Humane Genetics:

Epistemic Edition

What Are the Causes of Racial Disparities in the NFL and STEM, and how can we be sure our explanation is accurate?

Teacher Edition

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Donovan, B. M., Weindling, M., Amemiya, J., Salazar, B., Lee, D., Syed, A., … Snowden, J. (2024). Humane genomics education can reduce racism. Science, 383(6685), 818–822. https://doi.org/10.1126/science.adi7895

Donovan, B. M. (2021). Ending Genetic Essentialism Through Genetics Education. Human Genetics and Genomics Advances, 3(1), 1–13. https://doi.org/10.1016/j.xhgg.2021.100058

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Unit Overview

The goal of this unit is to reduce students' belief in racial genetic essentialism and improve their ability to refute essentialist arguments by increasing their understanding of 1) human population genetics, 2) multifactorial causation of complex human traits, and 3) how scientists reason with evidence and avoid reasoning errors.

Unit Skeleton

Unit Phenomenon: White people are overrepresented in STEM and underrepresented in the NFL, and Black people are underrepresented in STEM and overrepresented in the NFL.

Unit Question: What are the causes of racial disparities in STEM and the NFL, and how can we be sure our explanation is accurate?

Unit Big Idea: Most genetic variation occurs within racial groups and there is very little genetic variation between racial groups. Genes can be a cause of variation within a group if all group members experience the same environment. But because different races experience different environments, and because racial disparities decrease when environments become more equal, we should be skeptical of anyone who claims that racial disparities boil down to genes alone.

Chapter 1

Chapter 1 Question: What is an accurate understanding of genetic differences within and between racial groups?

Chapter 1 Big Idea: Most genetic variation occurs within racial groups, and there is very little genetic variation between racial groups.

Lesson	Question	Big Idea	Epistemic Idea
1	***What Are the Causes of Racial Disparities in the NFL and STEM, and how can we be sure our explanation is accurate?***	Racial disparities exist in representation in the NFL and STEM, and there are different possible explanations for why these disparities exist.	N/A

2	***How Do Robin and Taylor Think About Racial Difference?***	There is genetic variation both within AND between racial groups. The amount of genetic variation within a racial group can be modeled by increasing or decreasing the size of a circle; the amount of genetic similarity between racial groups can be represented by the amount of overlap between circles.	N/A
3	***How Genetically Different Are Same Race and Different Race People?***	The amount of genetic variation within any racial group is large, the amount of shared within-group variation is large, and the amount of between-group variation is small.	To help us avoid reasoning errors, we can create a simple Reasoning with Evidence Checklist. We start building this checklist with questions about misinterpreting evidence avoiding cherry picking.
4	***How Scientifically Accurate are Robin and Taylor's Models of Genetic Variation?***	We can construct an accurate consensus model of human genetic variation that visually represents high within-group variation, high shared-within group variation, and low between-group variation.	N/A
5	***How Scientifically Accurate are Robin and Taylor's Claims about Genetic Variation?***	We can support an argument with evidence that most genetic variation occurs within racial groups and there is very little genetic variation between racial groups.	We can use our Reasoning with Evidence Checklist to critique arguments and point out where there may be reasoning errors.

Chapter 2

Chapter 2 Question: What is the best explanation (genes or environment) for observed differences between racial groups?

Chapter 2 Big Idea: Environment is most likely a better explanation for racial disparities than genes because there is evidence that racial groups experience different environments, and when environments change, differences between races also change.

Lesson	Question	Big Idea	Epistemic Idea
6	***Are genes the only thing that can cause variation in complex human traits?***	An accurate causal model of human trait variation shows that the environment has a large effect, genetic factors a small effect, and unknown factors a moderate to large effect on human trait variation.	
7	***How can we know if genes or environment have more impact on racial differences, and how much do environments really differ by race?***	We have evidence that environments differ between races in the US. When environments are more equal, disparities between racial groups are smaller.	We can also evaluate reasoning evidence based on a new question about whether the claims stick to what is supported by the evidence or if they extend beyond it ("overextending").
8	***Are Genetic Differences Between Races or Environmental Differences Between Races a Better Explanation for Racial Differences in the NFL or STEM (genes or environment)?***	Genes can be a cause of variation within a group if all group members experience the same environment. But, because different races experience different environments, and because racial disparities change across environments, we should be skeptical of anyone who claims that racial disparities boil down to genes alone.	
9	***How can we use what we know to critique***	Misinformation about racial disparities can be refuted with scientific evidence.	We can use the Reasoning with Evidence Checklist to critique arguments and point

	misinformation about racial disparities?		out where there may be reasoning errors.

Unit-level Planning Resources (located at the end of this document)

- All Evidence Cards
- Robin and Taylor: Comprehensive Narrative

Pacing Guide

Lesson	**Approximate # of 45-minute class periods**
Building our classroom culture	2
1	1
2	2
3	3
4	2
5	2
6	3
7	3
8	3
9	2
Total Number of Class Periods	**23**

Prerequisites

This unit is appropriate for use in high school biology classes grades 9-12.

Before beginning this unit, students should have the following understandings:

- All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins.
- Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function.
- Different forms of a gene are created by different sequences of DNA found at the same location on a chromosome. These different gene forms are called alleles.

Alignment to NGSS

Building toward the following Performance Expectations (PEs):

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

Disciplinary Core Ideas (DCIs):

LS3.B: Variation of Traits

Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus, the variation and distribution of traits observed depends on both genetic and environmental factors.

Science and Engineering Practices (SEPs):

Asking questions

- Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of the design.
- Evaluate a question to determine if it is testable and relevant.

Developing and using models

- Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.

Analyzing and interpreting data

- Evaluate the impact of new data on a working explanation and/or model of a proposed process or system.

Constructing explanations

- Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.

Engaging in argument from evidence

- Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.
- Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
- Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions.
- Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.

Crosscutting Concepts (CCCs):

Patterns

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Cause and effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Scale, proportion, and quantity

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

Design for Epistemic Learning Goals

- The unit incorporates "grasp of evidence" epistemic ideals (Duncan et. al 2018) for the purpose of increasing students' ability to effectively identify reasoning errors in essentialist arguments about race and genetics.
    - This goal is *in service* of and *secondary* to the main unit learning goal of reducing agreement with genetic essentialism by race.
- The unit refers to the list of epistemic ideals as the **"Reasoning with Evidence Checklist."**
- The unit introduces checklist criteria slowly over time (one or two at a time), giving students practice in applying them before introducing more.
- The criteria are positioned as "what experts do" and students are positioned as non-experts who are learning to understand how experts reason with evidence.

- **Student science identity** can continue to be developed in the context of being able to *participate* in science as a knowledge-constructing community without being an *expert*.

Dimension (from *Grasp of Evidence*)	**Epistemic Ideal** (from *Grasp of Evidence*)	**"Reasoning with Evidence Checklist" Question**	**Nickname**	**Lesson Introduced**
N/A	[Avoiding misinterpretation/ misunderstanding of a data set]	*Is any of the evidence interpreted incorrectly?*	Misinterpreting	3
Evidence integration	**Variety of evidence** (multiple types/lines of evidence)	*Is any of the available evidence not included or addressed?*	Cherry-picking	3
	Consistency of support (evidence all points in one direction)	*Does some of the evidence not support the claim?*	Cherry-picking	3
Evidence evaluation	**Validity of inferences** (avoiding conclusions that go beyond what is warranted)	*Does the claim include anything that isn't directly supported by evidence?*	Overextending	7

References

Duncan, R. G., Chinn, C. A., & Barzilai, S. (2018). Grasp of evidence: Problematizing and expanding the next generation science standards' conceptualization of evidence. *Journal of Research in Science Teaching*, 55(7), 907-937.

Key Instructional Frameworks

The Humane Genetics Curriculum incorporates the below instructional frameworks to enhance student sensemaking and curriculum coherence. These summaries are also detailed further in Malerbi et al., 2026. https://doi.org/10.1007/s10519-026-10251-7

Anchoring Phenomenon

As outlined in the Next Generation Science Standards, the purpose of utilizing an anchoring phenomenon is to elicit initial student ideas about the causes of an observed phenomenon so students can then use evidence to evaluate the accuracy of these ideas over the course of a unit. This helps students arrive at an evidence-supported consensus explanation for the phenomenon by the unit's end ("Using Phenomena in NGSS-Designed Lessons and Units", 2016).

Using Phenomena in NGSS-Designed Lessons and Units. (2016, September). Next Generation Science Standards. https://www.nextgenscience.org/sites/default/files/Using%20Phenomena%20in%20NGSS.pdf

Evidence-Laden Narrative

This narrative uses fictional characters to tell a story of overcoming science denial (Darner, 2019). When students encounter information that runs counter to their current worldview, they are less likely to engage in analyzing that evidence. This can be problematic – if a student's current worldview does not align with the available scientific evidence, this student is unlikely to engage in the evidence analysis needed to align their view with the accepted scientific consensus view. Evidence-laden narratives can be used to encourage willingness to engage in evidence analysis and prevent denial of science ideas among students by using conversations between fictional characters to model for students how to change one's mind based on evidence (Darner, 2019). This curriculum utilizes two characters, Robin and Taylor, to help students evaluate the accuracy of essentialist and non-essentialist ideas.

Darner, R. (2019). How Can Educators Confront Science Denial? *EDUCATIONAL RESEARCHER*, *48*(4), 229–238. https://doi.org/10.3102/0013189X19849415

Contrasting Cases

Contrasting cases helps students develop the requisite knowledge necessary to evaluate evidence (Schwartz & Bransford, 1998). Students are first presented with hypothetical data sets, and then compare these hypothetical data and highlight the distinct ways they vary. This process helps students develop the relevant prior knowledge they need to interpret the key elements of the actual data. Students then analyze the actual data using their new knowledge and explain what the actual data demonstrate.

