowchart to write a computer program in pseudocode. The only rule for your program is that it should be easy to understand.

AI Robots

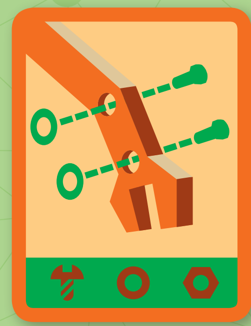
Artificial intelligence or AI is a type of computer program that acts as if it can think like a human. AI devices—like the personal assistant on your smartphone—can answer questions and hold conversations with people in ordinary language.

AI also lets robots interact with people more easily. Some AI robots learn to perform a task or follow directions by watching and listening to the people working with them. For search and rescue robots, AI helps them identify things they see or sense around them to make autonomous decisions about what to do next.

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

- Creating a program to problem solve for others.
- Sharing simple robot-building projects with younger children in the community.
- Finding and sharing information with others about resources in the community that offer robotics activities.

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 for a new kind of robot that helps or replaces people who work in difficult or dangerous situations.

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.

Underwater Robot

SoFi (pronounced "Sophie") is a soft robotic fish created by MIT's Computer Science and Artificial Intelligence Lab to help biologists explore life in coral reefs by collecting information with cameras and environmental sensors.

She's small, quiet, and wireless, so she can swim among real fish without disturbing them. Human operators steer her around using a special waterproof Super Nintendo video game controller. They can send her commands in the form of high-pitched sound waves, like whale songs.

SoFi picks up the signals through her hydrophone (underwater microphone) and sends back information about her location the same way.

Joseph DelPreto, MIT CSAIL

STEP 1 Pick a challenge

Some robots are designed to go into places humans can't go easily.

To allow them to work in difficult environments, these kinds of robots often have unique designs.

For example:

- Search and rescue robots can go into earthquakes, radiation-leak, or other kinds of disaster areas to locate survivors. They may look like small-scale tanks, planes, or quadcopters.
- Soft, stretchy, air-powered robots can crawl, slither, or swim to fit through tight openings.
- Suction or bumpy-fingered robots can climb up walls and other smooth surfaces.
- Robots so tiny they can be swallowed or injected can make repairs to the body from the inside.
- Small self-folding disposable origami robots can work together in **swarms** or be stored flat inside larger robots until needed.

Think about ways that robots can operate in extreme conditions—what problem could you solve with a new robot design?

STEP 2

Explore possible solutions

Robot designers look in all kinds of places for ideas that might lead to new kinds of robots.

They look at ordinary machines and think about how to make them autonomous.

They look at nature, particularly the animal kingdom, for ways to make robot bodies more efficient.

They look at humans to see how they handle their jobs and what could make those tasks easier.

Finally, they consider earlier robot designs and how they can be improved or adapted to serve a new purpose.

How could a robot help to solve your challenge? Now that you have defined the problem, look around for inspiration and brainstorm how a robot could help you reach your goal.

Questions to ask yourself:

- **What kind of place does your robot have to operate in? For example, will it be in the vacuum of space or in extreme heat?**
- **Does your robot work alone or does it interact with other machines or with people?**
- **Is there a size or weight limit?**
- **What materials can be used—does it have to be waterproof, fireproof, crush-resistant?**
- **How does the robot get around? For example, it might fly, swim, crawl, roll, or run.**
- **Can it be reused or is it single-use?**
- **What sensors does it need? If there are no sensors, does the robot detect what is around it?**
- **How is the robot controlled? Does it require human controllers or is it completely autonomous? If there are no electronics, does the robot's design let it respond to its environment?**
- **Does the robot have to be safe to use around humans (compliant)? Does it have to be people-friendly (social)?**

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 to take using 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

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.

When making robot prototypes, researchers often start by building primitive models. For instance, to create a robotic arm that responds to thought commands, they may first just build a working mechanical version of a hand.

In later versions, they may attach the hand to an arm. When those parts are working together, they may add remote control. Finally, when they have the kinks worked out of the other parts, they add electronic sensors and programming.

