beetles

Science and Teaching for Field Instructors

Student Activity Guide

Mating and Cloning

Ideas about biological inheritance and adaptation can be a fascinating lens through which to see the diversity of life around us. This activity brings these ideas to life through direct observation and rich discussion and offers students the opportunity to build beginning understandings of complex concepts of adaptations and natural selection.

In this Adaptations Activity—meant to follow the *Related and Different* and *Adaptations Intro—Live!* activities—students use the Field Guide to Mating in Flowering Plants and the Field Guide to Mating in Conifers, Ferns, and Mosses to find and explore flowers, seeds, berries, cones, and spores (evidence of plant reproduction), which offer students the opportunity to realize that there are plants mating all around them! A final discussion focuses on advantages and disadvantages of sexual (mating) and asexual (cloning) reproduction.

Students will:

- **Use a key to identify evidence of sexual reproduction in plants.**
- **Identify some advantages of diversity in populations.**
- **Discuss the advantages and disadvantages of mating and cloning as reproductive strategies.**

Grade Level:
Grades 5–8. Adaptable for older students.

Related Activities:
Whacky Adapty, Adaptations Intro–Live!, Structures and Behaviors, Blending in and Standing Out, Related and Different. Mating and Cloning is ideally led after *Adaptations Intro–Live!* and *Related and Different.*

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

Timing:
Approximately 45 minutes.

Materials:
See the Materials and Preparation section on page 3 for details.

Setting:
An area with enough different kinds of cones, seeds, flowers, ferns with spores, or moss to be interesting. Ideally, an area that also includes a plant that reproduces asexually. (Examples of cloning plants include redwood trees, aspens, blueberries, creosote bushes, willow trees, potatoes, ground ivy, strawberries, or a plant grown from a cutting of another plant.)

Equity, Inclusion, and Cultural Relevance (informed by Youth Outside)**:**
This activity has been designed to demonstrate how to create an equitable, inclusive, and culturally relevant teaching and learning experience. Read more, beginning on page 12.

NEXT GENERATION SCIENCE STANDARDS

For additional information about NGSS, go to page 14 of this guide.

FEATURED SCIENCE AND ENGINEERING PRACTICE	FEATURED CROSSCUTTING CONCEPT	DISCIPLINARY CORE IDEAS
Constructing Explanations	Stability and Change	Inheritance of Traits, Variation of Traits, Natural Selection, Adaptation

THE LAWRENCE HALL OF SCIENCE
UNIVERSITY OF CALIFORNIA, BERKELEY

Mating and Cloning

ACTIVITY OVERVIEW

Mating and Cloning	Learning Cycle Stage	Estimated Time
Introducing the Activity	Invitation	10 minutes
Investigating Reproduction in Plants	Exploration, Concept Invention	15 minutes
Discussion: Diversity Within Organisms of the Same Type	Concept Invention, Application	10 minutes
Reflecting and Wrapping Up	Reflection	10 minutes
TOTAL:		**~45 minutes**

TEACHING TIPS

Read the Instructor Support section. Beginning on page 10, you'll find more information about pedagogy, student misconceptions, science background, equity and inclusion, and standards.

Practice discussion first. This activity culminates in a discussion that requires high-level thinking and communication skills. Before launching into this activity, work to nurture a culture of discussion in your group by encouraging students to share ideas and different perspectives. Coach students on using language of uncertainty and engaging in thoughtful, productive disagreement. Use activities such as *Group Agreements for Science Discussions* and *Thought Swap* to build students' skills. See Discussion Leading Tips for Instructors for more support: (http://beetlesproject.org/resources/integrating-discussion-instruction/).

Find an area with flowers, seeds, cones, nuts, berries, ferns, or mosses. You don't need all these natural features, but you need enough evidence of plant reproduction so the activity will be interesting to students. In the spring, look for flowers; in the fall, look for seeds and nuts. Even in winter, you may be able to find cones, nuts, dead flowers, and other signs of plant reproductive structures. To prepare for the activity, take the keys (Field Guide to Mating in Flowering Plants and Field Guide to Mating in Conifers, Ferns, and Mosses) with you to an area and do some scouting. Look for multiple examples of a few things on the key for students to explore, such as a patch of pine cones, flowers, or dry grasses that have gone to seed. (Note: If the ground is covered with snow, you may need to wait until another time of year to do this activity.) Look for nearby cloning plants to show students toward the end of the activity. Examples of cloning plants include redwood trees, aspens, blueberries, creosote bushes, willow trees, potatoes, ground ivy, strawberries, or a plant grown from a cutting of another plant. If you can't find an example, print and bring a photograph of one of these kinds of plants to share with students.

Field card. At the end of this activity write-up, you'll find a condensed, pocket-sized version to use in the field.

MATERIALS AND PREPARATION

MATERIALS

For the instructor

- portable whiteboard
- whiteboard marker

For each student

- 1 copy of Field Guide to Mating in Flowering Plants handout (page 18)
- 1 copy of Field Guide to Mating in Conifers, Ferns, and Mosses handout (page 19)

PREPARATION

1. **Make copies of Field Guide to Mating in Flowering Plants and Field Guide to Mating in Conifers, Ferns, and Mosses.** You can find these two field guides on page 18 and page 19, respectively. Make enough copies for each pair of students to have one copy of each field guide.
2. **Prepare for the outdoor activity.** You will need to find an area with enough evidence of plant reproduction so the activity will be interesting to students. For more specific information about what to look for in the different seasons, refer to Teaching Tips (on page 2). If you are unable to find an appropriate plant, print and bring a photograph to share with students.

TEACHING NOTES

Other Adaptations activities. *Mating and Cloning* is meant to come at the end of a sequence of activities focused on concepts of adaptations and inheritance and is ideally led after *Adaptations Intro–Live!* and *Related and Different*. These activities will set up students with prior knowledge critical to their success with *Mating and Cloning*.

TEACHING NOTES

Discussion Routines. See the BEETLES activity *Thought Swap* (formerly known as *Walk & Talk*) or the BEETLES resource, Discussion Routines, for logistics on these discussion formats. Wondering why we changed the name from *Walk & Talk*? We received some feedback from our community partners on how we can use more inclusive language, and we decided to change the name so we were not normalizing walking as the only way of moving and talking as the only way of communicating.

Examples of how variations can help or hinder organism survival. If students need more support in understanding this question, offer an example of how variation in a trait could help or harm survival. For example, variations in animals' coloring may help certain individuals camouflage better than others, variation in beak shape may help some birds get food better than others, variation in seed structures may help some plants spread seeds better than others (e.g., fluffier seeds may float in the wind better), variation in thorniness may defend some plants from herbivores better than others.