Schwartz, D. L., & Bransford, J. D. (1998). A Time for Telling. *Cognition and Instruction, 16*(4), 475–522. https://doi.org/10.1207/s1532690xci1604_4

Academically Productive Talk

HGL incorporates discussion scaffolds known as academically productive talk moves to support student discussions. These talk moves encourage all students to participate, and the role of the instructor is to "guide students in practicing new ways of talking, reasoning, and collaborating with one another" (Michaels & O'Connor, 2012). Students are encouraged to explain their thinking and support their ideas with evidence.

Michaels, S., & O'Connor, C. (2012). Talk Science Primer. *TERC*. https://pod-stem.org/wp-content/uploads/2020/02/TalkScience_PrimerTERCPages1-6.pdf

Synthesis Modeling

To help students synthesize the key ideas in this curriculum, HGL has students create and iteratively refine models that incorporate all the available evidence to explain the anchoring phenomenon. Students construct these models using model-based reasoning principles in which students create the simplest model that best incorporates all the evidence, a practice known as synthesis modeling (Shemwell et al., 2015). They then use these synthesis models at the end of the curriculum to construct an explanation for the anchoring phenomenon.

Shemwell, J. T., Chase, C. C., & Schwartz, D. L. (2015). Seeking the general explanation: A test of inductive activities for learning and transfer. *Journal of Research in Science Teaching*, *52*(1), 58–83. https://doi.org/10.1002/tea.21185

Research Papers about this Curriculum

***Papers we believe are essential to read before teaching these materials in your own classrooms appear below in red font. Recommended readings appear below in black font.

Overview of the research behind this curriculum

Donovan, B. M. (2021). Ending Genetic Essentialism Through Genetics Education. Human Genetics and Genomics Advances, 3(1), 1–13. https://doi.org/10.1016/j.xhgg.2021.100058

Information about how to teach and adapt this curriculum for your own classrooms

Malerbi et al., 2026. https://doi.org/10.1007/s10519-026-10251-7

Evidence in support of the efficacy of these materials:

Donovan, B. M., Weindling, M., Amemiya, J., Salazar, B., Lee, D., Syed, A., Stuhlsatz, M., & Snowden, J. (2024). Humane genomics education can reduce racism. Science, 383(6685), 818–822. https://doi.org/10.1126/science.adi7895

Donovan, B. M., Semmens, R., Keck, P., Brimhall, E., Busch, K. C., Weindling, M., Duncan, A., Stuhlsatz, M., Bracey, Z. B., Bloom, M., Kowalski, S., & Salazar, B. (2019). Toward a more humane genetics education: Learning about the social and quantitative complexities of human genetic variation research could reduce racial bias in adolescent and adult populations. Science Education, 103(3), 529–560. https://doi.org/10.1002/sce.21506

Donovan, B. M., Weindling, M., Salazar, B., Duncan, A., Stuhlsatz, M., & Keck, P. (2020). Genomics literacy matters: Supporting the development of genomics literacy through genetics education could reduce the prevalence of genetic essentialism. Journal of Research in Science Teaching, tea.21670. https://doi.org/10.1002/tea.21670

Evidence that the curriculum is effective across different instructional modalities, sexes, races/ethnicities, and worldviews:

Wedow, R., Jeong, Y., Thompson, K. N., Malerbi, K. F., Brubaker, A., Weindling, M., Lo, S. M., Amemiya, J., & Donovan, B. M. How and for whom can genetics education reduce beliefs in genetic essentialism? Human Genetics and Genomics Advances. https://doi.org/10.1016/j.xhgg.2025.100548

Building Our Classroom Culture

Lesson Question: How can we best work toward our shared goal of thinking and behaving as a scientist?
Big Idea: Norms enable us to more effectively work toward our shared goal of thinking and behaving like a scientist. In science, the goal is *an accurate understanding of the world* (not "right answers," or "winning" arguments).
Overview: Science classes require students to engage in academically rigorous conversations to understand difficult concepts. In order to create an environment for students that is as safe as possible and facilitates academically productive conversations, it is important for teachers and students to agree upon behavioral norms they will follow when interacting with one another. In this lesson, the teacher will provide students with ideals (listed in the Teacher Reference Materials) to strive for in a science classroom, and students will use this framework to create behavioral norms. Students will construct and agree upon norms, practice these norms in groups, and reflect on their progress toward mastering these norms by setting up and writing in a journal. It is important to establish these norms early in the year so students are skilled in using them by the time they reach the Humane Genetics unit. The journals will also be an important tool for students to reflect on their learning throughout the year and for processing any strong emotional reactions to the curriculum – especially during the Humane Genetics unit.
Objectives ● Decide on behavioral norms that can be used throughout the year to have safe and productive classroom conversations.
 *Approximately _ 45-minute class periods*

Key Terms

ideals **norms**

Preparation

- Prepare a chart with the following ideals and have it ready to post for the class. (Leave room under each ideal to list class norms to be developed during this lesson).
    - We value gathering a diversity of voices and initial ideas
    - We critique ideas based on evidence, not people

- We are open to changing our minds based on evidence (even when it's uncomfortable)

Materials

MATERIALS	QTY
Reflection Journal (e.g. composition notebook)	1 per student
Chart paper	Class Set
Chart markers	Class Set

Procedure

TASK	NOTES & MATERIALS
Post the following question on the board: *"What does it mean to think and behave like a scientist?"* Give students a few minutes to respond individually to this question somewhere in writing.	Note: Circulate and look at student writing as they are working to get a sense of what students are thinking. You can use this knowledge to guide the next steps of this lesson. For example, take note if students write things like "being smart" or "having all the answers" as we want to (gently) push students to start to think about scientific culture as a way of generating, testing, and criticizing ideas about how our world works–not a just body of facts/knowledge. This awareness can continue to be built over time as you establish your classroom culture.
When they finish, have students share their ideas with their shoulder partner. Then call on several students to share for the class. Once you've heard several ideas, tell students that scientists are constantly working to develop an accurate understanding of the world. This is a science class, so throughout this year we will work to develop the same skills and practices that scientists follow. We	

<table>
<tr><td>will work to develop an answer to this question: How do we think and behave like scientists?</td><td></td></tr>
<tr><td>Tell students that scientists often disagree about what the most accurate explanations for things in the world are. These disagreements can often be good for the accuracy of scientific knowledge because they challenge individuals to see things in new ways. Even when scientists disagree, they need to continue to work together to achieve their goal. As scientists work toward accuracy, they do their best to follow a set of three ideals.

Post the following ideals for students to see:
1. We value gathering a diversity of voices and initial ideas
2. We critique ideas based on evidence, not people
3. We are open to changing our minds based on evidence (even when it's uncomfortable)</td><td></td></tr>
<tr><td>Ask students to individually think about the following question for 30 seconds: Why would gathering a <u>diversity</u> of voices and initial ideas help build a more accurate understanding of the world? Then have students share their ideas with their partner one at a time.</td><td></td></tr>
<tr><td>Call on a student to share an idea their group talked about. Summarize their answer next to ideal 1 on the board. Call on at least one other group (possibly more) to share another reason a diversity of voices/ideas is important. Write this on the board as well.</td><td rowspan="2"><u>Note</u>: The purpose of this activity is for students to appreciate the purpose of the ideals as well as the key elements of each. Solicit enough responses and add your own thoughts until you feel confident students have been exposed to the following ideas:
1. A diversity of voices provides more possible explanations, and helps us see things from different perspectives.
2. Critiquing ideas (not people) improves accuracy of evidence while respecting</td></tr>
<tr><td>Repeat the activity above but for the next two ideals using these questions: "Why is it important to critique ideas but not people?" and "Scientists have to be willing to change their minds if they see new evidence. Why do you think this is important? Can you give an example?" Have students reflect on these questions in writing at the same time and then discuss them both after students finish writing.</td></tr>
</table>

	the inherent value of people. 3. An accurate understanding can only be achieved by adapting to new evidence - science depends on accuracy, not winning an argument.
Point out to students that we've reflected on how thinking and behaving like a scientist leads us to a more accurate understanding of the world, and that's why we're going to practice thinking and behaving like scientists in this class. If we are going to do this, we need to figure out what the ideals we just discussed will look like in practice in our classroom. Hand out the *Classroom Norms Brainstorming* sheet in the student materials.	
Have students work in small groups (ideally 3-4). Have students read the instructions quietly. Explain to students that, now that we've discussed why these ideals are important, we need to agree on what they look like in our classroom. Demonstrate for the students how to brainstorm several behavioral norms for the ideal about valuing a diversity of voices and ideas. Explain that in order to value different ideas, we need to <u>hear</u> lots of different ideas. One of our behavioral norms could be to "share our ideas even if we aren't yet sure they're correct" so that the class can hear more ideas. This way, others can hear new ideas they hadn't thought of before. (Write this behavioral norm down and have students do the same.) Then explain that in order to value different voices we need to hear from different people. One way to do this is to "Keep track of how much we are speaking" so that everyone has a turn and one person doesn't dominate the conversation. This way, we notice who is and who is not speaking and	<u>Attending to Norms</u>: The Humane Genetics team has observed that students are more willing to share their initial thoughts out loud if they know these thoughts are not being assessed for a grade. If this is true in your classroom, making this clear for students may encourage a broader diversity of voices in the classroom.

