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What Can DNA Tell Us about Race?

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ABE Master Teacher Fellowship Program

AMGEN® Biotech Experience

Scientific Discovery for the Classroom

The curriculum projects designed by the 2020–21 ABE Master Teacher Fellows are a compilation of curricula and materials that are aligned with the Amgen Biotech Experience (ABE) and prepare students further in their biotechnology education. These projects were created over the course of a 1-year Fellowship in an area of each Fellow's own interest. Each is unique and can be adapted to fit the needs of your individual classroom. Objectives and goals are provided, along with expected outcomes. Projects can be used in conjunction with your current ABE curriculum or as an extension.

As a condition of the Fellowship, these classroom resources may be downloaded and used by other teachers for free. The projects are not edited or revised by the ABE Program Office (for content, clarity, or language) except to ensure safety protocols have been clearly included where appropriate. We are grateful to the ABE Master Teacher Fellows for sharing their work with the ABE community.

If you have questions about any of the curriculum pieces, please reach out to us at ABEInfo@edc.org. We will be happy to connect you with the author and provide any assistance needed.

What Can DNA Tell Us about Race?

Background:
Racism is a serious problem in the United States and is at the forefront of politics and media in our country today. There are common misconceptions surrounding definitions of race that can influence how people understand and think about these topics. An example of a common race misconception is the belief that people of different races are biologically distinct from people of other races and that individuals are born with certain natural abilities or limitations based on race. Part of the intention behind this unit is to teach students that race is not biologically defined and that, as humans, we share genetic similarities and differences with all people regardless of race. Although the concept of race is not genetically based, it is still a sociologically and culturally relevant concept, and it is intrinsic to how many students view their own and others' identities. It's important to acknowledge and hold space for students' ideas about what race means to them. Suggestions are made to accommodate and invite student voices in discussions of race.

Another focus of these lessons is to increase awareness of, and access to, biotechnology principles, practices, and pathways for all students regardless of background. Learning more about the science and practicing hands-on molecular biology techniques may interest students who have had no previous awareness of educational and career pathways into the biotechnology field. In addition to hands-on labs, which may peak student interest, this unit includes an exploration of different careers in biotechnology, as well as pathways to those careers. In the San Francisco Bay Area, where I live and teach, biotechnology is a booming industry with an assortment of diverse career opportunities and entry points. Students may be surprised to learn that they can gain entry into biotechnology jobs with a community college certificate, not just a 4-year degree or beyond. Biotechnology holds many opportunities for students with an interest in science, regardless of socioeconomic background or college ambitions. Increasing awareness of these opportunities is an important component of this series of lessons.

LabXchange resources are used throughout this unit. It is recommended that teachers and students be familiar with navigating LabXchange in advance. There are many resources and pathways to introduce educators and students to the platform, including the pathway Exploring Content on LabXchange. Teachers can set up classrooms in LabXchange that include resources and pathways, but each resource can also be linked to individually or searched for by students without creating student accounts.

These lessons are intended to be included in a genetics unit for a general high school biology course. Students should have the following prior knowledge: DNA's structure and function; DNA determines traits that are passed from parents to offspring; DNA provides evidence of common ancestry; natural selection drives adaptation to specific environments.

Assessment for this unit includes an independent project in which students answer the question *What is race?* through a medium of their choice. An Activity Table is included in Lesson 1 to allow students to accumulate information throughout different parts of the unit to help them address this question. The Activity Table should be kept by students for the duration of Lessons 1–3 and should be used at the end of each lesson to record important facts, information, and ideas.

Next Generation Science Standards Addressed

HS-LS3-1 Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.

HS-LS3-3 Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

HS-ESS3-1 Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

Estimated Time Required: 2.5–4 weeks, depending on lab activities. Three options for lab sequences are provided in Lesson 3. Labs should be determined and mapped out in advance as they may require ordering of materials and time for processing of samples. Estimated times for each lab are included in Lesson 3.

