beetles

Science and Teaching for Field Instructors

Student Activity Guide

Food, Build, Do, Waste

This activity gives students a way to look at how organisms are connected to ecosystems through the cycling of matter and the flow of energy. By the end of the activity, students will be able to make distinctions between how matter and energy are used and transferred and will be encouraged to apply this important crosscutting concept to the world around them.

First, students observe an animal, then they reflect on how it uses matter from food to build body structures and energy from food to do things. Students look at food as "packages" of matter and energy that animals (and plants) consume. They also think about wastes, such as poo, pee, sweat, heat, and carbon dioxide. This is a focused activity best used as part of an extended matter and energy-themed experience, and it works best after students have had time to explore, check out organisms in other ways, and be physically active.

Students will:

- **Discuss different uses of energy and matter in organisms.**
- **Understand food as digestible "packages" of energy and matter.**
- **Record how organisms use matter to build bodies and energy to do things.**
- **Identify energy and matter wastes produced by organisms.**

Grade Level:
Grades 5-8. Adaptable for younger or older students.

Timing:
50 minutes, or two 25-minute chunks

Related Activities:
You Are What You Eat; Decomposition Mission; Case of the Disappearing Log; Card Hike (*Ecosystems, Matter & Energy* cards); *Matter & Energy Diagram.*

Materials:
For instructor: portable whiteboard + marker
For each student: journal /paper + pencil; small snack
Optional: nets, clear plastic cups/containers, hand lens, field guides

Tips:
To ensure a successful experience, review the teaching tips found on page 2 and throughout this guide.

Setting:
Choose an area where students can spread out and each find an animal they can observe/draw for an extended period of time. Works well in a garden.

NEXT GENERATION SCIENCE STANDARDS

FEATURED PRACTICE	FEATURED CROSSCUTTING CONCEPT	DISCIPLINARY CORE IDEAS
Developing & Using Models	Energy & Matter: Flows, Cycles & Conservation	Life Sciences/ Matter & Energy

For additional information about NGSS, go to page 10 of this guide.

THE LAWRENCE HALL OF SCIENCE
UNIVERSITY OF CALIFORNIA, BERKELEY

Food, Build, Do, Waste

ACTIVITY OVERVIEW

Food, Build, Do, Waste	Learning Cycle Stages	Estimated Time
Introducing the Activity	Invitation	5 minutes
Exploring & Drawing	Exploration	20 minutes
Group Brainstorm	Concept Invention	10 minutes
Tracing Matter & Energy	Application	10 minutes
Wrapping Up	Reflection	5 minutes
TOTAL		50 minutes

TEACHING TIPS

Field Card. On page 13 is a condensed, pocket-sized version of the lesson that you can carry in the field.

Read the Instructor Support Section. Beginning on page 8, there's information about pedagogy, student misconceptions, science background, and standards.

Making the most of your time outside. To make use of students' time outdoors, make sure students will be able to find organisms they can actually observe and draw. These organisms need to be big enough so students can observe structures, active enough to observe some behaviors, but still or contained enough to draw. Options could include anything from a bug in a cup to a large mammal. Be sure to give students the opportunity to apply these concepts to other parts of the natural world after the activity.

Why teach about matter, energy, and ecosystems? You can help build a foundation for understanding systems on Earth, and global events such as climate change, by teaching students about matter and energy. These big ideas underlie food chains, food webs, energy pyramids, decomposition, photosynthesis, predator-prey interactions, and much more. Focusing on energy and matter provides a useful lens for looking at the natural world and takes advantage of students' fascination with something like a bug to lead them towards exploring bigger ideas related to understanding our ecosystems.

All materials created by BEETLES™ at The Lawrence Hall of Science.
Find the latest activities and information at http://beetlesproject.org.