make space for more voices. (Write this classroom norm down and have students do the same.)	
Tell students it is their turn to brainstorm some other classroom norms that will help the class value gathering a diversity of voices and ideas. Individually, have students write several other norms that would achieve this ideal.	
Tell students they are going to practice this ideal by sharing their ideas with their small group. Have all students in the group share one idea at a time until all ideas have been shared. The other students should write these down on their own papers.	
When groups are finished, call on several groups to share an idea for a classroom norm for the first ideal. Write each idea on the board as students share, and then ask the speaker to explain how this norm would help achieve the ideal of gathering a diversity of voices and ideas. Once you have a sufficient list on the board, tell students to choose (as a group) the two or three norms that they think would best achieve the ideal. Choose one you think is a good example and model your thinking for students by explaining your reasoning. Then have students do this for one or two more in their groups. Have them circle the norms they have chosen.	Note: If students seem to misunderstand the intended purpose of the norms, push them to explain their thinking. Students may not be able to articulate their thinking clearly the first time, so this is a great opportunity to support students and help them feel like valued, successful members of the classroom early on. This is an opportunity to balance validation with rigor.
Have students repeat this process for the other two ideals. They should brainstorm many ideas and then reach consensus as a group about the two or three norms they think are most important to include for each ideal and circle those.	Note: As students are working, circulate to prompt their thinking. If you notice that groups are missing the types of norms you believe should be included, nudge them in that direction through questioning.
Collect these papers and combine students' circled ideas into a common norms and ideals chart, entitled Classroom Norms. Make sure it is posted somewhere that is easily visible to the whole class. When creating the chart, also share the method you are using for pulling	

students' ideas together to ensure students see how their ideas were valued and incorporated. Then have the class provide feedback and make changes as appropriate. Remind students that the class will revisit it in later lessons, and the class can test and revise it throughout the year.	
Explain to students that it's important to practice these norms with one another in order to make them a habit. It also lets us test them out as a group and make necessary adjustments. Hand out the document *"Using Our Norms to Discuss Data"* in the student materials. Read the top two paragraphs aloud as a class. Then draw students' attention to the graphs of plastic bag data found in the student materials. Give students several minutes to individually review the graphs and make notes about observations on their papers using the I^2 (Identify, Interpret) strategy. They should first *Identify* things they see in the graphs, and then they should *Interpret* what these observations mean. Model an example of this for students so they know how to do it themselves. See the note to the right for more info. Next students will individually make a claim to answer the question: *Do you think the area where you live should start (or continue) a tax on plastic bags?* Then explain to students that, as a group, they will discuss their claims using the observations they made from the graphs. Students should follow the instructions on the student sheet to have a structured discussion and reflect on if and how they used their norms. Remind students that they should be thinking about practicing our ideals and norms as they are talking with one another. Once groups have sufficiently	Note: Here is more info about the I^2 strategy if you and your class are not familiar with it. Formative Assessment Opportunity: As students are discussing, note the proficiency of groups and individual students at practicing the ideals. Check in with groups that seem to be less proficient at or forgetful of some of the ideals. Ask questions: "Has everyone in your group voiced ideas? What are some ideas that you've heard that don't match all the evidence? What kind of information would change your mind about your answer?"

discussed the questions, have them summarize the ideas their group brought up.	
Ask the Spokesperson from each group to share an observation about if and how their group used the norms. Some may have felt more comfortable than others, but all could be improved. Let students know that the ideals and norms are goals to work toward, not something they should have mastered already. In order to keep improving at them, we need to reflect on our progress. Introduce that a good way to do that is through an ongoing **reflection journal**. We will use these this year so you and your students can communicate about each student's progress toward understanding the ideals and practicing the norms.	Journaling Note: See point number 1 in the Teacher Guidance for Journaling information below.
Have students set up their Reflection Journals, either physical or electronic. Then have students reflect on the questions below. Post these for students to see. Journaling Questions: 1. What is a norm your group demonstrated well? What evidence do you have for this? 2. Reflect on the activity you did with your group. Which of the classroom norms do you think you practiced well today? Why? 3. Which norm(s) could you improve on? Why? When students finish, describe the ways feedback and communication about the journals will happen. Ask students to note in their journals if they are OK or not with having something they write be shared anonymously with the class by the teacher by writing "OK to share" next to it. Collect the journals before students leave.	Note: See bullet points 3 and 4 in the Teacher Guidance for Journaling information below. *Specifically, let students know that they are **not graded** on their answers and that the feedback will not be shared with other students unless the student wants it to be shared.*

Teacher Reference Materials

Sample Norms to Support a Positive and Productive Classroom Culture:

***How do we think and behave like scientists?*:**	
Ideal	**Classroom Norms** *What will you say or do to live up to this ideal?* *What will you avoid saying or doing to live up to this ideal?*
We value gathering a diversity of voices and initial ideas	- We share our ideas even if we aren't yet sure they're correct. - We contribute our ideas even if they're different from everyone else's - We choose our words carefully so we don't harm others. - We keep track of how much we are speaking. - We encourage other people to participate if we haven't heard from them.
We critique ideas, not people	- We use statements like "I disagree with *the idea* that..." rather than "I disagree with Chris." - We base any critiques on the strength of evidence. - We do not base critiques on how much we like or don't like a person, or their personal characteristics.
We are open to changing our minds based on evidence (even when it's uncomfortable)	- When we disagree, we ask others to say more about their thinking so we can better understand. - We identify areas where we agree and disagree. - If we are uncomfortable, we reflect on why and decide how to proceed. - If we change our mind, we share this with others, and why.

Teacher Guidance for Establishing an Effective Journaling Practice

1. Format: Students will need to reflect on the norms throughout the course of the year if they are to improve at them. Choose a journaling format that will work for you and your students - a spiral bound notebook, loose leaf paper in a section of a 3-ring binder, an ongoing Google Doc. This needs to be something you and the students can refer back to on a regular basis. However, this should be separate from a science notebook (if a science notebook is something you implement in your classroom). Students should be able to go to their journals and see only journaling information - it should not be mixed in with other content.
2. Journal Storage: If you are using physical journals, it may be helpful to have a space in the room dedicated to storing these journals so that students don't lose them (or forget to bring them to class).
3. Feedback: Journals need to establish two-way communication between teacher and student as well as between student and class. These provide opportunities for further discussion and to surface important ideas for the entire class. The bullet points below offer several options for how to do this, but they are not exhaustive - brainstorm other ways that meet the needs of your students and work in your classroom.
    - Individualized feedback - teacher responds directly in each student's journal
    - Generalized feedback for class - After reading all student responses, the teacher may note themes/thoughts that occurred in multiple journals and relay these (anonymously) to the class.
    - Anonymous feedback from student to class - With a student's permission, the teacher shares a quote or paraphrase from a particular student but does not name the student. If using physical journals, copy the quote somewhere else before reading so students do not recognize the journal.
    - Named feedback from student to class - With a student's permission, the teacher names a student and shares their writing or has the student share their writing (out loud or by reading) with the class.
4. Sharing student thinking with the class: Whenever you pursue any of the last three feedback bullet points above, students need to explicitly opt in to this process. No thinking from a journal should ever be shared with the class (even if the thought is anonymous) without the express permission of the student. At the end of each journaling practice, you should ask students to note if all, part, or none of this entry can be shared with the class, and note if it is OK to attach the student's name or not. You should always follow up with individual students before sharing, especially if they have not indicated if it is OK to share part of their journal with the class.
5. Grading: Journals **cannot** be graded. Doing so would be highly detrimental to emotional safety in the classroom. The journals are intended to be an honest and safe way for students to communicate their thoughts and feelings.

Chapter 1 Big Idea

Most genetic variation occurs within racial groups, and there is very little genetic variation between racial groups.

Humane Genetics Lesson Plan 1: What Are the Causes of Racial Disparities in the NFL and STEM and How Can We Be Sure Our Explanation is Accurate?

Lesson Question: What Are the Causes of Racial Disparities in the NFL and STEM, and how can we be sure our explanation is accurate?
Big Idea: Racial disparities exist in representation in the NFL and STEM, and there are different possible explanations for why these disparities exist.
Overview: This lesson introduces students to the anchoring phenomenon for the unit, which is differences in representation of White and Black Americans in STEM fields and in the NFL. The data that students encounter show that Black Americans are overrepresented in the NFL and underrepresented in STEM fields. In contrast, White Americans are overrepresented in STEM fields and underrepresented in the NFL. Thus, the patterns for the two groups are opposite. The lesson provides students both with an opportunity to describe these disparities and also to come up with an initial explanation. This sensemaking is scaffolded through a story about two characters who disagree about how to explain the disparities. Robin thinks that nature (genes) is the best explanation. Taylor thinks that nurture (environment) is the best explanation. Both characters are wrong in different ways, though Taylor is more correct than Robin. By the end of the unit (but not the end of this lesson!), each character–and your students along with them–will figure this out. The story of how Robin's and Taylor's thinking changes is a story that plays out through all of the remaining lessons in this unit. Therefore it is very important that students understand what Robin and Taylor disagree about in the first place. That is the purpose of the first lesson–simply to understand the nature of their debate.
Objectives ● Construct an understanding of the differences between two different explanations for racial disparities in the NFL and in STEM by explaining how two students' (Robin and Taylor) claims differ.
 *Approximately one 45-minute class periods*

NGSS Alignment

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in argument from evidence Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.	**LS3.B: Variation of Traits** Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus, the variation and distribution of traits observed depends on both genetic and environmental factors.	**Patterns** Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Key Terms

ancestry
DNA
ethnicity
genes
ideals
norms
race

Preparation

- Have the Classroom Norms chart posted somewhere where all students can easily see and reference it.
- Consider what will be the safest way for your students to safely share their explanations of the disparities in STEM and the NFL with the class (3 options are provided in the Procedure below).
    - If you choose to use a Poll Everywhere or Google Form, you may want to have it prepared ahead of class and test how to share data anonymously.