Lesson 1: Ancestry and Genomics

Estimated Time: 1–1.5 hours

Learning Objectives

- Introduce students to the field of genomics and its uses in medical and evolutionary studies

Materials

- Internet access and computer or other internet capable device (1 per student)
- Sticky notes (5 per student)
- Activity Table: What Can DNA Tell Us About Race? (1 per student - paper copy or digital)

Vocabulary

- Genome
- Genomics
- DNA sequencing

Introduction: What Does It Mean to Trace Your Ancestry?

Open a class discussion by asking students if they've heard of Ancestry.com and 23andMe. Allow students to share their knowledge and impressions about the sites. What do they know about what these companies do? Do they know anyone who's had their DNA sequenced? What does it mean? How is it done? What information can you get from it? Would they ever want to have their own DNA sequenced? Why or why not?

Students read the *Scientific American* article, How Accurate Are Online DNA Tests?

- Before reading the article, distribute five sticky notes to each student.
- As they read, have students write down three important ideas and two questions.
- After reading the article, put students into small groups, bringing their sticky notes with ideas and questions. Students should stick their own sticky notes onto the table in front of them and take turns sharing what they wrote. Groups should then discuss and come to consensus on three main ideas and two questions to share with the class. Suggestions for how to choose main ideas and questions to share could include those that they have most in common or those that they find most interesting or most important as a group.
- Have groups share out their chosen main ideas and questions.
- Open the class up for comments or discussion.

What Is Genomics, and What Can We Learn from It?

Students learn more about the field of genomics by reading an article and watching a video on LabXchange, and demonstrate learning by answering Reflection Questions. This can be in partners or small groups or individually. Answers to Reflection Questions should be discussed as a class, and students should be encouraged to record information they learned or ideas they had in the first row of their Activity Table. (At this point, there may not be direct ties to the definition of race, but students should be able to at least complete the first two columns of the Activity Table.)

Article: A Brief Guide to Genomics
Reflection Questions:

1. What does it mean to sequence a genome?
2. What are three ways that human genome data can be useful in science and medicine?

Video: What Can We Learn from Sequencing Our Genomes?
Reflection Questions:

1. What can we learn from sequencing our genome?
2. What can we learn by comparing the human genome to the genomes of other living or extinct species?
3. What are some future directions of genomic research?

Activity Table: What Can DNA Tell Us about Race?

Instructions: As we explore definitions and concepts of race throughout the next several lessons, use this table to record important facts, information, and ideas about how we define race. At the end of the lessons, you will use these notes to help you construct a final project that defines what race means to you.

Activity	**What did you learn? (facts, information)**	**What did you think? (ideas, reflections)**	**How does this help you understand or explain what race is?**
Ancestry and Genomics			
Reflection and Class Discussion: What Is Race?			
RACE: The Power of an Illusion documentary			
Comparing mtDNA Sequences to Learn about Human Variation			

Lesson 2: What Can DNA Tell Us about Race?

Estimated Time: 2–3 hours, depending on length of class discussions

Learning Objectives

- Allow students space to explore concepts and ideas around race and its meaning.
- Help students understand that race is not a biological definition and that we are genetically as similar or different to individuals of other races as we are to individuals of our own race.

Materials

- Printed Intake Assessment: What Is Race? (1 per student)
- Projector, film, and internet access to show documentary *RACE: The Power of an Illusion*, Episode 1: *Measuring Genetic Variation Between Groups* (see Notes for links to the film)
- Activity Table from Lesson 1

Notes

Race is a complex and potentially contentious topic. Students have their own ideas about race, and the purpose of opening a dialogue about race is more about holding space for students to express their ideas and experiences and less about telling them what they should believe. It is important to create a welcoming space in which students feel safe to express their ideas and explore complex issues. For more information on creating space to talk about race, see the National Education Association's edjustice website: https://neaedjustice.org/social-justice-issues/racial-justice/talking-about-race/

