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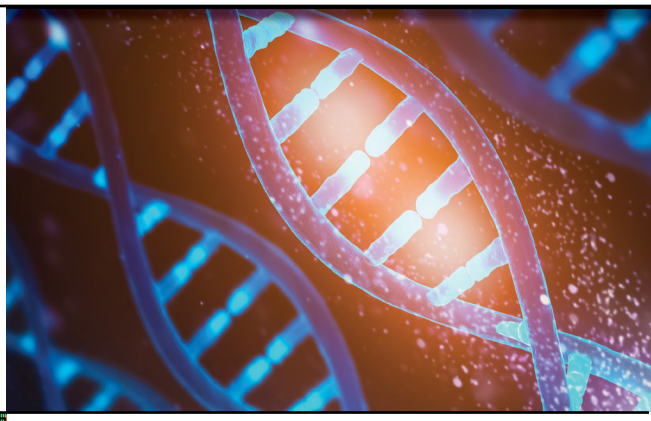
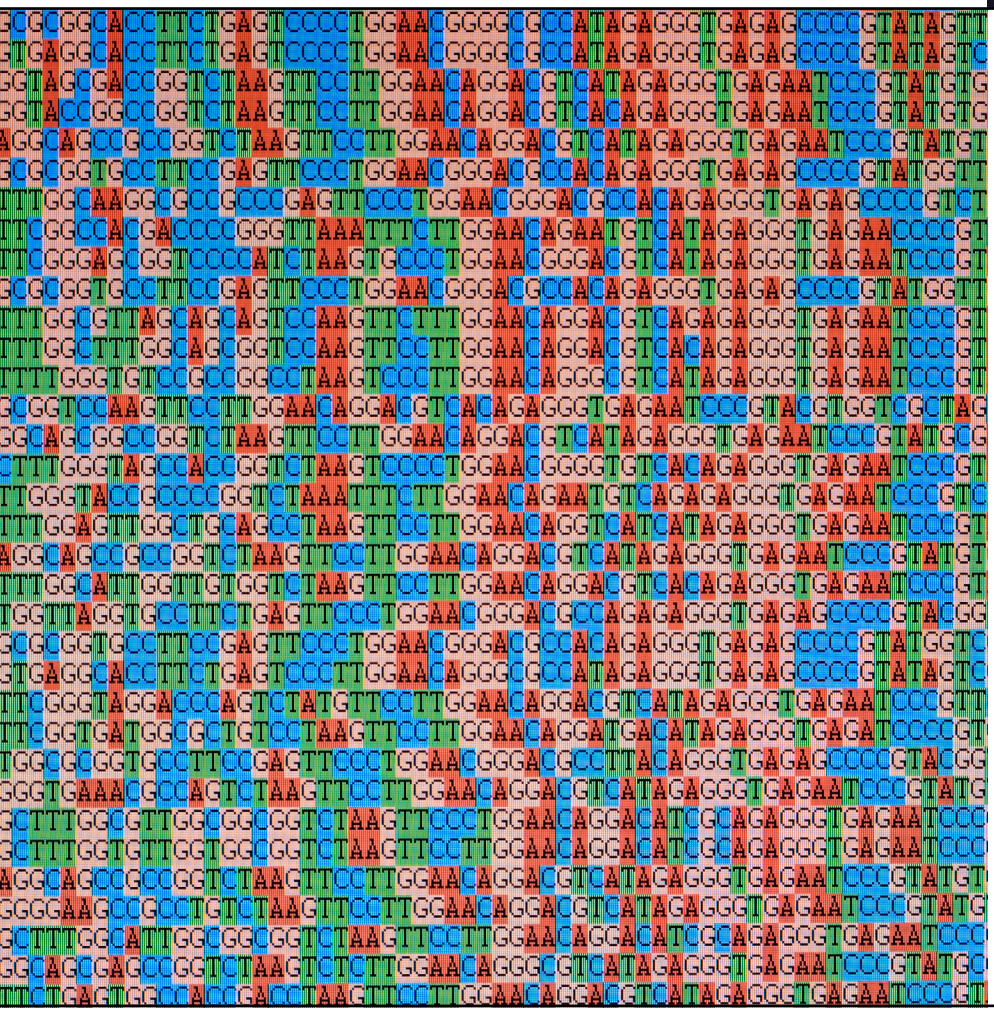
BIOTECHNOLOGY!





Part 5:

Biotechnology and Genetic Data

SUSTAINABLE DEVELOPMENT GOALS

developed by

Smithsonian
Science Education Center

in collaboration with

iap SCIENCE HEALTH POLICY
the interacademy partnership

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Smithsonian Science Education Center Guide Development Staff

Director - Dr. Carol O'Donnell

Division Director for Curriculum, Digital Media, and Communications - Laurie Rosatone

Science Curriculum Developer - Heidi Gibson

Contributing Interns
Emily Chen
Khadijah Thibodeaux

Research Mentors
Kadija Ferryman, Ph.D.
Irene Xagagoraki, Ph.D.

Technical Reviewers
Danielle Boyce, DPA, MPH

The contributions of the Smithsonian Science Education Center staff, Project Advisors, Research Mentors, and Technical Reviewers are found in the acknowledgments section.

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PART 5: BIOTECHNOLOGY AND GENETIC DATA

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 should we use and protect genetic data?					
Discover	Explore how genetic data relates to your identity. Discover more about how genetic data is collected and the information it contains.		*Identity Map* (Part 1)	25 minutes	171
Understand	Consider your concerns about uses of genetic data. Conduct interviews to understand community concerns.	• Pens or pencils • Paper		30 minutes + interview time	175
Act	Analyze different perspectives on the ownership and use of genetic data. Choose one perspective to share with another person or group.	• Pens or markers • Poster paper or class board		25 minutes	182
Task 2: How can environmental genetic data help identify and solve problems?					
Discover	Search for evidence of living things and find out how the evidence from eDNA can help answer questions.	• Pens or pencils • Paper		35 minutes + search and observation time	187
Understand	Analyze case studies of investigations using eDNA and design your own investigation.	• Pens or pencils • Paper		60 minutes	191
Act	Develop your ideas about the ethical considerations and other perspectives on the use of genetic data and use these ideas to modify your eDNA investigation.	• Pens or pencils • Paper	*Ethical Concerns List* (Part 1)	25 minutes	201

Task 1: How should we use and protect genetic data?

The information in a **genome** is called **genetic data**. The genetic data of your genome can tell researchers many things about you. This is true for humans and all living things. In this task you will ***discover*** more about what we can learn from **DNA**. Then you will investigate to ***understand*** more about how people in your community feel about sharing this information. Finally, you will ***act*** to decide how you think genetic data should be protected.

Meet Your Research Mentor

Meet Dr. Kadija Ferryman. Kadija (pronounced kah-DEE-jah) is one of the many researchers around the world thinking about how to use **biotechnology** ethically.

Kadija is a professor of bioethics and health policy at Johns Hopkins University in the United States. She has a PhD in anthropology. However, she also has knowledge and perspectives that came from other parts of her identity. Since Kadija is now working with you, it is important to understand who she is.

