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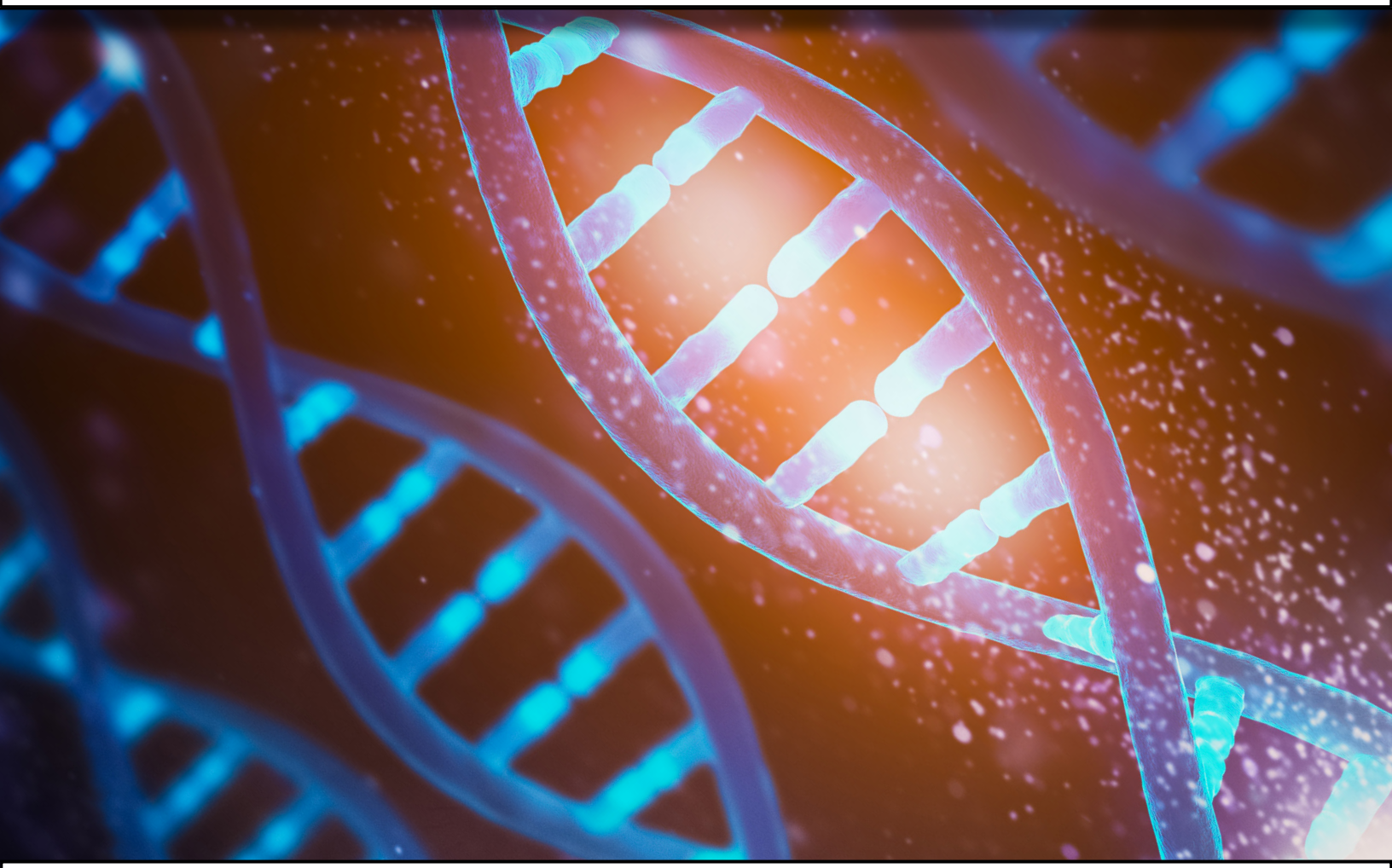
BIOTECHNOLOGY!

Part 1: Introduction to Biotechnology



SUSTAINABLE DEVELOPMENT GOALS

developed by
Smithsonian *Science Education Center*

in collaboration with
iap SCIENCE HEALTH POLICY
the interacademy partnership

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PART 1: INTRODUCTION TO BIOTECHNOLOGY

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: What is a sustainable future?					
Discover	Develop a personal identity map showing the different parts of who you are and create a futures mood board showing your ideas about the future.	• Paper • Pens or pencils • Objects that represent you (optional) • Class board or poster paper • Photos or magazines (optional)		25 minutes	7
Understand	Survey your community to discover different perspectives on a sustainable future.	• Paper • Pens or pencils		25 minutes + survey time	12
Act	Examine the Sustainable Development Goals, consider how biotechnology can play a role in a sustainable future, and pick the guide parts you want to use.	• Paper • Pens or pencils	*Futures Mood Board*	25 minutes	17

Activity	Description	Materials and Technology	Additional Materials	Approximate Timing	Page Number
Task 2: How can biotechnology help create a sustainable future?					
Discover	Explore what biotechnology is and how it plays a role in your life.	• Paper • Pens or pencils		25 minutes	20
Understand	Extract DNA and investigate different ways DNA can be used or changed.	• Alcohol • DNA source, fruit or other • Containers • Fork or spoon • Water • Salt • Detergent • Filter • Skewer or toothpick		45 minutes	27
Act	Consider different perspectives on using biotechnology for a sustainable future and create a list of ethical concerns.	• Paper • Pens or pencils	*Futures Mood Board*	25 minutes	35

Biotechnology! How can we ethically create a sustainable future for all using biotechnology?

Biotechnology can be an important tool to help reach a **sustainable** future for ourselves and our planet, but there are also risks and concerns. In this guide you will learn more about the potential of biotechnology while considering your ideas about the best way to navigate those risks and concerns.

While using the guide you will become an **action researcher** to identify and help solve problems in your community. Action researchers first ***discover*** their own existing knowledge, then they investigate to ***understand*** problems, and finally they ***act*** on what they have learned to make local and global communities better.

You will create and keep several sheets of paper or digital documents to help you record and remember information. You may want to use a notebook or folder to help organize the sheets you will use in the guide.

Remember: *In this guide you and your team are in charge. You can always change the instructions in the steps to make them work better for you and your team.*

Task 1: What is a sustainable future?

Who we are affects the way we think about and view the world around us. In this task you will first ***discover*** more about your own identity and perspectives about the future. Then you will ***understand*** more about biotechnology and related knowledge and perspectives of your community. Finally, you will ***act*** to decide what you want to investigate and think about further.