- *RACE - The Power of an Illusion* is a three-part documentary produced by UC Berkeley and California Newsreel in 2003 that explores the question: What is race? *Episode 1: The Difference Between Us*, which is used in this lesson, explores what genetics tells us about race and why the concept of race is not based in biological fact. The film is available for purchase or digital rental at http://newsreel.org/video/RACE-THE-POWER-OF-AN-ILLUSION, but the first episode can also currently be found online:https://www.racepowerofanillusion.org/clips
- https://capture.udel.edu/media/RaceA+The+Power+of+an+Illusion%2C+Ep.+1A+The+Difference+Between+us/1_de7u5ihx/180544301

Definitions and Norms

Inform students that you will be exploring and discussing issues around race. Discuss the definitions of race and expectations for discussions. Establish and agree on a set of classroom norms to maintain respectful discussions and allow everyone's voice to be heard. Work with students to establish a set of ground rules for respectful discussions, or present a set of norms and work with students to accept or modify the list. (A list of suggested norms is included below.) Display the ground rules and refer back to them as needed to maintain respectful dialogue.

Class Discussion:

According to Merriam Webster, race is defined as:

> any one of the groups that humans are often divided into based on physical traits regarded as common among people of shared ancestry

> *Usage: It shall be an unlawful employment practice for an employer … to fail or refuse to hire or to discharge any individual, or otherwise to discriminate against any individual … because of such individual's race, color, religion, sex, or national origin …*
> — Title VII of the Civil Rights Act of 1964, United States Code

In biology, race is:

> biology : a group within a species that is distinguishable (as morphologically, genetically, or behaviorally) from others of the same species
>
> *Usage: This quail species is diverse and can be classified into 21 recognized geographic races in North America …*
> *— Eric T. Thacker and Tim L. Springer*
>
> also : a usually informal taxonomic category representing such a group that is often considered equivalent to a subspecies

According to the biological definition, races do not exist in humans—no human groups are different enough from one another to be classified as subspecies. Humans are actually remarkably similar to one another, as we will explore in this lesson. And yet, the concept of human races does exist. This is a complex issue, and people have different points of view on what race means to them. In discussing this complex issue, it is important that we maintain respect for everyone and hold space for different ideas and perspectives that we may have. For this reason, we will agree to some norms or ground rules during our discussions.

Possible ground rules:

- Avoid inflammatory language and making assumptions about individuals or groups.
- Give everyone a chance to speak, and listen respectfully to what they say—don't just think about what you're going to say.
- It's okay to disagree as long as we do so respectfully—criticize ideas, not individuals.
- Communicate with the goal of sharing ideas, not trying to convince others of your point of view.
- Respect the privacy of others—allow others to share or not share as they wish, and keep any personal information shared to this classroom.

Intake Reflection and Class Discussion

Prior to viewing the documentary *Race: The Power of an Illusion*, have students reflect on their ideas about race by having them individually complete the Intake Reflection. After individual reflection, allow students to share ideas in pairs or small groups, and open a class discussion about what race means, how it is defined, and how it affects us as individuals and a society. After the discussion, give students a few minutes to record information and ideas in their activity table from day 1.

Intake Reflection: What Is Race?

Instructions: Think carefully about the following questions, and respond according to what you know and what you think about race.

1. What does race mean to you?

2. How do you think races are defined? How many races are there, based on what you have experienced or heard?

3. Do you think someone's race can be determined by a trait or set of traits that the person possesses?

4. How do you think people of one race are different from people of other races?

5. How do you think people of one race are similar to people of other races?

6. Do you think the similarities and differences between races are genetic? Do you think they come from our DNA?

7. If we compared the DNA of individuals from the same racial group, do you predict they would share more genetic similarity than individuals from different racial groups?