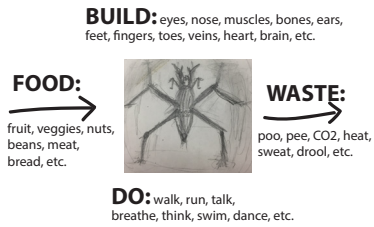
Introducing the Activity

1. **Eat some food & discuss: Why do organisms need to eat food?** Hold up a piece of food or give everyone a sample to eat. Ask:
   - *Why do we need to eat food?*
   - *Why is food important to living organisms?*
2. **Explain: Food = matter & energy organisms can digest.** Listen to student answers, then expand on what students have said.
   - *Food is the fuel we need to survive, grow, and reproduce.*
   - *Food is matter & energy "packaged" in a form that is digestible by an organism.*
   - *A piece of bread may seem like nothing special, but it's full of matter and energy, and our bodies are very good at getting what we need from what we eat.*
3. **Choose example organism (an exciting creature you find, a captive animal, or humans).** Choose an organism to use as an example in your introduction of the chart and activity. It may be one your group found and is excited about, a captive organism your site has (such as a tethered hawk, a goat etc.), or even humans in general.
4. **Make chart with Food, Build, Do, Waste at left, top, bottom, & right sides.** On a white board or paper, write the four words as shown in the margin. Explain that they're going to take a closer look at organisms in this area and investigate how they use matter and energy from food.
5. **Draw example organism in center, quickly demonstrating how to make an accurate scientific drawing.** Explain to students: You'll be making a diagram showing the organism, its parts, and your notes. You don't have to make a pretty picture- the goal is to record accurate observations. Draw the organism as accurately as you can. Use arrows to connect your notes, descriptions, and labels with parts of the organism. If your organism is very small, you might choose to draw it larger than life. Include the date and location on your page.
6. ***Briefly* brainstorm & record body parts built from matter from food by the chosen organism where it says, "Build."** Explain that all organisms' bodies, including ours, are made of matter, or "stuff," and we need matter to build our body structures. Ask them to brainstorm some parts of the organism built from matter, e.g., eyes, blood, toenails, heart, etc.]Record a few ideas on the diagram near where it says, "Build."
7. ***Briefly* brainstorm & record things the organism uses energy from food to do where it says, "Do."** Tell students organisms use energy from food to do things. Ask them to brainstorm some things the organism uses energy to do, walk, breathe, think, etc. Record a few ideas where it says, "Do".

TEACHING NOTES

Limit the activity to just animals at first. Plants can be much easier to find, but it's more challenging to visualize and trace how matter and energy move through them. It can be hard for students to think of things plants actually do, since they don't move very much. Of course all plants grow and reproduce, which can be thought of as *both* building and doing. Because it can be more directly engaging and familiar to observe the flow of matter and energy in an animal, consider having students observe animals first, and then introduce the same task with plants in a subsequent session.

Read more about how amazing food is on page 9.



Confusion around the term, "build." The term, "build," may be confusing to some students because they may think of things, like ant hills, that an organism might build apart from its body. Emphasize that in this case "build" refers to parts of the organisms' body built from matter in its food.

TEACHING NOTES

Brainstorming Wastes. Your students will probably think of poo & pee, which is, of course, always funny and interesting for kids to think about. Some students may also think of farts and sweat, or other ideas for wastes. Point out that heat energy given off by an organism is also considered waste, because the organism can no longer use it. All organisms give off heat energy as waste, including plants and fungi (even if we can't detect it). All organisms also release gases as waste (plants give off oxygen, while animals give off carbon dioxide). If students don't mention carbon dioxide/oxygen and heat as wastes, then you should make sure to point them out.

The amount of waste CO_2 & H_2O that organisms give off is significant. The average human gives off about 1 1/2 pounds of water and 2 pounds of carbon dioxide per day through breathing.

Students using evidence to predict what an organism eats. If students don't know what their organism eats and they seem up for it, you might challenge them to predict what the organism might eat, using evidence and reasoning, judging from the size and shape of the organism, mouth, the environment, etc. If the organism isn't moving very much, these will have to be mainly thinking exercises.

Drawing Accurately. Students often use visual symbols that represent what they are asked to draw instead of realistic drawings based on what they actually see. For example, when asked to draw a frog, students will often draw large, round eyes on the top of its head instead of looking at a frog and realistically detailing its features. Let them know that they don't have to worry about being a good artist, but encourage students to draw what they see and to add written notes to accurately represent what they observe.

8. ***Briefly* brainstorm & record wastes the chosen organism gives off where it says, "Waste" (include heat & CO_2).** Explain that organisms give off both matter and energy wastes. This is matter and energy from their food, that is no longer being used. Ask them to brainstorm some wastes the organism gives off, e.g., poo/feces, pee/urine, carbon dioxide, heat, sweat, farts/flatulence, etc. Record a few ideas and if it seems challenging for students, then you can contribute a few ideas they don't think of, such as heat & CO_2.

9. ***Briefly* brainstorm & record possible foods of the chosen organism where it says, "Food" (write "?" if they don't know).** Explain that the organism gets all its matter and energy from food. Ask them if they know what the organism eats. If you have resources to share with them, let them look up what their organism eats. Explain that they can write "?" if they don't know.

Exploring & Drawing

1. **Explain that students will search for an organism, then make a diagram/model, like the example the group did together.** Tell students they'll make a diagram with Food, Build, Do, and Waste in the corners, and their drawing in the center.

2. **Explain that students will use this diagram to understand how organisms use matter and energy as they cycle and flow through them.**

3. **Explain: scientists use models like this chart to represent something in the real world- like matter & energy & an organism- to better understand it & to show their thinking.**

4. **Explain how to find organisms in this location.** Describe how to look for organisms. See BEETLES *Ecosystem Literacy and Exploration Protocols* for more information on how to help students find and catch organisms. Tell them they're going to choose one organism to study in the area. Describe each of the following strategies (or other strategies appropriate for the ecosystem):

   - Finding a small creature under fallen logs.
   - Finding a small creature living on a plant.
   - Finding a small creature living on the ground.

5. **Give safety talk about finding organisms.** Give warnings about any harmful organisms you're aware of in the area. Give students tips on how to look for organisms safely, without hurting themselves or the organisms.

