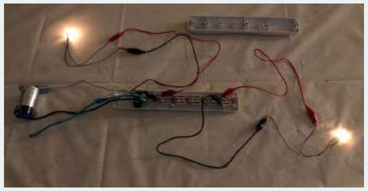
Lesson 2: What structures in the system enable energy transfer from one source to multiple devices, buildings, and neighborhoods?

Previous Lesson *We explored widespread blackouts in Texas. We modeled our electricity production system. We developed questions and brainstormed how we could design more reliable systems to meet our communities' energy needs. We decided to document the electricity infrastructure in our homes and communities to look for patterns that could help us understand how the system works.*

This Lesson

Investigation

2 days



We compared photos and drawings of structures that provide electricity in our buildings and neighborhoods. We dissected a power strip and connected it to a battery to power multiple devices. We read about the function of ground wires and circuit breakers. We developed a model of how structures of the power strip system enable it to transfer energy from one source to multiple devices. We used this model to draw parallels to larger-scale systems (buildings, neighborhoods) and test the effects of short circuits and broken circuits.

Next Lesson *We will read about an energy crisis that began in Ohio, and a strategy used by engineers to prevent short and broken circuits in power lines. We will keep track of our ideas in the Engineering Design Tracker. We will develop a new representation to model energy transfer through parts of the system. We will analyze electricity demand and supply data in Texas and use this to brainstorm ideas of where to go next.*

BUILDING TOWARD NGSS

HS-PS2-5, HS-PS3-1, HS-PS3-2, HS-PS3-3, HS-PS3-5, HS-ESS3-2, HS-ETS1-3, HS-ETS1-4

What students will do

2.A Collect data from a designed system (a power strip) and a network of interconnected subsystems (multiple powerstrips) on the interactions needed for and failure points in the transfer of electrical energy. (SEP: 3.6; CCC: 4.1; DCI: PS3.A.4)

2.B Develop, revise, and use a model to identify analogous structures that affect the electrical energy transfers across and between different (sub)systems at different scales (a powerstrip versus a building). (SEP: 2.3; CCC: 4.1, 6.1; DCI: PS3.B.2)

What students will figure out

- Energy will transfer from a source to a device when a complete circuit is formed, but it will stop transferring immediately when there is a break in any of those paths (a broken circuit).
- Plugging in an electronic device creates a giant circuit from that device to a power source that may be far away.
- When energy transfers through a circuit system without powering any devices, we call this a short circuit. A short circuit occurs when there is a direct conducting path from one side of the energy source to the ground or to the other side of the source. A single short circuit in a system can cause blackouts in the entire system.

Lesson 2 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	6 min		**NAVIGATE** Share what we took photos of and what we noticed.	A	home learning artifacts from Lesson 1
2	4 min		**IDENTIFY IMPORTANT SAFETY PRECAUTIONS** Identify important safety precautions and safer sources of energy we could use.	B	Safety poster
3	8 min		**DISSECT A POWER STRIP** Carry out Investigation A to dissect a power strip in groups.	C-D	*Power Strip Model*, Dissection (Investigation A)
4	10 min		**POWER THE CIRCUIT** Connect a single light bulb to a battery using the dissected power strip as an intermediate structure in the system. Connect multiple light bulbs and/or a motor to the power strip system and provide them with electrical energy.	E-G	Powered Circuit (Investigation B)
5	12 min		**DEVELOP A MODEL FOR EXPLAINING HOW THE POWER STRIP SYSTEM WORKS** Guide students in developing individual models for explaining how the parts of the power strip system are connected to transfer energy to devices. Collect the models for assessment.	H	*Power Strip Model*, whiteboard or piece of chart paper (optional)
6	5 min		**CLEAN UP AND ASSIGN HOME LEARNING** Clean up from the lab. Orient students to the goal of the home learning reading assignment.	I-K	*Electricity Related Parts*, *Power Strip Model*, Investigation A supplies, Investigation B supplies
					End of day 1
7	5 min		**NAVIGATE AND SHARE NEW IDEAS** Navigate into the day and share new ideas from the home learning.	L	*Electricity Related Parts*
8	12 min		**DEVELOP A CLASS CONSENSUS MODEL FOR HOW THE POWER STRIP SYSTEM WORKS**	M	*Power Strip Model*, colored markers (blue, red, and green), tape, blank paper (half

		Develop a class consensus model to represent how the structure of the power strip gets electricity to multiple devices from a single source.		sheet), Power Strip and Battery System Model poster, piece of blue yarn, piece of red yarn, Powered Object cards, Switch Description card
9	8 min	**DEVELOP A MODEL FOR CIRCUITS IN A BUILDING** Develop a model to represent structures in a building that are analogous to those in the power strip system. Use it to explain how energy is transferred to multiple devices in a building.	N-T	Power Strip and Battery System Model poster
10	7 min	**USE THE POWER STRIP MODELS TO INVESTIGATE ELECTRICAL DISTRIBUTION IN A CITY** Test that the light bulbs in each building system will turn on when they are hooked up to a battery. Combine all groups' buildings into one model "city" hooked up to a single power source and conduct an investigation.	U-V	Electrical Distribution in a City (Investigation C)
11	6 min	**USE THE MODEL CITY TO INVESTIGATE POWER OUTAGES FROM SHORT CIRCUITS AND BROKEN CIRCUITS** Conduct an investigation with the model city to simulate the effects of short circuits and broken circuits.	W-Y	
12	3 min	**ADD TO OUR COMMUNITY AGREEMENTS** Reflect on our progress in "Moving our science thinking forward", and add Community Agreements to the "Equitable" and "Respectful" categories.	Z	*Community Agreements*, Community Agreements poster from Lesson 1
13	4 min	**NAVIGATE** Raise new ideas and questions about the Texas case study.	AA	sticky notes, markers

End of day 2

Lesson 2 • Materials List

	per student	per group	per class
Dissection (Investigation A) materials		• power strip • Phillips screwdriver	
Powered Circuit (Investigation B) materials	• *Power Strip Model*	• D battery • tape • 4 incandescent grain-of-wheat light bulbs (1.5V 100mA) • 8 alligator clips • 2 additional alligator clips with one end stripped to tape to the battery • power strip • Philips screwdriver	• D battery • tape • 1 incandescent grain-of-wheat light bulbs (1.5V 100mA) • 2 half alligator clips with ends stripped to tape to the battery
Electrical Distribution in a City (Investigation C) materials		• D battery • tape 2 incandescent grain-of-wheat light bulbs (1.5V 100mA) attached to a dissected power strip and this nested inside a building model • 4 additional alligator clips	• dissected power strip • 18 alligator clips • 2 additional alligator clips with one end stripped to tape to the D battery • tape • tented sheets of paper labeled "Electrical energy source" and "Substation"
Lesson materials	• home learning artifacts from Lesson 1 • *Power Strip Model* • science notebook	• Investigation A supplies • Investigation B supplies • colored markers (blue	• Safety poster • whiteboard or piece of chart paper (optional) • Power Strip and Battery System

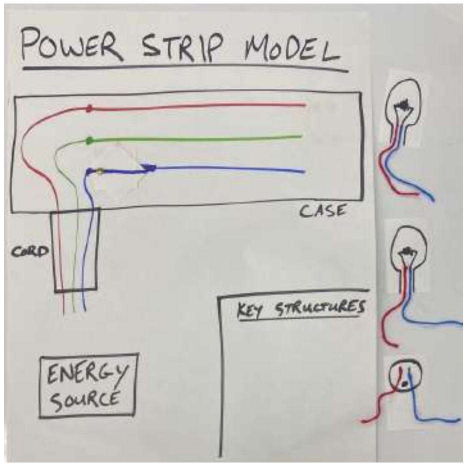
	• *Electricity Related Parts* • *Community Agreements*	• red • and green) • tape • blank paper (half sheet) • Power Strip and Battery System Model poster • piece of blue yarn • piece of red yarn • Powered Object cards • Switch Description card	Model poster • Community Agreements poster from Lesson 1 • sticky notes • markers

Materials preparation (90 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Three-hole-punch all handouts so they can be added to students' notebooks.