Building on understanding. This discussion builds on the BEETLES activity *Adaptation Intro—Live!* in which students learn and practice using the definitions for *inheritable traits* and *non-inheritable traits.* During this discussion, listen to get a sense of students' understanding of the concepts.

Sexual selection. Individual organisms not only need to survive until they're of reproductive age, they also need to have traits that are desirable to potential mates. This activity is focused more on general concepts around the benefits of mating and sexual reproduction and not on the specific traits that organisms might have to attract mates. See the Instructor Support section (beginning on page 10) for more information on how sexual selection, or having desirable traits, affects populations of organisms over time.

Introducing the Activity

1. **Invite students to *Thought Swap* (formerly known as *Walk & Talk*) or *Turn & Share* about the following questions and then ask a few students to share their ideas.** Build on and reference students' ideas and responses as you ask the second and third questions.
   - ▶ *We're all humans, but we're all different. Why aren't people identical to their biological parents and families?*
   - ▶ (Refer to an organism that students are familiar with in the ecosystem [e.g., deer, hawk, rabbit]). *Think about* [rabbits]. *What are some structures or behaviors they might be born with that might help some individuals to be more likely to survive?*
   - ▶ *What are some structures or behaviors they might be born with that might make some individuals less likely to survive? Why do you think so?*

2. **Offer a definition for *inheritable traits* and distinguish them from non-inheritable traits.** Note: If you have already done the *Adaptations Intro—Live!* activity, you may choose to skip this step or briefly ask students to define *inheritable traits* and *non-inheritable traits.*
   - **Inheritable traits.** Share that some traits of an individual organism are inheritable. Any trait you're born with is inheritable. This includes body structures, such as the shapes of your toes, and also instinctual behaviors such as breathing and flinching.
   - **Non-inheritable traits.** Share that other traits are **changes during individuals' lifetimes**. Traits, such as a scar, a broken arm, or big muscles from working out are not inheritable and don't get passed on to offspring.

3. **Call students' attention to two plants of the same species (e.g., two trees or large shrubs) and then ask students to briefly notice (without moving) some similarities and differences and make explanations about which traits are inheritable and which are not.**
   - ▶ *Take a look at these two* [trees, bushes, etc.]. *How are these individuals different from each other?*
   - ▶ *Which differences do you think are inheritable?*
   - ▶ *Which do you think are non-inheritable—happened during the individuals' lifetimes? Share your evidence and reasoning.*

4. **Share: Individuals that survive longer are more likely to pass on their inheritable traits, such as body structures, to their young.** Whenever possible, refer back to the examples of body structures that students shared about earlier.

5. **Ask students to share their thinking about how this might affect a population over time.** Listen to students' ideas and ask follow up questions to probe their thinking.

▶ *Certain inheritable traits help individuals survive and have young better than other individuals. How might the traits of individuals in the population change over generations?*

Investigating Reproduction in Plants

1. **Transition to focusing on how plants reproduce and ask students to *Think-Pair-Share* about the following question:**

    ▶ *How do you think plants pass on their traits to their young?*

2. **Listen to students' ideas and then share about types of reproduction in plants.** If students don't bring up these ideas, offer the following:

    - Many plants reproduce through parents combining DNA (sexually) by having male parts that produce pollen and female parts that make seeds when fertilized by pollen.
    - Sometimes plants reproduce through cloning.

3. **Call students' attention to a nearby plant with reproductive parts such as flowers, buds, seeds, or cones and ask students what they notice about the flowers, buds, seeds, or cones.**

    ▶ *Flowers, buds, seeds, and cones are all examples of plant reproductive parts.*

    ▶ *Without moving from where you are, share a few observations of any flowers, buds, seeds, or cones you can see.*

4. **Offer some examples and ideas of what evidence of plant cloning can look like.**

    ▶ *It can be harder to see evidence of cloning at first.*

    ▶ *But just about any plant can be cloned by making a cutting (cutting off a branch or shoot and then replanting it). Has anyone ever done this or seen this done?*

    ▶ *Sometimes plants can clone themselves, too. Evidence of plant cloning can include shoots coming off a parent plant or stump or stems growing sideways and rooting into new plants.*

    Call students' attention to shoots coming off a parent plant or stump or to another example of plant cloning.

5. **Share that students will focus on finding evidence of plant mating in the area and offer the idea that this kind of evidence is all around, if we know what to look for.**

6. **Offer 1 copy of the Field Guide to Mating in Flowering Plants and 1 copy of the Field Guide to Mating in Conifers, Ferns, and Mosses to each pair of students. Then, share that these field guides are a tool for finding plant mating structures.** Invite students to look at the guides and share that the guides include pictures and information about plant mating structures. Also share that students will use the guides to find evidence of plant mating in the area.

TEACHING NOTES

Connect to adaptations. If students are familiar with the concept of adaptations, share that this gradual change in the traits of individuals over generations is how populations adapt to their environments.

Allow this question to "run in the background." This activity is intended to give students time to think about, make observations, and discuss how they think plants reproduce. Students don't need to have an answer for this question right away at this early phase of the activity. This question sets the context for the latter part of the activity when students use the Field Guide to Mating in Flowering Plants and the Field Guide to Mating in Conifers, Ferns, and Mosses and begin to notice and identify evidence of plant reproduction.

Don't skip the partner discussions. Discussion gives students authentic opportunities to process content, formulate and share ideas, and to make meaning. Partnered discussions in *Turn & Shares*, *Think-Pair-Shares*, and *Thought Swaps* give every student in the group the chance to share and process their ideas and listen to those of their peers. Pair shares also help create an equitable and inclusive learning space. The opportunity to think through ideas and "rehearse" what to share with the whole group in a low-stakes situation is particularly beneficial for emerging multilingual learners and provides increased opportunities for all students to participate successfully. To learn more about creating an inclusive learning experience, see page 12 of the Instructor Support section.

TEACHING NOTES

7. **Highlight the following things in the field guides that students can look for:**
    - stages of a flower: flower bud → flower → faded flower → berry bud → seeds/berry → faded berry
    - male and female parts of flowers
    - different kinds of seeds
    - male and female conifer cones
    - fern and moss spores
    - tiny flowers (such as some grass flowers) that don't look like larger, more colorful flowers
    - seeds from a cone (How big are the seeds that turn into huge trees?)
8. **Share that the plant parts students find around them won't look exactly like the ones pictured in the field guides.** Share that plant parts students find might look different than the pictures in the field guides. There might be differences in color, shape, or size. For example, there is a flower shown in the field guide that is white with five petals, but students might find a flower like the one [refer to a flower nearby that students can see] that is [describe this flower's features that are different from the picture].
9. **Share that students will have several minutes to work in pairs to look for plant reproductive structures, match what they find to the field guides, and make observations about what they find.**
10. **Invite students to go outside in pairs and use the Field Guide to Mating in Flowering Plants and the Field Guide to Mating in Conifers, Ferns, and Mosses as they look for evidence of plant mating.** Invite students to look for evidence of plant mating in the surrounding area, using the keys/field guides to guide them. Discuss boundaries for exploring and offer warnings about any local hazards, such as poison oak or poison ivy.