Discover: *What is my identity and what are my hopes for the future?*

Our different experiences, backgrounds, and ideas give each of us a unique identity. Your **identity** is what makes you you. Our different identities often lead to different **perspectives**. Perspectives are the way we think about the world around us. Understanding your own identity and perspectives can help you understand other perspectives. This activity will help you think about your own identity.

1. Take out a piece of paper and title it "Identity Map." If you prefer, you can make an identity map using objects or digital tools. There are more details about how to do that in step 6.
2. On the paper, write your name in the center of the page or draw a small picture of yourself.
3. Draw a circle around your name or picture.
4. Answer the question, "Who am I?" or, "What describes me?" The list below can give you some ideas to consider, but you choose what you want to include. You can also include things that are not on the list. Record anything you can think of that is important to who you are.
   - Age
   - School or class
   - Race and/or ethnicity
   - Gender
   - Country or place where you live
   - Country or place that is important to you or your family
   - Ideas or beliefs that are important to you
   - Topics or subjects that interest you

- Hobbies or things you like to do for fun
- Physical traits (such as tall, black hair, blue eyes, wears glasses)
- Personality traits (such as loud, funny, sad, kind)
- Roles you have in your household (such as big sister, helper, cousin)
- Groups you belong to

5. Write each answer on the page around your name. Draw a line between your name and each answer. Figure 1-1 is an example of a written identity map. You can put your answers at the end of each line.

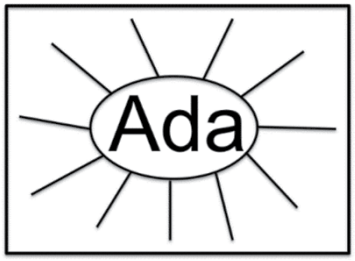

Figure 1-1: Example of a written identity map.

6. If you prefer, you can use objects around your home or class to create your map. To keep your map, you can take a picture or just remember it. Figure 1-2 is an example of an identity map using objects. You could also make a digital map using recordings or photos.

Figure 1-2: Example of an identity map using objects.

7. Now form a team. As action researchers you will work together with your team, made up of your classmates, for the rest of this guide. You will work together to understand your local area and make it better. Your team may be your whole class, or it may be a smaller group. Either is fine.

8. Share your *Identity Map* with the members of your team to find out what you have in common. Try to find matching identities with your teammates. For example, if you like to read for fun, see if you can find someone else who likes to read for fun. Find a few matching identities. Then move on to the next step.

> **⚠ Emotional Safety Tip**
>
> Sharing your identity with someone else can help build trust between you and that person. But it can be hard to share your personal identity with someone else. Only share parts of your *Identity Map* that you feel comfortable talking about.

9. Now try to find teammates who have different identities from you. Find a few people who have different identities. Then return to your place.
10. Think quietly to yourself about the different identities you found in your team. Everyone on your team is unique. Having a team that includes people with different identities means everyone has different information to share and different perspectives. As action researchers, you will work together as a team to find the best way to take action on the problems you identify. The different identities and experiences of each member of your team will help you make better decisions. For example, if you were born in the place where you live now but your teammate was born somewhere else, you each may know different things, which leads to different perspectives.
11. Read *Our Identities, Our Perspectives, Our Future*.

Our Identities, Our Perspectives, Our Future

Different people may have different perspectives on what they want the future to be like. Sometimes these perspectives are related to identities or personal experiences. Our identities can affect what we know about or what we think is important.

If there is something that is important to you now, you may want it to be part of your future. For example, maybe on your *Identity Map* you said you liked being outside. Then you might want easy access to the outdoors as part of your future.

Often books, films, or other media present ideas about what could happen in the future. These ideas can also help you imagine what kind of future you would want or not want.

In this guide you will be thinking about how you believe biotechnology can be a part of a sustainable future. But first you must think about what a sustainable future is.

An approach that balances different perspectives and can keep working for a long time is called sustainable. A **sustainable future** balances social, economic, environmental, and ethical concerns in a way that works well for people and the planet.

Your perspective about what a sustainable future should include is valuable. Other people may have different perspectives. Their perspectives are also valuable. Thinking about all these different perspectives together can help you envision a sustainable future that works for everyone, not just you.

12. Think quietly to yourself about what you want a sustainable future to include. You can use your own original ideas or ideas from other places. Use ideas from your experiences, books, movies, or other media, or conversations you have had to help you think about these questions.
    a. How would you want the future to be different than life now?
    b. Are there things you would like to remain the same?
13. Now take a piece of paper or open a digital document and divide it into two sections. Label one section "Hopes" and the other "Concerns."
14. In the *Hopes* section record your ideas by writing, drawing, or using digital images to represent your hopes for the future for you, your area, the people around you, and the whole world. Do not feel like your ideas have to be possible today—dream big!

15. As you think about your hopes for a sustainable future, you may also start to think about things that concern or worry you about the future. Record these ideas in the *Concerns* section.

> **⚠ Emotional Safety Tip**
>
> When thinking about the future it is okay to be worried or concerned. These feelings are natural, especially when the future feels uncertain. By thinking about your fears, you can make choices to try to make sure your fears don't happen.

16. Label a class board, a large piece of poster paper, or a shared digital document "Futures Mood Board." A **mood board** is a tool to help gather ideas, concepts, and styles to design something. In this case, you are designing the future.
    a. On one half of the mood board write "Hopes." Fill this half with words, drawings, pictures, or other ways to represent each person's hopes for a sustainable future.
    b. On the other half of the mood board write "Concerns." Fill this half with words, drawings, pictures, or other ways to represent each person's worries, fears, or concerns about the future for people and the planet.

> **⚠ Emotional Safety Tip**
>
> Sometimes you may want to keep hopes and concerns for the future private. Only share what you feel comfortable sharing.

17. Examine your *Futures Mood Board*.
    a. Do you notice things that surprise you about the hopes and concerns of your other team members?
    b. Do you notice any hopes and concerns that you have in common?
18. Read *Guidelines for Team Discussion*.

Guidelines for Team Discussion

- Remember, listening to many different perspectives and viewpoints is good.
- Open yourself to new ideas.
- Differences in your team can be useful. People with different identities can bring new knowledge and ideas.
- Be an active listener by facing the person and show them you are paying attention.
- Be respectful and expect respect. People may have different ideas, and that does not mean their ideas are wrong. Creating a team where all ideas are welcome is an important step toward making sustainable decisions.

