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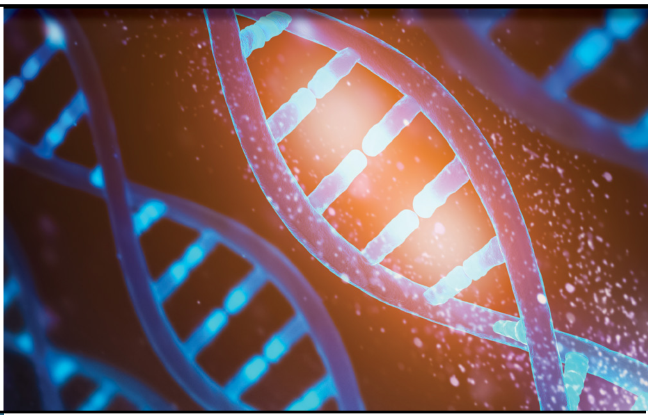
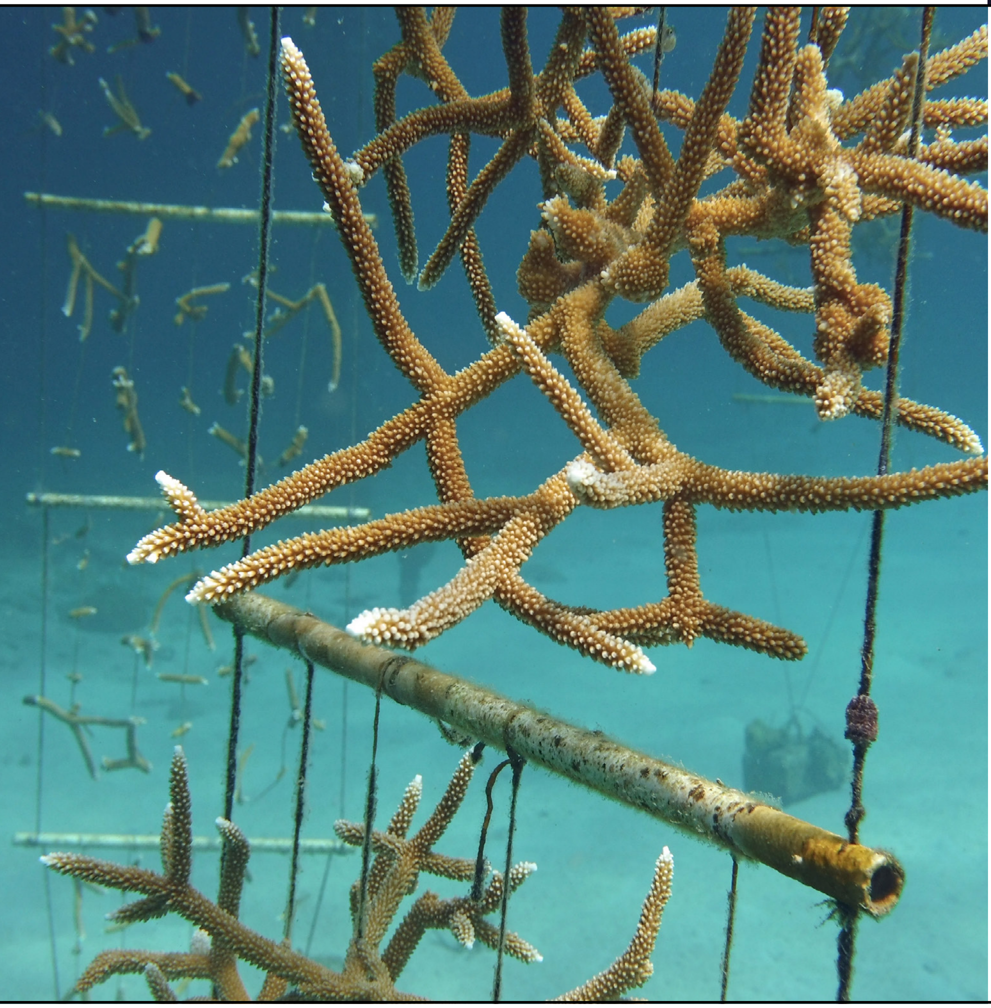
BIOTECHNOLOGY!





Part 6:

Biotechnology and the Environment

SUSTAINABLE DEVELOPMENT GOALS

developed by
Smithsonian
Science Education Center

in collaboration with
iap SCIENCE HEALTH POLICY
the interacademy partnership

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PART 6: BIOTECHNOLOGY AND THE ENVIRONMENT

Part 6

Find out More!

For additional resources and activities, please visit the *Biotechnology!* StoryMap at https://bit.ly/3pQUDpc.

Planner

Activity	Description	Materials and Technology	Additional Materials	Approximate Timing	Page Number
Task 1: How can biotechnology make our communities cleaner?					
Discover	Observe air, land, or water pollution in your community.	• Paper • Pencils or pens		45 minutes + observation time	212
Understand	Create a model of different pollution problems and how biotechnology can help make them better. Then apply what you have learned to a problem you observed.	• Paper • Pencils or pens • Scissors	Printout of Figure 6-5 (optional)	40 minutes	217
Act	Consider different perspectives on how you could address the problem you identified and create a plan.	• Paper • Pencils or pens		50 minutes	223
Task 2: How can biotechnology help restore biodiversity to ecosystems?					
Discover	Model the importance of genetic diversity to an ecosystem.	• Paper • Pencils or pens • Scissors	*Identity Map* (Part 1) Printout of Figures 6-11 and 6-12 (optional)	30 minutes	229
Understand	Investigate the potential of biotechnology to restore biodiversity to ecosystems.	• Paper • Pencils or pens • Scissors	Printout of Figures 6-13 and 6-14 (optional)	20 minutes + investigation time	237
Act	Create a set of rules about the use of biotechnology to encourage conservation. Share these rules or a conservation plan you create with others.	• Paper • Pencils or pens		20 minutes + action time	241

Task 1: How can biotechnology make our communities cleaner?

In this task you will ***discover*** what you already know about the problems with waste and pollution in your community. Then you will create a model to ***understand*** how **biotechnology** can be used to help reduce or eliminate waste and pollution. Finally, you will ***act*** to choose and suggest some of these solutions to your community.

Meet Your Research Mentor

Meet Dr. Susie Dai. Susie (pronounced SOO-zee) is one of the many researchers around the world trying to use biotechnology to help the environment. Her team tries to find ways to use living things, such as fungi and bacteria, to break down harmful chemicals in the environment.

Susie is a scientist and researcher at Texas A&M University in the United States. She has a PhD in chemistry. However, she also has knowledge and perspectives that came from other parts of her **identity**. Since Susie is now working with you, it is important to understand who she is.

To help you, Susie filled out an identity map, just like you did in Part 1. Susie's identity map includes the following things.