8. How do definitions of race affect individuals in our society? How do they affect our society as a whole?

9. What other ideas or experiences do you have surrounding the concept of race?

RACE: The Power of an Illusion, Episode 1: The Difference Between Us

Watch the film as a class, stopping at the indicated time points to have students reflect and share on the discussion questions below. Reflections can take the form of short writing prompts, think-pair-share, or whole-class discussion.

0:00–4:45 minutes (students preparing to compare their DNA): make predictions

Do you think the students are correct in assuming that they will have the most similarities with classmates who have the same ethnic or racial background? Explain your thinking.

4:45–9:30

Humans have less genetic variation than other species (1/1000 base difference). Why might this be true?

9:30–12:04

What does it mean that scientists' ideas about race are informed by the society in which they live?

12:04–28:15

Why is skin color an unreliable method of defining race?

28:15–33:09

What does it mean that traits like skin color, hair color, and eye color are not correlated with intelligence or athletic performance? What does that suggest about the idea that certain racial groups are predisposed to have specific athletic abilities?

33:09–34:45

Discussion: What can similarities and differences in the DNA tell us? What does it mean if two people's DNA have fewer differences?

34:45–36:00

What results did the students find about differences in their DNA? Is this surprising? Why or why not?

36:00–38:48

Most of the genetic variation between individuals occurs within their own racial group. There is as much or more genetic variation between individuals of the same racial group than there are differences between people of different racial groups. Show/analyze the following Venn diagram: https://onlinelibrary.wiley.com/cms/asset/e919e445-eab0-4f47-b1ff-6cd447905040/sce21506-fig-0001-m.jpg

What can we conclude about the genetic differences between populations of different ancestry?

38:48–45:00

Modern humans moved out of Africa about 100,000 years ago. Most of our history as a species was spent in Africa. What are some causes of the traits we think of as racial?

What does it mean that these traits arose independently of older human traits?

45:00–47:05

Show a figure of mean heterozygosity as a function of distance from East Africa: https://ars.els-cdn.com/content/image/1-s2.0-S0092867417311315-gr1.jpg

Explanation: Recall that being heterozygous means you have two different alleles for a gene. The heterozygosity of a population, or how likely it is for someone to be heterozygous for any given gene, is used as a measure of genetic diversity. Higher heterozygosity means more variation; low heterozygosity means less variation. What do you notice about this graph? Why is there more human genetic diversity in Africa than anywhere else?

Note: If students have trouble understanding the implications of the above data, it may be helpful to show them a map of early human migration: https://upload.wikimedia.org/wikipedia/commons/9/9e/Human_migration_out_of_Africa.png

47:05–49:00

Why might genetic data not be able to reliably predict our ancestry?

Written Reflection

If race is not biological, what is it? How does race affect humans? Why does the concept of race exist? Who benefits? Who is harmed? Do you think race is a concept that should exist? Explain your reasoning.

Lesson 3: Using Biotechnology to Analyze Variation in Human DNA

Estimated Time: 5–12 hours, depending on labs performed. Time estimates are provided below with each lab sequence option.

Learning Objectives

- Define biotechnology.
- Learn and practice biotechnology skills and techniques (micropipetting, gel electrophoresis, etc.).
- Compare DNA sequences to analyze variations in human DNA.

Materials

- Lab equipment and reagents specific to the labs being performed
- Internet access and devices (1 per student or pair of students)

Notes

The primary purpose of Lesson 3 is to introduce students to the principles and practices of biotechnology in hopes of increasing student awareness and interest. A secondary purpose is to give students hands-on experience in comparing and analyzing DNA sequence data. Many different labs exist that could fulfill these purposes. Three suggested options are described below.

Depending on the labs you choose, students may need additional introduction to the principles and techniques used. LabXchange has a wealth of introductory texts, videos, interactives, and simulations you can use for this purpose. The Exploring Biotechnology Pathway is an excellent comprehensive introduction to biotechnology principles and practices you can use in its entirety with students or to help locate individual resources that would be helpful to include in their lessons.