6. **Review boundaries & rules, assign partners, pass out materials.** Explain the boundaries of the search area, review what behaviors are acceptable, and which are not, and clearly explain what signal you'll use to get their attention, and how they are to respond. Pass out writing materials.

7. **While pairs of students explore & sketch, help them focus on matter & energy.** Circulate, ask questions, and troubleshoot. For example, ask: What

structures made from matter do you notice on your organism? How many legs? Antennae? What is the organism doing using its energy? Moving quickly or slowly? Breathing?

Group Brainstorm

1. **Ask students to release organisms carefully, as close to where they were found as possible.**
2. **Gather students with their diagrams, and erase all but Food, Build, Do, Waste on your whiteboard, & write "organisms" in the center.**
3. **For each category, do a Whip-Around (each student or pair says one thing), then record a few on the whiteboard and ask follow up questions.** Don't record during the Whip-Around, just let everyone contribute verbally. Then record a few representative suggestions, not all. Repeats are fine. Ask follow-up questions occasionally, as appropriate:

   - *BUILD. What parts of your organisms' bodies do they build with matter (include internal organs & fluids)?*
   - *DO. What do your organisms use energy to do (what you observed, or what you think it might do)?*
   - *WASTE. What wastes do your organisms give off (what you observed or what you think they might leave behind)?*
   - *FOOD. What might your organisms eat (what you observed or what you think it might eat)?*

Tracing Matter & Energy

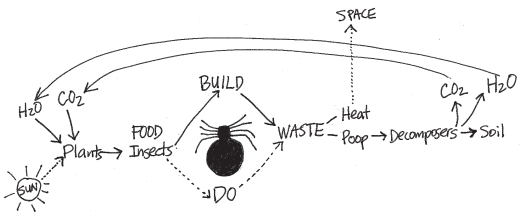
1. **Use student suggestions to draw a more complex model connecting the organism to food from plants, energy from the Sun, matter from CO_2 & H_2O in the air.** On a whiteboard, quickly copy one team's organism model (pick one the group seems interested in), and ask students for suggestions of arrows and words to add to connect the organism to the larger ecosystem. Start by tracing the food the organism eats back through the food chain to a plant source. Ask questions like, "It eats insects, but where did the matter and energy in the insect come from?" Then add energy from the Sun, and matter from CO_2 and H_2O in the air. Use dotted line or different colored arrows to show energy flow.
2. **Add waste arrows showing: heat energy going to space, matter waste released into the soil, and CO_2 & H_2O released into the air through decomposition.** Add an arrow showing heat waste going to space, then use student suggestions to trace a waste example (e.g.,: shed exoskeleton) as it decomposes and eventually becomes CO_2 & H_2O released into the air (atmosphere). Ask questions like, "it gives off poop as waste, but where does the matter and energy from the waste go?"To show a shorter path, use CO_2/H_2O as your waste example, then draw an arrow to connect these gases with those going into plants, completing a matter cycle.
3. **Explain that matter cycles through living systems like organisms**

TEACHING NOTES

You might want to take a break here. If your students seem fidgety and it seems like they could benefit from being active before continuing with a more focused group activity, consider taking a break before coming back together to do the Group Brainstorm.

See BEETLES Discussion Routines for logistics of Whip-Around.

These first three steps provide a deeper dive with focused students. Pay attention to the level of interest and understanding in your group. If they stay focused and seem ready for more, then use Steps 1-3 to go deeper with the NGSS cross-cutting concept of Energy and Matter: Flows, cycles, and conservation. See the background section for more information on these concepts. If they don't seem ready for this, then skip on to step 4.



TEACHING NOTES

Avoid language that supports the misconception that organisms change matter into energy. A very common misconception students (and many adults) have is that organisms turn matter into the energy they use. What is accurate is that there is energy in food, which gets released to be used by the organism. There is also matter in food, in the form of atoms, but it always remains matter - the atoms are not destroyed, and the matter doesn't change into energy. Matter from food can change into other forms of matter, and energy can be released in the process, but it's still matter. Even if students don't seem ready to fully learn about this, it's best for instructors to avoid using language that reinforces the misconception. See the background section for more on this challenging concept.

Save student examples. If possible, copy and save one or more samples of exemplary student work to show and inspire students the next time you present the activity.

It's important to help students apply the matter/energy lens to the natural world. It's interesting to look at the world through different scientific lenses that enrich our experiences and our expand our understanding. The main point of this activity is to provide students with an energy and matter "lens" to observe and explore the natural world. That's why it's important that during your time with students, you provide opportunities and encourage them to apply this lens to other discoveries and observations in the natural world.

See BEETLES activity *Walk & Talk* for logistics of this routine.

& ecosystems, and energy flows through Earth systems, & out into space. Explain that the matter in Earth's systems never disappears, but continues cycling as it changes into different forms of matter. Energy doesn't disappear either, but constantly flows from the Sun into Earth's systems, and then eventually out into space.

4. **Prompt students to add information to their models.** Explain to students that after the group's sharing, they probably have more ideas to add to their models. Give them a couple of minutes to add anything to the categories on their sheets.