Prepare a Safety poster with this principle written on it:

- Individually and as a class, we have an ethical responsibility to consider the possible personal, societal, and environmental impacts of any scientific investigation we plan or engineering solution we design.

Use colored markers (blue, red, and green) to prepare the Power Strip and Battery System Model poster as shown here.

Make a rotatable switch to add to the poster. On half an index card, draw a thick blue line from one corner to another. Hole-punch one corner and hole-punch the poster on one side of the gap in its blue line. Insert a brad fastener through the card and poster as shown below. This will allow the card to pivot back and forth. Lightly tape the switch into an open or closed position.

Gather 4 pieces of 8" long blue yarn and 4 pieces of 8" long red yarn.

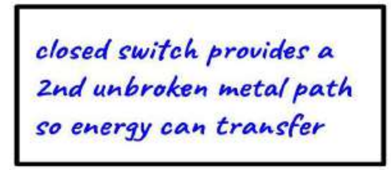
Prepare 3 Electricity-Powered Object cards as follows:

- Draw a light bulb on blank paper (half sheet). Tape 1 end of a red piece of yarn and 1 end of a blue piece of yarn to the bottom of the light bulb.
- Repeat this 2 more times.

Attach all of these pieces to the edges of the poster with tape. Later in the lesson, you will move Powered Object cards to new locations on the poster and then remove them between classes.

You will tape the remaining 2 pieces of yarn to the poster later in the lesson.

Write a Switch Description card describing the role of the switch as shown, and set it to the side.



Write a card with the word "Ground" in green pen, and set it to the side.

Later in the lesson, you will add these two cards to the poster and then remove them between classes.

Set aside some blank sheets of paper to add annotations to the poster (with tape), including one to record "Key Structures". At the end of the period on day 1, remove all the items taped to the poster in preparation for the next class; but at the end of the last period on day 1, leave them taped to the poster so they are there as reference for all classes at the start of day 2.

Of the four investigations (A, B, C, D), three build on supplies used in the prior lab:

- B uses new supplies along with those from A.
- C uses new supplies along with those from A and B, but with only a single light bulb connected to each power strip.
- D uses the same supplies as C.

Day 1:
Dissection (Investigation A)

- **Group size:** 3 students
- **Setup:**
    - For each group:
        - Use a wire cutter to cut the cord of a power strip about an inch from the plug. Dispose of the plug someplace where nobody can access it accidentally. **Plugging this into the wall could result in injury or death.**

        - Use a wire stripper to carefully remove the white insulation from the first couple of inches of the cord. Then use the wire stripper to remove about half an inch of

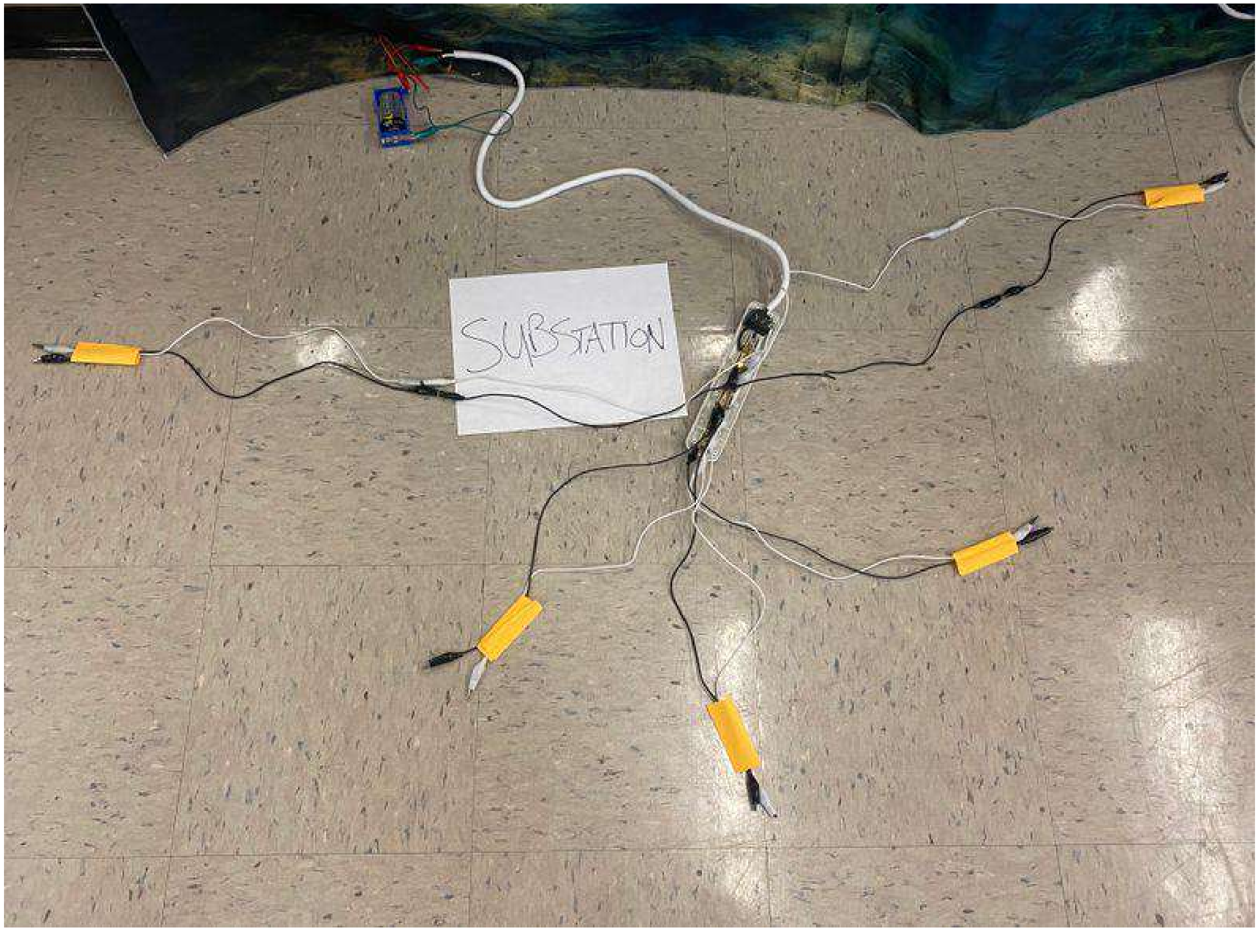
insulation from each of the 3 wires inside, exposing the copper wires within.
        - As a safety feature, some power strips have a single triangle-head screw (TA20)--remove this with a triangle-head screwdriver (turning counterclockwise) and dispose of it. Alternatively, you can snap the plastic column connecting the 2 sides of the power strip. Wear safety goggles as you pull the sides apart to avoid injury from small pieces of plastic that may fly off.
        - Loosen the 5 Phillips screws on the back of the power strip with a Phillips screwdriver (turning counterclockwise). Remove all but 2 of the screws to make dissection and reassembly faster for students. Save the extra screws in case any get lost.
        - Some power strips may have a “surge protector” circuit built into the switch assembly. Understanding how this circuit functions is beyond the scope of this unit, and leaving it in the power strip can make it difficult to see the important structures. This is why the powerstrips you are using in the kit provided with this unit do not have any in them.
        - Place all the related materials in a tote or other bin marked with tape as “A”.
- **Storage:** All materials can be stored and reused (only for labs A-D in this lesson) indefinitely.

Powered Circuit (Investigation B)

- **Group size:** 4 students
- **Setup:**
    - For each group:
        - Cut off the ends of 2 alligator clips for each group, and strip off about a half inch. This will make it easier for students to attach them to a battery.
        - Strip about a half inch off the end of the wires attached to 4 incandescent grain-of-wheat light bulbs (1.5V 100mA) to connect the alligator clips to them.
        - Add all of these and 8 more unstripped alligator clips, a D battery, and tape into a tote or other bin marked with tape as “B”.
    - For an additional control condition to refer to as a class:
        - Add 2 alligator clips with 1 end clipped and stripped, tape, a D battery, and 1 incandescent grain-of-wheat light bulb (1.5V 100mA).
    - At the end of the period, students will reassemble the power strip for the next class. Ask your last class to keep the power strip disassembled and only 1 of the light bulbs attached to it. This will simplify preparing the materials for Investigation C.
- **Safety:**
    - Keep these materials away from electrical sockets!
    - Do not reuse these dissected and reassembled power strips for anything other than labs A-D in this lesson.
    - Short-circuiting any part of the circuit will cause the battery to heat up quickly. Carefully feel the battery to ensure this isn’t happening.
- **Storage:** All materials can be stored and reused indefinitely.