Think about what you can build to demonstrate how your robot, or some part of it, works. As you're planning, keep these thing in mind:

- **Tools and materials—**What supplies do you have access to?
- **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 videos.
- **Packaging—**How can you make your robot look appealing to the people who will be using it?

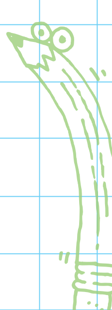

NASA

Canadarm

On the International Space Station, astronauts can stay inside and use the Canadarm2 (built by the Canadian Space Agency) to do work outside the spacecraft.

The 60-foot-long arm lets them grab and dock incoming spacecraft, such as resupply ships. The arm slides back and forth on a track system that runs along the entire width and can also be operated by ground control on Earth.

Sometimes astronauts hook themselves up to the arm during space walks to ride around the space station as they work.



STEP 4 Build a prototype

A prototype shows how a robot might look and act, but it doesn't always represent the entire robot. Early prototypes may focus on one important section at a time. To test the size and look, a prototype can also be a nonworking mock-up. If the proposed robot is large, the prototype can be a scale model which is roughly the same shape as the finished design but much smaller.

When you build your prototype, don't worry if it doesn't work like the real thing. It is more important to have something to show to others to demonstrate your idea than to make it perfect!

STEP 5 Get feedback on your robot

Testing a prototype is a vital part of the Design Thinking Process because it gives you feedback about what works and doesn't. That feedback can include your own observations and measurements, suggestions from other people you work with, and advice from supervisors and experts.

For any design project, however, the most important feedback comes from the people who will be using it. A design isn't successful unless the intended users can get it to do what they need it to do!

Share your design with friends, family, or technical experts to get their opinions, and use the feedback you gather to improve your design.

Squishy Grippers

One of the biggest challenges in robotics is creating a universal robot hand strong enough to lift heavy objects but gentle enough to avoid crushing delicate items.

Soft robotic grippers may be the answer. Some look like stubby octopus arms. They open and close when you pump air into chambers inside them.

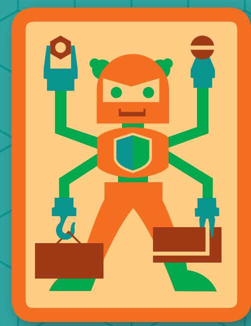
Jamming grippers use a sack filled with small grains of material. They start off floppy, like a bean bag chair. But when the air is sucked out of them, the grains pack themselves tightly around whatever they are touching, forming a solid holder.

Fun fact: The prototype for the original jamming gripper was built at Cornell University using a rubber party balloon filled with dry coffee grounds.

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

- Helping younger children build a simple robot prototype.
- Learning more about cutting-edge robot design and sharing that information with others.
- Finding more problems that can be addressed using robotics and looking for ways to solve them.

I'm inspired to:



Badge 3: Showcasing Robots

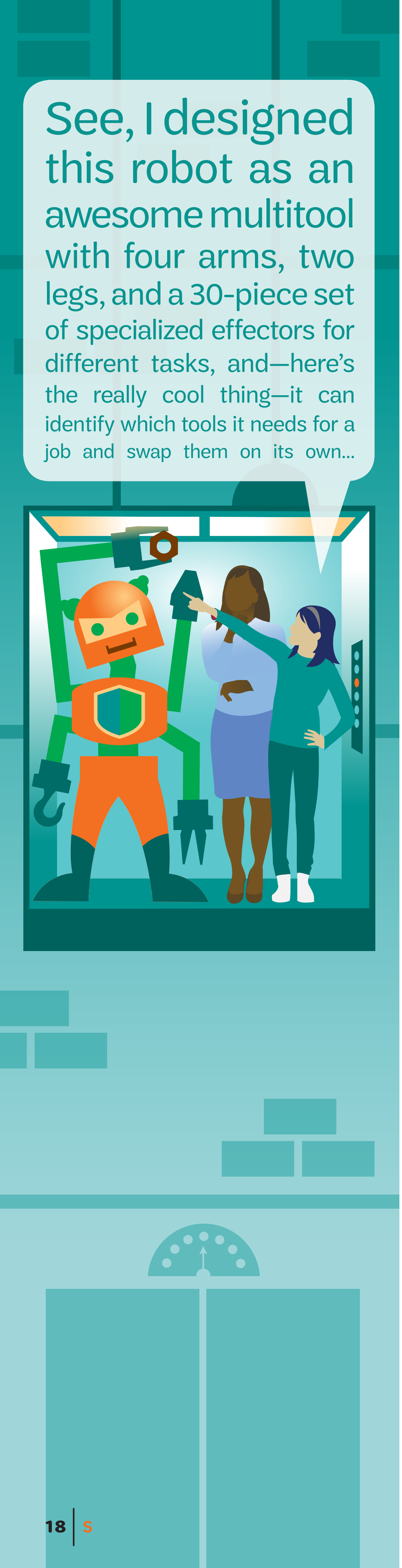
After engineers build their robots, they show them to others and enter them into challenges and competitions. Now that you've built your robot prototype, it's time to share your design with others and explore robotics competitions.