5. **Circulate, ask questions & troubleshoot.** Check for understanding by asking individuals to explain how they think matter and energy move through their organism.

Wrapping Up

1. **Show or eat a package of matter & energy (food) again, reminding them that it provides matter to build & energy to do things.** Remind students that everything an organism builds or does comes from this amazing package of energy and matter we call food.

2. **Continue to stir up discussion about matter & energy when students observe other animals.** When you find other organisms during your field experience, occasionally coach students to think about the organism through a matter & energy "lens." E.g. Did you see the bobcat stalk, pounce and miss the gopher? Did it take much energy to do that? Where does a bobcat get its energy from? What are some body structures the bobcat builds using matter from food? etc. Snakes, salamanders, bears, and dragonflies etc. can all be intriguing matter & energy puzzlers.

3. **Focus group on a plant, & brainstorm food, build, do, waste about it.** At some point, focus your groups' attention on a plant, and ask what kinds of structures it builds (that's the easiest one), what food it eats [sugars made from CO_2 & water using energy from Sun], what it does [grows, photosynthesizes, reproduces, opens and closes flowers], and what wastes it produces [oxygen, water, heat]. Let students ponder and struggle with these ideas.

4. ***Walk & Talk* reflection.** Use these or similar *Walk & Talk* questions as your group moves along after the activity:

   - *What helped you learn today?*
   - *What questions do you still have about how matter cycles and energy flows in organisms and ecosystems?*
   - *Every organism, including the one you studied, can be food for other organisms. What other organisms can you think of that might get their matter and energy from eating your organism?*
   - *What animals can you think of that are very active and need food with lots of energy, like seeds or meat, or need lots of food?*
   - *What animals can you think of that are not very active and can eat food with*

less energy in it, like grass, or can eat less food?

- *Brainstorm herbivores that get most of their matter & energy from plants.*
- *Brainstorm carnivores that get most of their matter & energy from meat.*

5. **[If you're eating together] Ask questions during lunch about matter & energy.** If you have picnic lunches with your students, or other opportunities to eat together, you might want to ask them questions about matter, energy and them as they eat.

TEACHING NOTES

Lunch discussion. Some groups eat meals with their instructors, and it can be a nice time to have an informal discussion with students who are interested. If that's the case, conduct a fairly casual discussion about matter, energy, and food, while they're actually consuming matter and energy.

Instructor quote. ""They were quick and enthusiastic in their responses to my follow up questions about the matter and energy in their lunches. I: What are we getting from our sandwiches? St: Matter and energy! I: What do we do with the matter? St: build our muscles and hair and bones and grow. I: What do we do with the energy? St: think and grow and hike up the mountain! I: Is there energy in the bread? St: Yes! I: Where did that energy come from? St: Wheat. I mean the wheat got it from the sun! Engaging discussion: I: What is energy? Is there energy in the sun? How can we sense energy from the sun? St: heat and light I: Is there energy in this log? How could we tell? St: We could light it on fire and get heat and light out. I: Is there energy in this apple? How could we get that energy out? St: We could light it on fire! If we eat it, we will digest it and get the energy out that way."

TEACHING NOTES

Instructor quote. "Students really responded well to this activity. They had wonderful in depth discussions about food, matter, and energy. It was pretty thrilling to facilitate. You could see, by the end of the class, that they all really understood why animals need to eat and what happens to the matter and energy when they do so. I've taught about matter cycles and energy flow many times to many different grade levels, and I think this lesson was the most successful I've ever felt. Towards the end I asked about how the pictures would look different with a plant in the middle, and students did a great job with that too. Students really responded to the application section, where they were able to explore independently and then sit alone from the group to think, draw, and write. After a fun-filled chaotic day, that quiet time was greatly appreciated."

Instructor quote. "It also helped us to visually tease apart the concepts of matter vs. energy, specifically in the context of "build" and "do". So many of my students came up with "growing" as an example of something an organism "does", which simply led to a discussion to address the question of "what is an organism doing when it is growing." My students quickly arrived at the conclusion that the organism is "making more organism."

Instructor Support

Conceptual Knowledge

At first glance, the content in this activity may seem simple, but it's not. Many students (and instructors) harbor misconceptions about matter and energy. The more you dig into the topic, the more complex it can be, which makes it interesting. Do your best to become familiar with the content in advance, ask students broad questions, seek out interesting pathways in their responses, and explore them together. Don't be afraid to venture into content you don't fully understand yourself, wondering aloud along with the students about interesting questions that emerge, admitting that it's challenging, and admitting your own confusions. Encourage them to apply the ideas and questions to anything they explore in nature.

Matter

Matter is the "stuff" things are made of. Wood is matter, bones are matter, water is matter, and even air is matter. Matter takes up space, but it's hard to feel that with air unless you capture some in a balloon or bag. Matter also has mass (weight), but that's also hard to feel with air, because it has so little mass. We live in a "sea of air," so it can be difficult to feel the weight of air when you're surrounded by it on all sides.