⚠ Emotional Safety Tip

Sometimes your team members may have different perspectives than you. That's okay. Listen respectfully but remember that just because someone else believes something does not mean you need to believe it. It is okay to pause a conversation if you are uncomfortable or upset.

19. As a team, discuss:

    a. Do you think a person with a different identity, like someone from somewhere else or who is much older, might have different hopes and concerns about the future?

    b. If so, why might it be important to include those ideas about the future when thinking about a sustainable future?

Understand: *What does my community know and think about the future and biotechnology?*

As an action researcher on the future and biotechnology, one of your jobs is to find out more about what other people in your **community** think about the future and how biotechnology might help create a sustainable future. Understanding perspectives in

your community can be an important part of considering what is sustainable and what actions you want to take. Helping your community starts by considering who is in the community and how they feel. You can investigate this using a survey.

1. First consider which community you want to focus on. A community is a group of people who share something, for example, your family, your classmates, your teachers, or your neighbors. A community can share space, like a local, national, or global community. Or a community can share an identity, like a religion, ethnicity, or common interest. If you think back to your identity map, you will probably realize you are part of many communities. Which community's perspective on biotechnology and the future would you like to understand? Discuss with your team and decide on a community you all belong to.
2. With your team, consider what would be important to know about the hopes and concerns your community has for the future. Write down a few questions you might like to ask.
3. Read *What Is Biotechnology?* and think quietly to yourself whether there are any ways you might use biotechnology in your life right now.

What Is Biotechnology?

Biotechnology is using living things, parts of living things, or things produced by living things to meet people's needs and improve their lives. It includes using parts of cells, whole organisms, or even ecosystems to meet our needs. It also includes making changes to parts of cells, organisms, or ecosystems to make them better fit people's needs.

4. In this guide you will be thinking about biotechnology and the future. You may want to start by asking people in your community general questions about the future to help you understand their perspectives, hopes, and concerns. Remember what you thought about that was related to your future hopes and concerns. Write down any questions you might want to ask your community. For example:
   a. What will be most important for our community in the future?
   b. What is the biggest threat to our community in the future?

5. You may also want to ask questions related specifically to biotechnology. Write down any questions you might want to ask. For example:
   a. What do you think biotechnology means?
   b. Are there things that excite you about biotechnology in the future?
   c. Are there things that scare you about biotechnology in the future?
   d. Or any other questions you would like to ask.
6. Read the *Survey Instructions* for more information about how to give a survey and pick your questions.

Survey Instructions

You can use a survey to understand the people in your community better.
A survey is a list of simple questions you can ask of a group of people.

Choosing people to survey

a. Think about the categories in your identity map. Use those categories to try to pick a diverse group of people to survey, to get a more accurate idea of what your community thinks and feels. For example, you may want to survey people of many different ages or of more than one gender.

Ways you could give a survey

a. Talk to people in person, on the phone, or using a virtual meeting.
b. Have people answer questions using paper, email, or an online survey.
c. Collect responses using a social media post.

Picking questions

a. Consider open-ended or close-ended questions. An example of an open-ended question is, "What would be part of a sustainable future?" An example of a close-ended question is, "Is limiting global temperature rise part of a sustainable future?" You usually can get more information from an open-ended question, but if you have a lot of answers, it can be difficult to keep track of all the different ideas. Using a close-ended question is quicker, but you may miss some ideas from your community.

b. Try to make your questions neutral. That means you are not trying to put your opinion in the question. For example, "Do you agree that biotechnology should be used to help create a sustainable future?" would not be neutral. The person answering the question might assume you want them to answer "yes." A more neutral question might be, "Do you think biotechnology can be part of a sustainable future?"

Tips for giving a survey

a. Make sure your questions are easy to understand and specific, such as, "What worries you about the future?" instead of, "What worries you?"
b. Think about the best method for the survey. Is there a safe and easy way to gather the opinions of a wide variety of people in your community?
c. Think about the best way to survey your community. For example, does everyone have access to the Internet if you want to do an online survey?
d. Some people you survey may not be familiar with the meaning of biotechnology. You may want to start off by sharing the definition of biotechnology with them before you start asking questions about biotechnology. For example, you might say, "Biotechnology is using living things or parts of living things to meet people's needs. Biotechnology can be used in lots of different ways, like to make different types of plants to eat or create new medicines."

Safety tips for giving a survey

Talk to your teacher or a trusted adult for guidelines. They will know what is safest in your community.

⚠ **Physical Safety Tip**

Never go out alone and always be aware of your surroundings. Pay attention to local guidance on whether it is safe to interact with people outside of your home.

⚠ Emotional Safety Tip

It can be hard to talk to other people in the community. You may feel shy or nervous. Someone may tell you they don't want to talk. That's okay! It doesn't have anything to do with you. It just means they don't want to share. You can show them respect by thanking them and moving on to another community member.

7. Examine the questions you listed and choose the questions you want to ask your community. You probably want to ask between five and ten questions in your survey. You may want a mix of close-ended and open-ended questions.
8. Decide on your survey methods, and choose where, who, and how you will conduct your survey.
9. Remember, including everyone is important. If you are working with a team, you may need to adjust the way you do your survey so that everyone feels safe, comfortable, and able to help. Those changes are okay! They are part of including everyone. Make sure to consider:
    a. Time: If the survey happens after school, does everyone in the team have time to do it?
    b. Comfort: If you decide to move around the community to do your survey, make sure everyone on your team feels safe and able to do this. If not, what is another way team members could help with the survey?
    c. Location: If the survey is going to happen in a specific place, how easy is it for team members to get to that place?
10. If you are working with a team, assign different jobs to people. For example, if you decide to do an online survey, decide who will type the survey, who will share it, and who will collect the results.
11. Finally, conduct your survey by yourself or with your team and record the results.

***Act:** How does biotechnology relate to a sustainable future for my local and global community?*

You asked your community about their hopes and concerns about the future and biotechnology. Now you can apply what you have learned to think more about the future your community wants and how that relates to a global future.

1. Take out your *Futures Mood Board* and examine the results of your survey. Are there hopes and concerns others in your community shared that are not yet part of your mood board? If so, add those ideas now.
2. With your team, use your mood board to discuss important goals for a sustainable future. These goals might be based on your hopes, like "everyone has access to clean energy" or they might be based on your concerns, like "no more extinction of animals."
3. Read *The United Nations and the Sustainable Development Goals*.

The United Nations and the Sustainable Development Goals

Achieving a sustainable future like the one you just thought about is complex. It takes many people working together in many places to create a sustainable future. When many people are working together it helps to have someone organizing. The United Nations, also called the UN, is a global organization designed to help governments and people around the world collaborate.