- 41 years old
- Asian woman
- Lives in Texas
- Is a working mom
- Was born in China and still has relatives there, but family lives in the US
- Likes science, engineering, and poetry; enjoys reading and writing
- Is short with black hair, and wears glasses or contacts
- "I felt very bad about being short when I was young. I gained more confidence after walking into the professional world. What you look like does not speak for who you are, but what you do is what characterizes you."

- Is a funny person, and loves humor! "I think of being hardworking as the salt, which makes life tasty; love is sugar, which makes life sweet; humor is the light beam, which makes life pleasant."
- Is the planner for her family. "I also volunteer in community events that I believe my expertise can contribute to; otherwise, I follow community leaders. There should not be too many cooks in a kitchen."
- Advice for young people: "Never forget what interests you when you are in school. The questions you ask at this age are important questions. You should seek those answers over your lifetime. I encourage everyone to always ask questions!"

Before you begin this task, think quietly to yourself about Susie's identity map.

- Are there things you have in common with Susie?
- Are there ways in which you are different from Susie?
- Can you see anything about Susie's identity, in addition to her university degrees, that would help her understand different perspectives or ideas about the environment?

Throughout this task you will notice Susie sharing ideas and experiences with you. She may help you understand better ways to do your research or share some of the research she has done.

Discover: *How do waste and pollution affect my community?*

Most communities have some kind of waste or **pollution**. Waste and pollution can take the form of plastic trash, used cooking or mechanical oils, leftover or unused food, smoke or **smog**, harmful chemicals, or other materials. Waste and pollution can be found in the air, on land, and in water. In this activity, you and your team will observe the waste and pollution already in your community.

1. Take out a piece of paper. By yourself, think about the following questions and draw or write your answers.
   a. Where have you already noticed waste or pollution in your community?
   b. Do you think you can make those parts of your community cleaner? Why or why not?

2. Read what Susie has to say. She explains the kinds of waste and pollution she is most concerned about in communities.

Susie says . . .

Many governments, including the United States government, have standards to make sure drinking water is safe. You can go to the Environmental Protection Agency website and find a very long list of **contaminants** that are part of those standards. You might say, "Oh, this pesticide is on that list, so I should not find this in the public water I drink."

But there are other chemicals that humans are constantly producing that may not be in the standards yet. We call those **emergent** contaminants. What I'm focused on now is those emergent contaminants. One of those contaminants is PFAS, or polyfluoroalkyl substances. PFAS are also known as "forever" chemicals because of how long it takes for them to break down.

3. Now you are going to make some observations about waste and pollution in your community. Choose a partner or a small group and pick one of the observations listed in *Community Observations* to complete in your community.

Community Observations

Make sure your team divides as evenly as possible into three groups to conduct your observations. Each group will observe either air, water, or land.

You can do the observations by moving around your local area yourself, or by collecting information using maps, photographs, social media posts, conversations with community members, or another method that works well for your team. Choose a kind of investigation that allows all members of the team to participate. You can also choose the area you want to observe. It could be just a small area around your school or it could be a bigger area, like your neighborhood or your town.

Remember that your task is just to observe and notice. It is okay if you can't answer all the questions in your section. It is okay if you notice something that makes you wonder or want to find out more. It is okay if you notice only one problem in your community. You are just collecting as much information as you can about your community!

Observation #1: Air

You will try to notice any waste or pollution in the air in your community. Use the following suggestions to help you make your observations.

- Are there any places where cars, trucks, or other vehicles wait while their engines are on (such as a bus lot or a school pickup/drop off area)?
- Are there streets with heavy traffic during certain times of day?
- Is it smoggy or smoky on certain days?
- Can you tell where the smog and smoke are coming from?
- Is it ever hard to breathe or exercise in your community?
- Are there factories, construction sites, or other spaces in your community that cause smoke, dust, or other kinds of air pollution?
- Do you notice any signs of smoke, smog, or pollution on statues, monuments, or buildings in the community?
- Is anyone from your community already trying to improve air pollution? What are they doing to help?

Figure 6-1: A city with a lot of air pollution.

Observation #2: Land

You will try to notice any waste or pollution on land in your community. Use the following suggestions to help you make your observations.

- Are there any places where the soil has been dug up, turned over, or disturbed, such as construction sites, gardens, or farms?
- Are there places like restaurants, car repair shops, gas stations, or factories where you notice liquids or solids from those businesses seeping into the ground?
- Where does food waste go in your community?
- Are there places with abandoned buildings, or where people dump appliances, cars, or electronics?
- Are there places where trash doesn't get picked up? Are there places with a lot of litter?
- Have any trees been cut down recently in your community?
- Are there any areas in your community that smell bad or different?
- Is anyone from your community already trying to improve waste and pollution on land? What are they doing to help?

Figure 6-2: Construction equipment digs up an area of land.

Part 6 Task 1

Observation #3: Water

You will try to notice any waste or pollution in water in your community. Use the following suggestions to help you make your observations.

- When it rains, were does water go in your community?
- Are there spaces that are **impermeable**, meaning water can't seep through to the ground (such as pavement)?
- Does your community have streams, rivers, ponds, lakes, wetlands, or **reservoirs**?
- Are there any places with standing water after a rainstorm, or places that take a long time to drain?
- Think about the street where you live or the street where your school is.
    - Do you know which way the water flows when it rains?
    - Does your community have storm drains?
    - Do you know where water in the storm drains ends up?
- Are there any buildings, businesses, factories, landfills, or construction sites that have materials, chemicals, trash, or food waste that could go into the water in your community during a heavy rainstorm?
- Is anyone from your community already trying to improve waste and pollution in water? What are they doing to help?

Figure 6-3: Water flows into a storm drain.

Part 6 Task 1

4. Think to yourself first, and then discuss with a partner:
    a. How does what you noticed during your observations make you feel?
    b. Are there any problems you want to solve more than others?
5. Read what Susie says quote about her research and why she does this work.
    a. How did noticing a problem help motivate Susie?

Susie says . . .

Many people in the United States have access to safe drinking water. But we cannot forget that some people do not. Those people may rely on **raw water**, which is water that has not been treated to remove contaminants. For example, 10% of the US population relies on private wells for their drinking water.

That got me into my current research, which has two parts. One part is trying to understand to what extent people are exposed to **toxic** chemicals in the environment. The other part is trying to understand how to **mitigate** and treat those risks.

It's important to understand how we can confine contaminants. I'm not saying we'll stop producing chemicals. But we as human beings need to be responsible and accountable to manage those things that we produce. We have to look at what we put in the environment, and look into solutions to **remediate** those contaminants.

Understand*: How can biotechnology help solve problems of waste and pollution in a community?*

In the Discover activity, you and your class made observations about the waste and pollution in the air, land, and water in your community. In this activity, you will model a community that has problems with pollution and waste in its air, land, and water. You will learn how biotechnology can help with these problems through something called **bioremediation**. Bioremediation is using living things to correct, stop, or reverse damage to the environment.

1. Choose a partner or a small group.
2. Take out a piece of paper or open a digital document.
3. Read *Community Problems with Waste and Pollution* and choose one problem that interests or feels most important to you and your group.