Day 2:
Electrical Distribution in a City (Investigation C)

- **Group size:** 4 students
- **Setup**
    - For each group:
        - Set aside a few sheets of paper that each group will fold in half and label and/or decorate to indicate a "building" in the community.
        - Place a dissected power strip with an incandescent grain-of-wheat light bulb (1.5V 100mA) attached.
        - Test that the light bulb(s) turns on by connecting the 2 ends of the power strip to a D battery.
        - Optional: For a more tangible representation of buildings in the model city, prepare a cardboard building structure for every group in your largest class. See *Preparing Cardboard Buildings* for directions.
- **Set up a demonstration area in an area separate from students' tables--a square approximately 4-6 feet on a side.**
    - For the city's electrical energy source, hook a single D battery up to the black and white wires of the dissected power strip. Make sure the plug is cut off the end of the power strip and the wires are stripped (not shown in the photo here).
    - Hook enough pairs of alligator clips to the strip to provide access points for groups to plug their building into, using extra alligator clips if needed. If possible, route the extra alligator clips a few feet away from the battery in multiple directions, to allow space for all buildings to connect easily. (Assume a square 4-6 feet on a side = 16-36 square feet of total space.)
    - Make sure the switch is turned off and no ends of wires are touching.
    - Label tented sheets of paper as follows:
        - Substation
        - Electrical energy source (power plant)



    - Place these at the corresponding locations in the system.
- **Safety:**
    - Keep these materials away from electrical sockets!
    - Do not ever reuse these dissected and reassembled power strips for anything other than labs A-D in this lesson.
    - Short-circuiting any part of the circuit will cause the battery to heat up quickly. Carefully feel the battery to ensure this isn’t happening.
- **Storage:** All materials can be stored and reused indefinitely.

Power Outages from Short Circuits and Broken Circuits (Investigation D)

- **Group size:** Whole class
- **Setup:**
    - This investigation uses mostly the same materials as Investigation C, but with only a single light bulb connected to each power strip.
    - You will also use a large paper clip (or pair of scissors) to cause an “accidental” short circuit. This should not be a wire, because a wire implies an intentional connection.
- **Safety:**
    - Keep these materials away from electrical sockets!
    - Do not ever reuse these dissected and reassembled power strips for anything other than labs A-D in this lesson.
    - Short-circuiting any part of the circuit will cause the battery to heat up quickly. Doing this at least once is important to demonstrate the effect that a short circuit has on a city, but take steps to make sure the battery doesn’t stay shorted for long.
- **Storage:** All materials can be stored and reused indefinitely.

Lesson 2 • Where We Are Going and NOT Going

Where We Are Going

This lesson builds a foundation for the rest of the unit, using several elementary and middle school grade band ideas that are established quickly, and also using high school level practices and crosscutting concepts. According to pilot testing, ideas about circuits developed in this lesson do not tend to show up on students' initial models created in the prior lesson, so it is essential that they be redeveloped and added before moving on to high school level ideas about energy transfer. The lesson reinforces and builds on the elementary grade band idea that energy can be transferred through circuits, and that a circuit is a structure that provides a continuous loop for a current to follow.

This lesson is designed to coherently build ideas related to the following disciplinary core ideas:

- **PS3.A.4** "Electrical energy" may mean energy stored in a battery or energy transmitted ~~by electric currents~~.
- **PS3.B.2** Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.

Note: We want to avoid any inaccurate assumptions about why two wires are required between an energy source and an electricity-powered object, while building toward an understanding of electric current later in the unit. In the next lesson, we will build an energy model of this same system and highlight the differences between this model and our "circuit diagram."

The lesson helps students recognize that similar structures enable energy transfer from an energy source to multiple devices, in systems at a variety of scales (power strips, building, neighborhoods) in modern electrical grids that serve our communities. This is a part of developing high school level ideas related to ETS2 (Influence of Engineering, Technology, and Science on Society and the Natural World).

The model developed on day 2 of the lesson represents a continuous path of wire between an energy source, a substation, and buildings in a neighborhood. This is a useful assumption for the model and is required for understanding the need for complete circuits in order to transfer energy across most parts of the electrical grid. In reality, substations and other points in the electrical grid contain transformers, which induce an electric current in physically separate circuits to increase or decrease the voltage. These are points at which there is a physical gap between one circuit and another. However, this nuance is not a necessary understanding for this unit.

The energy source in this investigation, a battery, is a stand-in for other energy sources in the electrical power grid that students will uncover in later lessons (e.g., turbines driven by wind, heated steam, burning coal or natural gas, and so forth).

Students will encounter or co-develop definitions for the following terms in this lesson: *circuit, switch, ground, substation, short circuit.* **Do not** post any words or ask students to add them to their Personal Glossaries until after your class has developed a shared understanding of their meaning.

Where We Are NOT Going

In this lesson, we are not explicitly discussing mechanisms for energy transfer **or** matter transfer. The models we develop only ask students to consider what connections make that energy transfer possible. In subsequent lessons (L3 and L5), we will refine our model using two separate representations for energy transfer across the system (in L3) and matter flow at a particle level (in L5). Going too deep into energy transfer is not the goal of Lesson 2. Avoid dwelling on this aspect of the system for now, as it will likely reinforce in students an incorrect mental model of matter transferring from battery to bulbs through **two** wires.

We will introduce the terms *current* and *voltage* in Lesson 5. It is important that students earn these words **after** investigating the way that electrical energy transfers due to the flow of electrons through a wire.

This is also not a lesson about parallel versus series circuits. Students will review and apply middle school ideas about electricity and circuits, but only to provide (1) a context for high school level ideas about energy conservation and transfer and (2) a complex and authentic design challenge with both local and global implications.

This lesson does not explain how or why most houses and businesses in the United States have three separate electrical lines going to them in addition to a grounding wire. In those cases, there are AC currents in two wires, one of which is out of phase with the AC current in one of the other wires. This provides buildings a higher net voltage than the standard 120-volt circuits. The higher voltage enables larger loads (especially electric ovens) to be powered with less current. As this lesson does not introduce *voltage* or *current*, avoid this complication, because most electrical sockets in residences have only two electrical wires with a 120-volt difference, and a third grounding wire. Nonresidential buildings may have even higher voltage feed lines.

This lesson does not distinguish a circuit breaker from a surge protector or a fuse. Though it does introduce the idea that these devices detect and respond to a power surge and automatically shut off or break the circuit by “tripping” an on/off switch, it doesn’t provide an explanation or a detailed mechanism for how this happens within them.

LEARNING PLAN for LESSON 2

1 · NAVIGATE

6 min

MATERIALS: home learning artifacts from Lesson 1

Introduce the purpose of the navigation routine. Show **slide A** and say, *Last time, we kicked off the start of a new unit by building a Driving Question Board to keep a record of what we are wondering. Now we will work together to make progress on those questions over the next several weeks. At the beginning of the day, or of a new lesson, we will use navigation to help us make connections between what we figured out the last time and what we want to do next.*

ADDITIONAL GUIDANCE	The Navigation Routine is used throughout OpenSciEd units. It takes a slightly different form every time it is used. Sometimes it resembles a traditional "bellringer" or "exit ticket" task or discussion question. However, it reaches beyond these traditional classroom activities by not only asking students to recall what they learned (or as OpenSciEd units typically say, "figured out"), but also by pushing students to consider what new questions we have and how to figure out answers to those questions.

Start by recapping the first two bullets of questions on the slide to remind students why we wanted to capture images of electricity infrastructure in our community. Students will bring in home artifacts such as photos, drawings, or descriptions.