Energy

Energy is much harder to define than matter, and has different definitions depending on the branch of science. In this context, energy can be defined simply as what organisms get from food that allows them to do things. If you're introducing students to the term, "matter," energy can also be partially defined as "not matter." Unlike matter, energy doesn't take up space or have mass. But if you want to go deeper, read on. Energy has no physical form; it's not a substance. When we say energy is transferred from one organism to another, we're not talking about a physical thing being passed from place to place, rather we're talking about transferring the *capacity* to do things, i.e. living and growing.

Weird and confusing, huh? Want more? Well alright then...

Energy can be described as being in two different categories: the energy of motion (kinetic energy) and the energy of position (potential energy). Light, sound, heat (thermal) energy, as well as the movement of objects, are all examples of the energy of motion. Chemical, gravitational, elastic, and nuclear energy are all examples of potential energy. Since potential energy does not involve detectable movement or sensation, these types of energy are commonly unrecognized. The greater the potential energy, the more capacity there is for something to happen.

Seriously? You want even more? OK then...

Energy is a measure of how much change can happen in a system – so it's typically represented with a number. It's a quantity that's always conserved, it's neither created nor destroyed. Something needs to happen for any type of energy to be released or transferred. In other words, energy is released or transferred during interactions. As a result of an interaction, energy can

transform from one type to another and the amount of energy associated with an object can change. These changes are what are being taken into account as we track the flow of energy through a system. Understanding energy flow and redistribution throughout a system is often a key to understanding the functioning of the system as a whole.

Food

Food provides all organisms with chemical energy and matter needed to live and grow. Food needs to be digestible by the organism to provide both matter & energy for the organism to live, build its body parts and grow. Organisms also need other kinds of matter to survive, such as water, oxygen, CO_2, nutrients, vitamins, but these substances are not considered food. Plants "package" energy and matter into food substances through photosynthesis, and all plants consume the food they make. The typical convention used in drawing food webs is to draw the arrows between organisms pointing toward the organism that consumes the food. The arrow indicates the direction of the flow of matter and energy.

Food substances (carbohydrates, fats, sugars, and proteins) are specific kinds of molecules that are broken down in the body through digestive processes. All organisms (including plants, animals and fungi) grow by breaking down food (including sugars made by plants and ingested by animals & fungi) and assembling the breakdown products into their body structures. After food is broken down into sugar (glucose) it enters the organism's cells and goes through a series of chemical reactions producing ATP, which is the process by which all cells obtain energy. In this way, food serves as a fuel to do things and also provides the molecules and building materials needed by organisms. That's why it's useful for students to think of food as a package of matter and energy.

Common Misconceptions:

- **Misconception.** Organisms convert matter into energy.
  More accurate information. This is a *very* common misconception, even among adults. Matter is not converted into energy in life systems on Earth. Matter changes into other forms of matter, but it remains matter. When organisms eat food, energy is used to do things and can be released as heat to eventually drift off into space, but the matter in food is released as CO_2 in breath, H_2O in breath & sweat, and organic matter in feces and urine. Even though chemical energy *in* matter can be transformed into usable energy by organisms, the matter in food does not turn into energy. Remember that energy is *not* a substance. The chemical substances in food are transformed into new substances (through chemical reactions), but there are no new atoms created or destroyed in the process. Under usual circumstances (certainly in all ecosystems and food webs on Earth), matter does not turn into energy. Try to avoid using language that might support this misconception.

- **Misconception.** Energy from the Sun is captured by the Earth and keeps cycling round and round in ecosystems.
  More accurate information. Eek! If that were true, Earth would be a

TEACHING NOTES

Food is Amazing! Food is the fuel we need to survive, grow and reproduce. But it's more than just the ingredients in food that fuel our bodies, it's how our bodies take the energy and matter that is packaged into a digestible form, and use it to start the metabolic "fires" that burn within us. Those fires are actually a complex set of biochemical reactions in our cells that create the right high energy molecules and conditions for us to extract the energy out of the matter that food is made of. To use our food efficiently, our bodies have specific pathways for different types of food sources: sugars and other carbohydrates are used to provide immediate energy to move and react, proteins are used to build important body structures, fats are used to store fuel for later use. We take all these processes for granted, but it's so amazing!

Only for those interested in geeking out on mass & energy. While physics teaches us about the important principle of mass/energy equivalence, (i.e., E =mc2), in most cases it makes sense to treat mass and energy as separate concepts. As explained earlier, during chemical processes, the atoms do not change and thus the energy associated with mass is constant and irrelevant to keeping track of any changes in energy. In particle physics, however, collisions–where we collide and annihilate matter and antimatter at high energies–do produce new particles and antiparticles with different masses. So in all non-nuclear cases, it's convenient to treat the mass-energy quite separately from other forms of energy, and to leave matter out of the equations for energy altogether.