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

- Jamaican-American, or "Jamerican"
- Both of my parents were born and raised in Jamaica, as well as all of my ancestors going back to the 1790s.
- Woman
- Native New Yorker; born and raised in New York City
- BA from Yale University, PhD from the New School for Social Research
- Interested in how we understand differences between human groups, digital technologies, justice and fairness in society
- Likes Caribbean and African diasporic dance, cooking, jogging, listening to podcasts, cycling, spending time with family and friends
- Has been wearing glasses since the fourth grade

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

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

Throughout this task you will notice Kadija 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 can we learn from DNA?*

Every person's genome is unique. It contains information that determines parts of your identity. There are many different ways this information can be used.

1. Take out your *Identity Map* from Part 1.
2. Examine it carefully. Find any parts of your identity that you think might be related to your DNA. For example, your identity map may include physical characteristics determined by your DNA. Or your identity map may include roles you play based on shared genetic relationships, such as daughter or brother.
3. Discuss with your team:
   a. Which parts of your identity do you think could be found in your DNA?
   b. Which parts of your identity are not found in your DNA?
   c. Can your DNA tell your story? Does your DNA leave out important parts of what make you you?

⚠ Emotional Safety Tip

Your genetics can affect who you are but they do not determine all parts of your identity. Sometimes people may assume certain things about you based on your genetics. But you are the one who decides who you are.

4. Think quietly to yourself:
    a. Are there ever parts of your identity that you want to keep private?
    b. How would you feel if other people could find out that information using your DNA?
5. Gather with your team. You will be investigating more about how genetic data is collected and analyzed. Read *Collecting the Sample*.

Collecting the Sample

The first step to using genetic data is to collect a sample of DNA. DNA can be found in every cell in your body. It can be found in your hair, sweat, blood, urine (pee), feces (poop), saliva (spit), and even little flakes of your skin that you leave behind.

6. With your team, discuss:
    a. Where might you have left samples of your DNA without realizing it? Make a list of all the places you can think of.
    b. Would you be comfortable if these samples were used to find more information about you?
7. Read *Analyzing the Sample*.

Analyzing the Sample

After collection, the DNA in the sample needs to be sequenced so the genetic data can be analyzed. Researchers use chemicals to extract DNA, just as you did in Part 1. Then researchers can use a DNA sequencing machine to find out the sequence of As, Ts, Cs, and Gs. This sequence is then sent to a computer for analysis and interpretation. Figure 5-1 shows an example.

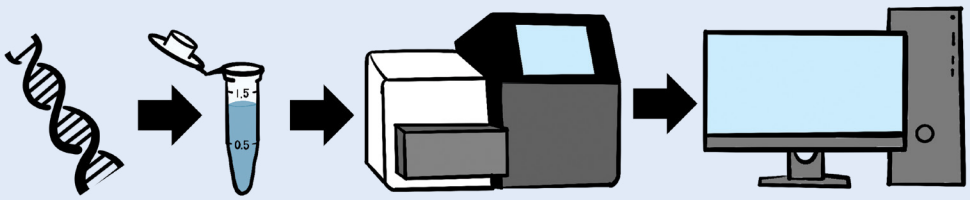

Figure 5-1: A DNA molecule is collected in a sample tube and sequenced in a machine, which then sends the data to a computer for analysis.

You may remember from Part 1 that scientists sequenced the whole human genome as part of the Human Genome Project. At that time, scientists had to sequence all the DNA in order, like reading a book from start to finish. It took a long time. Now scientists have found a quicker way to sequence DNA called **next-generation sequencing**. They sequence many parts of the DNA at the same time. Then they use a computer to reassemble the pieces in order. Humans share 99.9% of our DNA, so as long as there is enough of a part, it is straightforward to see where it fits into the sequence of the genome. Scientists use a **reference genome**, or an example of a living thing's genome, to help them understand the order of the DNA pieces.

8. Discuss with your team:
    a. How did the Human Genome Project make it easier to sequence genomes of other humans?
    b. There is now something called the Pan Genome Project in which scientists are trying to sequence the genomes of all living things. Why might this be useful?
9. Now that you have a DNA sequence, you need to discover what it means. Read *Using the Clues*. Can you figure out whose DNA you collected?

Using the Clues

Genetic data is often used by researchers to identify which living thing left behind a sample of their DNA. Genetic data can tell us a lot about the species or individual who left it behind. Researchers analyze the genetic data to find out more about the living thing it came from.

Who does the DNA belong to?

Imagine you are a researcher who collected a sample of DNA and wants to find out who the DNA belongs to. For this activity we will use a set of imaginary monsters. As a researcher, can you use the genetic data from genes A, B, C, and D in the collected sample to identify the monster who left it behind?

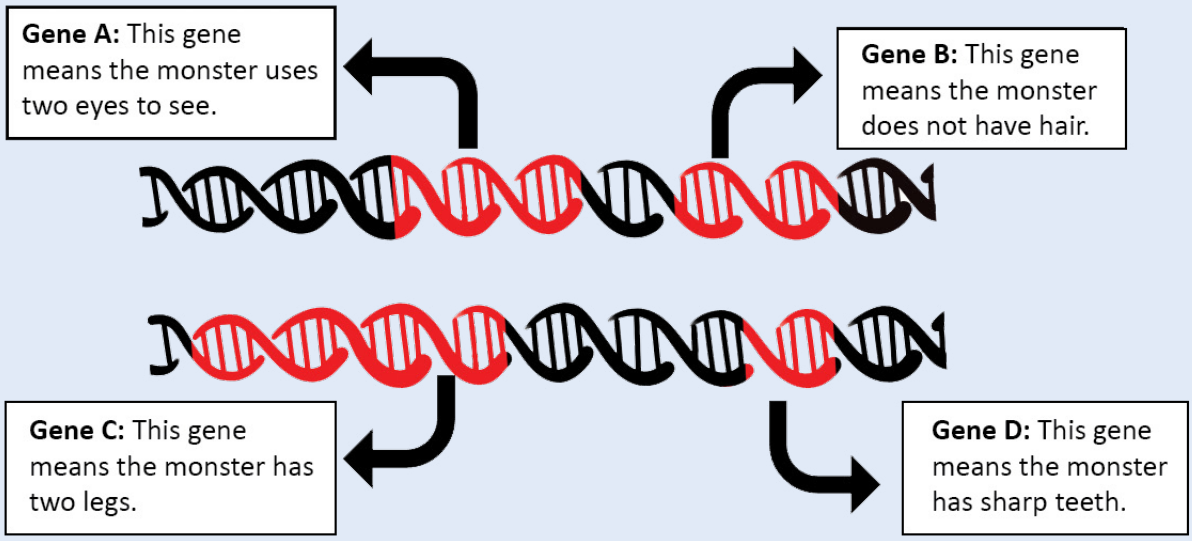

Figure 5-2: Imaginary monster genes.

Which monster did the DNA come from?