Steps

1. **Create a presentation about your robot**
2. **Present your robot pitch to others for feedback**
3. **Hold a mini robotics competition**
4. **Explore robotics opportunities in high school, college, and beyond**
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 Create a presentation about your robot

Many student robotics competitions require participants to make a short presentation about their project.

For your robot, develop an elevator pitch—a short, enthusiastic explanation of your project.

Here are some things to include:

- A brief description that is simple but grabs the listener's attention
- The type of people who will be using or helped by your robot
- Why people need it or its purpose
- Why it's better than the competition
- What you need to make your idea a reality

STEP 2 Present your robot pitch to others for feedback

Giving and receiving feedback is an important skill to develop. In robotics, most people work in teams. Learning how to communicate your ideas and opinions to others in a helpful way will make you a more valuable team member. People are more open to hearing what you have to say when you acknowledge the positive things they have done as well as make suggestions for how it might be done better.

Find a friend, family member, or community member with an interest in robotics education who will listen to the presentation and give you useful suggestions about how to make your robot—and your presentation about it—better.

STEP

3 Hold a mini robotics competition

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

- **Middle, high school, and college robotics competitions—**Student teams build robots, sometimes to fit a yearly theme, to face off against robots from other teams in local, regional, and national competitions. For example, you might have heard of FIRST or VEX robotics competitions.
- **Maker Faires, maker expos, and state and county fairs—**Maker Faires and maker expos are free to exhibitors and often feature robotics areas. They are frequently hosted at schools, libraries, museums, and county fairs. Exhibitors may receive ribbons in different categories.
- **Science festivals—**Science festivals are usually local 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.

Now that you've built a robot, hold a mini competition. Set the rules, create your game field, prep your robot, and let the competition begin!

Girl Scout at a robotics competition

Next Stop: Maker Faire!

Go to a local Maker Faire and you are sure to see robots of all kinds, from robots that make art, knit scarves, play music, cook pancakes to giant robots that shoot out flames.

Maker Faires and other maker events are held in schools, science centers, and fairgrounds around the world. They are a place where engineers, artists, and hobbyists gather to share their projects and see what new things are happening in their areas of interest.

Robotics teams, clubs, and individual robot makers, both kids and adults, often have booths where they show off their latest creations. It's usually free to exhibit at a Maker Faire, so they are a great place to get experience talking to the public about your robot projects.