TEACHING NOTES

About the *Next Generation Science Standards (NGSS)* The development of the *Next Generation Science Standards* followed closely on the movement to adopt nationwide English language arts and mathematics *Common Core* standards. In the case of the science standards, the National Research Council (NRC) first wrote a *Framework for K-12 Science Education* that beautifully describes an updated and comprehensive vision for proficiency in science across our nation. The *Framework*-validated by science researchers, educators and cognitive scientists-was then the basis for the development of the *NGSS*. As our understanding of how children learn has grown dramatically since the last science standards were published, the *NGSS* has pushed the science education community further towards engaging students in the practices used by scientists and engineers, and using the "big ideas" of science to actively learn about the natural world. Research shows that teaching science as a process of inquiry and explanation helps students form a deeper understanding of science concepts and better recognize how science applies to everyday life. In order to emphasize these important aspects of science, the *NGSS* are organized into three dimensions of learning: Science and Engineering Practices, Crosscutting Concepts and Disciplinary Core Ideas (DCIs). The DCIs are divided into four disciplines: Life Science (LS), Physical Science (PS), Earth and Space Science (ESS) and Engineering, Technology and Applied Science (ETS).

Read more about the *Next Generation Science Standards* at http://www.nextgenscience.org/ and http://ngss.nsta.org

hot planet. *Matter* cycles through ecosystems here on Earth, and does not usually leave the planet (some air molecules are lost into space, and sometimes a spacecraft flies away). A large amount of energy flows to Earth from the Sun in the form of light energy, and is captured by plants and "packaged" with matter in the form of food. But at every link in a food chain or food web, ~90% of the energy is lost from the ecosystem when it is released into the atmosphere as heat, and eventually drifts into outer space. About 10% of the energy is passed on to the next organism that eats it. So there is a constant flow of energy from sunlight into Earths' systems (during the day), and a constant flow out of the systems into space. This is why it's important to keep these ideas separate and **not** combine energy and matter into one driving force that cycles through all the systems on Earth. For example, by including the Sun in food webs (sometimes done to try to simplify energy flow and matter cycles) this can reinforce the inaccurate idea that energy is constantly cycling through Earth systems. By teaching kids that food is energy *and* matter, and that *matter cycles* and *energy flows*, we can give students a more accurate picture. Sometimes it can be less confusing to focus first on matter, and then introduce the more abstract concept of energy.

Misconception. Most of the mass of plants comes from soil and water.
More accurate information. This is also a very common misconception, even among science educators. Soil does *not* provide food for plants, but provides them with essential nutrients, similar to vitamins. A tiny fraction of the mass of a plant comes from soil, but most of the mass comes from carbon dioxide and water that are chemically rearranged into glucose through the process of photosynthesis.

Connections to the Next Generation Science Standards (NGSS)

BEETLES student activities are designed to provide opportunities for the "three-dimensional" learning that is called for in the NGSS. To experience three-dimensional learning, students need to engage in practices to learn important science concepts (Disciplinary Core Ideas) and relate that content to big ideas in science (Crosscutting Concepts). In simple terms, students should be exploring and investigating rich phenomena, and trying to figure out how the natural world works.

***Food, Build, Do, Waste* features the scientific practice *Developing and using models*, and the crosscutting concept *Energy and Matter: Flows, Cycles and Conservation*.** Students also have the opportunity to build some understanding of relevant Disciplinary Core Ideas in the Life Sciences. In this activity, students create a model for matter and energy moving through an organism, in order to track the flow of energy and the cycling of matter in ecosystems and explore how organisms are organized to make use of matter and energy from their environments.

Featured Science and Engineering Practices

Engaging students in Developing and Using Models. Models are used as tools in science to represent ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations. All models are inaccurate in some way(s), otherwise they'd be the "real thing." Models bring certain features into focus, (in this case, matter and energy), while obscuring others, for the purpose of making it possible to go beyond what is observable, imagine a world not yet seen, and build and revise scientific explanations. In Food, Build, Do, Waste, the diagram/chart students make is a model of an organism "system." This model is an explanation of how an organism takes in the inputs of energy and matter packaged in food, what it does with them, and tracks the output of wastes. Students use their model to predict the kinds of inputs, structures, actions and wastes different organisms in nature have, and to discuss how matter and energy move through ecosystems. In order to fully make use of these models as thinking tools, it's important for students to return to their own model, and revise or add to it, in order to show how their thinking and explanations have changed or expanded after the large group discussion.

Featured Crosscutting Concepts

Learning Science through the lens of Energy and Matter. According to the NRC's A Framework for Secondary Science Education, students should be considering questions like "How is energy flowing through this system/organism?" and "How is matter cycling through this system/organism?" Students apply this crosscutting concept throughout the activity, but they take it deeper, and can apply the ideas more broadly if you include the first 3 steps of tracing matter and energy. Creating a more complex matter and energy diagram including multiple organisms, gives students the opportunity to explore how matter cycles through an organism and the ecosystem around it, as well as to consider how energy flows through the larger systems of the Earth. Including these steps will deepen students' understanding of how matter and energy can move through ecosystems in general. It would also be possible to integrate the crosscutting concept Systems and System Models instead, by asking students to think of their models as models of the system of an organism. Be sure to point out to students that these "lenses" are tools they can use to deepen their thinking about any part of the natural world.