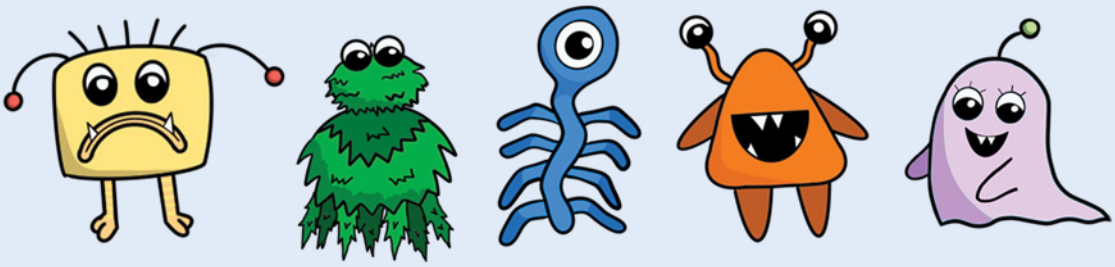

Figure 5-3: Imaginary monsters.

10. Think together with your team and discuss:
    a. Can you think of any situations in which someone might want to use genetic data from a sample to figure out which people had been in a certain place?
    b. Can you think of any situations where someone might want to use genetic data to know more about relationships between people, like whether a person is a family member?
    c. Can you think of any situations where someone might want to use genetic data to find out more about an individual's characteristics, like whether they might have DNA **variants** that are connected to disease?
11. Read what Kadija says. What do you think the similarities and differences in human DNA can tell us? Do you think it should change the way we think about people we think of as different?

Kadija says . . .

After sequencing the human genome, we found that all humans are 99.9% alike. But over the course of history, we as humans have spent a lot of time dividing ourselves up into different groups, categories, and "kinds" of people, and this has sometimes had harmful consequences. So what do we do with our 0.1% of genetic difference? Is that meaningful or not? Why or why not? Those questions really captivate me.

Understand: *How can genetic data be used?*

People's genetic data contains a lot of information that can be useful. Different groups often collect genetic data. Sometimes it is collected for research, for example to understand more about human diseases. Sometimes it is collected by companies that analyze genetic data to answer questions about ancestry and possible health outcomes. Sometimes genetic data is collected by law enforcement to try to solve crimes. In this activity, you will think more about how genetic data is used and the impacts of those decisions.

1. Read *Genetic Data Use One* through *Genetic Data Use Five* and answer the questions to consider by yourself.

Genetic Data Use One: Law Enforcement

Dutch investigators caught an art thief using DNA evidence. After an art heist, investigators found a sample of DNA left behind on a picture frame. The sample from the frame helped investigators identify several people who had contact with the stolen artwork, including a man who had previously been to jail for art theft. Authorities concluded that since this man's DNA was present at the scene of the crime, he must have been the person who stole the paintings. The accused thief says he is innocent. He says the paintings could have been stolen by any of the people whose DNA was left behind at the scene.

Questions to consider

a. If you were an investigator, how certain would you feel that you had caught the right person?
b. Are there instances you can think of when DNA evidence does not lead to a just outcome?

Genetic Data Use Two: Research

Governments, private companies, and research institutions are creating databases of genetic data they have gathered from many people. Researching the data in these databases can help answer questions about genetic diseases and potential treatments. Some of these databases are **open access**, or able to be freely accessed by other researchers. However, many databases have restrictions. Data in the databases are **deidentified**, meaning there are no names attached to genetic data. But some institutions are still concerned about privacy and so they limit access to the database or only share some genetic data. Other times, companies may want to keep ownership over data they have collected.

Kadija says . . .

One way that data can be kept private or confidential is by taking off identifying information. For some kinds of data, you can take off someone's name, address, or gender and still be able to use that information as anonymous data for a particular function. But with genomic information, that data is quite literally about you. How do you make genetic data anonymous and still use it in beneficial ways, such as for health research?

Questions to consider

a. What concerns do you have about data being open access? What advantages do you think there are?
b. Do you think a company should be able to own someone else's genetic data? If not, who should own it?
c. Review what Kadija says. Do you think it is possible to deidentify genetic data?

Genetic Data Use Three: Personalized Marketing

You can pay a company to gather the genetic data from your DNA, a process called **direct-to-consumer (DTC) testing**. Your results can show information about your **ancestry**, or what part of the world your ancestors came from. It can also show potential diseases you might be at risk for. Recently, through a partnership with a music streaming service, a direct-to-consumer testing company even created personalized music playlists based on your ancestry!

Questions to consider

a. Do you have any concerns about your genetic data being used to market things that might be interesting to you, based on your ancestry, like music or recipes?
b. What if the marketed items were based on your health information in your DNA? Is that different?

Genetic Data Use Four: Healthcare Decisions

Results from DTC companies can show if you are more likely to develop certain diseases. However, these results arrive to you virtually. There are no experienced health care professionals to help you interpret them. People may make decisions about their own behaviors, such as choosing to have children or keeping up with preventive health screenings, based on these results. They also may choose to share these results with relatives who may have similar results. DTC results are not always completely accurate or easily interpreted.

Questions to consider

a. Do you think there should be a requirement to have a health care professional talk to people who have a high risk of developing a disease, based on their DTC results?
b. What potential problems are there if people share results with their relatives when their relatives do not want to know the information?

Genetic Data Use Five: Data for Sale

DTC companies are paid by consumers to test their genetic data and share those results. However, pharmaceutical companies, research institutions, health and beauty companies, and technology startups all sometimes pay DTC genetic testing companies for access to a database of their users' deidentified genetic data. Figure 5-4 shows an example.