STEP

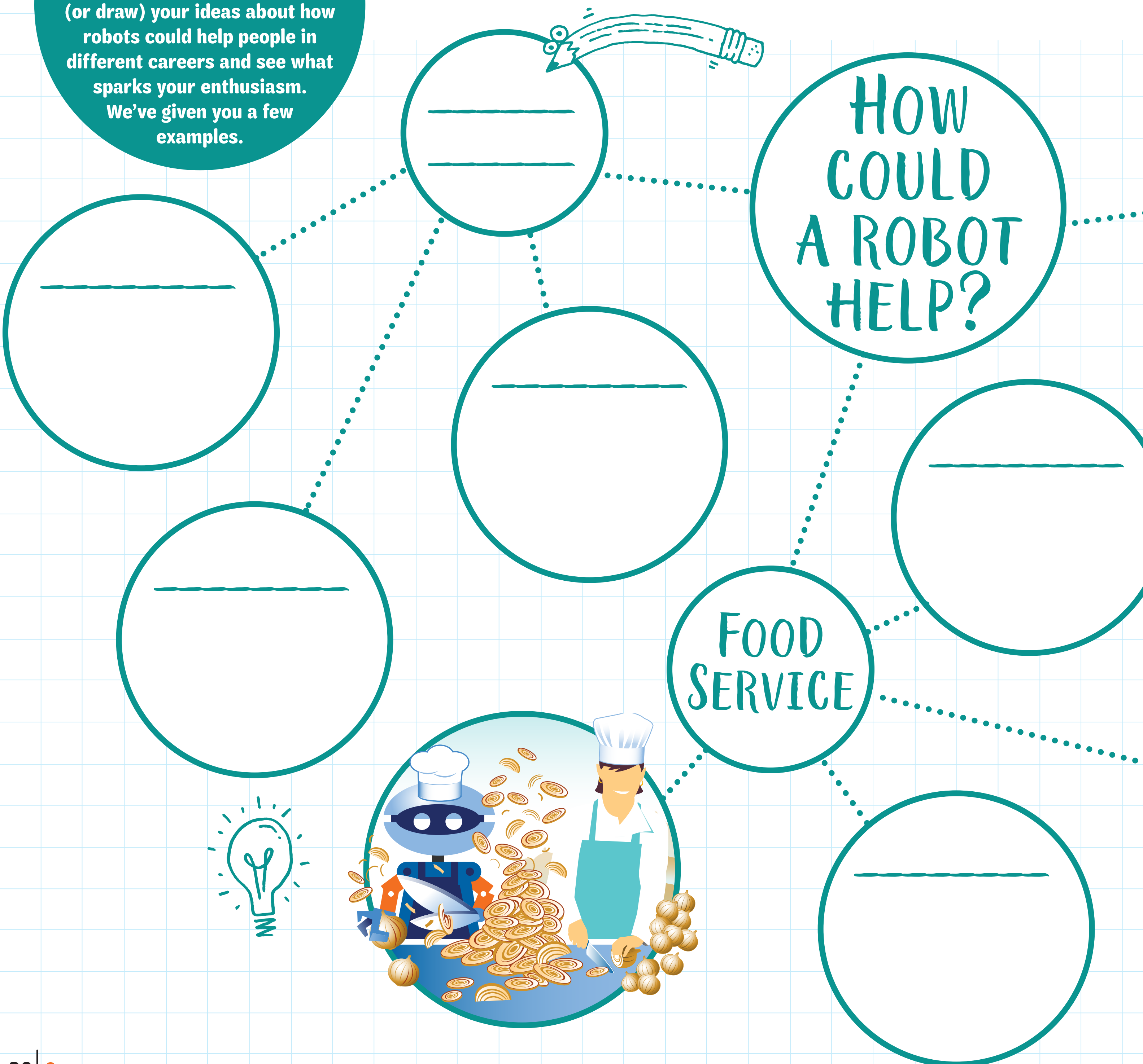
4 Explore robotics opportunities in high school, college and beyond