Materials

MATERIALS	QTY
Reflection Journals (e.g. composition notebook)	1 per student
Chart paper	Class Set

Chart markers	Class Set

Click here for Lesson 1 Slide Deck
https://docs.google.com/presentation/d/1WtZNdN-9Ikp3jtCYaYAIDUar-C-BOSV1IkX67Gyg53g/edit?slide=id.g2e7b854599b_0_5#slide=id.g2e7b854599b_0_5

Procedure

TASK	NOTES & MATERIALS
When you taught the lesson on *Building Our Classroom Culture*, you established several behavioral norms that will help students practice several scientific ideals.	*Do ahead of this class period.*
Remind students of the classroom norms you co-constructed and keep them displayed for the class, for the duration of this unit. Share with them that conversations about race are often difficult and need to be approached thoughtfully. These norms are critical for productive conversations about race and to safeguard students.	Attending to Norms: If your class has not been practicing the norms throughout the year, use this as an opportunity to remind students of these norms or take a few minutes to co-construct norms with your class. See instructions from the lesson titled *Building Our Classroom Culture* for guidance on this.
Hand out the student sheet entitled *"Representation in STEM and the NFL."* Read the text at the top aloud, or have student volunteers read aloud one paragraph each.	
Have students work with a partner to make a graph of the data, then describe the pattern in it.	Attending to Norms: Remind students of any classroom norms they have established similar to "*we choose our words carefully so we don't harm others*" before having any students voice patterns aloud. Remind them that differences by race can be a sensitive topic, and that they should speak respectfully when sharing the patterns they observe.
Ask a spokesperson from a table to describe *the pattern* (but not jumping ahead to any possible explanation they may have for it) they have identified to the class.	

Hand out the student sheet entitled *"How Would You Explain the Pattern?"* and read the first paragraph aloud to students. First have students individually consider and write down their own explanation.	<u>Attending to Equity</u>: Pay attention to any students that seem to be threatened about the nature of the phenomenon being discussed or the explanations given by others, particularly any students of color in your class. Check in with them as appropriate to hear their concerns. Also, let them know that the ultimate purpose of this unit is to help people understand that stereotypes are not true. <u>Attending to Norms</u>: Let students know that they may have emotional reactions to some of these statements, and that is fine. The goal is to balance ensuring that no student feels the need to be dishonest or not share, but also that no student feels targeted or harmed by hearing potentially biased language or ideas from a specific classmate.
Determine a way for students to safely share their explanations so everyone can see how their thinking compares to others in the class. Below, we suggest several different methods for this. - Option 1: Students can anonymously submit their answers through a survey site such as Poll Everywhere or a Google Form. You can then display the responses for the class to see. They should choose four responses that represent the overall diversity of explanations (e.g. the ones with the least overlap) and add them to their "How would you explain the pattern?" document. - Option 2: Have students anonymously write their explanation on a small whiteboard or sheet of paper and place it around the room. Then have students do a gallery tour. They should record and respond to four other statements in the same way described in Option 1 above. - Option 3: Have each student share their explanation just with the other students in their small group. (If you choose this option, carefully consider grouping strategy based on your knowledge of student interactions). Ask students to quietly take notes during this time to record if and how they agree or disagree with the other explanations offered by group members at their table. If you are concerned that an anonymous format will encourage students to share potentially	

harmful (even if honest) statements, we've suggested alternative options.	
Bring the class together and ask everyone to raise their hands and show with a "thumb-ometer" how much agreement or disagreement there seems to be in the class based on the other explanations they saw. Remind students that disagreement in science isn't inherently bad. In fact, scientists create new knowledge by trying to resolve their arguments. They do this by following the same ideals we have in our classroom: They gather a diversity of voices and initial ideas, critique these ideas, and remain open to changing their minds based on evidence. Then, write the focus question on the front board. ● What Are the Causes of Racial Disparities in the NFL and STEM? This is the question that doubles as the title of the unit. Tell the students that they will answer this question over the course of this unit and hopefully resolve any disagreements they are having by investigating actual evidence from scientific studies that are related to this question.	Note: Students may have noted that other racial groups are underrepresented or overrepresented in the NFL and STEM, and other types of careers. However, the materials provided for this unit will primarily be exploring the disparities in representation between White and Black populations to allow us to investigate one very powerful example carefully and in depth, providing a strong basis for transfer of ideas to other examples. Note: Some students may be more aware of systemic racism and its political and historical context than others. Depending on the students in your classroom, these issues may surface right away. If they do not, that is OK – know that Chapter 2 of this unit will present evidence to build students' awareness of the history of race and racism in the US. However, to best promote student learning and conceptual change, it is best to allow them to uncover this for themselves by working through the lessons, rather than attempting to front-load it through teacher explanation at this stage in the unit.

Introduce Robin and Taylor by telling the students that you have done this activity in the past and you have heard students disagree about the best explanation for the pattern we observed. These past students had conversations much like two characters you are about to meet: Robin and Taylor. Tell students that whose explanation is more accurate very much affects peoples' lives, and students will have a chance to respond to this conversation after they have finished reading it. Then hand out the student sheet entitled *"Robin and Taylor's Disagreement Part 1"* and read it out loud as a class.	<u>Attending to Equity</u>: Robin makes statements that could feel threatening to some students. Let them know that the purpose of this unit is to help people understand that stereotypes are not true. Pay attention to any students that seem to be threatened by Robin and Taylor's conversation, particularly any students of color in your class. Check in with them as appropriate to hear their concerns.
Tell the students the following: Imagine you just had the same experience as Taylor in this class. If you were Taylor, and you thought Robin's argument was wrong, what would you say to Robin? Have students silently and independently write their answer to the question "If you were Taylor, what would you say in response to Robin's explanation, right now?"	
Share with students: Taylor realized there were a lot of assumptions in Robin's argument, and in particular Taylor didn't agree with the assumption that people of different races are very different from each other genetically. Hand out the student sheet entitled *"Robin and Taylor's Disagreement Part 2."* Then, read each argument out loud as a class, finishing with the competing claims made by each character.	
Tell the students that in the next few lessons they will evaluate the scientific accuracy of Taylor and Robin's claims by exploring genetic data. Then ask each small group to identify what, exactly, Robin and Taylor are disagreeing about through their	<u>Formative Assessment Opportunity</u>: Look for the following ideas in each student's responses to these questions.

argument. Ask groups to record their responses on the student sheet in the appropriate place.	• Taylor thinks people of the same race are genetically different, but Robin thinks that people of the same race are genetically identical. • Taylor thinks that people of different races do not differ genetically, but Robin thinks that people of different races differ greatly in their genes. • For these reasons, Robin thinks genes are a good explanation for racial disparities whereas Taylor does not.
After all the students have recorded their answers to the two questions, summarize: "Taylor thinks people of the same race are genetically different, but Robin thinks that people of the same race are genetically identical. Taylor thinks that people of different races do not differ genetically, but Robin thinks that people of different races differ greatly in their genes. For these reasons, Robin thinks genes could be a good explanation for racial disparities whereas Taylor does not." Remind students: Before we can really understand whether genes are *causing* the racial differences in STEM and the NFL, we need to first resolve this argument about *how different* people of different races are in their genes.	
Ask the students to turn and talk with their neighbor about what they think about Robin and Taylor's claims. Have them record their thoughts under the question that says, "How do you think?"	Formative Assessment Opportunity: Circulate around the room and look at student answers to see how many of your students appear to agree with each character. Update your data table concerning which students strongly agree

	with each character because since both Robin and Taylor are wrong in different ways, over time students will likely need to undergo conceptual change during the unit.
Recognize with the class: Today's lesson could be particularly troubling or difficult as it mentions potentially hurtful statements linking social disparities with genes. It might bring up intense emotions for us that we're not used to feeling in science class. It's important for you to have a space to share those feelings, especially if you don't feel like doing it during class. In order to provide students with space to process today's lesson, have students reflect in their Reflection Journals. (See Journaling Note to the right for more information on the journals.) Let students know these journals will provide a method of feedback between students and you (the teacher) so you can see the effect the curriculum is having on your students and provide support and make adjustments to ensure the emotional safety of all your students. Have students use their same journals if you have been utilizing them throughout the year, or have students set up new ones if you have not. Post these questions on the board for students to see: 1. How did this lesson make you feel? (This could be related to what you talked about with your classmates and teacher, what you read for the lesson, and/or what you did during the lesson.) 2. Is there anything related to this lesson you think the class should know about or talk about? 3. How well did you and your classmates use the classroom norms? Provide some examples.	<u>Attending to Equity</u>: Listen to your students. Tell them that the conversations we are going to have will be difficult, but they are important, and they will help us to develop more accurate and less prejudiced views of how people differ. <u>Journaling Note</u>: ● If you have not yet been using journals in class, that's OK. Now is a great time to set those up. ● Let students know these journals are meant as another way of communicating with the teacher. They will not be graded. ● Let students know that only the teacher will see what the student writes. When students finish writing for the day, ask them to indicate if they would like their ideas to be strictly between the teacher and student or if they are comfortable having any of their ideas shared anonymously with the class.

Describe for students the types of answers they could give for the first two questions. They could write about how the lesson affected their emotions or identity, describe any content or life connections it sparked for them, or that it didn't have much of an effect on them. Remind students that these reflections are meant for them to process, so they can be as long or as short as necessary. When students finish, ask them to indicate if they would like their responses to only be read by the teacher or if they are comfortable having their ideas or direct quotes shared ***anonymously*** with the class.	
Tell your students that if anyone is feeling nervous and would like to talk further (not just in the journal) that they should do that. Provide them with several options for methods for doing this (e.g. staying after class, email, an anonymous suggestion box, etc.)	