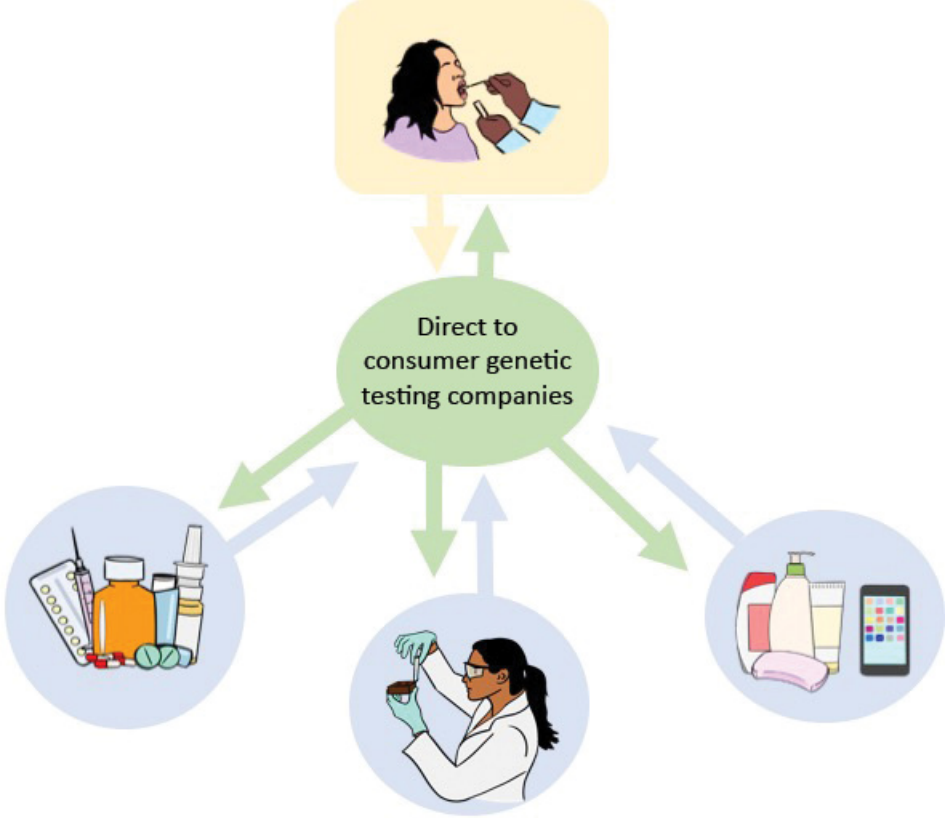

Figure 5-4: The DTC business model: Individuals share a genetic sample with DTC companies. These companies return the genetic data to the individual, but also sell it to pharmaceutical companies, research institutions, and other companies.

Questions to consider

a. Do you have any concerns about the way DTC companies sell genetic data?
b. What are the benefits to individuals of the DTC business model? What are the benefits to DTC companies?

2. Gather together with your team. Discuss the different examples and your answers to the questions.
   a. Did anyone in your team have different answers?
   b. How do you think others in your community might answer?
3. Read what Kadija says. What do you think is important to think about when discussing how genetic data is gathered or used?

Kadija says . . .

Genetic data in some ways is the most personal kind of information that there can be about a person. It's literally the sequence of the genetic material in your cells. We inherit our genetic data from our family members, so this information is personal to you, but some of it is also shared among your family members.

If we have access to this very personal data about an individual, how should we analyze that data? We can find out interesting things, such as what makes people sick. Genetic data is a very powerful resource, on one hand. However, we also have to think about how to use this very personal information in a way that's safe and just, and fair to individuals and to communities.

4. Now you will discuss these ideas with more people in your community. Read *Genetic Data Interview Instructions* and carry out your investigation.

Genetic Data Interview Instructions

You can interview people in your community to learn about their experience with or feelings on gathering and using genetic data. This can help you find out your community's opinions on genetic testing and the use of genetic data.

Choosing people to interview

a. Think about who might know the most about the use of genetic data. For example, it might be a teacher at your school, a person who has used a DTC test, a local scientist, people who work in health care, or leaders who make decisions for your community.
b. Every person in your community has a valuable perspective. Think back to your *Identity Map* from Part 1. Different parts of your identity help give you information. If you can, interview people from a variety of ages, genders, sexualities, jobs, incomes, religions, ethnicities, or other identities so you can get a variety of information. As a team, try to talk to people who live in all parts of your community.
c. Think about the many ways people can share information and try not to leave groups of people out. For example, some people in your community may not use your language. Try to find someone to help you translate so you can find out more about their experiences.
d. Conducting interviews can take a long time, so you may decide to interview just one person. That is okay. If everyone on your team interviews at least one person, you will have enough information to complete the activity.

Questions

With your team, develop a list of questions to ask during the interview. Think about the questions you answered as part of *Genetic Data Use One* through *Genetic Data Use Five*. Are any of those questions ones you want to ask during an interview?

Are there other questions you would like to ask your community? Be sure to include questions to help you find out about experiences or concerns you don't already know about. For example:

a. Do you have any experience with genetic data or testing?
b. Do you feel like genetic testing is safe? Is it safer to test yourself at home or at a clinic or research facility?
c. Are there any ways you or others in our community could benefit from genetic data?
d. What are the concerns about your privacy when receiving genetic testing?

Ways to record an interview

a. You can interview people many ways, such as in person, over the phone, using email, or through a social media platform.
b. You can use audio or video to record an interview.
c. You can write or draw to make a record of the ideas that are shared with you.

Tips for conducting an interview

a. Make sure to ask permission to record a person's answers.
b. Ask permission to share the interview with the rest of your team, class, or other people in the community. People might be more willing to share if their interview is anonymous.
c. If it feels as if someone didn't answer your question, don't be afraid to ask the question again in a different way.
d. Let the person you are interviewing answer the questions in the way they want. Be patient. Listen carefully. Understand that they might give answers you didn't ask for or expect.

Safety tips for interviewing people

Ask your teacher for guidelines. They will know what is safest in your community.

⚠ Physical Safety Tip

Never conduct an interview alone and always be aware of your surroundings. You might want to suggest recording the interview in a quiet public place.

⚠ Emotional Safety Tip

It can be hard to communicate with 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.

5. Examine the results of your interviews with the rest of your team.
   a. What common responses do you notice?
   b. Did anyone say anything that surprised you?
   c. How do you think the information you collected might be useful when making decisions about genetic data?

Act: *What rights do people, scientists, and companies have to genetic data?*

Biotechnology is changing rapidly. Researchers are now able to gather and sequence many more DNA samples much more quickly. When science moves quickly, sometimes people do not have an opportunity to think about different perspectives on the way it may be used. In this activity you will explore different perspectives about genetic data ownership and use, and consider which you would like to share with others.

1. With a partner, start by discussing what it means to own something. Then discuss what it means to own genetic data.
2. Now read Kadija's thoughts. Did her ideas make you think differently about anything?

Kadija says . . .

You might be interested in science and want to give a research study access to your genomic information for the common good. But because blood relatives have some similar genetic information, you would also be giving that research project access to your family's shared genetic information. Some of your family members might not want their information used as a part of this research! But because you want to, some of their information would be included in a research study.

3. Think back to the question of ownership from *Genetic Data Use Two*. With your partner, decide which people or groups might think they have some ownership over genetic data.
4. With your partner, think about the following potential owners of DNA and answer the questions together:
   a. Individual person:
      - Genetic data is information stored in an individual person's DNA. Does an individual automatically own their own data?
      - Do you own data gathered from samples you left around, such as samples from found hair or saliva?
   b. Relatives:
      - Your genetic information is very similar to that of your family and can be used to gain a lot of information about people related to you. Does that make genetic data collectively owned?
      - Should you be consulted before your relatives test their own DNA?
      - Should you have to ask your relatives before you test your own DNA?
   c. Private companies and public research institutions:
      - Private research institutions can **patent** genes they create in a laboratory. A patent is a license from the government that means an individual or company owns an invention for a period of time. This helps make sure they can profit from their research. Can a company own genetic data?
      - Should genes be patented like other things?