Suggested prompt	Sample student response
What kinds of things did you take photos of that we can use to look for patterns?	Wires, outlets, power lines, electrical boxes.
What did we think taking photos of those things might help us figure out?	They all relate to the electric grid, and we want to figure out how the grid works.

	We had a question about what structures in the system enable energy transfer from one source to multiple devices, buildings, and neighborhoods and we thought this could help answer that. It could help us spot similarities and differences in those structures.

Share patterns noticed across structures. Start with structures found outside of buildings, and then transition to structures found inside of buildings. Take less than a minute for each. End with focusing on the structure of the outlets. You can use the prompts below to guide this discussion.

Suggested prompt	Sample student response
What are some things you noticed across the photos you took of structures that you found outside of buildings?	(Accept all responses.)
What are some things you noticed across the photos of structures you found inside of buildings?	(Accept all responses.)
Let's look around the classroom. What kind of electricity infrastructure do you see?	There are outlets, wires, power strips, and switches.
A lot of us noticed outlets of various kinds. What kinds of patterns did you notice across the outlets that we find in this room and in our homes and other buildings?	They have three holes in them. They have two holes that are rectangular and one that is round, and there are usually two or four sets of these together.

Identify outlets as a common structure for further investigation. Say, *Since these three-hole outlet structures seem to be everywhere, they must be an important part of how energy is transferred to all the electricity-powered objects that need it inside a building. So, let's start there, as it might* *help us work backward in the larger-scale system to figure out how all these devices, buildings, and neighborhoods get the electrical energy they need. Let's get ready to dissect some of these smaller structures and figure out how they function.*

2 · IDENTIFY IMPORTANT SAFETY PRECAUTIONS

4 min

MATERIALS: Safety poster

Identify important safety precautions. Show **slide B**. Remind students that electricity can be dangerous. Emphasize the importance of considering safety protocols and the impacts of our decisions in science and engineering, whether in the science classroom or in a professional setting.

Give students 30 seconds to read the question on the slide, and then discuss it as a class.

Suggested prompt	Sample student response
*Tinkering with a power strip would be **dangerous** if it was hooked up to a wall socket. Why?*	Electricity from the wall can electrocute you. You can get badly hurt or die from it.

Reveal or point to the Safety poster that you prepared before class. Say, *Individually and as a class, we have an ethical responsibility to consider the possible personal, societal, and environmental impacts of any scientific investigation we plan ✱ or engineering solution we design. ✱*

Identify steps you have taken to be consistent with the safety statement. Remind students that you are also committed to this principle. Say, *I have cut off the end of the cord so no one runs the risk of plugging a dissected power strip into the wall. And I have identified a safe source of electricity we can connect it to instead. That source will be a 1.5V battery, which cannot transfer enough energy into our bodies for us to even feel a shock.*

SAFETY PRECAUTIONS	Do not reuse these power strips for anything other than the battery-powered investigations in this lesson. Ensure that the plug is **completely removed** and dissected, or disposed of. Never plug the dissected or reassembled power strip, or the removed plug, into a wall socket or connect the wires to a high-voltage battery or other power source. It will be a serious shock or electrical fire hazard.

✱ SUPPORTING STUDENTS IN ENGAGING IN CONSTRUCTING EXPLANATIONS AND DESIGNING SOLUTIONS

Taking time to consider safety in the larger context of *designing solutions* can help position students as active caretakers of each other and the environment.

✱ SUPPORTING STUDENTS IN ENGAGING IN PLANNING AND CARRYING OUT INVESTIGATIONS

An important element of planning and conducting an investigation or testing of a design solution at the high school level is to do so safely and in an ethical manner, including considerations of the personal, societal, and environmental impacts. Establishing this as an explicit principle and referring to it often will help students start to use it as a default lens to evaluate what they or others propose to do before doing it, such as when they outline or critique the protocols or proposed/alternate procedures for an investigation.

3 · DISSECT A POWER STRIP

8 min

MATERIALS: Dissection (Investigation A), *Power Strip Model*

Cue students to consider equitable participation. Distribute *Power Strip Model* to each student. Divide students into groups of 3. Show **slide C**. Read aloud, *What can you do to make sure everyone gets a chance to contribute their ideas?* Give students just a moment to think individually about this question.

Dissect the power strip. Distribute a set of Dissection (Investigation A) supplies to each group, and show **slide D**. Students should use their Phillips screwdriver to open up the power strip. They can carefully remove the metal strips, but they should not permanently disconnect anything. Remind students that they will need to reassemble the power strip at the end of the period for reuse by the next class.

While students work, direct their attention to *Power Strip Model*. Tell them to focus only on Part A for now. If they can't come up with anything yet, that's OK--they may have more ideas when we connect the power strip to an energy source.

ASSESSMENT OPPORTUNITY

Identifying at least two parts and/or interactions they observe inside (CCC: 4.1) the powerstrip. These might include:

- Three metal strips connected to wires of different colors
- Colored Insulation around wires / space between metal strips
- The alignment of certain holes in each socket to one of these metal strips.
- The switch connected to one color wire at two points

What to do: Support small-group sensemaking by asking probing questions about what students notice about the metal parts in the system and where they are connected. Encourage them to start recording this in Part A of *Power Strip Model* as they identify these parts.

Building toward: 2.A.1 Collect data from a designed system (a power strip) and a network of interconnected subsystems (multiple powerstrips) on the interactions needed for and failure points in the transfer of electrical energy. (SEP: 3.6; CCC: 4.1; DCI: PS3.A.4)

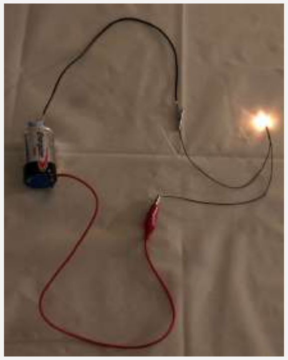
Foreshadow the next investigation. Tell students that after you distribute supplies for the next investigation, you will hook up a single light bulb to a single battery with no power strip, to establish a control condition for the whole class.

4 · POWER THE CIRCUIT

10 min

MATERIALS: Powered Circuit (Investigation B)

Review the parts of this investigation. Show **slide E**. Tell students that after you distribute supplies, their goal will be to light up multiple light bulbs as brightly as the one at the front of the room, but using the power strip as an intermediate energy transfer mechanism. Show them the control condition now at the front of the room. ✱



Distribute a set of Powered Circuit (Investigation B) supplies to each group. Each group will also need their dissected power strip from Investigation A.

Carry out the investigation. Have groups start the investigation. Remind students to complete Part A on the handout as they do so.

Monitor groups. Move around the classroom and listen to students' insights from the remaining parts of the investigation.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment.

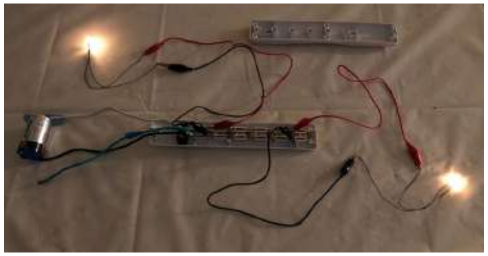
- Connecting alligator clips to different metal parts to determine which connections are needed for energy transfer from the battery to each light bulb and recording the results. (SEP: 3.6; CCC: 4.1; DCI: PS3.A.4)

✱ ATTENDING TO EQUITY

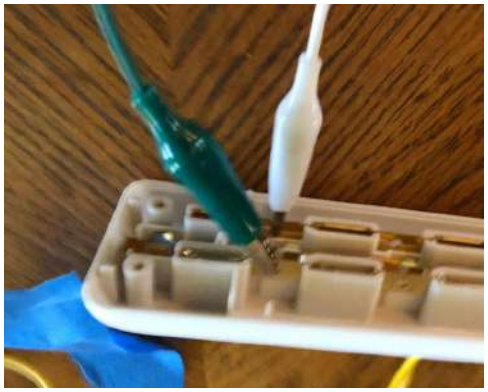
Supporting emergent multilinguals: You might need to spend a moment reminding students what it means to provide a *control* condition, particularly if your students are multilingual. A control provides a standard against which other conditions can be compared in a scientific investigation, but it means something very different in everyday language. Highlighting how words can have different meanings in different contexts (i.e., in science versus everyday use) gives emergent multilingual students the opportunity and space to discuss any preconceptions about the meaning of the word(s), and to draw upon their personal experiences.