Follow students' interests and connect their observations to reproductive success in plants. As you circulate, note what aspects of the search for plant mating parts engage students. Ask students to focus on how particular structures they're interested in might help with reproduction. For example, if students are particularly interested in seeds, you could extend the activity to think about the differences between seeds and how the traits of different seeds might help particular plant individuals disperse seeds and be more successful in producing young. If students are particularly interested in male and female flower structures, invite them to think about how pollen gets from the male structures to the female structures to allow fertilization and seed production.

11. **As students work, circulate, support, encourage, and be a co-investigator.** Circulate between pairs of students and support them in using the field guides. Listen to their questions and encourage them to make further observations to learn more. If students have found something particularly interesting, you might want to announce this to other students to engage them with it, too.
12. **After students have had time to explore with the field guides, offer time for each pair to share discoveries with another pair.**
13. **Gather the whole group and ask a few students to share their evidence of plant mating with the group.** Invite a few students to share (and point out) evidence they found of plants mating in the area. If there's something particularly interesting that comes up, you might want to encourage the whole group to check it out for themselves.
14. **Offer a reminder that some plants reproduce through cloning (asexually) and point out some plants that clone.** If possible, call students' attention

to plants in the area that can reproduce asexually through cloning. (Redwood trees, aspens, blueberries, creosote bushes, and willow trees often reproduce asexually.) Otherwise, offer examples that students may be familiar with, such as potatoes, how ground ivy and strawberries send out runners to clone themselves, or how you can often grow a new plant from a plant cutting.

Discussion: Diversity Within Organisms of the Same Type

1. **Facilitate a group discussion about why mating and diversity among individuals within a species could be advantageous for the species.** Ask follow up questions, encourage thoughtful disagreement, and hear ideas from many students.
   - ▶ *Why might it be helpful for a type of organism, like the plants we just investigated, to have diversity among individuals?* [Students might say something like: Variation in genes increases species' ability to respond to environmental changes, such as changes in regional climate or human impacts on the environment.]
2. **Share that mating leads to diversity—offspring produced through mating are always different from each other and from their parents, except in the case of identical twins—and offer some ideas about how diversity benefits populations.** Highlight how diversity can help a population be stable through hardships such as disease.
   - ▶ *Because offspring from sexual reproduction are different from their parents, mating and combining genes leads to more diversity in a population.*
   - ▶ *Diversity in a population can help populations of organisms be more stable.*
   - ▶ *For example, when a disease spreads through a population, some individuals may be resistant to that disease and survive, while others may not be resistant and may die. It is more likely to have some individuals that are resistant to the disease when there is variation in the population. If all individuals were the same and a disease to which they were not resistant spread through a population, all individuals would die.*
3. **Ask students to brainstorm advantages and disadvantages of cloning.** Share that in addition to plants that clone, there are other organisms that can produce genetically identical clones. For example, bacteria, aphids, whiptail lizards, some species of sharks (including hammerhead sharks), rays, anemones, and Komodo dragons can all reproduce by cloning.
   - ▶ *How could the ability to clone itself help these organisms survive?* [They can reproduce faster without needing a partner. They can reproduce when partners are not available.]
   - ▶ *What might be the disadvantages of cloning for any type of organism?* [Less diversity from generation to generation. A less diverse population has less chance of adapting to changes in the environment or to surviving diseases.]

TEACHING NOTES

Use *Turn & Shares* throughout the discussion. During this discussion, give students a lot of chances to *Turn & Share* to try out their ideas with a partner before you open up a question to the whole group to discuss. Follow the thread of students' curiosity and don't be afraid to allow the conversation to diverge from the questions listed.

Who is speaking, who isn't? In a discussion, it's important for each individual to have the opportunity to contribute. However, research summarized in the book *Failing at Fairness: How Our Schools Cheat Girls* by Myra and David Sadker shows that girls are called on significantly less than boys. Promote equitable participation by using wait time (pausing 3+ seconds before calling on students), including time for pair discussion, and intentionally calling on a range of different students. Toward the end of a discussion, try pausing and saying, "I'm going to wait for a moment in case anyone who hasn't spoken up yet has something they'd like to share." Use the activity *Group Agreements for Science Discussions* to offer your group the skills for paying attention to how their participation might be affecting the group and to enlist the group in working together to create an environment in which everyone feels supported to share their ideas. To learn more about creating an inclusive learning experience, see page 12 of the Instructor Support section.

Students don't need to leave understanding everything. This discussion gives students an opportunity to share what they know and for the instructor to add a little content to help increase understanding and curiosity about these concepts. Don't share everything you know about the topic; share just enough to increase student understanding and encourage curiosity. Follow students' interests during the discussion. If a topic is tedious, shift to a new one. If a topic is interesting to students, pursue it!

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"I find that kids love to talk about cloning, even if they don't have the maturity to talk about asexual reproduction. I had a group naturally steer a conversation into the risks and benefits of GMO's, the risk of an entire crop being wiped out by a plague, and the problem of superweeds." –Alison Petro, field instructor, Walker Creek Ranch

Instructors can have fun with students by painting the scene of a world full of identical cloned humans. "What if everyone was genetically the same as [use your name, a chaperone's name, a student's name, or a random name such as Michael]? If they got on the bus to go to school, the door would open, and there would be [Michael] driving the bus full of [Michaels]. At school, all the teachers would be [Michaels], everyone who worked at the school would be [Michaels], and all the students would be [Michaels], too. If a Michael leader did roll call, he'd say, 'Michael?', and everyone would say, 'Here!' If they found a salamander outside, that salamander would be . . . a salamander and not [Michael], because a salamander is a different species!"

Connecting diversity to social emotional learning (SEL) and group dynamics. This is an opportunity to connect to how a group of people with varied perspectives can lead to deep discussions, rich learning experiences, and resilient communities. If students seem especially interested in this discussion topic, encourage them to continue to share thoughts and perspectives.

4. **Facilitate a group discussion about the value of diversity in humans.** Invite students to think about diversity and cloning in the context of humans. Offer time to discuss in pairs before opening it up to the larger group.

   ▶ *What would it be like to live in a world of human clones? What if every single person was a clone? What would the disadvantages be? Describe what that might be like.*

   ▶ *What are the benefits of diversity in a human population?*

5. **Wrap up the discussion by summarizing the main points of what students discussed.** Briefly summarize the main points of the discussion. For example, you could say, "We started out talking about ____, and then Carlos brought up ____, which led us to talk about ____, and the point was made that ____." Reiterate how diversity is important for species' survival and resilience. If it seems appropriate, reiterate the following points:

   - A population of cloned individuals may be able to reproduce fast, but the population would lack diversity and could be wiped out by a disease that none of them had immunity against.
   - A population of individuals that is the result of sexual reproduction is more diverse and more likely to have some individuals with immunity against the disease.