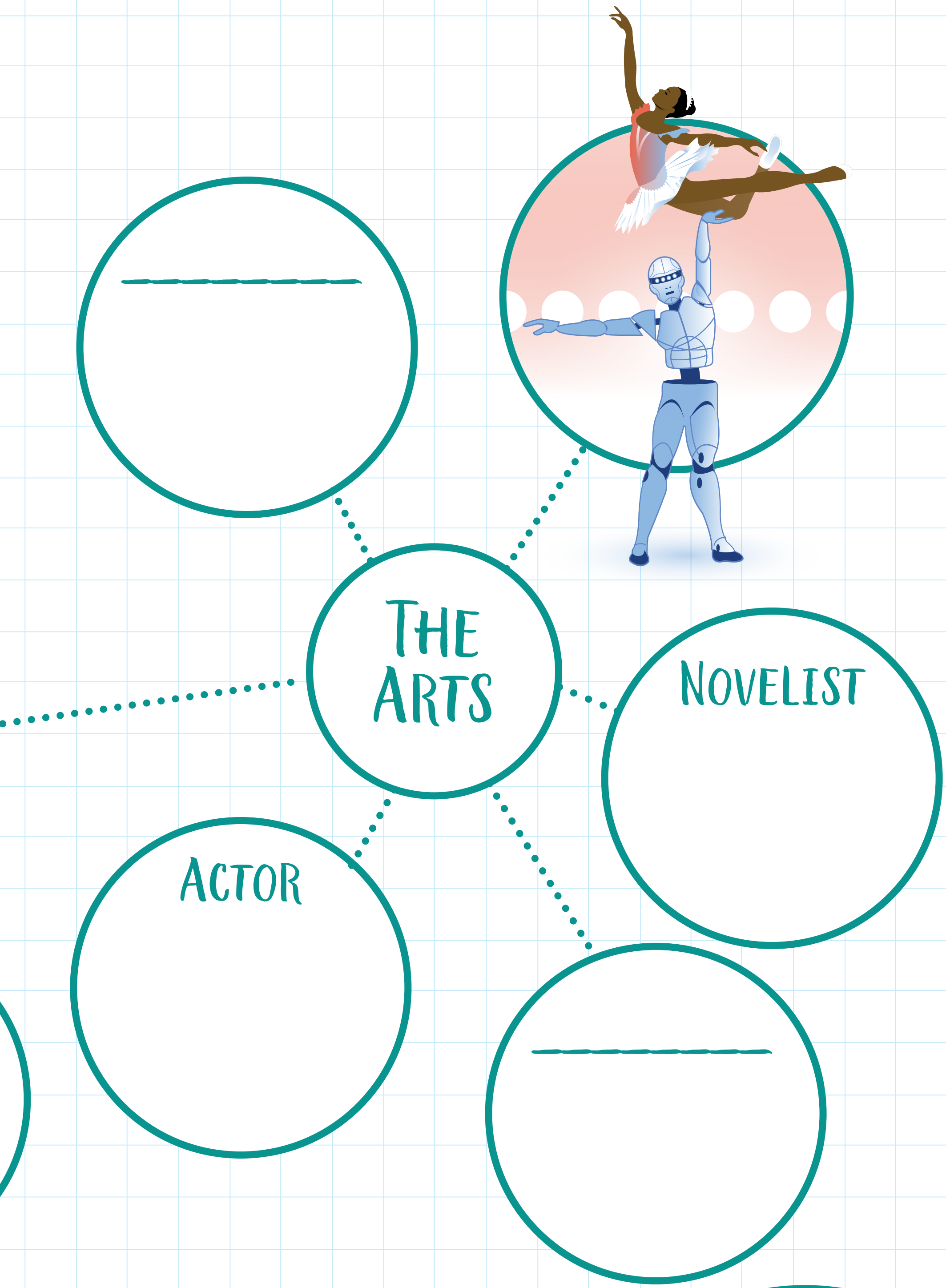
People who work with robots come from a wide range of backgrounds. Sometimes people work with robots after focusing on subjects or being in a profession that seems totally unrelated.

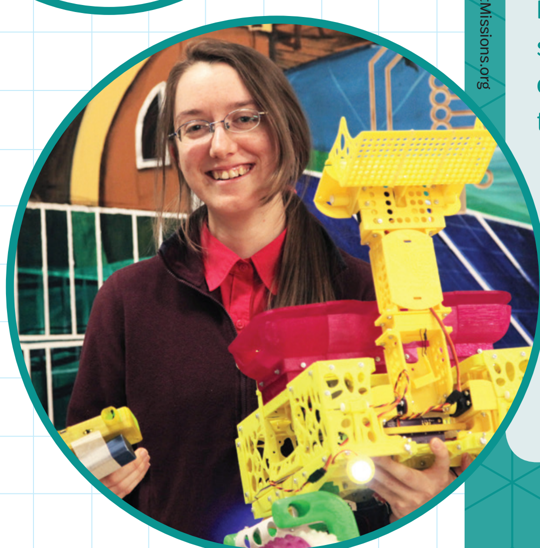
What sort of roboticist are you? Brainstorm what interests you and how workers in different careers could utilize robotics to make their jobs easier or more effective.