LAB SEQUENCE OPTIONS:

Option 1: Comparing mtDNA Sequences to Learn about Human Variation

This set of lessons was developed by Scott Bronson (of the Dolan DNA Learning Center of Cold Spring Harbor laboratory in New York), who is featured in the documentary *RACE: The Power of an Illusion, Episode 1*. In Activity 3, students compare their own mtDNA to those of other students in the class. To perform this analysis, a series of labs is performed in which students extract their own DNA, have their mtDNA amplified, run it out on an agarose gel, and then have it sequenced. This is the same analysis that is shown in the documentary from the previous lesson.

Having the opportunity to work with their own DNA is exciting for students and makes for an enriching and memorable experience. However, the process is costly (~$200 for reagents for 25 students plus sequencing costs), is time consuming (sequencing can take about 2 weeks, and there is extensive prep time for the teacher both in preparing labs and running assays outside of class time), and requires special equipment, such as a PCR thermocycler and centrifuge. The laboratory sequence can be found here, and reagent kits are described here. To access them, click the link, then select “laboratories” at the top of the page.

If reagents are prepared in advance, students should be able to perform the DNA extraction and PCR setup during one class period and run gel electrophoresis during a second class period. Supply ordering, PCR thermocycling, gel staining, sample sequencing preparation, and shipping for sequencing shuld be performed outside of class time and requires extensive planning and preparation. If student samples are to be sequenced, plan to do the labs at least 2 weeks in advance to allow time to receive sequencing data.

Estimated time:

- Full DNA extraction, PCR, sequencing: 2–3 hours in class
- mtDNA sequence comparisons (Activity 3): 1–2 hours in class
- Teacher preparation and assays: 6+ hours outside of class
- Sequencing time: ~2 weeks

Option 2a: ACTIVITY #2 - Comparing Public mtDNA Sequence Samples from World Populations
If the DNA extraction, amplification, and sequencing are not possible, Activity #2 of the lesson sequence above can be performed alone, which allows students to compare mtDNA sequences of individuals of similar and different racial groups that already exist in the database. It is recommended to include this activity to give students experience with DNA sequence analysis in the context of comparing racial genetic similarities and differences, along with a second lab activity (2b) to introduce students to a hands-on biotech experience.

Estimated time: 1–1.5 hours

Option 2b: Amgen Biotech Experience *Foundations of Biotech*
In this sequence of activities and labs, students learn about biotechnology and how it is used to research and treat disease. Students perform hands-on activities in which they learn to use a micropipette and perform gel electrophoresis of dyes. This is a simple lab series with minimal preparation time and detailed student instructions. It is a great way to introduce students to biotech techniques at a basic level.

Estimated time: 4–5 hours

Option 3: Amgen Biotech Experience Exploring Precision Medicine
In this ABE sequence, students learn about biotechnology and precision medicine. They learn that not all humans respond to medicines in the same way due to genetic and environmental differences. Students explore genotypic and phenotypic differences between individuals in the context of the PTC tasting gene. Students extract their own DNA, learn about and perform PCR and gel electrophoresis, learn about SNPs, compare DNA sequence data, and participate in activities that tie all of these tools and concepts back to the context of personalized medicine. The activities and labs are excellent but challenging. This series would be ideal for an advanced or honors-level class.

Estimated time: 8–12 hours

Assessment

I. Claim, Evidence, Reasoning

Based on the evidence from mtDNA comparisons, is race biological? Provide specific evidence from the data, and explain how the evidence supports your claim using concepts related to genetics and what can be learned from DNA comparisons.

II. Project: What Does Race Mean?

Based on your own experience and what you've learned in this series of lessons, reflect on what race means to you. Create a product that expresses your thoughts and ideas on the subject. The product could be an essay, a video, a collage, a drawing or painting, an infographic, a song, a presentation, a poem, a comic book, or another idea of your own. (Projects can be shared as a class, if practical.)