Community Problems with Waste and Pollution

This section describes several waste and pollution problems that a community might have.

Abandoned building: An abandoned building has lead paint on its indoor and outdoor walls. The lead paint has peeled off the building and lead has now gotten into the soil near the building. When it rains, some of that lead-filled soil washes away.

Shopping area: A shopping area has paved roads, paved sidewalks, and paved parking lots. These surfaces are impermeable, meaning rainwater cannot be absorbed. During storms the rainwater goes into storm drains instead. The rainwater contains waste and pollution like motor oil, pet waste, tiny rubber pieces from car tires, and cigarette butts.

Figure 6-4: Water from this paved road drains into a grassy area.

Part 6 Task 1

Construction site: A construction site is digging a large hole for a new building. Digging up the soil releases some of the **carbon dioxide** that was trapped in the soil. And some of the construction vehicles release carbon dioxide from their engines. Carbon dioxide is one of the causes of global climate change.

Athletic field: The community uses a chemical called an **herbicide** to prevent weeds from growing on the grass athletic fields. The herbicide washes away during heavy rainstorms and enters the local rivers, streams, and storm drains.

Backyards and parks: People in the community use a chemical **pesticide** to reduce or eliminate biting mosquitoes in their backyards and parks. But those pesticides may kill many other kinds of insects, including honeybees and ladybugs. They can also accidentally poison birds, cats, dogs, fish, and other animals.

Bus parking lot: A fenced parking lot is used to store all the school buses for the community. The buses run their engines when leaving, waiting, and returning, and release pollution into the air. Motor oil leaks from the buses. When the buses are washed, soap and other kinds of cleaning products end up on the pavement and seep into storm drains.

Asphalt road and roofs: The roads in the community are made with a material called asphalt. Some home and building roofs also use asphalt shingles on the roof. On hot, sunny days, the asphalt heats up and can release pollution into the air.

Pond: A pond in the community is near the shopping area and the abandoned building. Some of the water from these areas runs into the pond when it rains.

4. Write down or draw the problem you picked on your piece of paper. You can use the title of the problem, the description, a symbol, an illustration, or another marking to represent the problem you chose. For example, if you chose Shopping Area, you might draw a shopping bag and a parked car.
5. Read each of the *Bioremediation Solution Cards* in Figure 6-5. You will use one or more of these solutions to try to solve the problem you chose in your model.
6. If you can, print Figure 6-5 and cut out each solution card. You only need one set of *Bioremediation Solution Cards* for each group. You can also just read the solutions here and use the icons to record your ideas.

Bioremediation Solution Cards

Rain Garden

A rain garden is a group of plants that can quickly absorb and filter **runoff** from roofs, driveways, and sidewalks. The plants trap water and help it be absorbed into the soil more quickly. Rain gardens reduce the amount of standing water where mosquitoes can breed. The plants, fungi, and bacteria in the garden may also filter out some of the **pollutants** from the water. This helps to keep pollution out of the storm drains and waterways.

Evergreen Tree

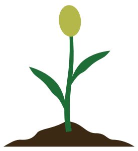
This type of tree can trap air pollution in its needle-like leaves, branches, and trunk. Evergreen trees have leaves all year round. Like all other plants, an evergreen tree absorbs carbon dioxide from the air. Because it is so tall and is alive during every season, it can absorb a large amount of carbon dioxide over time.

Sunflower

This plant uses its roots to absorb heavy metals, like lead, from the soil. Like the evergreen tree, it also absorbs carbon dioxide. But the sunflower dies off when the temperature gets too cold.

Water Hyacinth

This kind of plant lives in water. It can remove heavy metals like lead from water. It can also remove pollutants from water. It grows incredibly quickly.



Cover Plants

These are plants that are planted in areas with bare soil, like empty farm fields or construction sites. One example is the mustard plant. These kinds of plants keep soil, pollution, and heavy metals from being washed away by rain. They can absorb harmful materials and remove them from the soil, as well. They can also take carbon dioxide out of the air and help trap it in soil.

Figure 6-5: Bioremediation solutions for problems with waste and pollution. (continued)

Aquatic Bacteria

Certain kinds of bacteria can remove pollution and waste from water, such as motor oil or poop from humans or other animals. These bacteria break pollution and waste down into materials that are not harmful.

Soil Bacteria

Certain kinds of bacteria can help remove heavy metals like lead from soil. They use the heavy metals for energy and break them down into materials that are not harmful. Sometimes this process can take a long time.

Genetically Modified Bacteria

Scientists can change the **genome** of certain bacteria to help them break down heavy metals and pollution faster than bacteria found in nature.

Genetically Modified Plants

Scientists can add **genes** to a plant that help it make its own protection against pests. For example, there is a certain kind of bacteria that make a substance that kills flies. If genes from those bacteria are added to a plant, the plant can make the substance and protect itself from flies.

Biochemical Pesticide

A **biochemical pesticide** is **nontoxic** and is produced naturally by a living thing. One example is a scent that attracts certain kinds of pest insects to a trap or prevents them from mating.

Microbial Pesticide

Microbial pesticides use bacteria, fungi, viruses, or other small living things to kill pests or plants. For example, a certain fungus can grow on a caterpillar that is a pest. The fungus absorbs water and nutrients from the caterpillar until the caterpillar dies. Then the fungus can spread through the air to other caterpillars.

Figure 6-5: (continued)

7. Ask each member of your group to choose the bioremediation solution (or solutions) they think will solve the problem you chose. They can show their choice by placing the card on top of the problem, or by drawing the icons on your paper.
8. Now, as a group, add, rearrange, or remove the solution cards according to what you think will best help solve the problem in your model. Try to agree as a group how you want to solve the problem. Use these questions to guide you:
   a. Do any of these solutions seem easier to use than others?
   b. Do you think people in the community might be worried, curious, or want more information about some of the solutions?
   c. Will the solutions work for a short time or a long time?
9. By yourself, think about these questions:
   a. Was it easy to agree? Why or why not?
   b. Were there any solutions that made you worried, uncomfortable, or that you wanted to know more about before using?
   c. Were there any solutions that you were excited about?
10. If you would like, choose another model community problem and repeat steps 7 and 8.
11. Think about one problem that you noticed in your community during the Discover activity.
12. Are there any bioremediation solutions from the Understand activity that would help you solve that problem? Why or why not?
13. Researchers are working on many different types of bioremediation solutions. Read what Susie says about her research into how fungi can help remediate contaminants in the environment.
   a. Susie is trying to find a bioremediation "superhero." If you were also searching for a bioremediation superhero, what would you want it to do?

Susie says . . .

If you go out to the forest and look at a piece of dead wood, it has mushrooms growing on it, right? The mushrooms are breaking down the material in the dead wood. One of those materials is lignin. Lignin is the part of a plant's cell wall that is very hard to break down. That's why expensive furniture is made out of wood with lots of lignin. The furniture lasts a long time because of the lignin in the wood. Fungi, like the mushrooms on dead wood, can break down lignin.