6. **Offer the idea that as students discussed the benefits of diversity from sexual reproduction and the pros and cons of cloning, they were thinking about what makes species change and what makes them stable.**

   ▶ *When you were talking about the benefits of diversity from sexual reproduction, you were talking about how populations of organisms can change and how that affects individual and species survival.*

   ▶ *When you were talking about the pros and cons of cloning, you were thinking about a species being stable (not changing) and how this affects individual and species survival.*

7. **Share that scientists often think about stability and change in order to better understand the natural world and make predictions about what might happen in the future.**

   ▶ *Scientists often think about what causes a species or part of nature to be stable and what causes it to change, like we just did, in order to better understand how nature works and make predictions about what might happen in the future.*

Reflecting and Wrapping Up

1. **Ask one or more of these *Thought Swap* (formerly known as *Walk & Talk*) reflection questions:**

   ▶ *What surprised you about plant reproduction?*

- *We've focused on diversity within a species. What benefits do you think there might be to having a variety of different kinds of organisms (plants with deep roots, plants with shallow roots, tall and short plants, etc.) in an ecosystem that have different adaptations to survive?*
- *Do you think humans are more diverse or less diverse than other organisms?*
- *Did any of your ideas change during this activity? What made your ideas change?*
- *How might you explain or show some of what you learned in this activity to a family member?*
- *What questions do you still have about organisms and their relatedness?*

2. **Now and then, throughout the rest of your field experience, invite students to notice plant mating structures and clones.** If you are moving through different areas, such as an area with different flowers, nuts, or seeds, invite students to make observations and apply ideas about reproduction, passing on traits, and adaptation. For example:
   - Let's gather a whole bunch of these acorns (or nuts, cones, seeds) that are the result of sexual reproduction and see if we notice differences between them.
   - Let's see if we can find examples of different stages of flower buds/flowers/faded flowers/seeds/faded seeds on this plant. (Hold up or point to a specific plant.)
   - Let's see if we can figure out which are the male and female parts in these flowers. How do you think they are pollinated?
   - Check out all these smaller clone plants coming out of this stump.

Optional extension: Test out students' ideas with flying seeds.

- Experiment with ways to challenge students to think about which inheritable characteristics of plant reproductive structures would be most likely to be passed on. For example, if you are looking at seeds with wings on them, you might notice that some seeds have bigger wings.
- Students might suggest that bigger wings might be beneficial in helping the seed fly farther and land in a place where they will not be shaded by the tree they came from.
- To test out this explanation you could invite students to drop seeds with different length wings from a specified height and observe which ones travel farther.

TEACHING NOTES

Broad questions and science learning. Science is often viewed or taught as a collection of facts, and this is reinforced by science learning experiences that focus on memorization or recall of facts and narrow questions posed to students that invite only one correct answer. However, science is a way of knowing and a process for thinking and learning, not just a body of knowledge. Including broad questions in science learning (questions that have multiple possible responses, such as *How might cloning help these organisms survive?*) engages students in scientific sense-making, encourages critical thinking, and makes space for divergent perspectives and differing ideas to be shared. Weaving broad questions throughout science lessons also sends the message that students' ideas, perspectives, and creative and critical thinking are an essential part of science learning, contradicting the exclusionary idea that memorizing facts is what it means to be "good at science."

Going deeper with stability and change. Toward the end of the field experience, you might want to invite students to discuss what seems to be fairly stable in this ecosystem and what things seem to be changing. For example, you might say, "The trees in the flatter parts of the ecosystem seem stable, but the ones growing on the steep banks seem to be leaning, and some have fallen." You might also ask as a follow-up, "How might this affect traits of organisms in this area? For example, individuals with deeper roots might survive better on steep slopes and have more offspring, and so a type of tree might evolve to be better adapted to live on steep slopes." Encourage students to think about what is changing and what is stable in their surroundings throughout their field experience as well as when they go home.

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Instructor Support

Teaching Knowledge

Engaging students in discussion. In order for students to be able to engage in discussion, it's important to set up a culture of discourse in your group and to give students opportunities to discuss in pairs and in small groups before participating in a whole-group discussion. To establish a culture of discourse, create and nurture an atmosphere of respect and intellectual curiosity by responding equitably to students' ideas as a facilitator and facilitating—not dominating—the discussion. When you respond to students, do so in a neutral, accepting manner and then probe their thinking with follow-up questions. Encourage agreement and disagreement that builds toward a deeper understanding and establish that when there is disagreement about ideas, students will not be ridiculed for having the "wrong" answer. Emphasize that sharing ideas as a group is an important part of the learning process.

Conceptual Knowledge

Sexual vs. Asexual Reproduction

All living things have a code in each of their cells called DNA. This code is a set of instructions needed for an organism to develop, survive, and reproduce. When an organism goes through asexual reproduction, it creates a genetically identical clone of itself. During sexual reproduction, male and female DNA is combined and forms a new and unique DNA set of instructions for each of their offspring (except in the case of identical twins who have the same DNA set of instructions).

Diversity is one of the benefits of sexual reproduction. Every time an organism reproduces sexually, DNA from two organisms is combined to form a unique combination. That diversity helps the species survive. If a serious disease spreads through a population of a species of organism, those without immunity may die. However, because there is diversity, some are likely to survive and pass on their genes to their offspring. This is somewhat true with humans, too, as we have had horrific examples of how different individuals' immune systems respond to diseases, such as the coronaviruses. Fortunately, humans have been able to learn how to protect those with lower innate immune protection against certain diseases through prevention strategies, treatments, and vaccinations.

There are benefits to asexual/cloning reproduction, too. Asexual reproduction allows an organism to reproduce without putting out energy to find and attract a mate. While sexual reproduction provides the benefits of genetic reshuffling that leads to diversity in a species, asexual reproduction guarantees an exact copy of a successful organism. This is a good strategy when an organism is well adapted to its environment, and its environment is stable. It's also a good strategy for species that need to reproduce rapidly to colonize new areas, such as bacteria, protists, and some invasive plants.

Another source of diversity within a species comes from mistakes in copying DNA, known as mutations. On average, a human has approximately 60

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mutations that their parents don't have. Mutations can be helpful, harmful, or neutral for an organism's survival. Most mutations are neutral—they don't harm or help the organism. Some mutations do harm the organism, and some mutations help. Beneficial mutations can help an organism survive in its habitat, giving it a greater chance of having babies and passing on that mutation through the population, increasing the success of the species. Harmful mutations are less likely to be passed on because they decrease survival and reproduction. In these ways, mutations provide some diversity in population traits among asexually reproduced offspring.