Lesson 4: Careers and Pathways in Biotechnology

Estimated Time: 1.5–2 hours

Learning Objectives

- Identify career and educational pathways in biotechnology

Materials

- Internet access and device (1 per student or 1 per pair of students)
- Handout: Careers and Pathways in Biotechnology (1 per student)
- Padlet board or physical poster paper (1 per class) with sticky notes (1 or more per student)

Note:
You can prepare a LabXchange classroom and pathway in advance that includes a variety of career spotlight content that students can explore based on interest (click on hyperlinks to view tutorials). Alternatively, students can search for careers on LabXchange to find content that interests them.

Recommendations for items to search and/or include in LabXchange pathway:

- My Career in Genomics: several different videos highlighting different types of careers in genomics
- Spotlight on Scientists: several different video interviews with scientists highlighting their pathway into their current careers
- Science Spotlight: a wide variety of fields of science are introduced through short readings

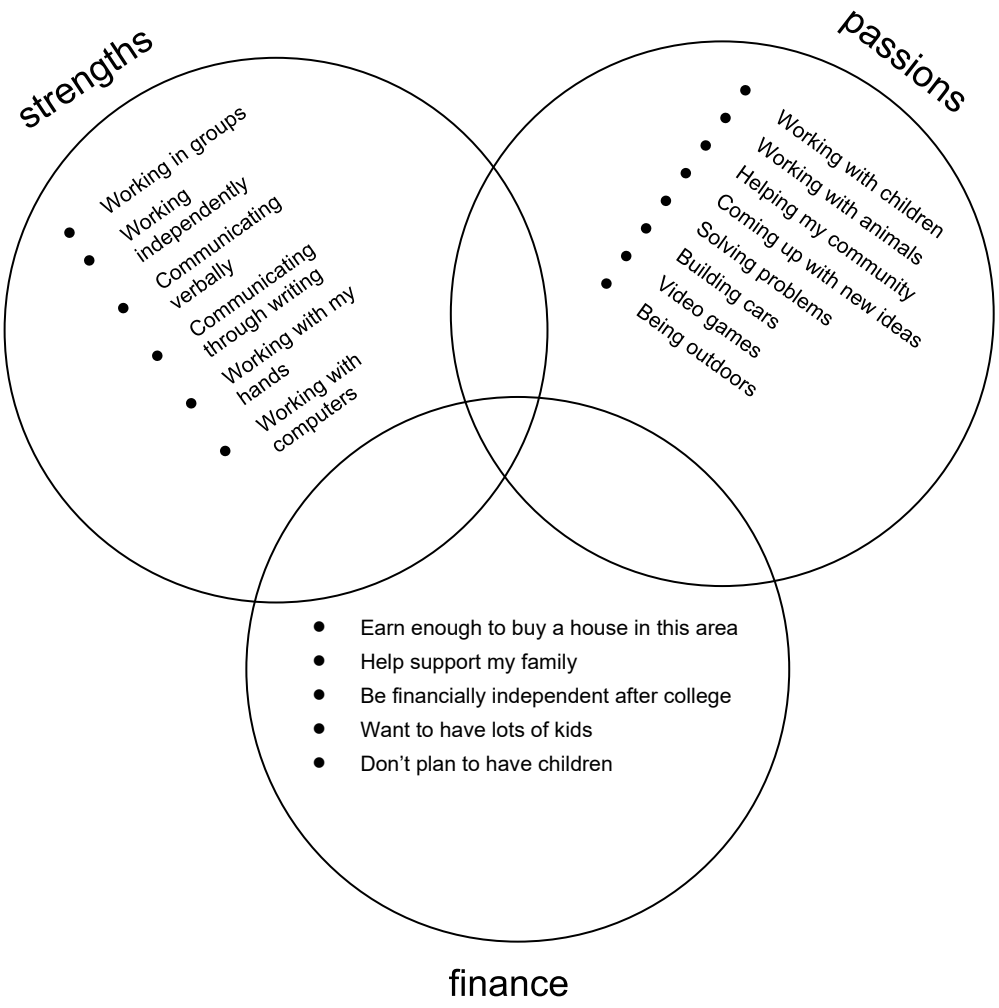
Introduction
Lead a class brainstorming session on types of jobs and careers in biotechnology. Use an online posting board like Padlet or a physical poster board and sticky notes to post student ideas.