Make a Mind Map

Sometimes it only takes one brain to brainstorm. Jot down (or draw) your ideas about how robots could help people in different careers and see what sparks your enthusiasm. We've given you a few examples.







RobotMissions.org

RobotGrrl and Robot Missions

Erin Kennedy (also known as RobotGrrl) of Toronto, Canada, began building robots when she was 13. Her first big project after college was RoboBrrd, a programmable open-source robot with a body made using craft sticks and felt. RoboBrrd won awards at Maker Faires and the gold medal at the RoboGames competition.

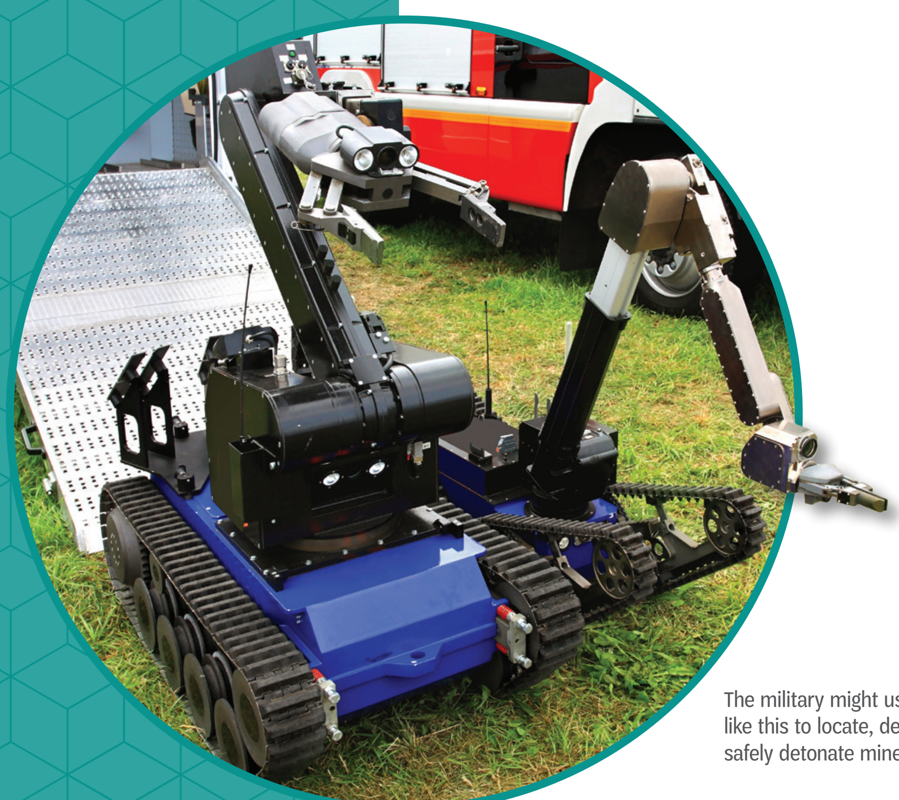
After studying new rapid prototyping technology through residencies at top robotics companies and schools, she started the organization Robot Missions. Robot Missions and a community of volunteers are working to develop an open-source 3D-printed robot named Bowie. Bowie has interchangeable parts that lets it collect shoreline debris like, bottle caps and cigarette butts.

Erin raised the money to start her project by creating a crowdfunding campaign in 2016 that took in over $10,000 from nearly 100 investors. Robot Missions helps to educate the public about robotics through school programs and public field tests at parks and beaches, drawing volunteers from Canada and the United States.

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
- Maker spaces
- Robot hobby clubs or organizations
- Robotics events



The military might use a robot like this to locate, detect, and safely detonate mines.

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

- Volunteering at robotics competitions in my community.
- Partnering with an elementary school to present a robot showcase.
- Helping my Girl Scout council hold a robotics event.

I'm inspired to:

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