A few years ago, the UN asked countries and people around the world to imagine a better world and a better future. They worked together to determine a list of goals. Then the countries of the UN came to **consensus** on the most important goals needed to get to a better world. These goals for the global community are called the UN **Sustainable Development Goals**, or SDGs.

Figure 1-3: United Nations Sustainable Development Goals.

4. Examine the different SDGs. Are there SDGs you think are important for a sustainable future that your team didn't discuss? Do you think those goals are also important? If so, add those ideas to your *Futures Mood Board*.
5. Parts 2 through 7 of this guide will help you explore how biotechnology can be a part of a sustainable future in different ways. Each of these parts will show the possibilities of using biotechnology and will support you to think about the risks. You and your team will try to balance these ideas and determine when biotechnology should be used. Parts 2 through 7 are about:
    a. Part 2: Biotechnology and Food Systems: Exploring how biotechnology can and should help create an equitable, sustainable agriculture and food system.
    b. Part 3: Biotechnology and Materials: Using biotechnology to create new materials, like sustainable building materials, plastic alternatives, and organs for transplant.
    c. Part 4: Biotechnology and Human Health: Diagnosing and treating medical issues using biotechnology.

d. Part 5: Biotechnology and Genetic Data: Examining the genetic data being collected and considering how and when it should be used.
e. Part 6: Biotechnology and the Environment: Using biotechnology to help fix issues like pollution and biodiversity loss. **Biodiversity loss** is a decrease in the variety of the many different living things on Earth.
f. Part 7: Biotechnology and Security: Investigating when you can and should use biotechnology to make your world more secure.

6. Figure out how much time you have to complete the parts of this guide. For example, your teacher may say you only have time to do one part, just a few parts, or maybe all of them.
7. If you do not have time for all the parts, discuss with your team and pick the parts that are most closely related to hopes or concerns from your *Futures Mood Board*. After the next task, you can start working on the parts you have picked.

Task 2: How can biotechnology help create a sustainable future?

Biotechnology is rapidly changing the things people can do or even imagine doing. In this task you will ***discover*** ways you are already using biotechnology and think more about how it could be used in the future. You will investigate to ***understand*** more about new tools in biotechnology and how they can be used. Then you will ***act*** on this information to start thinking about **ethics** and how biotechnology should be used.

Discover: *How do I use biotechnology now and how could I use it in the future?*

Technology is the materials and methods used to solve people's problems and meet their needs. For example, a long time ago people developed the method of using different materials to create wheels, which helped solve a transportation problem. Wheels are an example of technology. Biotechnology is using living things, parts of living things, or things produced by living things to solve people's problems and meet their needs. Although new biotechnologies are being developed every day, there are ways people have used biotechnology for thousands of years. We will start this activity by thinking about biotechnology in your life.

1. Think quietly to yourself. What do you think of when you think about a living thing? The first thing many people think of is an animal. Do you think animals have been changed over time to better meet human needs? Discuss your ideas with your team.
2. Read *Domestication and Selective Breeding* to find out more.

Domestication and Selective Breeding

Within any **species**, or specific type of living thing, there is a lot of **variation**, or differences. For example, think of the differences in the way people appear, their abilities, the behaviors they have, and the things that interest them.

Even before they understood how the process worked, people noticed the fact of **inheritance**—that some **traits** or characteristics of parents were often passed on

to their children, or **offspring**. Inheritance occurs in humans and in other living things. For example, the offspring of a fast-running horse is likely to be a fast runner. The offspring of a sheep that has very fine wool is likely to have fine wool. Animals that are friendly to humans are more likely to have offspring that will be friendly to humans.

Thousands of years ago people began to use the idea of inheritance to **domesticate** animals, which is the process of changing a species from its wild state to make it more useful for a specific purpose. People would breed two animals that had traits they wanted to encourage, in the hope that their offspring would have the same traits. This process is known as **selective breeding**.

Figure 1-4: Gray wolf.

The first domesticated animal was the dog. Its wild ancestor was closer to a wolf, but people used selective breeding and the resulting new species was friendlier to humans and could be used as a hunting assistant. Many other animal and plant species were domesticated over time, often developing traits quite different from their wild ancestors. Even within a domesticated species, humans have selectively bred plants and animals for different traits, such as size, color, or the ability to run long distances. Dogs are a good example of the wide diversity created by selective breeding within a species.

Figure 1-5 Variety of dogs.

Domestication and selective breeding are examples of biotechnology. Selective breeding produced many of the differences among the dogs shown in Figure 1-5.

3. Discuss with your team. What domesticated animals are you familiar with? List animals that people use as companions, as food, to produce products like milk or wool, or for labor, like carrying people or pulling loads. For each animal you list, try to think of what traits people may have been selecting for as they domesticated the animal. Write your answers on a class board or just discuss.
4. With your team, consider the pictures in Figure 1-6. Sometimes within one species (such as a cow) people have chosen different traits to select for. This results in different **breeds** or types within the species. In Figure 1-6, one of the cows is used to produce milk to sell. The other is used for its meat.
   a. What traits do you notice that are different between the two cows?
   b. Which traits might be important for milk or meat production?
   c. Which cow do you think is used to produce milk?

Figure 1-6: Dairy cow (left) and beef cow (right).

5. Examine the pictures in Figure 1-7. People have domesticated plants using selective breeding. Often, they tried to change wild plants so they produce more of their edible or desirable part, and are easier to grow and easier to harvest. Try to match the domesticated plant on the top with its wild ancestor on the bottom.

Figure 1-7: Domesticated plants and their wild ancestors.

6. Compare your answers with the ones listed below. How did you choose which ones to match? What do you notice about changes to each plant during domestication?

a. Carrots match with Queen Anne's lace.

b. Rice matches with rufipogon.

c. Corn/maize matches with teosinte.

7. Examine the wild cabbage plant in Figure 1-8. Just like animal breeders, plant breeders sometimes focus on specific parts of the plant to change. Which part do you think breeders selected for to produce the edible vegetables shown in Figure 1-9? Match each wild cabbage part to a specific vegetable.