	• Testing the effect of the switch and noticing it turns on or off all devices together. When the wire connected to the switch isn't used for any devices, the switch does nothing. (SEP: 3.6; CCC: 4.1) • Connecting additional devices in certain configurations (e.g., parallel versus series) either does or does not appear to affect the amount of energy transferred (brightness) to each light bulb. (SEP: 3.6; CCC: 4.1; DCI: PS3.A.4) **What to do:** Support small-group sensemaking by asking how many connections needed to be made back to the battery, and what other connections in the system needed to be made, in order to provide energy to the electronic devices. Some groups may discover a way to provide energy to the light bulbs by hooking them up in a series. As the focus of this investigation is not on distinguishing parallel versus series circuits, this is fine. If time permits, however, you could challenge these groups to consider whether the light bulbs are as bright as the one in the control condition, which may lead them to notice it is not and will motivate exploring other possible arrangements of the parts in the system. **Building toward: 2.A.2** Collect data from a designed system (a power strip) and a network of interconnected subsystems (multiple powerstrips) on the interactions needed for and failure points in the transfer of electrical energy. (SEP: 3.6; CCC: 4.1; DCI: PS3.A.4)
ALTERNATE ACTIVITY	If you have access to small 1.5V DC motors you can include these in students' lab supply bins so they can hook up these type of devices to the power strips as well
SAFETY PRECAUTIONS 	If the battery heats up quickly, this is a dangerous condition in the system called a short circuit. Remind groups to carefully check their battery periodically (e.g., every minute) to make sure this isn't happening. When a group detects this condition, have them detach the wires from the battery. Look for any locations where wires/connections that can be traced back to the two ends of the battery are accidentally touching each other without any electronic device (a light bulb or motor) between them and correct this before testing it again.

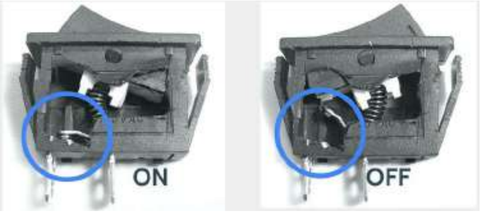
An example of part 2 of Investigation B is shown to the right, with only two light bulbs attached to the power strip: one attached to the back end and another to the front end. Either position is OK. Again, this image is for teacher reference only. Allow students space to tinker and make productive mistakes without providing explicit guidance about what the end product will look like.



Here is what the system may look like when students are attaching the alligator clips to the back side of the power strip.



Here is what the dissected power strip switch looks like. DO NOT encourage students to dissect the switch in the power strip, or the switch will likely no longer be functional. For any groups that have ideas or questions about the internal structure of the switch, emphasize that this line of thinking or questioning seems very productive, and that we should take some time in a few minutes to dig into this question as a class.



Reserve 2 minutes to lead this next discussion to motivate looking into the switch further before moving on to the next activity.

Explore how the switch works. Say, *How is this switch constructed to allow the power strip to turn all the devices on or off together? If we can't take apart the switch in our own power strip, how can you change the system to do the same task? Take a moment to find a connection that will change the circuit in the same way that the switch does.* Give groups 30 seconds to try to find a way to change the connection(s) in their dissected power strip system to produce the same outcome as turning the switch on or off. Say, *Let's now compare the structural change you made to the system with an image showing us what structures are inside these types of switches.*

If using Google Slides, display **slide F**. Explain that the switch in this animation is like the one in the power strip, but has the side cut open to show its internal structure. Show the animated gif, and give students 1 minute to talk about the question on the slide and the related images with an elbow partner.

If using Powerpoint or a PDF copy of slides, display **slide G**. Explain that the images show a switch like the one in the power strip, but has the side cut open to show its internal structure. Give students 1 minute to talk about the question on the slide and the related images with an elbow partner.

5 · DEVELOP A MODEL FOR EXPLAINING HOW THE POWER STRIP SYSTEM WORKS

12 min

MATERIALS: *Power Strip Model*, whiteboard or piece of chart paper (optional)

Develop a model for explaining how the power strip works. ✱ Show **slide H**. Emphasize that you are going to ask students to use their observations to develop a model for explaining how the structure of the objects they just observed enables the system to function.

List key structures. Before students make their diagrams, say, *Which groups made progress on Part A? Which key structures in the system enable the power strip to transfer energy from one source to multiple devices?* You may also choose to write the list on a whiteboard or chart paper at the front of the room, explaining that these parts may or may not be needed to explain how the power strip functions, and the list may or may not be complete, but that you wanted to record examples from all the investigation groups so everyone can consider whether they are

✱ SUPPORTING STUDENTS IN ENGAGING IN DEVELOPING AND USING MODELS

Students may think of a "model of the power strip system" as only a diagram of the power strip and may focus on capturing as much visual detail as possible. Help them realize that in science, modeling does not necessary parts. It doesn't matter whether this list is complete. Listen for students to suggest key structures such as the three strips of metal, the wires and the rubber coating, the switch, the batery, and the bulbs.

Complete Part B. Remind students that whenever we develop a model in science, it is made *for* **explaining something**, and it isn't just a model *of* **what we see**. In other words, it seeks to help explain how and/or why something happens. A diagram doesn't have to look much like a power strip to *explain how the structure of the power strip makes it possible to transfer energy from one source to multiple devices*. Remind students of the initial consensus model of the larger-scale system the class created in Lesson 1 as an example of abstract representation.

Instruct students to draw their model in Part B of the handout. Emphasize that you will collect this in a few minutes, so you can give feedback to help them improve their fluency in modeling. Look for students' diagrams to include the following details about the structure and connections inside the power strip:

- **Metal strips and wire structure(s) and interactions (connections):** Three continuous metal strips, connected to three different colored wires, are all inside the larger white cord.
- **Energy source to power strip connections:** Two separate metal paths from different ends of the battery need to be connected to different wires inside the power strip's cord.
- **Power strip connections to electricity-powered object connections:** Two separate metal paths from two different metal strips in the power strip need to be connected to each electricity-powered device in order to power them.
- **Switch connections:** One color wire is connected to one prong of the switch, and the same color wire leads away from the other prong. Turning the switch off/on does the same thing as completing/breaking the connection to this colored wire.

ASSESSMENT OPPORTUNITY	**What to look for/listen for in the moment:** Students' models of the power strip system should be a circuit diagram, showing which parts in the system need to be connected in order for the system to work as designed for energy to transfer from the source to multiple devices. Models should be clear enough to serve as a tool for identifying whether those connections exist. (SEP: 2.3, CCC 6.1, DCI: PS3.B.2) **What to do:** If students do not label the parts of the system, leave a sticky note on their model before returning these to students in the next period, prompting: *What are the key structures in the system? Can you label them?* If students' models do not show connections clearly enough to determine whether devices would receive energy, leave a sticky note prompting: *What structures are connected to what? How does your model help us see which devices receive energy?*

always mean drawing a representative picture. Instead, we're trying to capture the key parts and interactions that help explain something about a phenomenon. In this case, its purpose is to explain how the structure of the power strip makes it possible to transfer energy from one source to multiple devices.

Note that this model does not focus explicitly on mechanisms for energy transfer or matter transfer--these will emerge through other modeling later in the unit.

Building toward: 2.B.1 Develop and revise a model of connections of components involved in electricity infrastructure to explain how specific structures function to change the way electrical energy transfers within and between systems at different scales. (SEP: 2.3; CCC: 4.3, 6.1; DCI: PS3.B.2)

6 · CLEAN UP AND ASSIGN HOME LEARNING

5 min

MATERIALS: science notebook, *Electricity Related Parts*, *Power Strip Model*, Investigation A supplies, Investigation B supplies

Reassemble and sort the lab supplies for the next class. Show **slide I**. Tell student groups to follow the instructions on the slide for reassembling their power strips and sorting the supplies. Note: With your last class of the day, skip the reassembly step. Keeping the power strip disassembled and the light bulbs attached to it will make it easier for you to prepare the materials for Investigation C.