Featured Disciplinary Core Ideas

Building a foundation for understanding Disciplinary Core Ideas. The NGSS make it clear that students need multiple learning experiences to build their understanding of disciplinary core ideas. *Food, Build, Do, Waste* provides students with an opportunity to develop understanding of the life science core ideas LS1.C *Organization for Matter and Energy Flow in Ecosystems*, LS2.B *Cycles of Matter and Energy Transfer in Ecosystems,* and PS3.D, *Organization for Matter and Energy Flows in Organisms.*

As students engage in the initial group brainstorm, then observe organisms and make their diagrams, they'll build understanding of the idea that food provides animals with the materials they need for body repair and growth and the energy they need to maintain body warmth and for motion. (LS1.C)

TEACHING NOTES

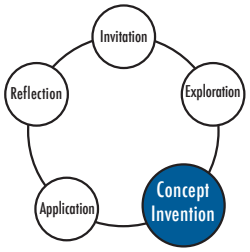
Importance of teaching science practices. "Engaging in the practices of science helps students understand how scientific knowledge develops...It can also pique students' curiosity, capture their interest, and motivate their continued study..." -National Research Council, *A Framework for K-12 Science Education.* Focus on these science practices will help to ensure a more scientifically literate public who will be better able to make thoughtful decisions.

About Crosscutting Concepts in the NGSS. Crosscutting concepts are considered powerful thinking tools for how scientists make sense of the natural world. The seven "big ideas" listed as crosscutting concepts are: Patterns; Cause & Effect; Scale, Proportion & Quantity; Systems and System Models; Energy & Matter: Flows, Cycles and Conservation; Structure & Function; and Stability & Change. These concepts may sound familiar, as they are quite similar to the themes referred to in science literacy documents as being important ideas that unify all disciplines of science and engineering.

TEACHING NOTES

Translating the codes for the *NGSS* performance expectations. Each standard in the *NGSS* is organized as a collection of performance expectations (PEs) for a particular science topic. Each PE has a specific code, provided here so they can be easily referenced in the *NGSS* documents. The first number or initial refers to the grade level: K - kindergarten, 1 - first, 2 - second,etc...MS - middle school, and HS - high school. The next letters in the code refer to the science discipline for the standard: LS, PS, ESS, ETS. The number following the discipline denotes the specific core idea within the discipline that is addressed by the PE, and the last digit identifies the number of the PE itself.

So...MS-LS2-2 means it's part of a middle school standard (MS) for life science (LS), addressing the second core idea (2) *Ecosystems: Interactions, Energy & Dynamics*, within the life science standards, that deals with Interdependent Relationships in Ecosystems. It's also the second performance expectation (2) that makes up the complete LS2 standard at this grade level.



***Food, Build, Do, Waste* and the Learning Cycle.** This activity brings students through a full learning cycle. Within a sequence of activities focused on developing understanding of matter and energy, this activity serves as a concept invention activity.

If you include the additional steps on matter and energy, students will build some understanding of the ideas that matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases, and water, from the environment, and release waste matter (gas, liquid, or solid) back into the environment. (LS2.A) If students focus on a plant, they will build understanding of the idea that plants acquire their material for growth chiefly from air and water. (LS1.C). Students may build some understanding of the idea that energy released [from] food was once energy from the sun that was captured by plants in the chemical process that forms plant matter (from air and water). (PS3.D)

Performance Expectations to Work Towards

When examined closely, it's clear that the *NGSS* represent complex knowledge and multifaceted thinking abilities for students. No single activity can adequately prepare someone for an *NGSS* performance expectation. Performance expectations are examples of things students should be able to do, after engaging in multiple learning experiences or long-term instructional units, to demonstrate their understanding of important core ideas and science practices, as well as their ability to apply the crosscutting concepts. As such, they do not represent a "curriculum" to be taught to students. Below are some of the performance expectations that this activity can help students work toward:

5-PS3-1.Use models to describe that energy in animals' food (used for body repair, growth, motion, and to maintain body warmth) was once energy from the sun. [Clarification Statement: Examples of models could include diagrams, and flow charts.]

5-LS2-1.Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.

MS-LS2-3.Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

5-LS1-1.Support an argument that plants get the materials they need for growth chiefly from air and water.

Activity Connections

This activity will support student understanding in a series of activities related to Matter, Energy, and Ecosystems. Before this activity you might want to do the name game, *You Are What You Eat*, to lightly introduce the idea of matter being used to build bodies, and using energy to do things. To continue to develop student understanding of these concepts, try BEETLES activities *Card Hike* (using the ecosystems, matter & energy cards), *Case of the Disappearing Log, Decomposition Mission*, *Matter & Energy Diagram,* and other activities listed in the *Ecosystems, Matter, & Energy* theme hike.