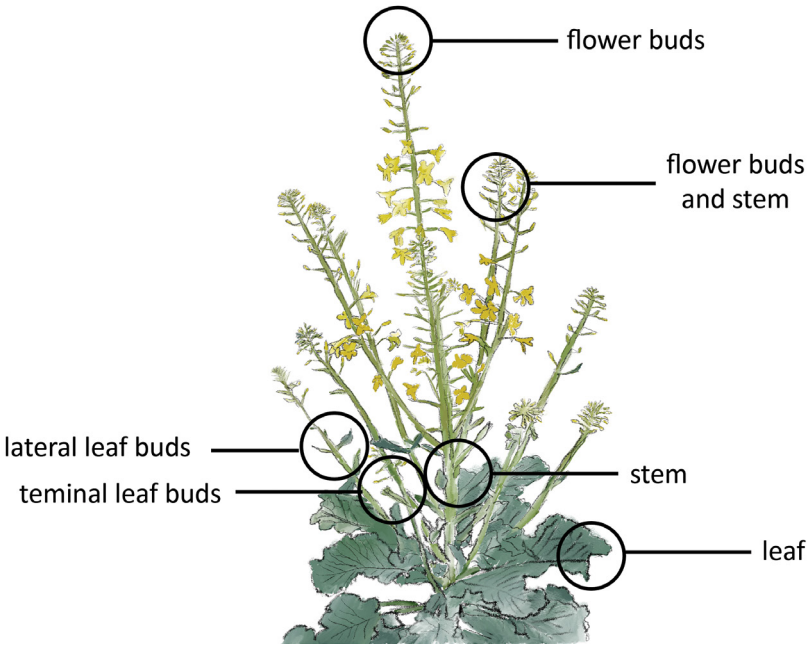

Figure 1-8: Wild cabbage plant.

Figure 1-9: Cauliflower, cabbage, kohlrabi, kale, Brussels sprouts, and broccoli (left to right).

8. Check your answers.

a. Selecting for the flower buds created cauliflower.

b. Selecting for the terminal leaf buds created cabbage.

c. Selecting for the stem created kohlrabi.

d. Selecting for the leaf created kale.

e. Selecting for the lateral leaf buds created Brussels sprouts.

f. Selecting for the flower buds and stems created broccoli.

9. Discuss with your team the way people use plants in addition to eating them, such as using them for clothing or building materials. Do you think people may have also used selective breeding to domesticate plants used in those ways?
10. In addition to plants and animals, did you know that people around the world often eat living things that are too small to see, called **microorganisms**? Discuss with your team. Do you think you eat any foods with microorganisms in them?
11. Read *Microorganisms and Food Preparation* to find out more.

Microorganisms and Food Preparation

People have been making bread and producing beer for thousands of years. What do these two processes have in common? They both use a microorganism, yeast, to create something to eat or drink. In baked goods like breads, yeast eats the carbohydrates (flours and sugars) in the bread dough and produces carbon dioxide gas. This carbon dioxide gas gets trapped in the bread dough and causes it to rise. When making beer, yeast eats the carbohydrates (sugars) in grain and produces carbon dioxide gas, which causes the beer bubbles, and alcohol.

Figure 1-10: Rising bread dough and baked bread.

Fermentation is a food preparation technique that adds microorganisms to food or encourages naturally occurring microorganisms to develop. Fermenting microorganisms eat carbohydrates and usually produce gases like carbon dioxide, acids, and/or alcohols. Many different types of food are the result of fermentation. Often more than one type of microorganism is part of the process. Fungi, like yeasts and molds, and different types of helpful bacteria are used to ferment foods and drinks in many places around the world.

For example, specific bacteria added to milk produces yogurt and cheese. Some cheeses also have types of molds added to them. Sometimes grains are fermented, like for sourdough bread or injera. Fermented vegetable and fruit products such as kimchi, miso, sauerkraut, chicha morada, and vinegar are common in many places.

Figure 1-11: Examples of fermented foods: kimchi, pickled cabbage, miso soup (top, left to right), yogurt, fermented pickles, sauerkraut (bottom, left to right).

Fermenting food often makes it easier to digest and introduces helpful bacteria to your digestive system. Fermentation can also preserve food. Using microorganisms in food preparation is an example of biotechnology. If you are interested in learning more about biotechnology and food, you can visit the *Biotechnology!* StoryMap to link to the Smithsonian's community research guide *Food!*.

12. With your team, list any ways you can think of that fermentation is used to produce things to eat and drink in your community. You may never have realized before that a food or drink was fermented, so here are some identification clues:
    a. How does it taste? Food with microorganisms often tastes yeasty, sour (from the acid produced), or alcoholic (from the alcohol produced).
    b. Are there bubbles created during the preparation? Bubbles can be a sign that gases are being produced by microorganisms. Think carefully, though, not all food or drink that is bubbly uses fermentation. For example, sodas have carbon dioxide added by the producers to create the bubbles.
    c. Is the food or drink mixed and then left to sit for a while? Microorganisms need time to grow. Fermented foods and drinks often are left to develop anywhere from a few hours to many years!
    d. Does the food or drink use cultures or starters in the process? Cultures and starters often contain the microorganisms needed to start fermentation.
13. Think quietly to yourself about how biotechnologies such as domestication, selective breeding, and fermentation have affected you and your life. How do you think human history would be different without the ways people have used and changed animals, plants, and microorganisms?
14. Think of a story about the impact on you of something produced using biotechnology—for example, the story of a pet, a favorite food, or plants you are familiar with. Share this story with a partner, your team, or write or draw it.

Understand: *What are some of the genetic tools of biotechnology?*

Domestication and selective breeding rely on the idea that offspring inherit traits from their parents. For many years, although people understood this idea of inheritance from parents, they didn't know how it worked. Finally, they realized **genetic data** is passed from parent to offspring. Genetic data is a set of instructions in each cell about how to build and maintain a living thing. Living things with a mother and a father receive a copy of the genetic data from both parents. However, it was not until the 1950s that scientists discovered the structure of the genetic data. A molecule, known as **DNA**, transfers and stores genetic data.

Discovering and understanding the structure of DNA changed biotechnology forever. It provided a new way to understand living things. Researchers also learned that by changing DNA, scientists could change the genetic data and traits of living things. Because DNA is so important to biotechnology, in this activity you will learn more about its structure and how it works. This will help you complete the rest of the guide.

1. Think quietly to yourself about these questions.
    a. What things around you do you think have DNA?
    b. What could you learn or do if you had access to that DNA?
2. Read *DNA Extraction Instructions* and carry out a DNA extraction.

DNA Extraction Instructions

DNA contains a huge amount of information and it is found in every living thing. Breaking cells apart and pulling something out, or **extracting** the DNA is often the first step in biotechnology research and applications. In this experiment, you will complete a DNA extraction yourself.