As students clean up, disassemble the control condition. Put these materials aside to reassemble for the next class you teach.

Assign the exit ticket. Show **slide J**. Have students write their answer to the question on the slide on the back of *Power Strip Model* as an exit ticket.

Motivate home learning. Show **slide K**. Read the text at the top of the slide aloud to remind students that the structure of the power strip is similar to the way in which multiple outlets in a building can be hooked together to ensure that they can all get electricity from just three wires coming into the building. Distribute *Electricity Related Parts* to each student. Read the text at the bottom of the slide aloud to encourage students to think of the power strip as a physical model of other connections. ✱

Collect *Power Strip Model* with the models and exit ticket responses before students leave.

✱ ATTENDING TO EQUITY

All students will benefit from a reminder to annotate *Electricity Related Parts* as they read at home. The CATCH method of annotating is a good choice if students are familiar with it. A description of the CATCH method can be found in the OpenSciEd Teacher Handbook: High School Science. Additionally, students who do not read at or above grade level will benefit from a reminder that the Google version of *Electricity Related Parts* is accessible to screen reading technology and online translator services.

End of day 1

7 · NAVIGATE AND SHARE NEW IDEAS

5 min

MATERIALS: science notebook, *Electricity Related Parts*

Share new ideas from the home learning. Show **slide L** and pose its questions:

- *What questions did the investigations from last class raise for you that the reading helped answer?*
- *What new ideas did the reading give you about how electrical energy systems function in our own neighborhoods, or about what might have happened in Texas?*

Ask students to share some of the things they identified in the reading that are related to either of these questions. Sample student responses include:

- Transferring electrical energy to any electronic device in a building requires at least two separate, continuous paths of charge-conducting metal wire (a complete circuit).
- There are at least two wires that come into a building to provide these paths.
- There is often a third wire that all the electrical sockets' center holes are connected to, which comes out of the building and goes into the ground as a safety feature for surges in energy.
- There are other safety features, such as circuit breakers that open (break) the circuit in conditions where there is too much electrical energy transferring through the system.
- Maybe something caused a lot of short circuits or broken circuits in Texas.

8 · DEVELOP A CLASS CONSENSUS MODEL FOR HOW THE POWER STRIP SYSTEM WORKS

12 min

MATERIALS: *Power Strip Model*, colored markers (blue, red, and green), tape, blank paper (half sheet), Power Strip and Battery System Model poster, piece of blue yarn, piece of red yarn, Powered Object cards, Switch Description card

Motivate developing a model of electrical wiring in buildings from what we know about the power strip. Say, *In the last class, we started considering how the structures inside the power strip transfer electrical energy to multiple outlets. We saw that they are similar to the structures in a building that transfer energy to multiple outlets from just three wires coming into the building. You've identified some of those structures in the reading.* Distribute the models on *Power Strip Model* that you collected at the end of the last class, with feedback.

Introduce the goal of the Building Understandings Discussion. ✱ Say, *Let's develop a map of some of those basic structures in both systems--a power strip and a building--so we can better understand how these systems function.*

✱ STRATEGIES FOR THIS BUILDING UNDERSTANDINGS DISCUSSION

Be explicit with students about your role in this discussion, which is to press them for evidence when they bring up ideas for how the types of interactions compare. Tell them, *My role in this discussion is to press for evidence, regardless of whether the ideas are*

Ask students for examples of a set of nonverbal signals (e.g., ASL signs) to adopt as a class for signaling agreement, disagreement, and wondering/questioning, as a way to ensure equitable participation in ideas that others are proposing.

right or wrong. So you might hear me ask, "Where did you see that?" It is my job to push us as a class to articulate the evidence we have to support our ideas.

KEY IDEAS

Purpose of this discussion: To come to consensus about what the key parts and connections in the power strip are. These are the same parts and connections you looked for in the previous Assessment Guidance box, when you gave feedback to students on their models.

Listen for these ideas:

- **Metal strips and wire structure(s) and interactions (connections):** There are three continuous metal strips, connected to three different colored wires, which are all inside the larger white cord.
- **Switch connections:** One color wire is connected to one prong of the switch, and the same color wire leads away from the other prong. Turning the switch on/off does the same thing as completing/breaking the connection to this colored wire.
- **Energy source to power strip connections:** Two separate metal paths from different ends of the battery need to be connected to different wires inside the power strip's cord.
- **Power strip connections to electricity-powered object connections:** Two separate metal paths from different metal strips in the power strip need to be connected to each electricity-powered object in order to power them.

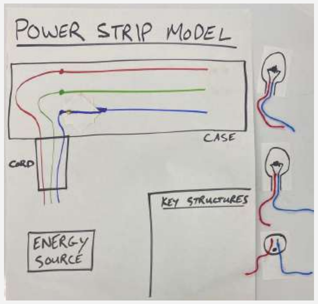
Establish consensus around key parts. Show **slide M**. Use the prompts below to facilitate this part of the discussion.

Suggested prompt	Sample student response
What were some of the parts inside the power strip that you included in your models of that system?	Three metal strips. Wires connecting to each strip. A switch. The cord holding the three wires together.

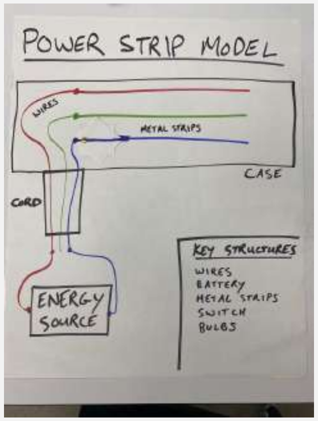
What was the energy source for the power strip when we used it to light up multiple light bulbs?	The battery.
Which wires did you connect to the energy source?	The black wire and the white wire. Any two wires would work, but the switch only worked if we used the black wire.

Assemble the Power Strip and Battery System Model poster as a class. Follow the steps below to assemble the poster.

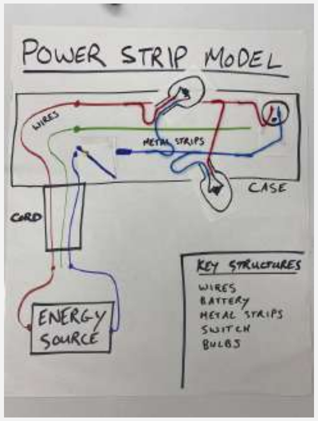
Hang (or uncover) the Power Strip and Battery System Model poster, with the bulbs, yarn, and other components nearby. Say, I've started representing some of these structures here, too. I've used three colors to represent the different strips of metal and the wires that connect to them all the way back to the prongs on the plug. To get us started, what are some key structures that we definitely need to include in our model? Write down key structures on blank paper (half sheet) taped in the "Key Structures" box as students mention them: wires, battery, metal strips, switch, bulbs.



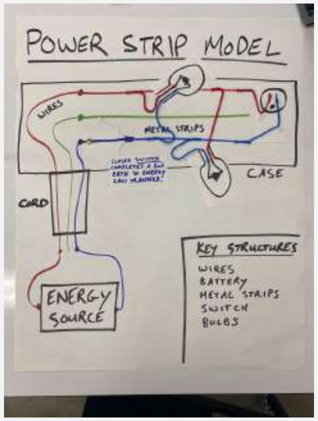
Ask students, What parts of this system did you connect to the battery, and what part of the battery did you connect them to? As students mention them, tape one piece of blue and red yarn between each end of the battery and the blue and red wires of the power strip.



Ask students, Which part of the system did you connect to each of the two wires on the light bulbs to get them to light up? Hold up one Powered Object card. Say, This represents any one of the devices we used yesterday that needs electrical energy transferred to it in order to work (light up). As students mention them, tape one piece of blue yarn from the card to the blue wire of the power strip, and tape one piece of red yarn from the card to the red wire of the power strip. Repeat this for the two other Powered Object cards.