5. Divide your team into three groups. These groups will consider three out of the four perspectives you learned about in Part 1. For right now, do not worry about the environmental perspective. Instead, assign each team to one of these perspectives:
    a. **Social** is about the interaction of people in a community. The health, education, and well-being of people are the most important thing from this perspective.
    b. **Economic** is about money, income, and the use of wealth. Economic growth, including making sure people have jobs and enough money, is the most important thing from this perspective.
    c. **Ethical** means the fairness of something. Doing what is right and having a just community where everyone is treated fairly is the most important thing from this perspective.
6. Have each group use a large piece of paper or the board to list their ideas from each perspective. Write or draw answers to these questions:
    a. Thinking about this perspective, how might you want to use genetic data?
    b. What are any concerns about the use of genetic data from this perspective?
    c. Who should own or be considered when thinking about genetic data from this perspective?
7. Use Kadija's thoughts to help you consider whether there is anything you missed listing on your sheets. If there is, add those ideas now.

Kadija says . . .

With genetic data, privacy can be a privilege that only some people have the right to. Some law enforcement agencies are able to collect genetic information or biological information about people who have merely been arrested, not even convicted of a particular crime. Who gets to be "genetically private" can be different in some places, depending on what social group you belong to or are associated with. If you are in a group that is sometimes targeted, sharing your genetic information may be risky.

8. If you used a piece of paper, tape it on a wall or somewhere people can examine it.
9. Move around and examine each group's work. If you think something listed is important to remember or you would want to share it with others, find a way to mark it either by drawing a star, circling it, checking it, or another method.
10. Come back together as a team and examine all the information your team thought was important from the three perspectives. What are the new perspectives that individuals, companies, researchers, or other groups should consider?
11. By yourself, pick one important perspective you would like to share or remember. Decide who you want to share this perspective with and create a way to do that. For example:
    a. If you want to remember information yourself, you might write a short reflection or draw a picture to help you remember the important perspective on genetic information.
    b. If you want to share with a family member, you might write them a letter explaining the perspective you want to share.
    c. If you want to share with a company or group of researchers, you might compose a social media post tagging them. If you feel comfortable, you can post it.
12. Keep a copy of your perspectives sheets to use in Task 2.

Task 2: How can environmental genetic data help identify and solve problems?

Just like human genetic data, genetic data in the environment can be gathered from many places and used in many ways. **Environmental DNA**, or eDNA, is a sample of all the DNA of the many living things that are present in an environment. In this task, you will ***discover*** how eDNA can help you answer questions about the living things around you. Then you will use case studies to ***understand*** how eDNA analysis can be used to research questions from public health to conservation to archaeology. Finally, you will ***act*** on this information by creating an experiment with eDNA that considers different perspectives.

Meet Your Research Mentor

Meet Dr. Irene Xagoraraki. Irene (pronounced i-REEN) is one of the many researchers around the world using biotechnology. Irene will be your research mentor to help you understand more about how biotechnology can help us learn more about the people and other living things around us.

Irene is a professor of environmental engineering at Michigan State University in the United States. She has a PhD in environmental engineering. However, she also has knowledge and perspectives that came from other parts of her identity. Since Irene is now working with you, it is important to understand who she is.

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

- 52 years old (born in 1970)
- Bachelor's degree from the University of the Aegean in Greece, and PhD from University of Wisconsin-Madison
- Greek by birth, US-Greek dual citizen
- Female
- Lives in Michigan, United States
- Crete, Greece, is an important place to her and her family
- Interested in education, science, nature, geopolitics

- Likes spending time by the water, walking in nature, hiking, gardening, photography, puzzles, live music, dancing, movies
- Brown eyes, brown hair, Mediterranean look
- Kind, down-to-earth, conscientious, funny
- Mother, wife

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

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

Throughout this task you will notice Irene 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 can we use biotechnology to learn more about our environment?*

Earth and its system of many living things is complex. Sometimes we want to make good decisions to help people and the planet, but we do not have enough information. For example, maybe we don't know which or how many living things are in a place. Sometimes eDNA can help solve this problem.

1. Read *Living Things Search Instructions* and follow the steps.

Living Things Search Instructions

Sometimes you can directly observe a living thing, for example if you see a plant or a bug. Sometimes you can use other evidence to know whether a living thing has been in a place. For example, a person might leave personal items behind like a jacket or bag. Another living thing might leave paw prints or scat (poop). In this investigation, you will be listing all the living things you can directly observe or find evidence of.

Pick a research area

Pick a place to do your research. It does not need to be very large. If you can use an outdoor location, that might be best. However, even in an indoor location there are usually many different types of living things. Find a partner and make sure you pick a place where both partners can move around easily.

Identify evidence

Think about what you might use as evidence—for example, things a living thing left behind, like a specific smell, food, scat, leaves, claw marks, pieces of hair or fur, prints, trails, holes, homes, or nests.

Prepare to observe

Take out a piece of paper to make a list of all the living things you observe or find evidence of. Draw two columns on your list. Label one "Living Thing" and the other "Evidence." Figure 5-5 shows an example.

Living Thing	Evidence

Figure 5-5: Sample Observation List of living things and evidence of them.

You can use any of your senses to make observations on your *Observation List*.

a. If you observe a living thing, write it down in the *Living Thing* column and then write how you observed it under *Evidence*.
b. If you know which living thing was in a place because of evidence you find, write it down in the *Living Thing* column and the evidence in the *Evidence* column.
c. If you can find evidence of a living thing but you don't know which living thing it is evidence of, just write down the evidence in the *Evidence* column.

Make your observations

Write or draw the things you observe on your *Observation List*.

Analyze your results

With your partner, consider:

a. Are there any living things you feel sure have been in your research area that you did not observe or find evidence of? For example, maybe you have noticed spiders in your research area before but did not find any today.
b. What would you need to do to make sure you found evidence of all the living things in your research area?

2. With your team, discuss:
    a. Can you think of any way biotechnology might help researchers know which living things have been in a place?
    b. Why do you think that might be helpful?
3. Read *Finding eDNA*.

Finding eDNA

Scientists can use eDNA analysis to collect a sample from a place and find out which living things are present. Especially when living things are hard to find or are microscopic, this can give them a lot more information. They can even discover living things they did not know were there!

eDNA can be used to gather information about many different types of environments. Samples of air, water, soil, sand, ice, and snow can all be used for eDNA analysis. For example, air may have small pollen particles that contain DNA and pond water may have small pieces of DNA from all the things living in the pond. Using eDNA gives scientists a quick, affordable way to learn about an environment.

To study eDNA, scientists often go through several steps:

a. Collect a sample from the environment.
b. Extract the DNA by separating it from everything else in the sample.
c. **Amplify**, or make many copies, of the extracted DNA.

d. Sequence the DNA.
e. Compare the sequenced DNA to databases of living things to see which ones are in the sample.

Remember in Task 1 when you learned about how scientists are collecting reference genomes. Examine the eDNA steps. Why would a database of many different reference genomes be important to help you identify which types of living things are present?

4. Match each of the investigations in Figure 5-6 with one or more sample locations where you could take eDNA samples. Share your answers with your team. Do others on your team agree on the best location for the sample?