What you will need

- Alcohol: At least 70% concentration of rubbing (isopropyl) alcohol or ethanol. You can buy this at a chemist, drugstore, or places where first aid items are sold. Do NOT use alcoholic beverages; the experiment will not work.
- DNA source: You can choose your source—strawberries, bananas, peas (fresh, dried, or frozen) all work well, as do many fruits and seeds. Choose something that is easily available for you.
- Containers: A plastic bag, a bowl, or a cup. You will use this to hold the DNA source while you are mashing it. You'll also need another container to mix some ingredients.
- Fork or spoon: To mash your DNA source.
- Water: Use any clean water you have available.
- Salt: Everyday cooking salt is fine.
- Detergent: Dish soap or shampoo both work well.
- Filter: Any coffee filter will do. If one is not available you can use a paper towel, a very fine sieve, or even an old T-shirt.

- Clear container: A glass or plastic cup works best, but you can use a bowl if that is what you have.
- Skewer or toothpick

Directions

a. Put your alcohol in a freezer for 24 hours before you start.

b. Put your DNA source in a container and mash or grind it so it forms a paste. You need about 100 ml (1/2 cup) of the DNA source. You can place it in a plastic bag, like in Figure 1-12, or put it in a bowl or cup and use a fork or spoon to mash it. This process breaks up the cell walls in the plants.

Figure 1-12: Smashed strawberries in a plastic bag.

c. In another cup or bowl combine around 100 ml (1/2 cup) water, 5 g (1 teaspoon) salt, and 10 ml (2 teaspoons) detergent. Mix thoroughly.

Figure 1-13: Salt, water, and detergent mixture.

d. Add about 10 ml (2 teaspoons) of this water mixture to your mashed-up DNA source. Mix gently. The detergent will help break up the lipids (fats) in the cell membranes and release the DNA. The salt helps make the DNA easier to extract.
e. Strain the mixture through the filter into the clear container.

Figure 1-14: Filtering the strawberry mixture.

f. Take your alcohol out of the freezer and pour it gently down the side of your clear container. Pour about as much alcohol as you have DNA source mixture.
g. Watch carefully. The alcohol will sit in a layer on top of your DNA source mixture. However, DNA will begin to **precipitate**, or come out of solution, in the alcohol. Cloudy white wisps will start to appear in the alcohol as the DNA precipitates. Let your mixture sit for 5 to 15 minutes to get the most DNA.
h. You can twirl a skewer or toothpick in the alcohol layer to pick up the DNA. It will be sticky and a little slimy. This visible substance is the DNA from many cells that is stuck together.

Figure 1-15: Toothpick showing DNA extracted from strawberries.

Going further

Now that you have extracted the DNA from one source, try another source. DNA is part of every living thing. However, it can be tricky to extract it from the roots, leaves, and stems of plants. You can also extract DNA from animal products, like chicken liver. For some things you may need a blender to break up the cells rather than just mashing them by hand.

You can extract DNA in everything from seed pods you collect from plants to your own saliva (spit)! What can you find around you to use as a DNA source?

3. Discuss the results of your experiment with your team.
    a. Were you able to extract DNA?
    b. What do you think you could do with DNA once it is extracted?
4. Read *DNA: Instructions for Life*.

DNA: Instructions for Life

The information in DNA is stored in **bases**. There are four types of bases: adenine (A), cytosine (C), guanine (G), and thymine (T). The bases form a long sequence that stores information about how to make different proteins.

Each base type pairs with one other type, so A always pairs with T and C always pairs with G. These matches are known as **base pairs**. You may know that DNA is a double helix molecule. Each side contains a sequence of bases paired with the other matching set of base pairs, as shown in Figure 1-16.

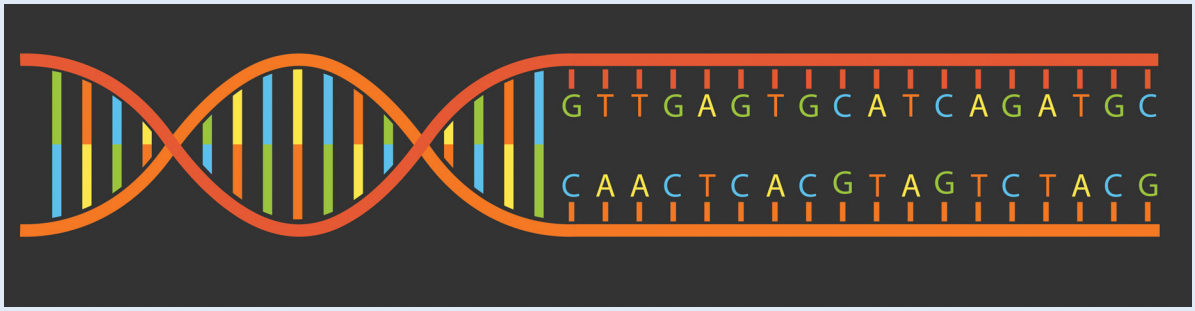

Figure 1-16: Illustration of a double helix with matching base pairs.

If you want to make sure you understand, you can use the sequence here and fill in the matching base pairs. The first few matches are done in red for you.

A T A C C G C A T T A T C G C G G A A A T C T C G A T
T A T G

In 1990, scientists around the world decided it was important to determine the entire human **genome**, or sequence of DNA, which is around 3 billion base pairs in total. Researchers from 20 institutions in six countries worked together as part of the Human Genome Project and in 2001 they published the sequence of almost the entire human genome. Researchers continued to improve their knowledge and in 2022 filled in the final gaps. The first human genome sequence produced in 2001 cost about US$1 billion to produce. Today, sequencing an entire human genome costs less than US$1,000, and the cost continues to go down.

5. Discuss with your team:
   a. Why do you think it was useful to sequence the whole human genome?
   b. The genomes of different humans are 99.9% the same. Why do you think there is still a need to sequence individual human genomes?
   c. Researchers have also been sequencing the genomes of other living things. What might they hope to learn from that information?
6. Read *Gene Expression and Variation*.

Gene Expression and Variation

You know that genetic data is carried by the molecule DNA and copies of a parents' DNA are given to their offspring. But how does this genetic data create different traits? Long strands of DNA are organized into smaller sections called **genes**. Genes can be copied and used by a cell to produce proteins. Cells "read" the sequence of bases pairs in a gene to find out how to form a specific protein. Producing these proteins is called **gene expression**.

Genes code for specific proteins that create specific traits. Some traits, like whether a person has a detached earlobe or can roll their tongue, are determined by a single gene. Other traits, such as a person's height and skin color, are determined by multiple genes.

Even small changes in the sequence of the base pairs in a gene can create big changes in the protein.