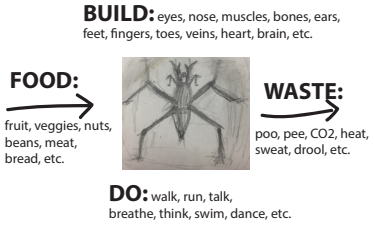
FIELD CARD

Cut out along outer lines, & fold along the centerline. This makes a handy reference card that will fit in your pocket

Food, Build, Do, Waste

Introducing the Activity

1. Eat food and discuss: Why do organisms need to eat food?
   - *Why do we need to eat food?*
   - *Why is food important to living organisms?*
2. Explain Food = matter & energy organisms can digest:
   - *Food is the fuel we need to survive, grow, and reproduce.*
   - *Food is matter & energy "packaged" in a form that is digestible by an organism.*
   - *A piece of bread may seem like nothing special, but it's full of matter and energy, and our bodies know exactly what to do with it!*
3. Choose example organism.
4. Make chart with Food, Build, Do, Waste at left, top, bottom, & right sides:
5. Draw example organism in center, quickly demonstrating how to make an accurate scientific drawing. Explain:
   - *The drawing doesn't need to be pretty; draw as accurately as possible, include organism, structures & notes, use arrows, draw small organisms larger, include date & location.*



6. Briefly brainstorm, & record body parts built from matter from food by the chosen organism where it says, "Build."
7. Briefly brainstorm & record things the organism uses energy from food to do - where it says, "Do."
8. Briefly brainstorm & record wastes the chosen organism gives off where it says, "Waste" (include heat & CO_2).
9. Briefly brainstorm & record possible foods of the chosen organism where it says, "Food" (write "?" if they don't know).

Exploring and Drawing

1. Explain: you'll search for an organism, then make a diagram/model, like the example the group did together.
2. Explain: you'll use this diagram to understand how organisms use matter and energy as they cycle and flow through them.
3. Explain: scientists use models like the chart to represent something in the real world - like matter & energy & an organism, to better understand it, & to show their thinking.
4. Explain how to find organisms in this location.
5. Give safety talk about finding organisms.
6. Review boundaries & rules, assign partners, pass out materials.
7. While pairs of students explore & sketch, help them focus on matter & energy.

Group Brainstorm

1. Ask students to release organisms carefully, as close to where they were found as possible.
2. Gather students with their diagrams, and erase all but Food, Build, Do, Waste on your white board, & write "organisms" in the center.
3. For each category, do a Whip-Around (each student or pair says one thing), then record a few on the whiteboard and ask follow up questions:
   - *BUILD. What parts of your organisms' bodies do they build with matter (include internal organs & fluids)?*
   - *DO. What do your organisms use energy to do (what you observed, or what you think it might do)?*
   - *WASTE. What wastes do your organisms give off (what you observed or what you think they might leave behind)?*
   - *FOOD. What might your organisms eat (what you observed or what you think it might eat)?*

Tracing Matter and Energy

1. Use student suggestions to draw a more complex model connecting it to food from plants, energy from Sun & matter

(continued on next page)

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Find the latest activities and information at http://beetlesproject.org.

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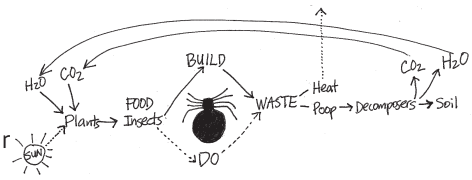
from CO_2 & H_2O in the air.



2. Add waste arrows showing heat energy going to space, matter waste released into soil, as well as CO_2 & H_2O released into air through decomposition. Connect plants to gases in air.
3. Explain that matter cycles through systems like organisms & ecosystems, and energy flows through systems, & out into space.
4. Prompt students to add information to their models.
5. Circulate, ask questions & troubleshoot.

Wrapping Up

1. Show or eat package of matter & energy (food) again, reminding them that it has matter to build & energy to do.
2. Continue to stir up discussion about matter & energy when students observe other animals.
3. Focus group on a plant, & brainstorm food, build, do, waste about it.
4. Walk & Talk reflection:
   - ▶ *What helped you learn today?*
   - ▶ *What questions do you still have about how matter cycles and energy flows in organisms and ecosystems?*
   - ▶ *Every organism, including the one you studied, can be food for other organisms. What other organisms can you think of that might get their matter and energy from eating your organism?*
   - ▶ *What animals can you think of that are very active and need food with lots of energy, like seeds or meat, or need lots of food?*
   - ▶ *What animals can you think of that are not very active and can eat food with less energy in it, like grass, or can eat less food?*
   - ▶ *Brainstorm herbivores that get most of their matter & energy from plants.*
   - ▶ *Brainstorm carnivores that get most of their matter & energy from meat.*
5. [If you're eating together] Ask questions during lunch about matter & energy.

ABOUT BEETLES™

BEETLES™ (Better Environmental Education Teaching, Learning, and Expertise Sharing) is a program of The Lawrence Hall of Science at the University of California, Berkeley, that provides professional learning sessions, student activities, and supporting resources for outdoor science program leaders and their staff. The goal is to infuse outdoor science programs everywhere with research-based approaches and tools to science teaching and learning that help them continually improve their programs.

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