Asexual Reproduction in Plants

People often know about flowers and pollination, but they aren't aware that many plants can actually reproduce asexually, too. This can happen in the following ways:

- Plants can send out runners—stems that grow horizontally at the soil surface and can form new roots and buds—as is common in strawberry plants and many grasses. These new roots and buds become new plants.
- Plants can send out rhizomes, which are similar to runners but grow underground. This is common in many grasses, sedges, and weeds. The rhizomes reach out underground and grow new plants.
- Some plants (e.g., potatoes, onions, tulips) can form bulbs or tubers underground. These tubers can grow new, genetically identical plants.
- In some plants, part of a plant's stem can bend over and root in the soil to grow a clone. This is called layering. This can also happen with some trees, such as California Bay Laurel trees.
- When cut or damaged, some trees (such as redwood trees) can sprout clones from their roots, growing new genetically identical trees.
- The ovaries of some plants can produce seeds without fertilization in a process called apomixis. This occurs in several species of daisies, roses, and grasses but is less common than the other methods of asexual reproduction.

Sexual Reproduction in Plants

Even though asexual reproduction is common for many plants, sexual reproduction is also abundant. Sexual reproduction happens when the male and female cells of plants fuse together to form genetically distinct offspring.

In flowering plants, the male cells are produced in the stamen of the flower, and the female cells are produced in the ovary of the flower. The stamen produces pollen grains, which get transferred to the ovary through pollination, so fertilization can happen. Plants can be pollinated by self-pollination (when male and female cells from the same flower or different flowers on the same organism, fuse) or by cross-pollination (when cells from two different organisms combine), which is usually facilitated by insects or wind. Fertilization causes the flower to lose its petals and grow seeds—which contain a combination of the parents' DNA—and fruit to form. The seeds can then be dispersed by wind, water, or animals, and if the conditions are right, can grow into new, genetically distinct plants.

In conifers, the process is similar, but instead of having flowers with male and female reproductive parts, conifers have cones. Male cones, similar to the stamens of flowers, produce pollen, which must be transferred to female cones for fertilization to happen. Seeds develop within the female cones, tucked into the scales of the cone and then get released to form new plants when the scales open up.

There are other means of reproduction in plants as well, some of which are quite complex. For example, most ferns reproduce through alternate generations of asexual and sexual forms. The plant that most people picture when they think of a fern—a feathery stalk— is the asexual form. It produces and releases spores, which can germinate to form a tiny, kidney-shaped plant (the sexual form) that has male and female reproductive parts. Fertilization happens when the male and female cells made by these tiny plants combine, and then a new fern can grow.

Thinking About Plant Reproduction, Genetic Inheritance, and Adaptations

This activity can be a great opportunity for students to start thinking about the benefits of sexual vs. asexual reproduction. If a plant is damaged, it's awesome for the plant to have the ability to reproduce asexually and sprout new, genetically identical plants from the roots. Another form of asexual reproduction, putting out runners (stems that grow horizontally across the ground and then root and sprout new genetically identical plants) can allow plant species to spread quickly, taking advantage of open space when it is available without needing to rely on seeds or pollination for distribution. However, without sexual reproduction, there isn't any opportunity for the combination of DNA. Each method has advantages and disadvantages, which is why so many plants are able to reproduce both sexually and asexually. If environmental conditions were to change over time and a plant species only relied on cloning, individual plants that were better suited for survival wouldn't be able to cross pollinate, and as a result, the whole plant population would be less likely to be able to adapt to the new conditions. Thinking about these kinds of ideas can support students' understanding of adaptations and can be foundational to their understanding of evolution.

Supporting Equitable, Inclusive, and Culturally Relevant Learning Experiences

This BEETLES student activity has been intentionally designed to create an equitable, inclusive, and culturally relevant learning experience for a community of learners. BEETLES design principles [http://beetlesproject.org/about/how-do-we-approach-teaching/] ensure that each activity is student-centered and nature-centered. This enables all learners to access, participate, and engage in the learning experience.

When learners engage directly with nature, they all have access to learning, regardless of their prior knowledge or experiences. Centering learning on students' in-the-moment observations of nature builds an inclusive learning experience by focusing the conversation on an experience shared by every student, as opposed to relying on students' prior knowledge or past experiences. As students engage with nature, instructors are in the role of the "guide on the side." This approach shifts power from the instructor to learners, challenges the typical learning situation in which the instructor is the only expert, encourages students to share their ideas and experiences, and makes learning a more decentralized and collaborative experience.

When learners think like a scientist and practice academic language, they develop critical thinking skills that support them to become more independent learners—learners who have skills and thinking tools they use to learn, regardless of the level of support available from a teacher or instructor. Giving students the opportunity to think like a scientist by making observations, asking questions, and constructing explanations supports students' growth as learners and offers them the opportunity to build critical thinking skills and learning behaviors they can apply in any context. Many students in schools that have historically been under-resourced due to racist school funding policies, redlining, income inequality, and police profiling have fewer opportunities to develop as independent learners. Specifically ensuring that students in these kinds of schools have opportunities to develop as independent learners is an issue of equity. Learning and practicing critical thinking skills in an engaging outdoor context supports students to succeed back in their classrooms, in science, and in other academic disciplines. Offering opportunities for students to discuss ideas with their peers and knowledgeable adults makes science more accessible by connecting it to students' own actions and discoveries in the moment—not to knowledge they may not have or experiences they may not have had.

Through discussion, learners make connections to prior knowledge, share their lived experiences, listen to different perspectives, and have time to process the material. Productive discussions in which many voices are heard and the group builds off one another's ideas create an experience in which students see themselves and one another as sources of expertise. This ensures that instructors don't fall back on positioning themselves as the only source of accurate or important information. Participating in discussions also supports students to develop cognitive rigor and the ability to take on more advanced learning tasks. Discussions make student thinking and ideas visible to the instructor. When instructors value, appreciate, better understand, and connect to students' lived experiences, they create a more inclusive and culturally relevant learning space. Finally, multiple opportunities for discussion provide time and space for neurodiversity—allowing students to process information in different ways. Using discussion strategies such as *Turn & Share* or *Thought Swap* (formerly known as *Walk & Talk*) that are part of every BEETLES student activity can help ensure that students have these kinds of opportunities for discussion.

Specifically, *Mating and Cloning* promotes an equitable, inclusive, and culturally relevant learning experience by:

- using broad questions to invite students to share their observations, prior knowledge, perspectives, and experiences with one another and with the instructor.