Demonstrate changing the orientation of the on/off switch in the model. Twist it back and forth, then leave the switch in an off/open position. Ask students, How many continuous metal paths from the energy source to the electricity-powered object are there when the switch is in the open position? What about the closed position? Twist the switch to an on/closed position. After students respond, emphasize that when there are two paths to or from the two ends of the energy source, the devices get electrical energy transferred to them. Explain that this condition is called a closed circuit, and this is because you can trace a continuous circuit, or loop, between the energy source and the device it is transferring energy to. Trace this path for students along one circuit on the poster. Tape the prepared Switch Description card that says “closed switch provides a 2nd unbroken metal path so energy can transfer” near the switch on the poster.



9 · DEVELOP A MODEL FOR CIRCUITS IN A BUILDING

8 min

MATERIALS: Power Strip and Battery System Model poster

Introduce the goal of the next Building Understandings Discussion. ✱ Say, *Let’s develop a map of what some of those basic structures are in both systems--a power strip and a building--so we can better understand how these systems function.* Show **slide N**.

Say, *To ensure equitable participation from everyone, remember our nonverbal signs for agreeing or disagreeing with claims that others are making.* Encourage students to take out their copy of *Electricity Related Parts* as a reference. Use the prompts below to facilitate the discussion.

KEY IDEAS

Purpose of this discussion: To come to consensus about which parts and connections in the electrical system of a building (larger scale) are analogous to parts and connections in the power strip (smaller scale), based on what students uncovered in the reading.

Listen for these ideas:

- **Wire structure(s) and interactions (connections):** There are three different colored wires inside the larger white cords running through the walls. Insulation makes it hard for electrical connections to be made to these wires accidentally.

- **Switch connections:** There are on/off switches that do the same thing as completing/breaking the connection to one colored wire. A circuit breaker or fuse is just an automatic switch that turns off when things aren't safe.
- **Energy source to wire connections:** Two separate metal paths from different ends of the power source are connected to different wires coming into the building.
- **Ground wire:** One separate metal path in the building leads into the ground. It is not usually insulated. If there is extra electrical energy in other parts of the system, the ground wire gives it a safe place to go.

ASSESSMENT OPPORTUNITY	
	What to look for/listen for in the moment: Listen for the key ideas outlined in the box above. The power strip serves as a physical model of the building at a larger scale. Many structures are present in both, and students should highlight similarities in the models of those two systems. (SEP: 2.3 CCC: 4.1, 6.1) • Students' connections may include: circuit breakers, switches, insulation, and ground wire. **What to do:** • If students do not connect structures from the reading to the power strip, say, *How does that structure relate to our model of the power strip?* • If students do not explicitly emphasize structure and function, ask for more with a targeted question such as, *How does the structure of the wires in the building function to help us get electricity safely?* • If students do not recall the function of a particular structure in this system (e.g., circuit breaker, insulated wires, ground wire), prompt them to take a minute to look back at *Electricity Related Parts* for any related information and underline it before sharing out. **Building toward: 2.B.2** Develop, revise, and use a model to identify analogous structures that affect the electrical energy transfers across and between different (sub)systems at different scales (powerstrip, building, community). (SEP: 2.3; CCC: 4.1, 6.1; DCI: PS3.B.2)

Suggested prompt	Sample student response
How does the scale of a building compare to the scale of the power strip?	The building is much bigger. The wires in a building have to be longer to make those connections.
Even though the systems work at much different scales, we can still look for similarities. How is the structure of the power strip similar to structures in a building that transfer electrical energy?	There are three wires, and there is a switch, and you can hook devices up to the wires.
How many wires go to each socket in a building?	Three.
What sort of structures are in a building that break the energy transfer in a circuit on purpose?	Wall switches, GFCIs, circuit breakers.
What did you notice about the wires that run through the walls of buildings that's similar to the structure of the power strip cable?	They each have three wires in one single cable. They're all together in one wrapping.

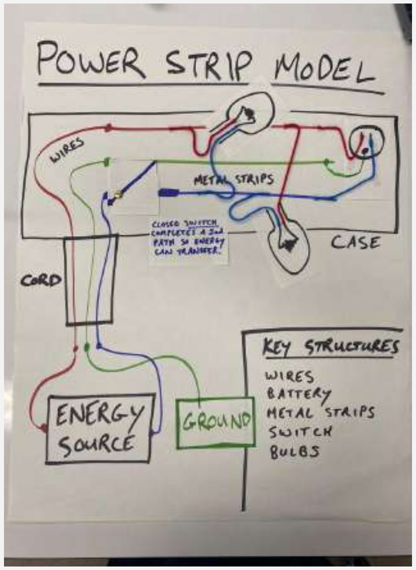
Introduce the model's representation of wires in a building. Show **slide O**. Say, *In the reading, you saw images showing that the wires connecting a building's electrical outlets to its electrical panel typically look like a single cable, as shown here. But as you said, if we peel back the surrounding sheath on the cable, we can see separate, insulated wires within it. Though the wires in the photo are black, copper, and white, the model on the slide uses blue, green, and red for easier identification on the white background.*

Compare how outlet wire connections are represented. Show **slide P**. Say, *You also saw an image showing that the outlets are connected to three wires as well. These three wires connect to the three wires in the cables in the walls, like the outlet shown on this slide. How does this compare to how we connected the electricity-powered devices in our model of the power strip?* Listen for students to say that we connected only two wires to the metal strips, and that we didn't connect anything to the green wire.

Describe why some devices have two prongs on the cord. Show **slide Q**. Say, *Some electricity-powered objects that don't use a lot of energy have plugs with only two prongs on them. Their prongs only touch the blue and red wires shown on the diagram.*

Introduce the connection to the energy source. Show **slide R**. Explain that at least two wires need to be connected to an energy source that can transfer electrical energy through the circuit, and that such energy sources are typically far away from the buildings to which they provide energy. Emphasize that the energy source isn't shown in the model, and that the dotted lines represent that these wires extend for many miles back to an energy source (or sources).

Problematize the function of the green wire. Say, *OK, let's talk a bit about the function of this third wire, shown in green, that is connected to the middle hole in the outlets.* Show **slide S**. Give students 1 minute to discuss the question on the slide with an elbow partner.



Ask students for their thoughts on the role of the ground wire, then ask why we didn't include a ground connection in our power strip model. Ask, *Should we add it? Do those connections matter for how the power strip is constructed?* If students think it's important to add a ground connection, tape the prepared Ground card to the bottom of the Power Strip and Battery System Model poster, then use a green marker or yarn to connect it to the green wire.
Show **slide T**. Say, *This model shows only a single circuit breaker. In this case, that circuit breaker switch is right near where the wires come into the building, which is where that electrical panel is typically located.*

Poll students on their use of a circuit breaker. Say, *How many of you have had someone in your building reset the surge protector or circuit breaker after it automatically shut off and broke the circuit?*

Motivate developing a neighborhood-based model. Say, *Now let's think again about scale to connect back to our initial consensus model from Lesson 1. In our discussion just now, we mapped connections between structures in the power strip and structures in a building. Let's see how we can use these patterns to scale up a step further, to model how multiple buildings in a neighborhood are connected to the same energy source. If each group wires their own building, we can then connect these buildings into a neighborhood.*

10 · USE THE POWER STRIP MODELS TO INVESTIGATE ELECTRICAL DISTRIBUTION IN A CITY

7 min

MATERIALS: Electrical Distribution in a City (Investigation C)

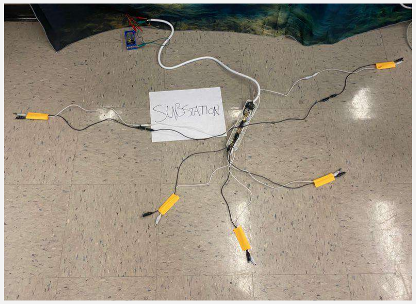
Assemble the model buildings and test their lights. Distribute Electrical Distribution in a City (Investigation C) supplies to each group. Display **slide U**. Have students confirm that only 2 light bulbs are hooked up to their powerstrip and test that it runs on when they hook it up to a battery. Debug the connections, if necessary.

ADDITIONAL GUIDANCE	We are limiting the total number of these lights you hook up to a 1.5V battery to 2 per strip, which will be 14 total. Because each bulb will draw 100mA, this many bulbs will draw just over 1.4 A. Connecting additional lights will start to draw more current and reduce its life.