In my research, we are trying to use the same systems in a fungus that can break down lignin to break down contaminants like forever chemicals. We are using tools that nature already has in place, but that people haven't really appreciated yet.

There are fungi that we have worked with in the past for bioremediation, but I am trying to find a new fungus that can do a better job than the ones we already know. What I hope to do is find a superhero that can break down many contaminants at once!

Act: *How can I solve waste and pollution problems in my community?*

In the Discover activity you noticed the problems with waste and pollution in your community. You learned about how biotechnology can help solve problems in the Understand activity. Now it is time for you to use what you have learned about your community and about biotechnology to plan and share how to solve problems in your community.

1. Think back to the *Bioremediation Solution Cards*. You are going to rank each solution according to how comfortable and confident you would be using it and whether you think you would have the power to use this solution in your community. Figure 6-6 shows an example.

Most (11)
11. Rain garden
10. Cover plants
9. Sunflower
8. Water hyacinth
7. Aquatic bacteria
6. Soil bacteria
5. Evergreen tree
4. Biochemical pesticide
3. Microbial biopesticide
2. Genetically modified bacteria
1. Genetically modified plants
Least (1)

Figure 6-6: An example of solutions ranked by how comfortable and confidant you would feel using them and whether you think you have the power to use them in your community.

2. Consider the solutions you ranked at the bottom of the scale. Think to yourself:
   a. Would learning more about those solutions make you feel more comfortable and confident? How or where could you find more information?
   b. Who would you need to communicate with in your community to get more power to suggest or use those solutions?
3. Thinking about the **social**, **economic**, **environmental**, and **ethical** perspectives of biotechnology solutions is an important part of taking action. With your partner or a small group, read *Perspectives on Waste and Pollution Solutions*.

Perspectives on Waste and Pollution and Solutions

Social

Genetically engineered bacteria can help break down the harmful pollution and metals in soil and water more quickly than bacteria found in nature. But the risks of releasing genetically modified bacteria into the natural environment are still being studied. Some people in a community may not feel comfortable introducing

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genetically engineered organisms into the environment. They might voice concerns such as, "Can the **DNA** from these bacteria transfer to other living things?" Is it right to use genetically engineered organisms if some people are worried? How should communities make this decision, and who should be involved?

Economic

Plants like sunflowers and evergreen trees can help remove pollution from the air and soil. But it costs money to buy, plant, and take care of these plants. It also takes time to get permission to plant them, decide where to plant them, and take care of them once they are planted. Who in a community should be responsible for using their time and money to take care of plants to help with waste and pollution?

Environmental

Water hyacinths can help to remove pollution and heavy metals from water. They are inexpensive, grow fast, and work quickly to clean water. But when they are not native to an area, they can spread quickly, block other plants from growing, harm fish populations, and clog rivers, streams, and ponds. Would you use water hyacinth if it was not native to your community? Why or why not?

Figure 6-7: Invasive water hyacinths cover the entire surface of this river.

Ethical

A community may have many different problems with waste and pollution. These problems may affect some groups of people more than others. How should a community decide which problems are the most important to solve?

4. Choose one perspective from *Perspectives on Waste and Pollution Solutions* to discuss with your partner or a small group. Try to agree on an answer to the question at the end of each one. When you are done, find another group that chose the same perspective. Compare your answers.
5. Read what Susie has to say about the perspectives she has to consider when researching bioremediation. Do you think any of those perspectives will be important to your community?

Susie says . . .

One of the very important goals of bioremediation is that it works quickly and is affordable.

If my boss says, "Deal with this chemical within two weeks," I have to get it done in two weeks! If Congress says, "By 2025 we have to achieve this remediation goal," and I say it will take me 100 years to do it, those politicians will kick me out of the room. If I want to produce a biofuel, but it's $20 a gallon, who is going to buy that at the pump station?

Using a fungus to clean up a contaminant is not fast enough for modern society. That's why my research is trying to move things faster!

We want to help a natural organism, like a fungus, remediate in a reasonable amount of time. What we hope to do is to combine bioremediation with other potential systems and tools that already exist in engineering, chemical engineering, or environmental engineering, and can be readily integrated into the systems we already have.

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6. By yourself, think back to the problems you noticed in your community from the Discover activity.
    a. Is there one problem in your community that you feel confident you could help to solve? Choose just one.
    b. Are there any bioremediation solutions from the Understand activity that could help you solve that problem?
7. After you have selected a problem you feel you could solve, answer these questions and record your answers on a piece of paper or digital document.
    a. How could you get started right now on solving this problem in your community?
    b. Who in your community could help you with this solution?
    c. What makes you worried about trying this solution?
    d. What makes you excited about trying this solution?
8. Find a person in your household, school, or community to share your ideas with. Explain your solution and ask for feedback.
9. Read what Susie says about how to engage with the community. How do you think you might try to use education and outreach to get your community to understand bioremediation?

Susie says . . .

Sometimes you have a wonderful solution, but the people in the community do not agree with you. But you can never push any agenda. We are a human society. We have to consider the current standards and make small steps to get the community to accept our solution. Education and outreach can help. We can educate our community and our next generation.

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Task 2: How can biotechnology help restore biodiversity to ecosystems?

Many living things around the world are struggling because of the impacts of humans on the planet. Human activities often have a negative impact on **biodiversity**. Biodiversity is the variety of the many different living things on Earth. In this task you will ***discover*** more about the biodiversity problems caused by people. Then you will investigate to ***understand*** more about how biotechnology can provide useful tools to help conserve biodiversity. Finally, you will ***act*** to increase knowledge and understanding of biodiversity and biotechnology issues in your community.

Meet Your Research Mentor

Meet Dr. Mary Hagedorn. Mary (pronounced MARE-ee) is one of the many researchers around the world trying to use biotechnology to help the environment.

Mary is a research scientist at the Center for Species Survival at the Smithsonian Institution in the United States. She has a PhD in marine science. However, she also has knowledge and perspectives that came from other parts of her identity. Since Mary is now working with you, it is important to understand who she is.

To help you, Mary filled out an identity map, just like you did in Part 1. Mary's identity map includes the following things.

- Female
- Lives in Hawaii, USA
- Likes to cook, travel, swim, snorkel, garden, and read
- Only girl in a family of seven brothers
- Explorer: "Have been an explorer since I was a small child, as I constantly explored the space in and around my neighborhood"
- Traveler: "Traveled internationally on my own in high school and lived with a family in Sicily"
- During graduate school, traveled and lived throughout Central and South America working on science research

- "After I got my doctorate, I traveled and lived in a small village in West Africa, which transformed me as I learned more about this wonderful community that cared for each other as part of the social good."
- Caring: "I would like to think that the social good of caring for others could also be extended to caring for and protecting our ecosystems and our planet, so that every child can grow up to see and experience beautiful and wild places on Earth."

Before you begin this task, think quietly to yourself about Mary's identity map.

- Are there things you have in common with Mary?
- Are there ways in which you are different from Mary?
- Can you see anything about Mary's identity, in addition to her university degrees, that would help her understand different perspectives or ideas about the environment?