Let's use an **analogy** to explain. Imagine rather than the four letters (a, c, g, and t) representing the bases of DNA, the DNA instructions used the letters of the alphabet to share information.

Take out a piece of paper and something to write with. You will model a cell "reading" a gene of its DNA. For each bolded sentence, follow the instructions. In this analogy an initial gene might be read like this:

Start here: Read this sentence then draw a box.

As part of the model analogy, you probably just drew a box.

However, sometimes when DNA is copied the cell might make a mistake and copy one letter wrong. Genes with one or more differences like that are called **variants**. In this analogy, the mistake might be quite small but will change the meaning. Follow the instructions in the sentence below.

Start here: Read this sentence and then draw a fox.

How is what you drew this time different? In the example, the "b" from box changed to an "f" which changed the meaning of the sentence.

Sometimes small changes like this do not create a problem. However, sometimes they can mean the person with the variant is unable to make a certain protein properly. Diseases like Tay-Sachs, cystic fibrosis, and sickle cell anemia are caused by variants like this.

In the past, once a problematic variant occurred, there was no way to fix it. However, in 2012 scientists began using a new biotechnology tool called **CRISPR-Cas9.** CRISPR is sometimes called "DNA scissors" because it can snip DNA in very specific places to add, delete, or change base pair sequences.

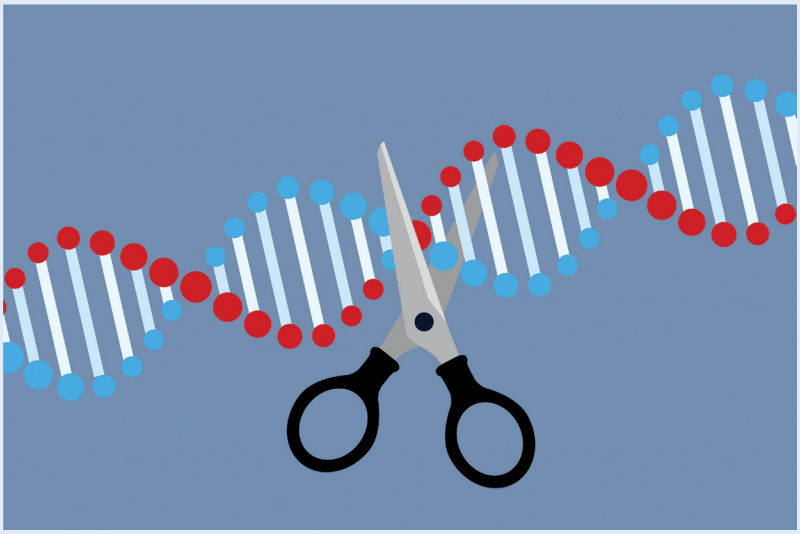

Figure 1-17: Illustration of CRISPR-Cas9, sometimes known as DNA scissors.

The development of these techniques means it is easier than ever before for people to change genes in very specific ways—a process called **gene editing**. For example, in this analogy, by using CRISPR the word "fox" could be changed back to the original word "box."

Or by using CRISPR, new instructions could be added. Continue modeling a cell reading a gene and follow the instructions below:

Start here: Read this sentence and then draw a box and a rainbow.

Or by using CRISPR, scientists can take a piece of the gene out. Here's an example of that using the sentence analogy. Follow the instructions in the bold sentence.

Start here: Read this sentence.

Or by using CRISPR, scientists can take a piece of the gene out and replace it with another base pair sequence. Follow the instructions in the bold sentence to model an example of that.

Start here: Read this sentence and then think of a box.

Or by using CRISPR or other techniques, scientists can stop genes from being expressed. This is called **gene silencing**. Follow the instructions in the bold sentence to model an example of that.

Stop here: Read this sentence and then draw a box.

Examine what you drew on your paper. Did you get different instructions after the gene was edited?

CRISPR and other similar gene editing tools mean it is possible to change specific parts of the genome of any living thing.

Using gene editing tools, gene expression can change in many ways. By changing the DNA in genes, the proteins they code for can be changed. Mistakes in gene copying can be fixed and new instructions can be added. Using gene silencing, a gene that is causing a problem can be "turned off."

If you would like more information about how gene expression and editing works within a cell, you can find more resources in the *Biotechnology!* StoryMap.

Parts 2 through 7 share more details about how gene editing and other biotechnology tools have opened up many new possibilities for human health, the environment, and many other areas.

7. Discuss with your team:
    a. Can you think of a specific way or ways a gene editing tool could be used to help people or the planet?
    b. If you can't, don't worry, you will be learning more during the rest of the guide.

Act: *What concerns do I have about using biotechnology sustainably?*

Biotechnology tools can change the world around us in dramatic ways. However, just because things can be done does not mean they should be done. In this activity you will start to consider how and when you think biotechnology should be used.

1. As a team, take out a piece of blank paper or use a section of a class board. Divide your paper or the board into four sections and draw a circle in the middle, as shown in Figure 1-18. In one section write "Social," in one write "Economic," in one write "Environmental," and in one write "Ethical."

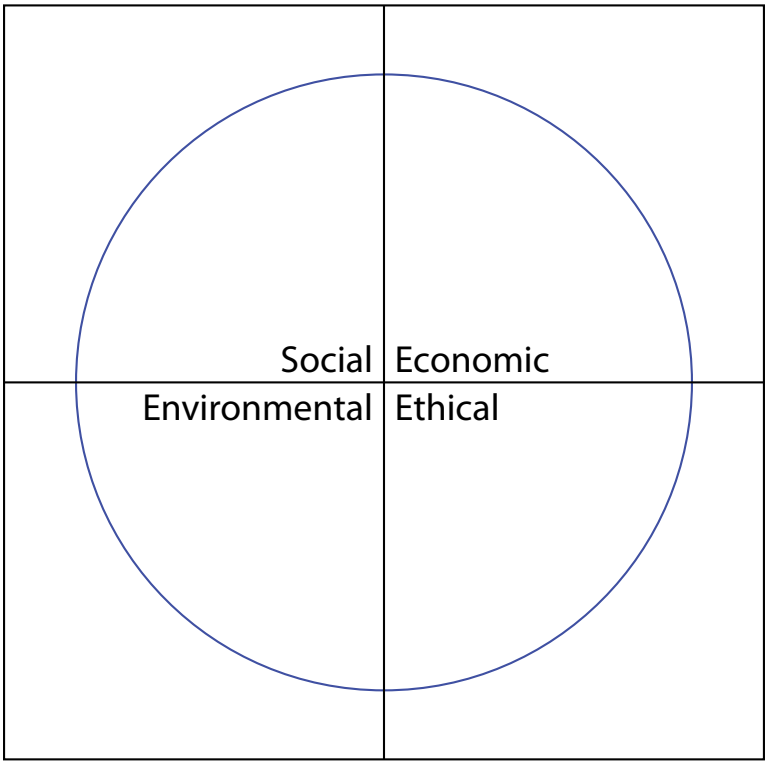

Figure 1-18: Perspectives sheet.