TEACHING NOTES

"Classroom studies document the fact that underserved English learners, poor students, and students of color routinely receive less instruction in higher-order skills development than other students." (Allington and McGill-Franzen, 1989; Darling-Hammond, 2001; Oakes, 2005) –Zaretta Hammond, *Culturally Responsive Teaching & the Brain*

- providing space for students to come up with connections between what they are observing and prior experiences and knowledge, which supports their learning and retention.
- providing a simple key, which students can use to pursue their own interests within the subject area.
- engaging students in meaning-making discussions that prepare them to take on increasingly rigorous learning tasks in the future.
- offering opportunities for students to engage in NGSS Science and Engineering Practices such as *Constructing Explanations* and *Obtaining, Evaluating, and Communicating Information* that are transferable learning skills that students can continue to apply in other academic disciplines.
- providing a lesson structure in which the instructor acts as a "guide on the side" and builds a collaborative learning environment in which students make observations, share ideas, and see themselves and one another (not just the instructor) as sources of expertise.
- offering strategies—such as pair talk, wait time, and intentionally making room for students who haven't shared yet—that the instructor can use to support equitable student participation in discussions.

Overall, these factors contribute to creating a student-centered approach in which "the ultimate goal . . . is to help students take over the reins of their learning." (Zaretta Hammond, *Culturally Responsive Teaching & the Brain*, 2014). This approach to teaching supports students in becoming independent learners who are able to succeed, regardless of any individual teacher or learning context. BEETLES has intentionally designed the sequence and structure of this activity to support learning experiences in which all students feel capable of success and have the tools to carry that success into other domains.

Using student-centered and nature-centered learning approaches is just one piece of the work we can do to create equitable, inclusive, and culturally relevant learning experiences. Instructors must also work to become more aware of their own unconscious biases and triggers around culture, identity, and race that impact their interactions with students and affect their students' sense of inclusion.

Connections to Next Generation Science Standards (NGSS)

BEETLES student activities are designed to incorporate the three-dimensional learning that is called for in the NGSS. Three-dimensional learning weaves together Science and Engineering Practices (what scientists do), Crosscutting Concepts (thinking tools scientists use), and Disciplinary Core Ideas (what scientists know). Students should be exploring and investigating rich phenomena and figuring out how the natural world works. The abilities involved in using Science and Engineering Practices and Crosscutting Concepts—looking at nature and figuring things out, using certain lenses to guide thinking, and understanding mating and cloning more deeply—are mindsets and tools students can take with them and apply anywhere to deepen their understanding of nature, and they're interesting and fun to do!

TEACHING NOTES

Resources on unconscious bias. There are many great resources on understanding and shifting unconscious bias. Here are a few books and organizations we have looked to consistently to work on our own unconscious bias and to better understand how it can affect teaching and learning in the outdoors:

- *White Fragility : Why It's So Hard for White People to Talk About Racism* by Robin DiAngelo
- *Culturally Responsive Teaching & the Brain* by Zaretta Hammond
- Youth Outside [http://www.youthoutside.org/]
- The Avarna Group [https://theavarnagroup.com/]
- Center for Diversity & the Environment [https://www.cdeinspires.org/]

In *Mating and Cloning*, students engage in the Science and Engineering Practice of *Constructing Explanations* and have the opportunity to relate what they learn to the Crosscutting Concept of *Stability and Change*. Students will build understanding of Disciplinary Core Ideas related to *Inheritance of Traits*, *Variation of Traits*, *Natural Selection*, and *Adaptation*.

Featured Science and Engineering Practice

Engaging students in *Constructing Explanations*. According to the National Research Council's *A Framework for K–12 Science Education*, a major goal of science is to deepen human understanding of the world through making explanations about how things work. Students should develop their understanding of science concepts through making their own explanations about natural phenomena.

- In *Mating and Cloning*, students begin to engage in this practice when they construct explanations about which inheritable traits might help individual plants to survive.
- Students continue making explanations based on evidence about why diversity is useful to organisms and why cloning provides advantages and disadvantages.
- In order for students to be fully engaged in this practice, they need to go beyond just making explanations as described above. They also need to consciously use language of uncertainty (*I think that . . .*), base their explanations on evidence, and consider alternate explanations based on that evidence.

Featured Crosscutting Concept

Learning science through the lens of *Stability and Change*. Understanding how stable a system, organism, or object is, when it will change, and what causes it to change helps scientists make predictions about cause-and-effect relationships in nature. The lens of *Stability and Change* can also be an important tool for understanding flows of matter and energy into, out of, and within a system. Some systems may seem stable at one scale but may be changing at another scale, so when you think about stability and change, scale is an important idea to keep in mind.

- In *Mating and Cloning*, students think about how sexual and asexual reproduction affect the stability of populations and species and cause them to change over time.
- Though the idea is not formally introduced until the end of the activity, students start thinking about stability and change when they discuss how the traits of individuals in a population might change over generations.
- Students go a little deeper into thinking about stability and change as they discuss the pros and cons of sexual and asexual reproduction and, in particular, the implications with regard to survival.

Featured Disciplinary Core Ideas

Building a foundation for understanding Disciplinary Core Ideas. Students need multiple learning experiences to build their understanding of NGSS Disciplinary Core Ideas. *Mating and Cloning* gives students an opportunity to

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About the Next Generation Science Standards (NGSS). The development of the NGSS 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 toward 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 to 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 (DCI's). The DCI's 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/

TEACHING NOTES

develop understanding of some life science core ideas related to *Inheritance of Traits* (LS3.A), *Variation of Traits* (LS3.B), *Natural Selection* (LS4.B), and *Adaptation* (LS4.C).

- As students observe individuals of the same plant species and try to identify characteristics of those plants that are inherited vs. those that came about during the individual's lifetime, they build understanding of how organisms vary in how they look and function because they have different inherited information. (LS3.B, LS4.B)
- As students consider the advantages of sexual reproduction and asexual reproduction, they build initial understandings of how particular organisms can only survive in particular environments, how species can change over time in response to environmental conditions, and how traits that support survival become more common over time. (LS4.C)
- As students consider how diversity within a species offers survival advantages, they build understanding of ideas related to how certain traits give some individuals an advantage in surviving and reproducing, a building block of the concept of natural selection. (LS4.B)

You can informally assess students' understanding of these concepts during different stages of the activity in individual interactions with students and by listening carefully during the group discussions. This information can help you decide which ideas to focus on in future lessons so follow-up activities or discussions can be used to further student understanding.

Performance Expectations to Work Toward

No single activity can adequately prepare students for an NGSS Performance Expectation. Performance Expectations are designed as examples of things that students should be able to do to demonstrate their understanding of content and big ideas in science after engaging in multiple learning experiences and instruction over a long period of time. They are *not* the curriculum to be taught to students. Following are a few Performance Expectations this activity can help students work toward.