Throughout this task you will notice Mary sharing ideas and experiences with you. She may help you understand better ways to do your research or share some of the research she has done.

***Discover**: What are the biodiversity issues caused by people?*

Life on Earth depends on biodiversity. Many different living things are part of the ecosystems on which life depends, including human life. In this activity you will find out more about your relationship with biodiversity. You will also explore the threats to biodiversity at different levels.

1. Take out your *Identity Map* from Part 1 and examine it closely. Remember that each person is unique.
    a. What are some things about your identity that makes you different from others around you? Pick one thing to share.
2. As a team, use a board, a shared piece of paper, or a shared digital document to create a *Team Identity Map*.
    a. Draw a circle in the center, just like you did for your identity map.
    b. Label this circle "Our Team."

   c. Have each team member add to the *Team Identity Map* by drawing or writing the part of their identity they picked to share.
3. As a team, examine the *Team Identity Map*. Discuss:
   a. What is the advantage of having people with many different identities be part of the team?
   b. Are there ideas or types of knowledge you have as a group that you would not have as individuals?
   c. Is this true for people in general? Is it useful to have lots of different skills and interests?
4. Read what Mary says about why she thinks diversity is so important. Why do you think diversity is important? Share your thoughts with a partner.

Mary says . . .

In countries that have diversity of thought, diversity of beliefs, diversity of backgrounds, diversity of abilities, we do better in facing problems. This is because when you only think in one way, you will tend to answer a problem in only one way. So having diversity of thought, people, and beliefs helps us become stronger and have a variety of different approaches. It's the same thing in plants, in animals, in other living things: When you have more diversity, it just gives you more options to respond to different challenges.

5. Read *What Are Types of Biodiversity?*

What Are Types of Biodiversity?

The variety you find among people is partially due to small differences in their genomes. This can be thought of as **variations** in the sequence of genes, which can lead to all sorts of differences in individual humans.

The same is true for other **species**. A species is a type of living thing, like a human or a dog or a coconut tree. Variations in the genome of a species are called genetic diversity. High **genetic diversity**, which is a large variety of different **traits** in the population, gives the population a greater chance to survive threats and stresses in the environment. Even if a specific individual within a population doesn't survive a threat, a species with high genetic diversity is more likely not to go extinct. Figure 6-8 shows some of the genetic diversity of dogs.

Figure 6-8: Different breeds show the genetic diversity in dogs.

However, diversity isn't only within a genome. Having lots of different species present in a place is also important. This is called **species diversity**. Species fill many different roles in an **ecosystem**. An ecosystem is a community of living and non-living things. Some species produce food, like plants. Others eat plants, like humans and deer. Others **decompose** or break down once-living things, like fungi and bacteria. Many species are involved in each of these roles within an ecosystem. Generally, when a greater number of species live in a place, the ecosystem is better able to overcome challenges, like a changing climate or the loss of one species in the ecosystem. Figure 6-9 shows an example of a coral reef ecosystem with many different species. How many can you spot?

Figure 6-9: Example of species biodiversity within a coral reef ecosystem.

A variety of ecosystems is also an important part of biodiversity. There are many types of ecosystems, from a swamp to a mountain meadow to a coral reef. A wide variety of ecosystems is called **ecosystem diversity**. Ecosystem diversity encourages a broader range of species and is important for the planet. For example, think of how many different types of species could live in the ecosystems found in Figure 6-10.

Figure 6-10: A place with a variety of ecosystems: lake, rocky beaches, pine forest, and snowy mountains.

6. Discuss with your team:
    a. How do you think genetic diversity, species diversity, and ecosystem diversity relate to one another? For example, does genetic diversity lead to species diversity?
    b. Why do you think it is important to have biodiversity on Earth? Make sure you think about how all species, including humans, are connected to one another.
7. You will be using elkhorn coral populations as an example to investigate how genetic diversity affects the ability of a population to survive. Read Mary's thoughts. What are some of the problems facing the species of elkhorn coral in the Caribbean?

Mary says . . .

The ocean in the Caribbean is in a very bad shape. It's small and it only has about 60 species of coral. It has a history of pollution, diseases, and other local stressors. Imagine you have all these beautiful islands, and they all have these amazing corals around them. Over time some of these corals were blown up to make bays and things like that. It only got worse as more people went into the Caribbean, in terms of tourism and boats and traffic. You also have global stressors, such as climate change, on top of that. Some scientists predict that by the mid-2030s, only 1% of global corals will still exist.

8. Read *Genetic Diversity Card Game Instructions* and play the game.

Genetic Diversity Card Game Instructions

The problem

Elkhorn coral is a species of coral that lives in the Caribbean, Florida, and the Bahamas. Although elkhorn coral are just a single species, they are a very important part of their ecosystem. Elkhorn coral form dense groups called **thickets** in shallow water. These thickets provide places for fish and other wildlife to live. However, human impacts threaten the elkhorn coral population.

Your goal

Your goal is to have as many elkhorn coral individuals survive as possible.

Types of cards

There are two types of cards:

a. Elkhorn Coral Cards (12): Each of these cards represents an individual coral that is part of the elkhorn coral population. Each individual is genetically

Part 6 Task 2

unique and has different traits and abilities. Four traits are represented in the cards:

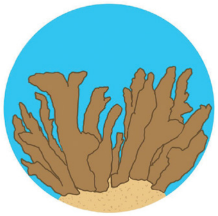
- Myxococcales level: Myxococcales is a bacteria that helps elkhorn coral resist white band disease. Some coral encourage the growth of more myxocaccales around them.
- Heat resistance: The ability to live in warming water
- Deep sea level: The ability to live in deeper water
- Oxygen strength level: The ability to survive when there is less oxygen in the water

b. Scenario Cards (4): Each card shows a situation that could happen to the coral population.

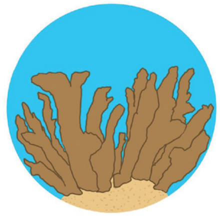
Playing the game

1. Print and cut out the Elkhorn Coral Cards in Figure 6-11 and the Scenario Cards in Figure 6-12. If you cannot print the cards, you can write the information from the cards on a piece of paper and cut it apart.
2. Divide the Elkhorn Coral Cards evenly among your group. There are 12 cards, so if possible make your group a size where the cards can be evenly distributed.
3. Place the Scenario Cards face down between the players.
4. Have one player pick a Scenario Card and read it to the group. Each scenario will focus on a specific trait.
5. Each trait on the Elkhorn Coral Cards has a different number value. If the number is below the allowed number on the Scenario Card, discard the Elkhorn Coral Card.
6. After each round, count how many corals are left.
7. Then draw another Scenario Card and continue.
8. Keep playing until all four Scenario Cards have been used.
9. How many corals are left at the end?
10. Play again to see if the number of corals left at the end changes if you pick the Scenario Cards in a different order.