Teacher Reference Materials

N/A

Humane Genetics Lesson Plan 2: How Do Robin and Taylor Think About Racial Difference?

Lesson Question: How Do Robin and Taylor Think About Racial Difference?
Big Idea: There is genetic variation both *within* AND *between* racial groups. The amount of genetic variation *within* a racial group can be modeled by increasing or decreasing the size of a circle; the amount of genetic similarity *between* racial groups can be represented by the amount of overlap between circles.
Overview: The debate between Robin and Taylor introduced in Lesson 1 is, in part, a disagreement about the amount of within- and between-group variation, and by extension, shared within-group variation, that exists in human racial groups. This lesson introduces definitions of all three concepts, and it introduces a useful representation for each form of variation through Venn diagram modeling. Students construct Venn diagram models to represent how Robin and Taylor conceptualize human genetic variation differently. They also use their Venn diagram models to represent how they (themselves) currently conceptualize genetic variation within and between human groups.
Objectives • Construct an understanding of within-group variation, between-group variation, and shared-within group variation by drawing accurate models that represent how Taylor and Robin think about racial difference. • Use an understanding of within-group variation, between-group variation, and shared-within group variation to draw a model that represents your own understanding of human genetic variation.
 *Approximately two 45-minute class periods*

NGSS Alignment

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.	**LS3.B: Variation of Traits** Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus, the variation and distribution of traits observed depends on both genetic and environmental factors.	**Scale, proportion, and quantity** The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

Key Terms

ancestry
between-group variation
DNA
ethnicity
genes
ideals
norms
race
shared within-group variation
within-group variation

Preparation

- Have the Classroom Norms chart posted somewhere where all students can easily see and reference it.
- Identify a space that will work for the physical modeling activity – you may want to reserve a gym, plan to go outside, or determine how to rearrange the furniture in your classroom.

Materials

MATERIALS	QTY
Chart paper	class set
Markers	class set

Click here for Lesson 2 Slide Deck
https://docs.google.com/presentation/d/1s9Sj7LIdl92tZksVGed5gXt_SWe7cbkKQGLF2timcEM/edit?usp=drive_link

Procedure

TASK	NOTES & MATERIALS
Have students recall: in the last lesson, we talked about racial disparities in STEM and the NFL, and discussed Robin and Taylor's opinions about these disparities. Today, we're going to take a closer look at how Robin and Taylor think about racial difference.	Formative Assessment Opportunity: Walk around the room and check to see that students accurately understand each character's claim.

Write the focus question for this lesson on the front board: • How Do Robin and Taylor Think About Racial Difference? Then, have students take out their student sheet entitled *"Robin and Taylor's Disagreement Part 2"* and re-read it. Using a think-pair-share, have one student revoice Taylor's argument in their own words. Then, have the second student re-voice Robin's argument in their own words. Then, have each pair of students discuss what they think about both character's claims.	
Explain to students that the purpose of today's lesson is to better understand how to model how humans are similar and different from each other. Then, we will use that knowledge to better understand how each character is thinking about the amount of genetic differences between human races. Then have students silently and independently read the first two paragraphs of the student sheet "*Modeling Human Variation to Understand Robin and Taylor's Claims,*" in the student materials, which introduce the activity for the lesson.	
List a few ways that you differ from other people. For example, you could say hair color, skin color, eye color, shape of your earlobes, your height, etc. State that we often assume many of these are genetic, and we often associate some of them, especially skin color, with race. Remind them that differences in physical characteristics can be a sensitive topic, and that any patterns should be discussed only in terms of factual differences, *never* linked to value judgements or other personal characteristics.	<u>Attending to Norms</u>: Remind students of any classroom norms they have established similar to "*we choose our words carefully so we don't harm others*." <u>Attending to Equity</u>: For students who cannot or may not wish to stand up, they may wish to write their height on a piece of paper to easily

Tell students that to visualize the amount of variation we have within our own classroom, we can complete a modeling activity. Teacher note: depending on class size, this can be facilitated as one model, or two models in which the class is randomly assigned to one of two groups. We recommend for classes of 22 students and up, to break the class into two groups. (Smaller classes can simply make one whole-class model.) Have students push their tables to the sides of the classroom. Tell students to review their norms and for this activity in particular, make sure to respect personal space and refrain from touching peers when discussing and assessing traits. Have them follow the instructions to complete the table in the student materials. (If there is time, you may first want to demonstrate how to assess how different you think your trait is from another person and assign it a number. You may have another adult in the room or a student volunteer help you with this.) Bring the class back together and ask them: was it ever hard to decide how to assign a number to represent how different your trait was from another student's trait? If so, why? After collecting students' ideas and experiences, validate their perceptions that these traits are spectrums – they are continuous, and even though genetics play a role, the environment does as well.	display it for peers to compare with their own height.
Next, tell students we are ready to make some models. First, let's model only the variation in **height**. Explain the rule for the model is that you have to stand one foot away for each difference you have with each other person. So, if you have three differences with one person, then you need to stand three feet away from them. Everyone (in the class or in one group,	Formative Assessment Opportunity: Check that students understand that the size of the circle represents how much variation, or difference, exists in the classroom. You could simply ask all students to show you

depending on class size) needs to do this for everyone else. There will be some re-shuffling to achieve this! Make the classroom model(s) and at the two-minute mark tell everyone to freeze in place. Explain that if we were to draw a line around everyone in the classroom/group, then the area of the circle created would represent the amount of variation - in this one trait - within our classroom. Note: If you broke the class into two groups, also note that each group's circle is likely a different size. That means that one group had more *within-group variation* than the other one did. Explain that if we did this activity in another classroom or using someone else's set of traits we might get a circle with a smaller or larger area. Now, let's see what it looks like to model **hitchhiker's thumb**. Repeat the instructions for this trait. Once students have stopped moving, have them notice where they are in relation to others – it might look pretty different! Call on a student to describe whether their circle got smaller, bigger, or stayed the same and why. Ask another student to revoice what the first student said.	with their hands (by placing them close together or far apart) what happens to the size of the circle when the amount of variation, or difference, goes from being small to large, or large to small.
Now ask the class to do something different. We are going to combine all 4 of the traits and make one model that considers variation in all of them at once – have students use the "total" column for this model. Make the classroom model(s) and at the two-minute mark tell everyone to freeze in place. Note that it was probably harder to find the right position! Ask a student to voice what their new circle represents. Then ask the class to consider: what if we did this for 100 traits? What if we did it for the whole genome?	Attending to Equity: This activity has the potential to make some students visibly more distant from a majority of the classroom based on traits connected to their race. Use your professional judgment about what you know about your students and overall classroom composition to inform how you approach this activity. If you have

	concerns about how well students are adhering to the classroom norms you may wish to modify this activity by not including skin color as a trait on the list of four.
Have everyone put their tables back into the right place and sit down. Hand out the reading "*What is Variable DNA and How Do Biologists Think About It?*"	
Read out loud as a class the first paragraph of the student sheet entitled "*What is variable DNA and how do biologists think about it?*" Ask students to think-pair-share in their own words what variable DNA is.	Formative Assessment Opportunity: Use wait time and call on a few pairs of students to define in their own words what variable DNA is. Have another group of students revoice this definition and state whether they agree with it or not and why. Have a third pair of students explain how variable DNA differs from non-variable DNA.
Have student volunteers read the definitions of within- and between-group variation on the student sheet aloud. Ask students to think-pair-share in their own words what between-group variation and within-group variation are.	Formative Assessment Opportunity: Ask groups to share their thoughts. Use wait time. Then, call on a pair and have them give an example of what within group variation is. Do the same for between-group variation with another pair of students. With a third pair of students ask them what the difference is between within and between group variation.
Have students silently read the second paragraph of "*What is variable DNA and how do biologists think about it?*"	

Project the pictures of the diagram on the first page of "*What is variable DNA and how do biologists think about it?*" Describe to students what each picture means.	Within- and between-group variation slides
Have each student read the definition of shared-within-group variation at the bottom of the page and then have them revoice what it means in a think-pair-share.	Formative Assessment Opportunity: Ask students: What happens to the amount of shared-within group variation as the amount of between group variation increases? Use wait time. Then, call on a student. If the student answers correctly by saying it would decrease, then ask another student in the classroom to explain how this relationship would be represented in a Venn diagram. If the student answers incorrectly, by saying there would be more overlap, then ask if anyone thinks there would be less overlap, and why? Then, ask a third student which of the two answers seems to be better supported by the way that Venn diagrams work.
Hand out the remainder of the student materials for this lesson, which are the pages that describe Models 1-4. Have students silently read through the next page of the student materials describing Model 1. Project the **imaginary** Model 1 onto a screen (the model with three same sized circles that barely overlap). Explain and point out to students how the within group, between group, and shared within group variation is represented in the model.	
In small table groups, have students answer the questions associated with models 2-4. Go around the room and check for understanding for each of the three concepts (within-group, between-group, shared	Formative Assessment Opportunity: Push students to explain their thinking. For example, if a group says that model one shows that same