2. Read *Different Perspectives* and think about what the different perspectives mean. Write words or draw pictures within each section of the circle to help you remember the concerns of people thinking about each perspective.

Different Perspectives

People may have different perspectives. Often a person's perspective may be related to parts of their own identity or experiences.

Considering different perspectives can help uncover solutions for a sustainable future. Sustainable means balancing the needs of different people and other living things over the long term. When thinking about sustainability, it is important to consider four types of perspectives: social, economic, environmental, and ethical.

- **Social** is about the interaction of people in a community. The health, education, and well-being of people are the most important things from this perspective.
- **Economic** is about money, income, and use of wealth. Economic growth, including making sure people have jobs and enough money, is the most important thing from this perspective.

- **Environmental** is about the natural world. Protecting the Earth and its natural systems are the most important things from this perspective.
- **Ethical** means that something is fair. Doing what is right and having a just community where everyone is treated fairly are the most important things from this perspective.

3. Now read the *Biotechnology Scenarios*. In each section of your *Perspectives Sheet*, draw pictures or write words that show ways this situation might be helpful from that particular perspective. Also draw or write ways that you think the scenario might concern or worry people thinking from this perspective.

Biotechnology Scenarios

Scenario 1: A researcher modifies the DNA of a human egg cell by editing a gene to makes the cell more resistant to disease.

Scenario 2: Plant biologists use CRISPR to modify the DNA of a rice plant to insert a gene that makes the plant need less water to grow. Next year they will start to use this modified plant in local farms.

Scenario 3: A gene therapy treatment that inserts new DNA sequences into targeted body cells helps cure a rare disease. The treatment is only available at a few hospitals and costs US$450,000.

Scenario 4: A company collects and sequences DNA samples, which enables clients to better understand their family heritage and risk of specific diseases. This data could potentially be used by employers or insurance companies to make decisions about whether to hire or insure people. However, right now the company's privacy policy currently states the data will only be used by the company itself.

Scenario 5: A mosquito species carries and infects people with the disease Zika. A team of researchers introduces a genetic modification to that species of mosquito. The genetic modification will slowly destroy the population of mosquitoes over time by limiting their ability to reproduce. The researchers hope this will stop the spread of Zika. The team plans to release the modified mosquito into the wild.

4. Examine all the concerns from the *Perspectives Sheet* with your team. Are there specific **themes**, or main ideas, that you notice? If so, make a note of these themes.
5. Several **themes** often emerge when thinking about using biotechnology ethically. Examine the themes that follow and make a note if they are reflected in some of the things you thought about from a social, economic, environmental, and ethical perspective.
    a. Access: Who gets to use and benefit from biotechnology?
    b. Privacy: What personal data is available and how can it be used?
    c. Unbalanced ecosystems: Natural systems are **interdependent,** which means different parts of the system depend on one another. Will the biotechnology unbalance the system in an unanticipated way?
    d. Persistence: Will the modification remain in the body of a living thing or in larger natural systems? Will the modification spread uncontrollably?
    e. Decision-making: Who should get to decide these issues? How do the decisions of one person or group affect others?
    f. Safety: What is the potential for harm?
6. Discuss with your team which ethical themes you think are most important to keep in mind as you consider whether biotechnologies should be used.
7. Pick some or all of the themes listed here, as well as any other themes you think are important. Create a list, chart, infographic, piece of artwork, or other method to help you remember these themes. Keep this *Ethical Concerns List*; you will need it in other Parts of this guide. If it is a visual reminder, you may want to post it somewhere in your classroom.
8. Go back and examine your *Futures Mood Board*. Think quietly to yourself or share with your team:
    a. In your hopes for the future, could some hopes be threatened by the ethical themes you identified?
    b. In your concerns about the future, could some concerns become more likely due to the themes you identified?

Congratulations!

You have finished Part 1.

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.

Action researcher: A person who works with their community to discover, understand, and act on local and global problems they learn about

Analogy: Comparing two things to help provide clarification

Base pairs: The matches that DNA bases form with one another**:** A always pairs with T and C always pairs with G

Bases: The four types of DNA units that store information: adenine (A), cytosine (C), guanine (G), and thymine (T)

Biodiversity loss: A decrease in the variety of the many different living things on Earth

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

Breeds: Different types within one species, for example two breeds of dogs

Community: A group of people who share something in common, such as a space or an identity

Consensus: A balanced decision that works for everyone in the group

CRISPR-Cas9: A biotechnology tool that cuts DNA in very specific places to add, delete, or change base pair sequences

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

Domesticate: The process of changing a species from its wild state to make it more useful for a specific purpose

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

Environmental: About the natural world

Ethical: Something that is fair

Ethics: The fairness of something

Extract: Pulling out a part from within a larger thing

Fermentation: A food preparation technique that adds microorganisms to food or encourages naturally occurring microorganisms to develop

Gene editing: Changing genes in very specific and targeted ways

Gene expression: Producing a specific protein from a gene

Gene silencing: A process in which scientists stop genes from being expressed

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

Genetic data: The set of instructions within a cell on how to build and maintain a living thing

Genome: The complete sequence of DNA of a living thing

Identity: The characteristics that make you y ou

Inheritance: The process in which traits or characteristics of parents are passed on to their children

Interdependent: When different things, people, or parts of a system depend on one another

Microorganisms: Living things that are too small to see without magnification

Mood board: A tool to help gather ideas, concepts, and styles to design something

Offspring: The children of parents

Perspectives: The different ways we think about the world around us

Precipitate: When part of a solution turns into a solid

Selective breeding: The process of breeding two living things with desirable traits in the hope that their offspring will have the same traits

Social: Relating to the interaction of people in a community

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

Sustainable: An approach that balances different perspectives and can keep working for a long time

Sustainable Development Goals (SDGs): Seventeen goals for a better world created by the countries of the United Nations

Sustainable future: A future that balances social, economic, environmental, and ethical concerns and that works well for people and the planet

Technology: Materials and methods used to solve people's problems and fill their needs

Themes: Main ideas

Traits: Characteristics

Variants: Genes with one or more differences from the original

Variation: Differences in living things