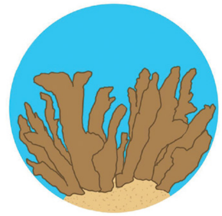
Elkhorn Coral Cards



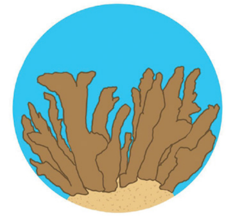
Myxococcales level: 4
Heat resistance: 5
Deep sea level: 7
Oxygen strength level: 8



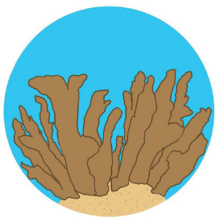
Myxococcales level: 2
Heat resistance: 6
Deep sea level: 5
Oxygen strength level: 7



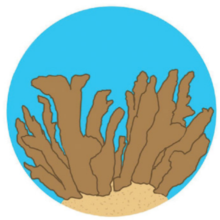
Myxococcales level: 1
Heat resistance: 6
Deep sea level: 3
Oxygen strength level: 2



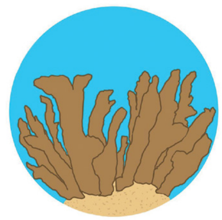
Myxococcales level: 8
Heat resistance: 7
Deep sea level: 7
Oxygen strength level: 7



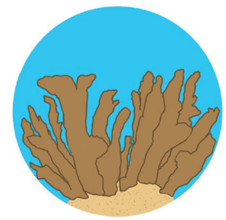
Myxococcales level: 0
Heat resistance: 1
Deep sea level: 1
Oxygen strength level: 3



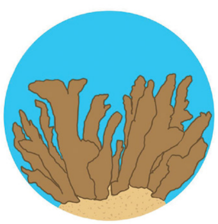
Myxococcales level: 2
Heat resistance: 1
Deep sea level: 3
Oxygen strength level: 3



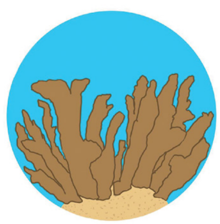
Myxococcales level: 4
Heat resistance: 2
Deep sea level: 5
Oxygen strength level: 1



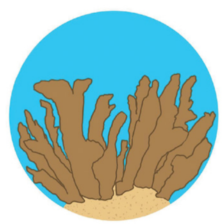
Myxococcales level: 3
Heat resistance: 6
Deep sea level: 4
Oxygen strength level: 4



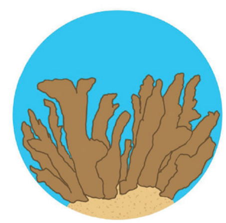
Myxococcales level: 6
Heat resistance: 5
Deep sea level: 3
Oxygen strength level: 6



Myxococcales level: 9
Heat resistance: 8
Deep sea level: 6
Oxygen strength level: 7



Myxococcales level: 1
Heat resistance: 4
Deep sea level: 2
Oxygen strength level: 6



Myxococcales level: 4
Heat resistance: 6
Deep sea level: 1
Oxygen strength level: 7

Figure 6-11: Elkhorn Coral Cards.

Scenario Cards

Scenario: Habitat Loss and Pollution

Runoff from agricultural lands and other sources has polluted shallow waters. The pollution makes it difficult for corals to grow in shallow waters and increases the growth of harmful algae. Only elkhorn corals that can live in deeper water can survive.

Action: Discard all Elkhorn coral cards with deep sea levels 4, 3, 2, or 1.

Scenario: Climate Change

Oceans are warming due to climate change. This heat can stress coral and cause coral bleaching. Some elkhorn coral live alongside helpful heat-resistant algae that help the corals survive even with coral bleaching.

Action: Discard all elkhorn coral cards with heat resistance levels 5, 4, 3, 2, or 1.

Scenario: Invasive Species

The lionfish is an invasive species to the Caribbean. It eats fish that would usually eat algae off coral. This upsets the reef ecosystem and means less oxygen is available for coral. Some coral can survive on less oxygen.

Action: Discard all elkhorn coral cards with oxygen strength levels 6, 5, 4, 3, 2, or 1.

Scenario: Disease

White band disease is spread by aquatic snails and stimulated by human pollution. It destroys the coral tissue in elkhorn coral, slowly killing entire reefs. Only elkhorn corals that support large amounts of a bacteria called Myxococcales will be able to survive.

Action: Discard all Elkhorn coral cards with Myxococcales levels 6, 5, 4, 3, 2, or 1.

Figure 6-12: Scenario Cards.

11. After you finish playing the game, discuss with your group:
    a. How did human activities cause the problems with the elkhorn coral?
    b. What could people have done differently to change the scenarios?
    c. What do you think would be most important to change about the scenarios if you were trying to help keep the elkhorn coral alive?
    d. Why was the genetic diversity of the coral important when trying to survive the scenarios?
    e. What if all the corals had no genetic diversity and so all had the same ability to survive different threats? What would the risk be for the species?
    f. Is the genetic diversity of the surviving corals greater or less than before they faced the different scenarios? How might this affect the elkhorn corals' ability to survive threats in the future?
12. Think back to your *Team Identity Map*. Discuss with your team:
    a. How do different people with different characteristics help a group respond to challenges?
    b. How are the differences in your team similar to the genetic diversity of corals?
    c. Do you think it is important to have a team with different traits?
    d. Is it also important to have different traits and ideas among populations of people in your local community or globally?
13. By yourself or with a partner, think about the living things in your local area. Can you think of a species that lives near you that you think would be important to protect? What do you think the threats to that species might be?

Understand: *Can the tools of biotechnology help with conservation?*

You know that people can have a negative impact on biodiversity. But there are also ways people can help, for example, by reducing pollution or controlling invasive species. Biotechnology can also help preserve and restore genetic diversity.

1. Gather together with your team in a circle. The practice of **conservation** is about protecting, preserving, and restoring biodiversity. Go around the circle three times and share any ideas you already have about ways people can take conservation actions. If you are not sure, that's okay, you will learn more soon. Just do your best.

a. First, share ways that people can protect biodiversity by stopping any further damage to the environment.

b. Second, share ways that people can preserve biodiversity by keeping the genetic and species diversity that currently exists.

c. Third, share ways that people can restore biodiversity by adding genetic, species, or ecosystem diversity back to the environment.

2. Read what Mary says. Why do you think **biobanks** might be a part of protecting, preserving, and restoring biodiversity? A biobank is a library of samples of different organisms. Often these samples are **cryopreserved**, or frozen in a way that they can be thawed and still be alive. When a seed, egg, or tissue is biobanked, it preserves the genetic diversity of that living things so it can be studied or added back into an ecosystem in the future.

Mary says . . .

Biodiversity stabilizes ecosystems and maintains them. Even when there are threats, adaptation is easier with higher levels of biodiversity. We can preserve genetic and species biodiversity through biobanks. Once you put something in liquid nitrogen and it's frozen but alive, it can stay there for tens or maybe even hundreds of years. So biobanks do buy us some time by maintaining biodiversity and genetic diversity.