Have each group label a paper tent with the name of a building that people in a community might need; for example, a grocery store or a gas station. They can decorate the paper tent how they'd like if they have time.

ALTERNATE ACTIVITY	If there is time, this could be an opportunity for your students to build and decorate their own cardboard boxes, bringing some of their creative-crafting skills into the science classroom. The default suggestion is to prepare boxes ahead of time using *Preparing Cardboard Buildings* and distribute them to the student groups. If you do this, have students choose what building their boxes represent (a hospital, a store, a school, a detached house, an apartment complex) and label them. Students can add paper tents on top of the buildings they create or decorate the cardboard directly.

Set up the class energy source and substation. While students work on their buildings, set up the demonstration area in another part of the room. Plan for this to take up a square space 4-6 feet on each side. If possible, route extra alligator clips or wires in pairs a few feet away from the battery in multiple directions, to allow space for each group to connect their building easily. Spreading out will help clarify the role of individual buildings and other system components (substation, wires, switches), and facilitate student-to-student talk in the class discussion about parallels to structures in students' own neighborhoods.



Label the energy source and substation. Make sure the power strip switch is turned off.

Combine the buildings into a model neighborhood. When students are ready, have them bring their buildings and give you their batteries as they gather around the demonstration area. Instruct them to connect their buildings to the substation with one of the pairs of wires provided.

Display **slide V**. Have students turn and talk to discuss how this model shows how multiple buildings in a neighborhood could get electricity from one energy source.

Explain that a typical substation has a similar function as the power strip in this system, serving as a common junction point for distributing energy to multiple customers. A typical residential substation serves this function for approximately 1,500 customers. Remind students to consider scale--when you plug in an electricity-powered device, you are creating a giant circuit from that device near you to a power source that may be very far away.

A single 1.5V D battery should be enough to light up seven "buildings" at two bulbs per "building," but the lights may dim. If the battery is old, the lights will likely dim too much, which may be misleading for students. One possible solution to this problem is to prepare a "stronger" 1.5V battery--this means attached multiple D batteries in parallel--with positives connected to each other. If you happen to have apparatus for this, such as the holders on the left in the image shown, use them. If you don't, use paper clips and tape as shown to create your own parallel battery pack.

ADDITIONAL GUIDANCE	We are simplifying how we are thinking about circuits at this point. The unit does not investigate the role of transformers. Though transformers could be thought of as physical gaps between two circuits, one could also think of them as power sources. As we will discover in Lessons 5 and 6, all energy transfer via circuits is due to the propagation of electric and magnetic fields through empty space between matter. From that perspective, the transformers in an electrical grid are just one more location where there is some empty space in the system.

Turn on the switch of the substation power strip. Have the class make note of which buildings' lights go on. Point out any building where the lights didn't go on, and explain that this may be due to a short circuit or a broken circuit in the system.

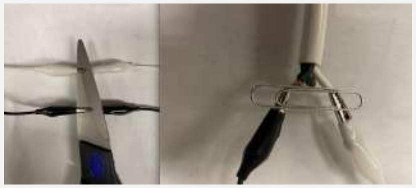
11 · USE THE MODEL CITY TO INVESTIGATE POWER OUTAGES FROM SHORT CIRCUITS AND BROKEN CIRCUITS

6 min

MATERIALS: science notebook

Simulate the effects of broken circuits and short circuits. Show **slide W**. Say, *We learned that there are circuit breakers built into buildings, and even into many power strips, that will automatically break the circuit if a short circuit is detected. Similar safety features are built into points in the electrical system, like a substation, which is a single point in the electrical wire network that connects thousands of buildings. Let's see what happens to electrical energy in the system when there is a broken circuit.*

Break one of the lines before the substation to show that all the connected buildings lose power. Identify this as a broken circuit. Then reattach that wire and break a line to one of the buildings to show that only that building loses power. Identify this as a broken circuit in a different part of the system.



Lay a large paper clip across two lines on the wire connecting the substation to a building. This connection needs to be strong, to show that all buildings lose power in this condition. If the lights only dim slightly, the connection isn't strong enough. You may instead try attaching the alligator clips to the metal, while maintaining the original connection.

Identify this as a short circuit. Say, *If a short circuit is created, most of the energy will transfer down that path rather than through the other circuits. Notice that the entire neighborhood loses power. However, if we switch off the part of the circuit that contains the short circuit, the rest of the system gets power back.*

Consider the role of circuit breakers during accidents. Show **slide X**. Say, *Now that we've seen the effect of a short circuit, consider what might happen during an accident. Imagine a tree has fallen on a power line and created a short circuit and an electrical fire. How can a circuit breaker, either in a building or at a substation, help limit the scale of a power outage due to that short circuit?*

If students' answers aren't clear, demonstrate the short circuit again. Say, *If the short circuit is in this building, then the entire neighborhood goes dark. But watch what happens to the neighborhood when we turn* ***off*** *the switch to that building. This is one role that a circuit breaker plays in our buildings and substations.*

Add new words to our Personal Glossaries, and add to our Progress Trackers. Present **slide Y**. Give students a chance to record their thinking in their *Progress Trackers*. Also take a moment to give students a chance to add to their students' Personal Glossaries. Some words the class might decide to add include *switch, circuit, ground*, and *substation*. You might also consider adding the phrases *incandescent*, *insulator*, *short circuit* and *broken circuit*.

Name the model neighborhood. Ask students what we should call the model neighborhood we built. In this *Teacher Guide*, we sometimes refer to it as "Electric City."

ALTERNATE ACTIVITY	**Extension opportunity:** This step in the lesson sequence is another opportunity for creative input from students outside of what is described here. They may want to make a sign, or spend more time decorating and labeling their buildings or the city itself. If students feel invested in their city, this setup can be used again in Lesson 3 and Lesson 7.

12 · ADD TO OUR COMMUNITY AGREEMENTS

3 min

MATERIALS: science notebook, *Community Agreements*, Community Agreements poster from Lesson 1

Reflect on our Community Agreements. Ask students to look back at our Community Agreements. Then ask, *What would it look like in a group if participation were equitable and respectful?* Look for ideas about everyone getting to talk, or everyone's ideas being heard. Students might also mention that some people prefer to express themselves in other ways, including the nonverbal ones you introduced earlier.

Add to our Community Agreements, with a focus on the "Equitable" and "Respectful" categories. Present **slide Z**. Ask, *What can we add to our Community Agreements to support equitable participation?* Have students turn and talk to develop some ideas for how we could make participation more equitable, and then share out after a minute. Add their ideas to that category on the Community Agreements poster from Lesson 1, and ask students to keep track of new agreements on *Community Agreements*, added to their notebooks in Lesson 1.

Look for at least 2-3 ideas. Consider getting the conversation started by suggesting an agreement such as: "We recognize and value that people think, share, and represent their ideas in different ways."

ADDITIONAL GUIDANCE	If students suggest ideas for the teacher only, such as "You should call on everyone," explain that you definitely want to make choices that will encourage equitable participation, and that you appreciate feedback, but that this time is for agreeing on things we can *all* do to support the culture we want to see.

ALTERNATE ACTIVITY	As in Lesson 1, if students have a lot of ideas, you may want to start a new piece of chart paper to keep track of them. In later lessons, you will have the opportunity to distill these ideas, and you can add them to the Community Agreements poster then.

13 · NAVIGATE

4 min

MATERIALS: sticky notes, markers

Navigate with a Turn and Talk. Show **slide AA**. Say, *In this lesson, we figured out how a circuit is needed to transfer energy from a source to electricity-powered devices.* Have students talk with a partner for 1-2 minutes about the question below and then discuss it as a class.

Suggested prompt	Sample student response
What new ideas or new questions does this raise for you about our Texas case study?	Did the weather cause broken circuits? Did ice and snow break the power lines? Did the wind blow down wires? How many power lines fell down during the storm in Texas?

Emphasize that we should plan to investigate these questions next time. Remind students, if time permits, that they can add these questions to the Driving Question Board before class is over. Distribute sticky notes and markers for this.

Additional Lesson 2 Teacher Guidance