Investigation	Sample Location
1. Use eDNA to detect **invasive** carp, a kind of fish, instead of using nets. 2. Use eDNA to find out which species of birds are living in an area instead of tagging them. 3. Use eDNA to understand biodiversity in deep areas of the ocean. 4. Use eDNA to find out whether ancient humans lived in a specific place. 5. Use eDNA to determine the diversity of land animals instead of using cameras. 6. Use eDNA to evaluate the health of endangered sea turtles instead of drawing their blood. 7. Use eDNA taken from core samples of a 20,000-year-old glacier to find out how the surrounding plants have changed. 8. Use eDNA to identify lynx tracks in the snow more easily, instead of using expert identification.	a. Sand b. Air c. Snow d. Water e. Soil f. Ice g. **Sediment** (material that settles at the bottom of a body of water)

Figure 5-6: Investigations using eDNA and the types of samples they might use; can you match the investigation with the best locations?

5. With your partner, think about the living things that were missing from your list during the living things search.
   a. Where in your research area would you need to sample eDNA to find evidence of these living things?
   b. What types of things could you find out about your research area if you took eDNA samples? Read what Irene says to help give you ideas.

Irene says . . .

There is a wealth of information in eDNA. You can learn so much stuff; you can be a detective. I think it is very exciting, lots of fun!

Understand: *What types of problems can we use environmental genetic data to identify?*

You know that analyzing eDNA can give you more information about the living things in a specific place. But how do researchers use this information? In this task you will explore four different ways eDNA is being used in research. Then you will design a research experiment of your own for your local community.

1. Take out a piece of paper and title it "eDNA Experimental Design Organizer." Draw six rows and five columns. Label the rows and columns as shown in Figure 5-7. You will be using this paper to help you remember what you learn during this activity. If you do not have time to do all four case studies, just pick one or two to help you learn more about eDNA before you design your own eDNA experiment. More information about the real-world experiments described in the case studies can be found in the Biotechnology! StoryMap.

eDNA Experimental Design Organizer				
Study	**Type of eDNA**	**Collection Method**	**Analyzing Results**	**Making Decisions**
Invasive Species Case Study				
Public Health Case Study				
Conservation Case Study				
Ancient DNA Case Study				
Your Study				

Figure 5-7: eDNA Experimental Design Organizer.

2. Read *Invasive Species Case Study* and use the information you learn to fill in your *eDNA Experimental Design Organizer*.

Invasive Species Case Study[1]

Imagine you are plant biologist studying invasive species. You are worried that a plant called the tree of heaven is starting to invade a new area. The tree of heaven is an invasive plant from Asia that grows rapidly and crowds out native species in the United States. It even poisons the ground around it so other plant species cannot grow. The earlier you find the invasive tree of heaven, the better chance you have to remove the plants before they become widespread.

You want to monitor your research area to make sure there are no tree of heaven plants. Right now, your team members go out and do a **visual survey**, which means they move around an area looking for different types of trees. Recently, you learned eDNA can be used to analyze air samples. You wonder if this method might detect the pollen from invasive trees and if it would be a better method than a visual survey.

Your team completes a visual survey. They also collect air eDNA samples to analyze. Figure 5-8 shows their results.

Visual Survey Species	Air eDNA Analysis Species
Black willow	Black willow
Honey mesquite	Honey mesquite
	Siberian elm
	Tree of heaven

Figure 5-8: Tree species found using a visual survey and using air eDNA analysis.

Analyzing results

As a scientist, you can use your results to answer the following questions. Write or draw what you think is important in your *eDNA Experimental Design Organizer*, then discuss with your team:

a. How were the results different using a visual survey method and an air eDNA analysis method?
b. Did you detect the invasive species you are studying?

c. Which method helped you detect that species?
d. This study was done only with trees, but do you think eDNA analysis would work better than visual surveys for detecting all types of plants? Which plants might it not work as well for?
e. What would you conclude? Is the tree of heaven present in your research area?

Making decisions

Scientists and other decision-makers use information they have gathered to help make better decisions. Use what you learned to decide which actions to take next, write or draw your ideas in your organizer, and then discuss with your team. Pick one option. Do you think the community should:

a. Launch an effort to remove the invasive tree of heaven before it spreads and hurts the local ecosystem.
b. Take no action, since the visual survey did not find the tree of heaven.

Scientists also need to decide what kind of research they will do next. Pick one option and discuss your reasoning with your team. Do you think you should:

a. Monitor your research area for all types of invasive plants using visual surveys.
b. Monitor your research area for all types of invasive plants using eDNA analysis.
c. Monitor your research area for all types of invasive plants using visual surveys and eDNA analysis.

3. Think about the way air eDNA was used in the *Invasive Species Case Study*. Can you think of any other way to use eDNA to consider which species are in your community? If so, write or draw your ideas in the *Your Study* row of your *eDNA Experimental Design Organizer*.
4. Read Irene's description of another source of eDNA.

Irene says . . .

What is **wastewater**? Wastewater is a mixed water that contains human excrement—anything from the toilet—but also much more. Anything from the shower, the laundry, the dishwasher, the sink, in most cities even storm water and industrial water all end up in your wastewater.

Wastewater contains **microorganisms** such as bacteria and viruses that come from humans who have been infected by them. These microorganisms are diluted in a huge amount of water where there is also dish soap, storm water, many chemicals, and many impurities. If you are looking for human viruses in wastewater you have to look for a needle in a haystack. You have to concentrate and isolate the viruses, which means starting with a large volume of water with some human viruses in it, and ending up with a smaller volume of water with the same number of viruses in it. You can then take a subsample of your concentrated sample and do eDNA extraction, and after some molecular analysis you can get genetic codes for the viruses that were found in your sample. Those genetic codes give you indications of the viral infections that are present in the population that produced the wastewater.

Figure 5-9: A researcher working in a wastewater facility.

5. Read *Public Health Case Study* and use the information you learn to fill in your *eDNA Experimental Design Organizer*.

Public Health Case Study[2]

Imagine you are a public health researcher during the COVID-19 pandemic. You want to know when COVID-19 is spreading widely in your community to help you make decisions. The earlier you can predict that COVID-19 cases are going up, the sooner you can try to help.

You have heard about a method called wastewater surveillance. Wastewater surveillance uses eDNA analysis to find out what is in the wastewater that comes from toilets, showers, sinks, dishwashers, and washing machines. Wastewater can include DNA from the people living in a place, as well as DNA from viruses, bacteria, and other living things.

Your team decides to use wastewater surveillance for a year, starting in September 2020. You analyze the number of **genomic copies** of the SARS-CoV-2 virus, which causes COVID-19. Genomic copies are copies of a specific type of gene in a sample. How many there are shows how common something is in a population. For example, the number of genomic copies of the SARS-CoV-2 virus should show how widespread that virus is in a population.

The results gathered through wastewater surveillance are shown in Figure 5-10. The solid blue area shows the weekly average number of COVID-19 cases reported across several communities in southeastern Michigan. The orange line shows the number of genomic copies of the Sars-CoV-2 virus.