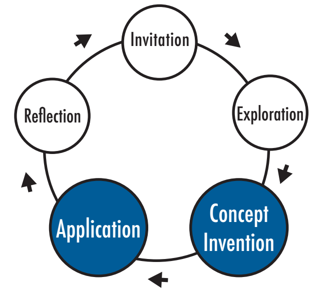
- **3-LS4-2.** Use evidence to construct an explanation for how the variations in characteristics among individuals of the same species may provide advantages in surviving, finding mates, and reproducing.
- **MS-LS1-4.** Use an argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants, respectively.
- **MS-LS3-2.** Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.
- **MS-LS4-4.** Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.
- **MS-LS4-6.** Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.

Translating the codes for the NGSS Performance Expectations. Each standard in the NGSS is organized as a collection of Performance Expectations (PE's) for a particular science topic. Each PE has a specific code, which is 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 grade, 2 = second grade, 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, 3-LS4-3 means the Performance Expectation is part of a third-grade standard (3) for life science (LS), addressing the fourth core idea (4), Biological Evolution: Unity and Diversity, within the life science standards, which deals with Adaptation. It's also the third Performance Expectation (3) that makes up the complete LS4 standard at this grade level.

Activity Connections

Mating and Cloning is meant to be used toward the end of a sequence of activities and learning experiences focused on content around *Adaptations*, *Inheritance of Traits*, *Variation of Traits*, and *Natural Selection*. BEETLES activities to engage students in building understanding of these concepts include *Whacky Adapty*, *Adaptation Intro—Live!*, *Structures and Behaviors*, *Blending In and Standing Out*, *Related and Different*, and *Card Hike*.

TEACHING NOTES



Learning cycle. As part of an Extended Trail Experience, this activity functions primarily as a Concept Invention/ Application.

Field Guide to Mating in Flowering Plants

Flowers, fruits, seeds, and male and female flower parts are all evidence of plant mating. Male parts make pollen. Mating happens when pollen reaches a female part, and seeds/fruit form.

flower bud →

flower →

faded flower →

berry bud →

seeds/berry →

faded berry

Flowering Plants: Seeds and Fruit

Seeds develop when pollen fertilizes a flowers' eggs. Fruits and seeds come in many shapes and sizes.

seeds that fly

different kinds of seeds

maple fruit and seeds

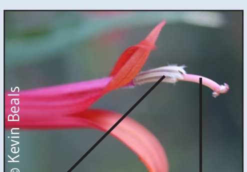
Some fruit protects its seeds.

buckeye fruit and seeds

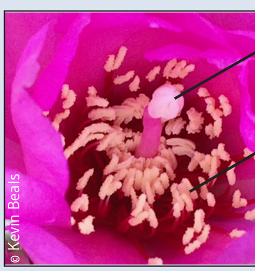
Some fruits are tasty, and seeds are spread when animals eat them.

blueberry fruit with seeds inside

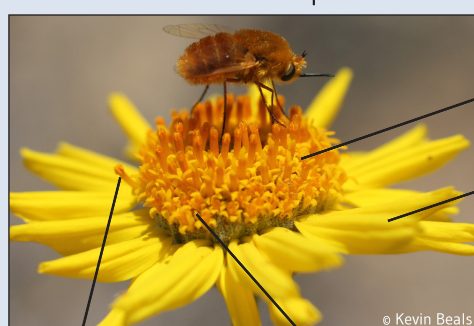
Flowering Plants: Most Flowers Have Both Male and Female Parts in the Same Flower



grass flowers and seeds



Some flowers are made up of lots of little flowers.



Flowering Plants: Male and Female Parts in Separate Flowers

Field Guide to Mating in Conifers, Ferns, and Mosses

Cones on conifer and spores on ferns and mosses are evidence of plant mating.

Conifers

Female Cones
These are the bigger cones most people think of as cones. After they have been fertilized by pollen from male cones, female cones open to release seeds.

Male Cones
Male cones are small and often grow in bunches. Male cones make pollen. Mating happens when the pollen from these cones reaches female cones.

female pine cone

male pine cones

male and female pine cones

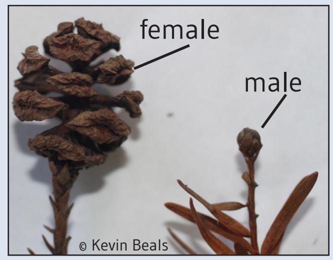
young female cone

male cone

female Douglas fir cone

seeds from female pine cone

Redwood cones



seeds from female redwood cone

Ferns

Fern spores
Sometimes, spores can be found on the undersides of ferns. Ferns use spores for reproduction.

Mosses

moss spores

Moss spores
Moss spores form when male sperm cells fertilize female moss parts.

FIELD CARD

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Mating and Cloning

Introducing the Activity

1. Invite students to *Thought Swap* (formerly known as *Walk & Talk*) or *Turn & Share* about the following questions and then ask a few students to share their ideas.
   - ▶ *We're all humans, but we're all different. Why aren't people identical to their biological parents and families?*
   - ▶ (Refer to an organism that students are familiar with in the ecosystem [e.g., deer, hawk, rabbit]). *Think about* [rabbits]. *What are some structures or behaviors they might be born with that might help some individuals to be more likely to survive?*
   - ▶ *What are some structures or behaviors they might be born with that might make some individuals less likely to survive? Why do you think so?*
2. Offer a definition for *inheritable traits* and distinguish them from non-inheritable traits.
   - **Inheritable traits.** Share that some traits of an individual organism are inheritable. Any trait you're born with is inheritable. This includes body structures, such as the shapes of your toes, and also instinctual behaviors such as breathing and flinching.
   - **Non-inheritable traits.** Share that other traits are **changes during individuals' lifetimes**. Traits, such as a scar, a broken arm, or big muscles from working out are not inheritable and don't get passed on to offspring.
3. Call students' attention to two plants of the same species (e.g., two trees or large shrubs) and then ask students to briefly notice (without moving) some similarities and differences and make explanations about which traits are inheritable and which are not.
   - ▶ *Take a look at these two* [trees, bushes, etc.]. *How are these individuals different from each other?*
   - ▶ *Which differences do you think are inheritable?*
   - ▶ *Which do you think are non-inheritable—happened during the individuals' lifetimes? Share your evidence and reasoning.*
4. Share: Individuals that survive longer are more likely to pass on their inheritable traits, such as body structures, to their young.
5. Ask students to share their thinking about how this might affect a population over time.
   - ▶ *Certain inheritable traits help individuals survive and have young better than other individuals. How might the traits of individuals in the population change over generations?*