within-group) by asking students to elaborate on their reasoning for each question.	amount of within group variation across groups, then ask them to explain to you why the model does not show that the amount of within group variation differs across groups.
Write these questions on the board: "Which model (2, 3, or 4) shows the greatest amount of shared within-group variation? Why?" (This could be model 3 or 4). "Which model (2, 3, or 4) shows the greatest amount of between-group variation? Why?" (Model 2). As a whole class, discuss the answers to these questions and use the "wait time", "asking for evidence," "who can rephrase or repeat", and "agree/disagree why" talk moves.	<u>Formative Assessment Opportunity</u>: Use enough wait time so that the majority of students in your class have their hands raised after you pose one of the questions. When you call on a student for their answer do not call on the first student with their hand raised. Once they give their answer ask them to give evidence from the Venn diagram models that supports their answer. Then, cold call on another student to revoice what the first student said. Then, ask the original student if the revoice accurately captured their thinking. Then, ask another student if they agree or disagree with the answer and why. Repeat with question two.
In small groups, direct students to the next pages in the student materials. Have each student draw what the Venn diagram model would look like for Robin and Taylor's claim. When they are finished collect this student sheet to use as an assessment.	<u>Formative Assessment Opportunity</u>: This is the embedded formative assessment for the lesson. Look for specific characteristics and justifications in each student's model. ● Students should write that Robin is thinking about racial difference

	with a model in which the between group variation is greater than the shared within group variation. So, they should draw his model with circles that barely overlap. ● Students should write that Taylor is thinking about racial difference with a model in which there is no between group variation. So, they should draw his model with circles overlapping entirely. ● Also, Taylor thinks there is a lot of within group variation and Robin thinks it is too small to matter. So, students should draw the circles in Robin's model as much smaller than the circles in Taylor's model.
Show students the Venn diagram for each character's claim. Refer back to the focus question and explain that Robin is thinking about racial difference with a model in which the between group variation is greater than the shared within group variation. So, his model has circles that barely overlap. Taylor is thinking about racial difference in which there is no between group variation. So, his model has circles overlapping entirely. Taylor thinks there is a lot of within group variation and Robin thinks it is too small to matter. So, the circles in Robin's model are much smaller than the circles in Taylor's model. Project Robin and Taylor's models on the board or draw them.	
Hand out the page of the student materials, entitled *"How do you think about genetic variation?"* Have	<u>Formative Assessment Opportunity</u>: This task will

students complete it individually and then turn it in to you.	allow you to assess both how students are thinking about genetic variation and how well they are able to model what they are thinking. As you are reviewing student work, identify students who will need additional support to understand modeling and/or genetic variation within and between groups.
Wrap up class with a reflection similar to: "In this lesson, we modeled Robin and Taylor's claims about racial difference, but we don't yet know which model is most accurate – we need to look at the scientific data. Next time we have class, we will look at some actual data!"	
Tell students to think back to Robin and Taylor's claims, and quietly review how we modeled them in this lesson. Have students respond to today's lesson in their Reflection Journals. Post these questions for students to see: 1. How did this lesson make you feel? (This could be related to what you talked about with your classmates and teacher, what you read for the lesson, and/or what you did during the lesson.) 2. Is there anything related to this lesson you think students should know about or talk about? Ask students to indicate if they would prefer their thoughts stay only with the teacher or if they would be comfortable having the teacher share these thoughts anonymously with the class.	

Teacher Reference Materials

N/A

Humane Genetics Lesson 3: How Genetically Different Are Same Race and Different Race People?

Lesson Question: How Genetically Different Are Same Race and Different Race People?
Big Idea: The amount of genetic variation within any racial group is large, the amount of shared within-group variation is large, and the amount of between-group variation is small.
Epistemic Idea: To help us avoid reasoning errors, we can create a simple Reasoning with Evidence Checklist. We start building this checklist with two common errors: misinterpreting evidence and cherry picking.
Overview: Lesson 3 builds on Lesson 2 by giving students the opportunity to apply their knowledge about within-group variation, between-group variation, and shared within-group variation to make sense of patterns of human genetic variation. The evidence in this lesson shows students that most genetic variation is found within any single population and only a little extra variation is found between populations. This evidence should help students understand that the claims about human variation made by Robin and Taylor are both wrong. Robin was wrong to claim that most genetic differences occur between races and that genetic differences within a population are too small to matter. In fact, the opposite is true. Taylor was wrong to claim that human races do not differ at all genetically. In fact, human groups do differ genetically, but they do not differ as much as Robin thinks. Finally, the class starts a Reasoning with Evidence Checklist and adds the first two items to it, in preparation for reading and identifying errors in what Robin and Taylor said after they saw the same evidence.
Objectives ● Use evidence to understand it is wrong to claim that genetic differences between individuals of the same race are too small to matter. ● Use evidence to understand that it is wrong to claim that most genetic differences must be between different races. ● Use evidence to understand it is wrong to claim that people from different racial groups don't really differ at all in their genes. ● Construct the understanding that even when shown the same evidence, people can come to different conclusions. This is often because people make errors in reasoning with evidence. ● Construct and apply understanding of the first two Reasoning with Evidence Checklist items: ○ Misinterpretation ○ Cherry picking
 *Approximately three 45-minute class periods*

NGSS Alignment

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and interpreting data Evaluate the impact of new data on a working explanation and/or model of a proposed process or system. **Engaging in argument from evidence** Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions.	**LS3.B: Variation of Traits** Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus, the variation and distribution of traits observed depends on both genetic and environmental factors.	**Scale, proportion, and quantity** The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

Key Terms

ancestry
between-group variation
DNA
ethnicity
genes
genome
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norms
race

shared within-group variations
within-group variation

Preparation

- Have the Classroom Norms chart posted somewhere where all students can easily see it.

Materials

MATERIALS	QTY
Blue, red, and green markers or highlighters	2 sets / table
White board or chart paper	class set
Markers	class set

Click here for Lesson 3 Slide Deck
https://docs.google.com/presentation/d/1qOlZpsLBJw3vRC4kmp7I_ODvCAIQ0wYJIx_9meBqjhl/edit?usp=sharing

Procedure

TASK	NOTES & MATERIALS
Have student volunteers remind the class what we were wondering at the end of the last lesson – that is, that Robin and Taylor have very different models of how genetically similar people of different races are – but to know who is right, we are still wondering what the scientific evidence will actually show us. Write the focus question for the lesson on the front board: *How Genetically Different Are Same Race and Different Race People?* Then, reintroduce the debate between Taylor and Robin by posting their competing claims on the board: • Taylor's claim: Individuals of the same race differ from each other genetically, but people from different racial groups don't really differ at all in their genes. • Robin's claim: Most genetic differences must be between different races. The genetic differences between individuals of the same race are too small to matter. Then draw or post Robin's and Taylor's Venn diagram models next to these claims. Explain that Robin and	Materials: White board or chart paper and markers.

Taylor disagree about the amount of within-group and between-group variation. Ask students to discuss with a partner: ● How much within- and between-group variation is represented in each model?	
Share with students that they are going to look at evidence cards of actual data about human genetic variation. Sometimes these cards will use U.S. Census race terms like Black and White, but sometimes they will use ancestry terms like European ancestry or Middle Eastern ancestry. Race is a social category that someone identifies with or that is assigned to them. Ancestry refers to the population group or groups someone is descended from. Also keep in mind, people of European ancestry overlap significantly with people considered White, but these are not the same thing. Remember, we've already gathered a bunch of ideas from each other. Then, we gathered ideas from Robin and Taylor. Now, we're going to be looking at evidence, then we're going to use this evidence to critique Robin's and Taylor's ideas. And remember, it's always ok to change our minds about things after we see the evidence!	Note: The ancestry or race terms that are included in each evidence card are the terms that the researchers used in the paper that the card is based on. Robin and Taylor will sometimes conflate race, ethnicity, and ancestry terms early on in the unit but will improve in their accuracy as the unit progresses. This is the kind of progression we hope to see from students as well. As a teacher, when referring to racial or ethnic groups, U.S. Census race categories and ethnicities should be used. When referring to ancestry (genetic or otherwise), ancestry terms should be used. Whenever possible, help students use the most accurate terms and understand why these terms are most accurate. Note: The references to the studies these evidence cards are based on are provided at the bottom of each card. If students have questions about the reliability of the articles, let them know they've all been published in scientific journals and have been

	reviewed by other scientists for accuracy (peer-reviewed).
Hand out the student sheet "*Evaluating Evidence of Human Genetic Variation*" and have each student silently read the first page to themselves. Hand out blue, red, and green markers. Take any questions from students about the first page, and summarize the idea that they are first going to *imagine* what the perfect data to support each claim could be, so when they look at the real data, they can easily see who is *closer* to correct.	Materials: Blue, red, green markers/highlighters.
Instructional Steps for Evaluating the Evidence	
Organize students into small groups to evaluate the evidence cards.	
Use the Lesson 3 slides to share the overall procedure with students – they will: 1. ***Imagine*** what this evidence would look like if it perfectly matched Robin's and Taylor's claims. 2. Read ***real*** evidence from scientific research and highlight: a. information about within group variation in blue b. information about between group variation in red c. information about shared within group variation in green 3. Determine how closely the actual evidence aligns with Robin's and Taylor's claims. 4. Repeat for new evidence (3 sets total).	
Use the slides to walk through Evidence Card 1 as an example as a class.	Note: The first evidence set supports Taylor's claim that individuals of the same race differ from each other because each group has different alleles at the same locus, but it refutes his claim that racial groups don't really differ in their genes, because each group differs in the

	proportion of people who have each allele. The first evidence card refutes Robin's claim that most genetic differences are between races because all of the groups share similar sets of alleles and it also refutes his claim that genetic differences between individuals of the same race are too small to matter. So, the first evidence card supports Taylor more than Robin. But, Taylor is still wrong when it comes to his claim about between group variation. You can look at each group's response in their graphic organizer to evidence set one if you want to assess their knowledge for this portion of the learning segment. Kids who understand should select the box that "supports Taylor more" and their reasoning should reflect the reasoning laid out in the above description.
Then have groups repeat the procedure themselves for cards 2 and 3.	Formative Assessment Opportunity: If you do this with the evidence cards yourself, ahead of time, then you can walk around the room and compare your pattern of underlines to your students' patterns, which will tell you if they are grasping the three different concepts of variation. (Of course, there may be a few different patterns of