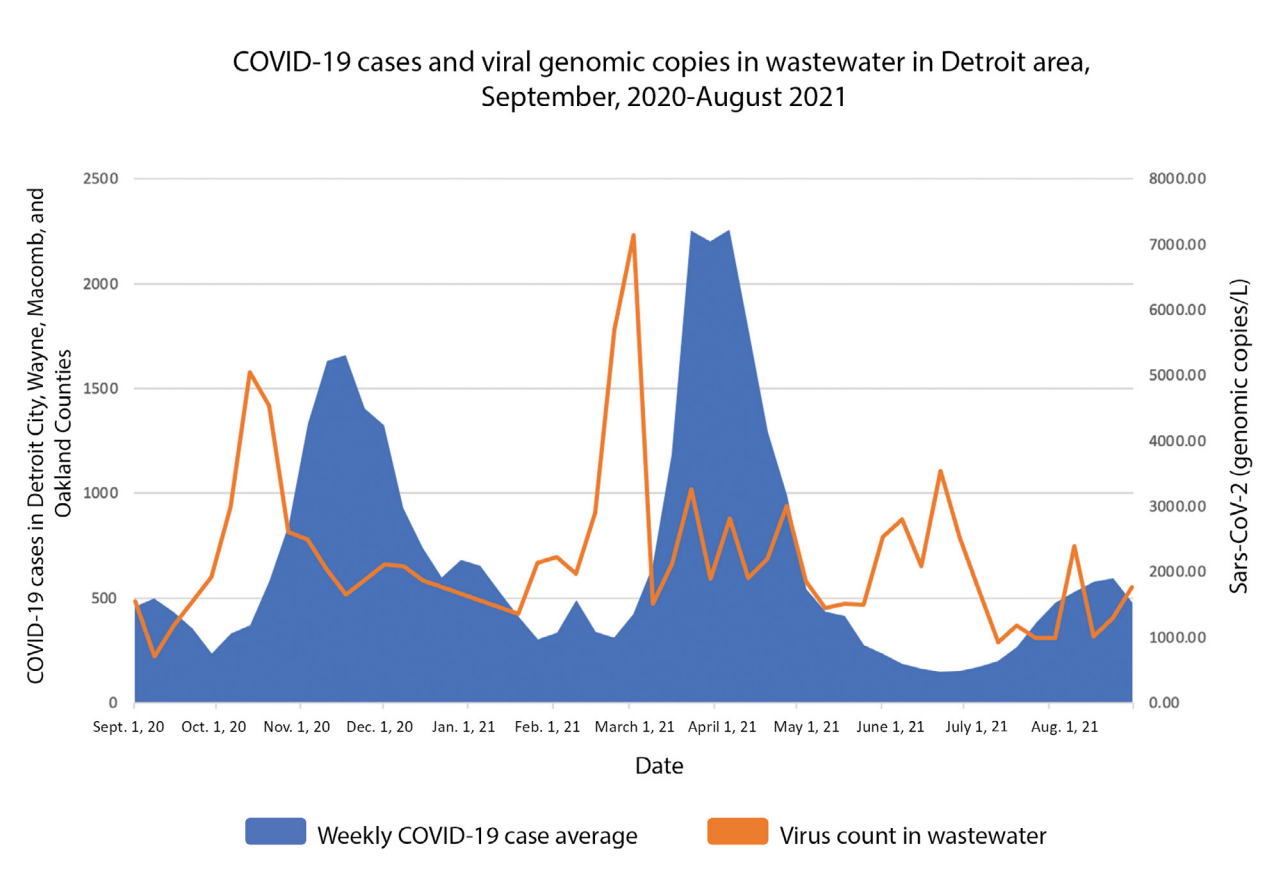

Figure 5-10: Total cases of COVID-19 in southeastern Michigan and number of genomic copies of the virus found in community wastewater, September 2020-August 2021.

Analyzing results

Use your results to answer the following questions. Write or draw what you think is important in your *eDNA Experimental Design Organizer*, then discuss with your team:

a. When were the highest peaks of the genomic copies of SARS-Cov-2?
b. When were the highest peaks of COVID-19 cases?
c. What patterns do you notice about the peaks of the genomic copies and the peaks of the cases?
d. About how long was there between a peak of the genomic copies and a peak of cases?

Making decisions

Scientists and other decision-makers use information they have gathered to help make better decisions. Imagine it is the end of August 2021 and you need to decide what to do next. There are many tools you can use to prepare for widespread disease, like increased community testing, masking, and planning for more medical workers. However, the community only wants to take protective actions when it is most important. Decide which action you think you should take next and record your ideas in your organizer. Then discuss with your team. Pick one option. Do you think the community should:

a. Prepare for the number of COVID-19 cases to drop.
b. Prepare for the number of COVID-19 cases to rise.

6. Read what Irene says. What are some advantages to using wastewater for analysis?

Irene says . . .

If you want to monitor an upcoming disease, how possible is it to collect clinical samples from everyone in the community and test for all potential pathogens? You are faced with two impossible tasks: collect clinical samples from everyone in the community, and test for all possible pathogenic microorganisms they may be infected with.

So I thought, "What's the easiest way to collect a community **composite sample**?" One way is to collect wastewater. You can run complex tests on a composite sample that would be expensive and difficult to run for every person.

7. Think about the way eDNA was used in the *Public Health Case Study*. Can you think of any way to use eDNA for public health in your community? If so, write or draw your ideas in the *Your Study* row of your *eDNA Experimental Design Organizer*.
8. Read *Conservation Case Study* and use the information you learn to fill in your *eDNA Experimental Design Organizer*.

Conservation Case Study[3]

Imagine you are a conservation biologist studying a local population of rare and endangered tortoises. You are wondering if the many local foxes (which are not endangered) might be eating tortoises and causing the tortoise population to decline.

Your team decides that studying fox scat (poop) would be the best way to figure out if the foxes are eating the tortoises.

You first decide to collect fox scat and visually examine the tortoise remains (bones, scales, and shells) in the samples. Out of the 212 fox scat samples you collected, you find remains from other small animals, but you find zero recognizable tortoise parts.

Zero seems like a really low number, so you decide to test your results by using eDNA analysis on the scat samples. This time, you find evidence of tortoise DNA in 27 of the 212 fox scat samples.

Analyzing results

Use your results to answer the following questions. Write or draw what you think is important in your *eDNA Experimental Design Organizer*, then discuss with your team:

a. Why do you think you found evidence of tortoise parts in the fox scat only through eDNA analysis?
b. Why might this information be important?

Making decisions

Scientists and other decision-makers use information they have gathered to help make better decisions. Use what you learned to decide which actions to take next and record your ideas in your organizer. Then discuss with your team. Pick one option. Do you think conservationists should:

a. Try to discourage the foxes from eating the tortoises. For example, you could make foxes think that tortoises taste bad by putting out foul-tasting fake tortoises.
b. Do not take action to stop foxes from eating tortoises, since it seems like it is not a big problem.