With students, review what biotechnology is and come up with a working definition. Ask students to think of and post one or more examples of jobs or careers that a biotechnologist could have. (If students have trouble identifying careers, they can search online.) Have them post their examples on the board.

After examples have been posted, have students review all of the examples posted. As they view examples of biotechnology jobs, ask them to think about the types of characteristics, skills, education, and/or training that might be required for those jobs. Brainstorm a list as a class.

Careers and Pathways in Biotechnology
Students will explore careers and pathways in biotechnology on LabXchange and biotech-careers.org. The ABE PO has created a series of Amgen Staff profile videos that may also be useful. Distribute the Careers and Pathways in Biotechnology worksheet to students. Students can work individually or in pairs.

Students may need support in completing the Venn diagram in Step 1. It may be helpful to provide or brainstorm examples of things that could belong in each category. Some examples are listed below.

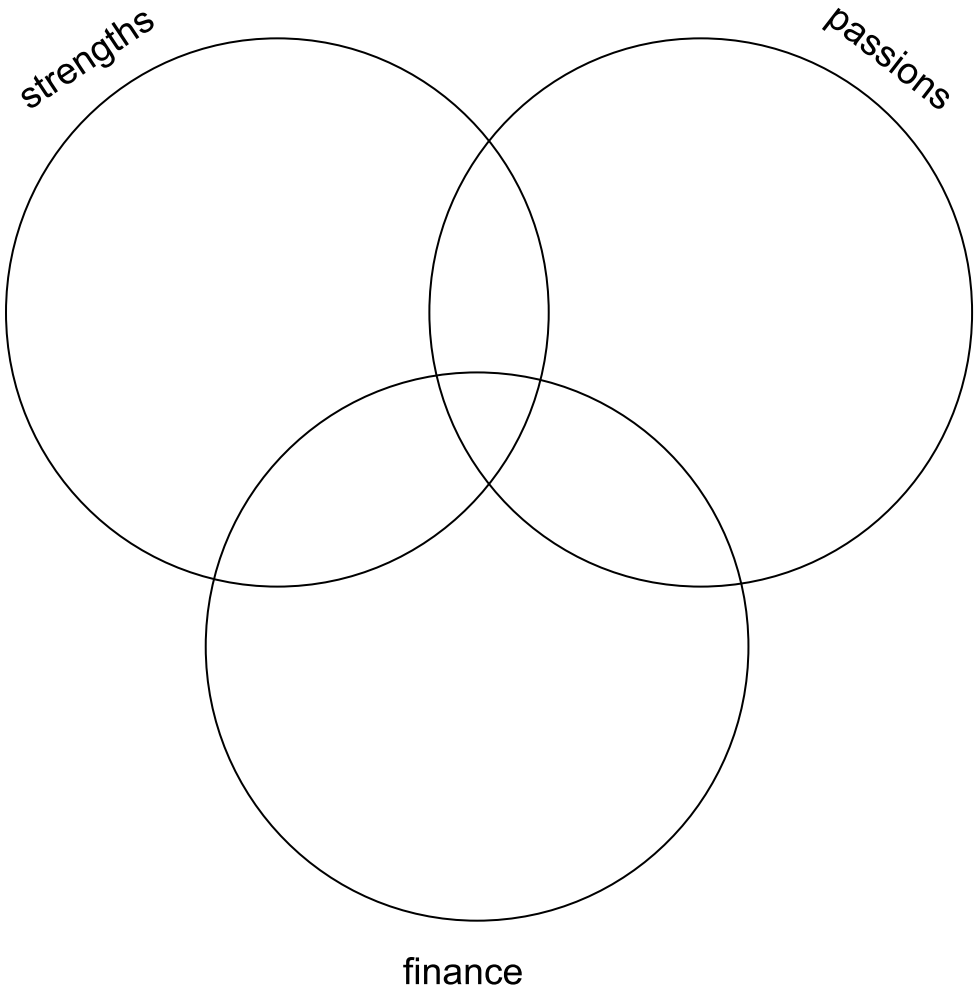


After learning about specific careers, pathways, and jobs in biotechnology, have students share what they learned about specific careers in small groups and as a class. Have students add jobs to the posting board that was created during the introduction, and as a class add to the list of characteristics, skills, education, and/or training that was created. Invite students to share what they learned, things that surprised them, and questions they have.

Careers and Pathways in Biotechnology

1. Watch the LabXchange video *Choosing a Career:* https://www.labxchange.org/library/items/lb:LabXchange:94656ca4:video:1

   Think about three categories of things to consider when choosing a career: strengths, passion, and finances. Complete the Venn diagram similar to the one shown in the video (2:53) by filling in information about yourself.



2. Reflection: What are the most important factors for you in a job or career?

3. Choose one or more careers or scientists to learn more about on LabXchange.

   Which career did you learn about?

   What are two things that stood out to you about this scientist or career?

   What did you like or dislike about this career?

   What questions do you still have?

Explore the website *Welcome to Biotech Careers*: http://www.biotech-careers.org/

1. Click on the **Biotech Companies** tab. Explore the middle map by clicking on it. Further explore areas that have a high number of biotech companies by clicking on the pink and red dots.