	underlining that are still correct, but it might be helpful as a quick reference for you). - Evidence card 2 supports Taylor more than Robin for the exact same reasons as evidence set 1. Additionally, the evidence that the decline in within-group variation with distance from Africa is small further supports Taylor's claim that there are genetic differences between individuals of the same race. This same evidence refutes Robin's claim that the genetic differences between individuals of the same race are too small to matter. Look for students to select "supports Taylor more" in the graphic organizer. - Evidence card 3 refutes Taylor's claim that there are no genetic differences between races and it also refutes Robin's claim that most genetic differences occur between races because two people from two different ancestry

	groups are only 5% more genetically different in their variable DNA than two people of the same ancestral group. At the same time, 95% of human genetic variation is found within groups. This supports Taylor's claim that individuals of the same race differ genetically, and it refutes Robin's claim that the genetic differences between individuals of the same race are too small to matter. So, evidence card 3 supports Taylor more than Robin, but Taylor still has an inaccurate understanding of between group variation. Look for students to select "supports Taylor more" in the graphic organizer. Note: If printing in black and white, project just the map in the slides so students can see the dots in color.

Optional Extension: There are optional additional evidence cards for this lesson that you may include if you have the time and feel your students would benefit from additional evidence for genetic variation within and between racial groups. You can find these Optional Extension Evidence Cards here:
Lesson 3 Optional Extension Evidence Cards

https://docs.google.com/document/d/1PC2G-KU3daW1LJIC1UauoBuABxHYrGcp2-0tsoURyj4/edit?tab=t.0	
Use these speaker notes and accompanying slides to summarize the evidence on human genetic variation. Speaker notes: Lesson 3 - Speaker Notes for Human Genetic Vari... https://docs.google.com/document/d/1xNsxsiN2PJkoihcppKneYVPYrGFIbOos0og97GHuKMs/edit?tab=t.0	Note: If students previously expressed difficulty or concern with assigning a number to how different they were in skin color to others during the Lesson 2 modeling activity, the data on skin color presented here can be used to show that this discomfort was justified - skin color is very much a spectrum and *not* categorical.
Have each student independently create their own argument using the student materials entitled *"What Do You Think Now About Taylor and Robin's Claims?"* You may allow time for students to ask questions and answer them before starting their independent work.	Formative Assessment Opportunity: Look for the following claims: ● Right now, I think both characters have the wrong ideas about between group variation but, when it comes to within group variation, Taylor is right, and Robin is wrong. Look for any of the following evidence: ● Each group shares similar sets of alleles, but each group differs in the proportion of people who possess each allele (card 1). ● 95% of genetic differences occur between individuals of the same group. ● Genetic variation within groups declines with distance from Africa (card 2).

	● Only 5% of genetic differences occur between groups (card 3). Look for any of the following reasons paired with the appropriate evidence from above: ● Evidence shows that Robin made an incorrect claim about within and between group variation because if each group shares similar sets of alleles then this shared within group variation means that there is genetic variation in each group and much of that variation is shared between groups. Also, this evidence shows that Taylor made an incorrect claim about between group variation because if each group differs in the proportion of people who possess each allele, then the groups do differ, proportionally speaking. ● Evidence shows that Taylor made a correct claim about within group variation and Robin made an incorrect claim about within group variation because most genetic variation is found within groups. ● Evidence shows that Taylor made a correct claim about within group

	variation and Robin made an incorrect claim about within group variation because while some groups have more within group variation than others, all groups still have within group variation. There are no groups where there is zero within group variation. ● Evidence shows that Robin and Taylor both made incorrect claims about between-group variation because there are genetic differences between groups, but they are proportionally small.
Share with the class: “Robin and Taylor clearly have two very different ideas about racial difference. If they were to see the same evidence we just did, do you think they would change their minds?” Give students a minute to turn and talk to a partner about this question. Then call on a few volunteers to share. (Look for a variety of student responses such as “yes, the evidence clearly shows they were both somewhat wrong” and “no, I know people don’t like to change their mind very much, especially about things like race.”) Share with the class: “Most people, Robin and Taylor included, have a bias toward wanting to “be right” and “win” an argument. But in science, our goal is accuracy. So when we think like scientists, we have to be on the lookout for this bias, because it can lead to two people interpreting the same evidence differently, and coming to different conclusions.	

In order to get some practice, let's first consider a scenario that's less complicated and may feel more familiar. Let's look at two different ways a teacher might interpret the same evidence about how 'good' his class is when he's away and the class has a substitute teacher. I'm guessing you'll all think one interpretation is very unfair! Let's see why."	
Display the slides that start with "Avoiding Reasoning Errors." Hand out the student materials *"Pizza Party or No Pizza Party?"* to each student. Read aloud, or ask a student volunteer to read aloud the scenario.	
Have students use the I^2 (*identify, interpret*) strategy to annotate and make sense of each graph in the student materials.	Note: Here is more info about the I^2 strategy if you and your class are not familiar with it. (It was first introduced in the "Building Our Classroom Culture" lesson that was ideally completed at the beginning of the year.)
After they've finished their annotations, have students turn and talk with a partner to share their interpretations. Encourage students to discuss any disagreements and make sure they both feel confident they understand what the graphs are telling them.	Formative Assessment Opportunity: Students' WIS (what I see) and WIM (what it means) statements should show understanding that in general, the substitute teachers had a similar number of disruptions as the regular teacher, but sub 1 was an outlier. They should also note that students generally made fewer mistakes on assignments with subs than they did with the regular teacher. Attending to Norms: Remind students to refer to the

	classroom norms that should still be posted when working with partners. You may want to remind them of the norms under the ideal of "we critique ideas, not people" to facilitate productive disagreement as they work to make sense of the graphs.
Share with the class: "When we use evidence to try to support a claim, we are *reasoning* with evidence." "Now that you have a sense of what the data show, let's look at two different ways the teacher could reason with the same evidence and arrive at different conclusions. Remember: if they're arriving at different conclusions, it's likely at least one of them is making some reasoning errors."	
Pass out 2 different colors of highlighters (or markers/colored pencils) to each student. Tell students they are going to use orange to highlight any phrases that seem like they might be *reasoning errors*. They will also use a pen or pencil to annotate next to the highlighted phrase *what they think is wrong with how the teacher is reasoning with evidence*. Depending on your students' prior experience with arguments you may want to tell students not to get too caught up in which phrases/parts of the sentence are reasoning vs evidence vs a claim. (See Note.) The main point is the annotating - *why* do they think there is a reasoning error? Read the first two sentences of *Teacher decision 1* aloud to the class. After reading the second sentence, ask students why it might be a problem to only discuss the information from substitute 1. Have them discuss this with a seat partner, and then call on a group to share. Ask another group if they would agree or if they have	Materials: 2 different colors of highlighters/markers (e.g. orange, blue) Note: If your students have prior experience analyzing and writing arguments using the Claim-Evidence-Reasoning or CER framework, you may want to leverage that to have them zero in on the reasoning. If not, however, it's fine to tell students not to get caught up in deciding which words/phrases to highlight. Emphasize that the main point is to be able to explain in their annotations why they think there is a reasoning error.

anything else to add. Then have students highlight this sentence and annotate the class's rationale for highlighting it. Point out that this is an example of someone making an error when they are reasoning with evidence. Tell students to now work with their partner to highlight any other times they think the teacher made an error when reasoning with evidence. They should work with their partner to do this. Circulate around the room to see what students are highlighting and why. Probe their thinking, and consider encouraging seatmates who have something different from each other to share and discuss.	Note: If possible you may want to connect with the English Language Arts teachers at your school and see if your students already have practice with any annotation strategies and encourage consistency with those in your approach to this activity. Formative Assessment Opportunity: Students should notice that the teacher only focused on one data point with the disruptions (overlooking other important evidence) and misinterpreted the second graph to be about grades rather than number of mistakes.
Bring the class together to discuss. Have a few students share what they highlighted and why. Then use the slides and speaker notes to share what you would have highlighted and why.	Note: Students may highlight different words or phrases than the example in the slides – this doesn't necessarily mean they don't understand the reasoning errors. Look at their annotations (giving the *reasons* for what they highlighted) and listen for the ideas they share in the class discussion to determine how well students are picking up on the reasoning errors.
After a few have shared, ask students to identify any patterns in what their classmates shared. If students don't use these words exactly, make sure to conclude by verbalizing these two key errors:	