It's so important to create biobanks because sometimes social processes can be slow, and changes in education and policies can take a long time. Biobanks can give us that time to try and come to grips with what's going on, and still not lose vast amounts of genetic diversity and biodiversity on the plant.

3. Take out the cards from the Genetic Diversity Card Game from the Discover activity. You will now have a chance to play this game again, but with some tools from biotechnology to help you.

4. Print and cut out the cards from Figures 6-13 and 6-14. If you cannot print the cards, you can write the information from the cards on a piece of paper and cut it apart.

Biotechnology: Biobanking

Biobanking is a preservation technique that can store biological material, including DNA, for long periods of time. Scientists and researchers are able to study these preserved materials in controlled settings. They could also be used to reintroduce the biobanked genetic diversity back into an ecosystem.

Action: Must be played before using the cloning and selective breeding cards.

Biotechnology: Cloning

Cloning uses preserved cells and DNA to create copies of a previously existing living thing. Scientists and researchers might use cloning to help introduce genetic diversity into species that are endangered.

Action: Choose three elkhorn coral cards to revive from your discarded pile.

Biotechnology: Selective Breeding

Selective breeding is when humans choose two animals within a species to mate, to try to produce **offspring** with desirable traits. Scientists can use biobanked materials to selectively breed elkhorn coral for more genetic diversity.

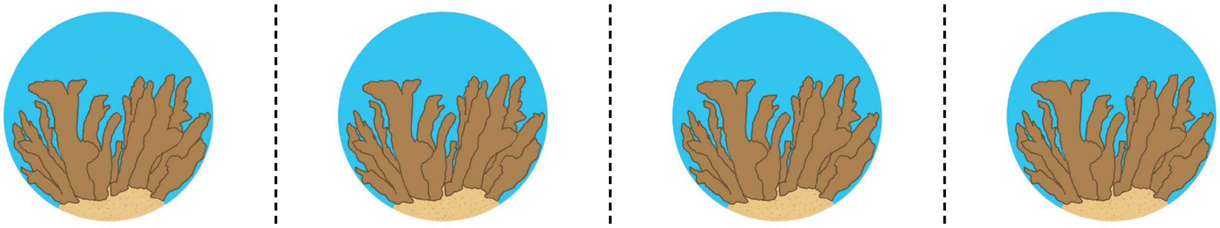
Action: Choose two coral cards that are still in the game to represent parents, and take a new blank Elkhorn Coral Card. Create a new Elkhorn Coral Card from your blank that uses the traits of the parents (Figure 6-15 shows an example). Add the new card to the game.

Biotechnology: Gene Drive

Gene drive is a technique using **CRISPR** that modifies specific genes and makes sure the modified genes are inherited by the next generation. Gene drives can change the genetic makeup of a species over time.

Action: Gene drive prevents the corallivorous snail from passing on white band disease. All elkhorn corals remaining in the game cannot contract this disease.

Figure 6-13: Biotechnology Cards.



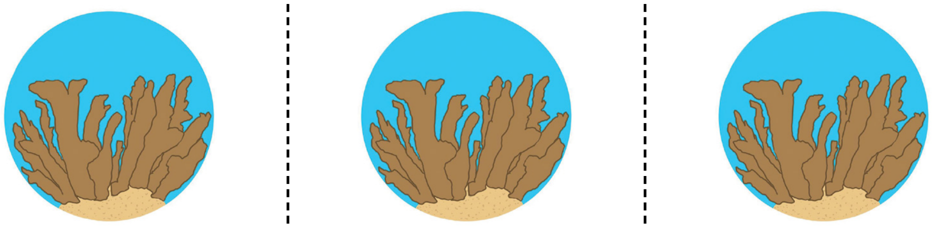
Myxococcales level:
Heat resistance:
Deep sea level:
Oxygen strength level:

Myxococcales level:
Heat resistance:
Deep sea level:
Oxygen strength level:

Myxococcales level:
Heat resistance:
Deep sea level:
Oxygen strength level:

Myxococcales level:
Heat resistance:
Deep sea level:
Oxygen strength level:

Figure 6-14: Blank Elkhorn Coral Cards—use these to create new cards.



(EXAMPLE PARENT 1)
Myxococcales level: 4
Heat resistance: 5
Deep sea level: 7
Oxygen strength level: 8

(EXAMPLE PARENT 2)
Myxococcales level: 2
Heat resistance: 6
Deep sea level: 5
Oxygen strength level: 7

(EXAMPLE NEW CORAL)
Myxococcales level: 4
Heat resistance: 6
Deep sea level: 7
Oxygen strength level: 8

Figure 6-15: Example of how a new coral card can inherit selected traits from two parent cards.

5. Place the Biotechnology Cards face up on the table. Distribute the other cards the same way you did when you played the game before.
6. Start playing the game again, but this time when time you pick a Scenario Card, you also have the option to pick and use a Biotechnology Card.
7. Compare your results this time with your results from the first time you played the card game. Did the biotechnology help you protect, preserve, or restore genetic diversity?

8. By yourself or with a partner, think about the species you wanted to keep healthy from the Discover activity. How can you find out more about the conservation of this species? Do some research to find out more about the situation of this species. Is it in danger? What threats does it face? For example, you could:
   a. Use the Internet, a library, or other written materials to learn more about your species.
   b. Reach out to an organization, such as a nature or science center, to find out if they have more information.
   c. Find a local scientist who researches your species and contact them to learn more.
9. Now consider, what actions do you think you could take to help your species? Be sure to consider:
   a. Ways you could take action to reduce the threats to your species
   b. Ways biotechnology tools could help protect, preserve, or restore your species
10. Take out a piece of paper or open a digital document and title it "Conservation Plan." This *Conservation Plan* will be your plan to help your species. Write or draw:
    a. Which species are you focusing on?
    b. What are the threats to this species?
    c. What would you like to do?
    d. What methods, such as reducing pollution, biobanking, or cloning, would you use?

Act: *How should we use biotechnology to have an impact on ecosystems?*

Biotechnology provides powerful tools to help conserve species and ecosystems. However, these types of interventions must be carefully considered. In this activity you will think about your approach to using several types of biotechnologies.

1. Read *The Black-Footed Ferret Case Study*.

The Black-Footed Ferret Case Study

Black-footed ferrets once lived all over the prairies of North America. However, by the mid-1900s the species was declining rapidly because of human activities. Scientists thought the ferrets were extinct, but managed to find one remaining population in the 1980s. To preserve the species, all of the remaining animals were brought into captivity. Seven were able to breed and their DNA is the foundation for today's black-footed ferrets. Today around 10,000 black-footed ferrets are descended from the original seven and many have been reintroduced into the wild.

Figure 6-16: A black-footed ferret.

However, the level of genetic diversity is very low, since all the black-footed ferrets come from the original seven. **Inbreeding**, or producing offspring from close relatives, means all the black-footed ferrets are genetically as closely related as half-siblings. When an individual has DNA from two closely related parents, the likelihood of problems caused by genetic mutations increases. However, scientists are trying to increase the genetic diversity of the population through biotechnology.