   a. Which three geographic areas in the country have more than 500 biotech companies?

   b. How many are in our area?

2. Click on the **Careers** tab, and browse through the list of careers. Choose two careers to learn more about. Complete the information below for each career:

   a. Career 1
      i. Career title:
      ii. Average salary:
      iii. Brief summary of job duties:
      iv. Education or training required:

   b. Career 2
      i. Career title:
      ii. Average salary:
      iii. Brief summary of job duties:
      iv. Education or training required:

Click on the link that says, "InoVATE*BIO* colleges provide instruction in 37 areas." View the different biotechnology degrees and certificates. Choose one or more that interest you, and click to learn more about them.

What type of degree or certificate is required for this career? How long does it take to complete?

On the biotech-careers.org homepage, click on “Biotech Jobs” at the top of the page. Then click on “Search for Jobs.” Enter your city into the search tools, and search for jobs within 25 miles.

3. How many biotechnology job listings are within 25 miles of your city?

4. Choose a job in the area that interests you. Click on it to read the full job description.

    a. What types of responsibilities does the position include?

    b. What types of training, education and/or experience is required?

    c. If it’s shown, what is the salary range for this job?

    d. Reflect on what you learned about this job. What are some things you might like or dislike about it? List pluses and minuses in the table below.

Good	Bad
• • •	• • •

Reflection

1. What new information did you learn about careers and education in biotechnology?

2. Do you think a career in biotechnology is something that would interest you? Why or why not?

3. What steps could you take to learn more about preparing for careers that interest you, whether they’re in biotechnology or another field?

Other Resources:

- Race ≠ DNA: https://www.labxchange.org/library/items/lb:LabXchange:6ac03ccd:html:1
- Teaching Diversity: The Science You Need to Know to Explain Why Race Is Not Biological: https://journals.sagepub.com/doi/pdf/10.1177/2158244015611712
- Towards a More Humane Genetics Education: https://bscs.org/our-work/rd-programs/towards-a-more-humane-genetics-education/
- Testing Common Misconceptions about the Nature of Human Racial Variation: https://online.ucpress.edu/abt/article/79/7/538/18928/Testing-Common-Misconceptions-about-the-Nature-of