9. Think about the way eDNA was used in the conservation case study. Can you think of any way to use eDNA for conservation in your community? If so, write or draw your ideas in the *Your Study* row of your *eDNA Experimental Design Organizer*.
10. Read *Ancient DNA Case Study* and use the information you learn to fill in your *eDNA Experimental Design Organizer*.

Ancient DNA Case Study[4]

Imagine you are an archaeologist studying the ancestors of modern humans, early **hominins**. You are interested in knowing where different types of hominins lived hundreds of thousands of years ago. You are exploring where ancient hominins known as Denisovans lived, compared to where ancient hominins known as Neandertals lived.

You collect eDNA in layers from a cave in Russia. Layers with higher numbers in the chart are buried deeper. The layers show the following results:

Layer 11.2 (shallowest layer)	Denisovan DNA (fossil)
Layer 11.4	Neandertal DNA (fossil and sediment)
Layer 12.1	Denisovan DNA (fossil)
Layer 12.3	Neandertal DNA (fossil)
Layer 14	Neandertal DNA (sediment)
Layer 15 (deepest layer)	Denisovan DNA (sediment)

Figure 5-11: Hominin eDNA found in cave layers.

Analyzing results

Use your results to answer the following questions. Write or draw what you think is important in your *eDNA Experimental Design Organizer*, then discuss with your team:

a. Was there evidence of hominins in the cave?
b. Why was eDNA analysis helpful in finding out who was in the cave and when?

Making decisions

Scientists and other decision-makers use information they have gathered to help make better decisions. Use what you learned to decide which actions to take next and record that in your organizer. Then discuss your ideas with your team. Pick one option. As an archaeologist should you:

a. Only test for eDNA in places where evidence of hominins has already been found.
b. Test for eDNA even in places that seem likely to have evidence of hominins, even if no fossils have been found so far.

11. Think about the way eDNA was used in the *Ancient DNA Case Study*. Can you think of any way to use eDNA to understand the history of people or other living things in your area? If so, write or draw your ideas in the *Your Study* row of your *eDNA Experimental Design Organizer*.
12. Examine your *eDNA Experimental Design Organizer*. You have learned about how DNA is used in ecology, public health, conservation, and archaeology. There are other uses as well. If you can think of any other information you might find out using eDNA analysis, write or draw those ideas on your organizer.
13. Pick one thing you would like to learn about your area or community using eDNA analysis. Write or draw that idea in the *Your Study* row of your *eDNA Experimental Design Organizer*.

14. Think about how you would design your investigation and describe it in your organizer. Be sure to answer:

    a. What type of eDNA sample you would use, for example, soil, air, sediment, sand, water, snow, or ice?

    b. How and where would you collect the sample?

    c. What type of results would you expect to get?

    d. What could you learn and what decisions could be made from this eDNA analysis?

Act: *Should we use biotechnology to help identify problems in the environment?*

Just because eDNA can be used to find out information does not always mean it should be used. In this task you will consider more about ethical and other perspectives. You will also consider the importance of involving the local community when you make decisions about research that could affect them. Then you will use these ideas to modify your eDNA experiment.

1. Take out your *Ethical Concerns List* from Part 1 and remind yourself what those concerns were.
2. Now think about the *Public Health Case Study* from the Understand activity. Discuss with your team: Do you notice any potential ethical concerns about gathering eDNA for public health reasons? Be sure to think about:

    a. Privacy: When collecting wastewater samples, it could be possible to obtain samples from the place where a household connects to the sewer system. If that sample is analyzed, it would reveal information about the people living in that household, including their genetic data and any diseases that are present. Is this a concern?

    b. Justice: You could examine the overall prevalence or risk of certain diseases in certain communities. While this can be useful to help design ways to help the community, what if health or life insurance companies used that information to charge people living in the community higher rates? Is this a concern?

3. With your team, discuss rules or approaches that could help address any ethical concerns. Read what Irene says to learn how her research group approaches the issue of privacy. Do you think this is a good approach?

Irene says . . .

The issue of privacy is very important. To make sure we address it, we collect samples from places that include the wastewater from thousands of people. We're zooming out and looking at the bigger scale. We don't focus on the specific households that the wastewater comes from. We focus on a population of a city or of a county at large. That way no one who looks at our results can pinpoint a specific household or a person.

4. Think back to the other case studies. Are there other ethical concerns you can think of?
5. Examine the three perspectives sheets you worked on in groups during Task 1. Do you have anything you would like to add to the social, economic, or ethical perspectives on the way genetic data can or should be used?
6. Now, with your team, create a sheet for the fourth perspective: environmental. Write or draw answers to these questions:
    a. What are the important uses of genetic data from this perspective?
    b. Are there any concerns about the use of genetic data from this perspective?
    c. Who should own or be considered when thinking about genetic data from this perspective?
7. Look at the eDNA experiment you designed from the Understand activity. Examine it carefully. Are there any potential concerns you notice from any of the four perspectives? If so, create a way to address those concerns.

8. Now pick three other people on your team and explain your experiment plans to them. Then switch roles. When researchers design a community investigation, they need to make sure they pay attention to the opinions and feelings of people living in the community. Surveys, meeting with community leaders, and holding a meeting with the public can all help with this process. By explaining your ideas to your team, you are learning about the perspectives of others in your community in a limited way.
9. When a teammate is explaining their experiment to you, think carefully. Would you have any additional concerns? If so, share those ideas with your teammate.
10. After receiving feedback from your team community, examine your experiment again. Is there anything you would like to change? What can you do to address any concerns?
11. If you feel comfortable, present your research idea to your community! You could use a poster, give a talk, or use another creative way to share your experiment with your classroom, school, or in another local space. Discuss:
    a. What question did you chose to answer using eDNA?
    b. How did you design your experiment?
    c. How have you considered the four perspectives, including the ethical perspective, and did you make any changes because of these perspectives?

Congratulations!

You have finished Part 5.

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.

Amplify: To make many copies of something

Ancestry: Information about your ancestors, such as the parts of the world they came from

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

Composite sample: A mixture of individual samples

Deidentified: Data that can be used for research without having names or other information that would identify where the data came from

Direct to consumer testing (DTC): When an individual pays a company to gather data from their DNA

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

Economic: Concerned with money, income, or the use of wealth

Environmental DNA (eDNA): A sample of all the DNA of the many living things that are present in an environment

Ethical: The fairness of something

Genetic data: The information in a genome

Genome: The complete sequence of DNA of a living thing

Genomic copies: Copies of a specific type of genome

Hominin: A species closely related to modern humans

Invasive: Not native to an area

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

Next-generation sequencing: A way of sequencing DNA much faster by reading many sequences at one time and then reassembling them into the entire genomic sequence

Open access: Able to be freely accessed by other users

Patent: A license from that government that means an individual or company owns an invention for a period of time

Reference genome: The most common gene sequences across a population

Sediment: Material that settles on the bottom of a body of water

Social: The interaction of people in the community and their education, health, and well-being

Variants: Genes with one or more differences

Visual survey: To move around an area looking for a type of living thing

Wastewater: The combined water and waste produced by using toilets, showers, sinks, dishwashers, and washing machines

End Notes

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