Investigating Reproduction in Plants

1. Transition to focusing on how plants reproduce and ask students to Think-Pair-Share about the following question:
   - ▶ *How do you think plants pass on their traits to their young?*
2. Listen to students' ideas and then share about types of reproduction in plants.
   - Many plants reproduce through parents combining DNA (sexually) by having male parts that produce pollen and female parts that make seeds when fertilized by pollen.
   - Sometimes plants reproduce through cloning.
3. Call students' attention to a nearby plant with reproductive parts such as flowers, buds, seeds, or cones and ask students what they notice about the flowers, buds, seeds, or cones.
   - ▶ *Flowers, buds, seeds, and cones are all examples of plant reproductive parts.*
   - ▶ *Without moving from where you are, share a few observations of any flowers, buds, seeds, or cones you can see.*
4. Offer some examples and ideas of what evidence of plant cloning can look like.
   - ▶ *It can be harder to see evidence of cloning at first.*
   - ▶ *But just about any plant can be cloned by making a cutting (cutting off a branch or shoot and then replanting it). Has anyone ever done this or seen this done?*
   - ▶ *Sometimes plants can clone themselves, too. Evidence of plant cloning can include shoots coming off a parent plant or stump or stems growing sideways and rooting into new plants.*

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Call students' attention to shoots coming off a parent plant or stump or to another example of plant cloning.

5. Share that students will focus on finding evidence of plant mating in the area and offer the idea that this kind of evidence is all around, if we know what to look for.
6. Offer 1 copy of the Field Guide to Mating in Flowering Plants and 1 copy of the Field Guide to Mating in Conifers, Ferns, and Mosses to each pair of students. Then, share that these field guides are a tool for finding plant mating structures.
7. Highlight the following things in the field guides that students can look for:
   - stages of a flower: flower bud → flower → faded flower → berry bud → seeds/berry → faded berry
   - male and female parts of flowers
   - different kinds of seeds
   - male and female conifer cones
   - fern and moss spores
   - tiny flowers (such as some grass flowers) that don't look like larger, more colorful flowers
   - seeds from a cone (How big are the seeds that turn into huge trees?)
8. Share that the plant parts students find around them won't look exactly like the ones pictured in the field guides.
9. Share that students will have several minutes to work in pairs to look for plant reproductive structures, match what they find to the field guides, and make observations about what they find.
10. Invite students to go outside in pairs and use the Field Guide to Mating in Flowering Plants and the Field Guide to Mating in Conifers, Ferns, and Mosses as they look for evidence of plant mating.
11. As students work, circulate, support, encourage, and be a co-investigator.

12. After students have had time to explore with the field guides, offer time for each pair to share discoveries with another pair.
13. Gather the whole group and ask a few students to share their evidence of plant mating with the group.
14. Offer a reminder that some plants reproduce through cloning (asexually) and point out some plants that clone.

Discussion: Diversity Within Organisms of the Same Type

1. Facilitate a group discussion about why mating and diversity among individuals within a species could be advantageous for the species.
   - ▶ *Why might it be helpful for a type of organism, like the plants we just investigated, to have diversity among individuals?* [Students might say something like: Variation in genes increases species' ability to respond to environmental changes, such as changes in regional climate or human impacts on the environment.]
2. Share that mating leads to diversity—offspring produced through mating are always different from each other and from their parents, except in the case of identical twins—and offer some ideas about how diversity benefits populations.
   - ▶ *Because offspring from sexual reproduction are different from their parents, mating and combining genes leads to more diversity in a population.*
   - ▶ *Diversity in a population can help populations of organisms be more stable.*
   - ▶ *For example, when a disease spreads through a population, some individuals may be resistant to that disease and survive, while others may not be resistant and may die. It is more likely to have some individuals that are resistant to the disease when there is variation in the population. If all individuals were the same and a disease to which they were not resistant spread through a population, all individuals would die.*
3. Ask students to brainstorm advantages and disadvantages of cloning.
   - ▶ *How could the ability to clone itself help these organisms survive?* [They can reproduce faster without needing a partner. They can reproduce when partners are not available.]

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- *What might be disadvantages of cloning for any type of organism?* [Less diversity from generation to generation. A less diverse population has less chance of adapting to changes in the environment or to surviving diseases.]

4. Facilitate a group discussion about the value of diversity in humans.
   - *What would it be like to live in a world of human clones? What if every single person was a clone? What would the disadvantages be? Describe what that might be like.*
   - *What are the benefits of diversity in a human population?*
5. Wrap up the discussion by briefly summarizing the main points of what students discussed.
   - A population of cloned individuals may be able to reproduce fast, but the population would lack diversity and could be wiped out by a disease that none of them had immunity against.
   - A population of individuals that is the result of sexual reproduction is more diverse and more likely to have some individuals with immunity against the disease.
6. Offer the idea that as students discussed the benefits of diversity from sexual reproduction and the pros and cons of cloning, they were thinking about what makes species change and what makes them stable.
   - *When you were talking about the benefits of diversity from sexual reproduction, you were talking about how populations of organisms can change and how that affects individual and species survival.*
   - *When you were talking about the pros and cons of cloning, you were thinking about a species being stable (not changing) and how this affects individual and species survival.*
7. Share that scientists often think about stability and change in order to better understand the natural world and make predictions about what might happen in the future.
   - *Scientists often think about what causes a species or part of nature to be stable and what causes it to change, like we just did, in order to better understand how nature works and make predictions about what might happen in the future.*

Reflecting and Wrapping Up

1. Ask one or more of these *Thought Swap* (formerly known as *Walk & Talk*) reflection questions:
   - *What surprised you about plant reproduction?*
   - *We've focused on diversity within a species. What benefits do you think there might be to having a variety of different kinds of organisms (plants with deep roots, shallow roots, plants with tall and short plants, etc.) in an ecosystem that have different adaptations to survive?*
   - *Do you think humans are more diverse or less diverse than other organisms?*
   - *Did any of your ideas change during this activity? What made your ideas change?*
   - *How might you explain or show some of what you learned in this activity to a family member?*
   - *What questions do you still have about organisms and their relatedness?*
2. Now and then, throughout the rest of your field experience, invite students to notice plant mating structures and clones. For example:
   - Let's gather a whole bunch of these acorns (or nuts, cones, seeds) that are the result of sexual reproduction and see if we notice differences between them.
   - Let's see if we can find examples of different stages of flower buds/flowers/faded flowers/seeds/faded seeds on this plant. (Hold up or point to a specific plant.)
   - Let's see if we can figure out which are the male and female parts in these flowers. How do you think they are pollinated?
   - Check out all these smaller clone plants coming out of this stump.

ABOUT BEETLES™

BEETLES™ (Better Environmental Education Teaching, Learning, and Expertise Sharing) provides environmental education programs nationally with research based approaches and tools to continually improve their programs.

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Lawrence Hall of Science is the public science center of the University of California, Berkeley. *www.lawrencehallofscience.org*

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