In the 1980s scientists added frozen tissue from Willa, an unrelated black-footed ferret, to a biobank. In 2020 Willa's biobanked tissue was used to create a clone, Elizabeth Ann. Willa and Elizabeth Ann are genetically identical. If Elizabeth Ann is bred with existing black-footed ferrets, her DNA can add genetic diversity to the population. As you learned with elkhorn corals, genetic diversity is very important for species survival.

2. Divide your team into six groups. Have each group discuss one of the following questions. Then share your answers with the rest of your team.
   a. Since people caused the problems with the black-footed ferret population, do you think they are responsible for helping to create a healthy population?
   b. Right now Elizabeth Ann lives in captivity. Would releasing her descendants into the wild in the future be okay with you?
   c. Elizabeth Ann is a clone of Willa. But what if her genes had been genetically engineered to add the maximum amount of genetic diversity to the black-footed ferret population? Would that be okay with you?
   d. Some scientists worry that if people know there is a way to add back genetic diversity through biobanking, then they will not act quickly to stop problems like habitat destruction or climate change. Do you agree?
   e. What if the black-footed ferrets were already extinct? Would it be okay to use biotechnology tools to restore the population?
   f. In some countries, cloning as a technology is used frequently in livestock production (such as cows or pigs). Should the rules for cloning a wild species be different than the rules for cloning a **domesticated** species?
3. As a team, imagine you are in charge of creating a set of rules that would decide if and when a species can be restored, using biotechnologies such as cloning. Write down the rules you decide on. Use what you have learned in this task to help you make decisions. For example:
   a. When should species be restored? Does the species have to be going extinct or just struggling?
   b. Which species should be restored? Does it make a difference how important human activities were in creating problems or how important the species is to an ecosystem?
   c. If it means a species will be restored, is it okay to release cloned individuals into the wild?
   d. Is it okay to genetically engineer a species to survive better, such as adding an ability to tolerate disease or heat?
   e. Who should be consulted when these decisions are being made?
   f. Who should be able to make the final decision?

g. What other rules do you think should exist?
h. Are there things that should be done now, like biobanking, to create options for biodiversity restoration in the future?

4. By yourself, apply those rules to your *Conservation Plan*. Does anything need to change? Make those changes to your plan now.
5. Read Mary's ideas about the importance of conversations and other social processes to help the environment. Consider the conversations your team has had, the rules you created, and your *Conservation Plan*. What do you think is most important to share with others?

Mary says . . .

We can't just restore coral reefs because we have done biobanking or selective breeding. The situation is more complex. You've got public perceptions and management decisions, in addition to already existing global and local threats. Those are the just a few of the factors. The public doesn't understand that we can do this one little piece (biobanking), but the big thing is how we think about helping the environment and restoring it. Things are more complicated when you consider the entire interacting social aspects rather than just the scientific aspect.

6. Choose one group and share your rules or conservation plan with them. For example:
   a. Family and friends: You could have a conversation about the use of biotechnology for conservation with family or friends. You could share the rules you created and ask others if they would create the same rules.
   b. Research scientists: You could find researchers working on the conservation of species you identified in the Understand activity. You could have a meeting or write them a letter and share both your conservation plan and the rules you developed.
   c. Government officials: Often governments are in charge of making rules. Find out which part of your government might be in charge of making rules

about the use of biotechnologies in conservation. Write them a letter or send them a social media post explaining the rules you suggest and why they are important.

d. Pick another group you think should be involved in making these decisions.

Congratulations!

You have finished Part 6.

Find out More!

For additional resources and activities, please visit the *Biotechnology!* StoryMap at https://bit.ly/3pQUDpc.

Glossary

This glossary can help you understand words you may not know. You can add drawings, your own definitions, or anything else that will help. Add other words to the glossary if you would like.

Biobank: A library of biological samples of different living things

Biochemical pesticide: A nontoxic substance produced by a living thing that helps fight pests such as insects

Biodiversity: The many different living things on Earth

Bioremediation: Using living things to correct, stop, or reverse damage to the environment

Biotechnology: Using living things, parts of living things, or things produced by living things to solve people's problems and meet their needs

Carbon dioxide: A greenhouse gas that is part of Earth's atmosphere; increasing carbon dioxide levels in the atmosphere is one of the causes of climate change

Cloning: Using preserved cells and DNA to create exact copies of a previously existing living thing

Conservation: Protecting, preserving, and restoring biodiversity

Contaminant: A substance that makes water unsafe to drink or another material unsafe or unusable

CRISPR: A biotechnology tool that cuts DNA in very specific places to add, delete, or change base pair sequences

Cryopreservation: A storage method used in biobanks where samples of live organisms are frozen and later thawed for research or use

Decompose: Breaking down living things so their matter can reenter the ecosystem

DNA: A molecule in all living things that transfers and stores genetic information

Domesticated: A species that has been changed from its wild state to make it more useful for a specific purpose

Economic: About money, income, and the use of wealth

Ecosystem: A community of interacting living and non-living things within a physical environment

Ecosystem diversity: The variations in the different types of ecosystems

Emergent: New or just introduced

Environmental: About the natural world

Ethical: The fairness of something

Gene: A section of the base pair sequence in DNA that codes for specific traits

Gene drive: A technique that edits specific genes in one generation of species to make sure the edited genes are inherited by all their offspring, rather than being inherited by random chance

Genetic diversity: Variations in the genome of a species or population

Genetically modified: A living thing that has DNA that has been changed by humans

Genome: The complete sequence of DNA of a living thing

Herbicide: Chemicals used to control or kill undesirable plants such as weeds; typically used in farming

Identity: The characteristics that make you you

Impermeable: Not allowing anything, such as liquids or gases, to pass through

Inbreeding: When close relatives mate and produce offspring

Microbial pesticide: Using bacteria, fungi, viruses, or other small living things to kill pests or plants

Mitigate: To make less severe or less harmful

Nontoxic: Something that will not harm living things

Offspring: The children of parents

Pesticide: A substance used to eliminate pests, such as insects, that might harm cultivated plants

Pollutants: Harmful materials that cause pollution

Pollution: Natural and unnatural harmful materials that are introduced into an environment

Raw water: Water in the environment that has not been treated to remove contaminants, such as rainwater or water from a stream

Remediate: Correct, stop, or reverse damage to the environment

Reservoir: A large human-made place to store water

Runoff: Water that runs off roofs, driveways, sidewalks, and agricultural lands, often picking up chemicals and soil in the process

Selective breeding: A process in which humans choose two animals within a species to mate to try to produce offspring with desirable traits

Smog: A mixture of harmful pollutants in the air at ground level

Social: Relating to the interaction of people in a community

Species diversity: The variations in the different types of living things within an area

Species: A type of living thing, like a human or a dog or a coconut tree

Thickets: Dense groups of elkhorn coral

Toxic: Harmful or poisonous

Traits: Characteristics

Variations: Differences in living things