- *misinterpreting evidence* - *not including some of the evidence*.	
Project the slide titled Reasoning Errors. Use the speaker notes to walk through them with the class, introducing the two kinds of reasoning errors, and then advance to the next slide to explain why the second one is often called "cherry picking."	
After students have read the description of "cherry picking," have them turn and talk with a partner to try to explain it in their own words. Ask a few pairs to share their definitions with the class. Then say "let's see what it looks like when we avoid these errors."	
Have students read just *Teacher decision 2*. Tell students that we can use blue to highlight any phrases that seem like they show the teacher *avoiding reasoning errors*. Have them also use a pen or pencil to annotate next to the highlighted phrase *what they think is good about how the teacher is reasoning with evidence*. Circulate around the room to see what students are highlighting and why. Probe their thinking, and consider encouraging seatmates who have something different from each other to share and discuss.	<u>Formative Assessment Opportunity</u>: Students should notice that the teacher included some reference to all of the data and didn't misinterpret the second graph.
Bring the class together to discuss. Have a few students share what they highlighted and why. Then use the slides and speaker notes to share what you would have highlighted and why.	<u>Note:</u> Students may highlight different words or phrases than the example in the slides – this doesn't necessarily mean they don't understand the reasoning errors. Look at their annotations (giving the *reasons* for what they highlighted) and listen for the

	ideas they share in the class discussion to determine how well students are picking up on ways to avoid the reasoning errors.
Bring the class back together and reflect on where we are using framing similar to: "Now we have some actual evidence in hand to assess Robin and Taylor's claims. Soon, we're going to take a look at how Robin and Taylor reasoned when they saw this same evidence. Did either of them make any errors in reasoning when adding this new evidence to their arguments? Before we jump in, we need to find out more about how we can make sure to avoid these errors in reasoning." Advance to the next slide, which shows the Reasoning with Evidence Checklist. Use the speaker notes to introduce the purpose of this Checklist to students. Let them know we will keep this handy throughout the unit, to make sure Robin and Taylor aren't making any errors in their arguments.	
Remind students of the question we are trying to figure out: *How genetically different are same race and different race people?* Tell them that next, they will try to apply the Checklist to Robin's and Taylor's new arguments about this question. Frame for students: "How do we think Robin and Taylor reacted, when they saw this same data in class? Do you think either of them changed their minds? Do you think either of them made reasoning errors? Turn and talk with a partner about your predictions."	

Pass out the student materials *"Robin and Taylor Respond to the Evidence."* Pass out two colors of pens/highlighters (e.g. blue and orange). Tell students that, just as before, we can use one color (e.g. orange) to highlight errors, and the other color (e.g. blue) to highlight where errors are avoided. Have students individually follow the instructions to read and annotate Robin and Taylor's new arguments, then meet with a partner to share ideas.	Materials: Two colors of pens or highlighters (e.g. orange and blue). Formative assessment opportunity: Robin's argument has more serious flaws than Taylor's and more strongly misinterprets the data to suit his original claim. Circulate around the room to check that students are picking up on this by observing their annotations and conferring with them as needed.
Give students a minute to look at your highlights on the slides. Invite the spokesperson for student pairs to share if they highlighted any of the same things, and if so why. After a few pairs have shared, summarize using the speaker notes to make sure students get the key takeaways. Remember: which exact words or phases are highlighted matter much less than the reasons for the highlights.	
Conclude by eliciting from students what they noticed about Robin and Taylor's arguments: - Did Robin or Taylor change their minds? - Did either or both make reasoning errors? - Who made more reasoning errors?	Listen for responses such as: - No, they both stuck to their original claims. - Yes they both made errors. - Robin made more errors. (Taylor's only error was not including every single evidence set.)
Wrap up the lesson by summarizing:	

"Robin and Taylor didn't change their minds when they saw this new evidence – but they made some reasoning errors. In the next lesson, we will construct a venn diagram model for the patterns of human genetic variation we have learned about in this lesson, and we will continue to add to and use our Reasoning with Evidence Checklist to make sure our model isn't based on any reasoning errors."	
Have students respond to today's lesson in their Reflection Journals. Post these questions for students to see: 1. How did this lesson make you feel? (This could be related to what you talked about with your classmates and teacher, what you read for the lesson, and/or what you did during the lesson.) 2. Is there anything related to this lesson you think students should know about or talk about? Ask students to indicate if they would prefer their thoughts stay only with the teacher or if they would be comfortable having the teacher share these thoughts anonymously with the class.	

Teacher Reference Materials

Lesson 3 - Speaker Notes for Human Genetic Variation Slide Lecture
https://docs.google.com/document/d/1xNsxsiN2PJkoihcppKneYVPYrGFIbOos0og97GHuKMs/edit?tab=t.0

Lesson 3 Optional Extension Evidence Cards
https://docs.google.com/document/d/1PC2G-KU3daW1LJIC1UauoBuABxHYrGcp2-0tsoURyj4/edit?tab=t.0

Humane Genetics Lesson Plan 4: How Scientifically Accurate Are Robin and Taylor's Models of Genetic Variation?

Lesson Question: How Scientifically Accurate are Robin and Taylor's Models of Genetic Variation?
Big Idea: We can construct an accurate consensus model of human genetic variation that visually represents high within-group variation, high shared-within group variation, and low between-group variation.
Overview: Lesson 4 requires students to synthesize the concepts learned from Lessons 2 and 3 by engaging students in an activity where they will create a scientifically accurate Venn diagram model (like those made in Lesson 2) to fit the actual data (from Lesson 3) about human genetic variation. In Lesson 2, students engaged in a similar task by creating models that represented how Taylor and Robin conceptualized the amount of within-group, between-group, and shared within-group variation. Then, they were asked to create a model that described their own conception of human genetic variation. In Lesson 3, students then made sense of five different pieces of evidence about human genetic variation. In this lesson, individual students will construct a new model that represents the data from Lesson 3. Then, as a whole class, students will create a consensus model of human genetic variation. They will use the consensus model to critique Taylor and Robin's models of human genetic variation. Then, students will reflect on how their thinking about genetic differences between racial groups has changed since they began the unit.
Objectives • Construct an understanding of within-group variation, between-group variation, and shared within-group variation in humans by creating a Venn diagram model. • Describe how this new model of human genetic variation is different from their old model with regards to how it represents each form of variation. • Critique the models of human genetic variation underlying Robin and Taylor's claims.
 *Approximately two 45-minute class periods*

 **NGSS Alignment**

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts

Developing and using models Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.	**LS3.B: Variation of Traits** Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus, the variation and distribution of traits observed depends on both genetic and environmental factors.	**Scale, proportion, and quantity** The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

Key Terms

ancestry
between-group variation
DNA
ethnicity
genes
genome
ideals
norms
race
shared within-group variations
within-group variation

Preparation

- Have the Classroom Norms chart posted somewhere where all students can easily see it.
- Have the Reasoning with Evidence Checklist posted somewhere where all students can easily see it.

Materials

MATERIALS	QTY
Compasses (for drawing circles)	1 / table
Colored pencils	1 set / table
Butcher paper	1 sheet / table
Markers	1 set / table

Click here for Lesson 4 Slide Deck
https://docs.google.com/presentation/d/1kqFagNyaHXfRmlncyn5uoTJjB7DvWhn2pzS-9HNmf_s/edit?slide=id.g2e7b0575f6b_0_2#slide=id.g2e7b0575f6b_0_2

Procedure

TASK	NOTES & MATERIALS
On the front board have the following findings written down to remind students of the evidence we analyzed in the last lesson: Any two humans share 99.9% of their DNA and only 0.1% of human DNA is variable. When looking at variable DNA: ● 95% is found comparing individuals within the same ancestry group. ● People from different ancestry groups are only 5% more different from each other than people from the same ancestry group. ● The greatest amount of genetic variability occurs within people of African ancestry. And, as you get farther away from Africa the amount of genetic variability within any given population decreases. Have the focus question for this lesson written on the front board. *How scientifically accurate are Robin and Taylor's Models of Genetic Variation?* Tell the students that the purpose of the lesson is to use this evidence to answer this question.	
Ask students to discuss with a partner what each of these findings mean in their own words.	Formative Assessment Opportunity: Go around the room and check for understanding. Note: Students may not all agree about what these findings mean yet. That's fine.

	One of the goals of this lesson is to help students clarify their understanding of the evidence they encountered in Lesson 3.
Consensus is best reached by following the ideals we have been working on as a class this year: ● "*We value gathering a diversity of voices and initial ideas*;" ● "*we critique ideas, not people*;" and ● "*we are open to changing our minds based on evidence (even when it's uncomfortable)*." Make sure the norms chart based on these ideals is still posted for students to see. Tell students that using our norms will be key to developing consensus today.	Attending to Norms: Take time to explain to students (or elicit students' ideas about) why these ideals are so crucial for reaching consensus. Also, take time to highlight specific norms your class constructed that will help to achieve the ideals.
Have each student look at the model of human genetic variation that they created in Lesson 2. Then, have the students discuss with a partner what they would change about their original Venn diagram model now that they have become aware of these facts.	Attending to Norms: Remind students to pay particular attention to the norms under the ideal of "*We are open to changing our minds based on evidence, (even when it's uncomfortable)*."
Tell the students that the purpose of today's lesson is to create a model of human genetic variation that best represents these findings about human genetic variation. Hand out the student materials entitled "*Creating Your Model of Human Genetic Variation that Fits the Data*." Have students read the first page and create their own individual model. Ask students to justify how their model represents each of the data statements.	Materials: Have compasses for each student and colored pencils available. Formative Assessment Opportunity: Look at the model drawn by individual students at the beginning of the lesson and check to see that the African circle is slightly larger than the European circle, and that both of these circles are slightly larger than the Asian circle. Check to see that the circles overlap more than they do not overlap. The model should look like this:

	 The critical aspect of this task is that students have created a model that represents the proportion of between-group variation correctly, which involves constructing a model in which the area of non-overlapping area is about 5% of the total area of the Venn diagram. Most students will not create a perfect model, so you will need to look for models that have more overlap than non-overlap.
Then, have each table group create a consensus model on butcher paper. The group will need to label the consensus model to show how it represents the findings on within-group variation, between-group variation and shared-within group variation.	Materials: Butcher paper, markers, compasses. Attending to norms: Remind students to refer to their norms chart during this discussion. You may want to have them assign one team member the role of monitoring the norms.
When they are finished with the small group consensus models, bring the class back together. Next we're going to look at all the other groups' ideas and try to come to consensus. We're going to notice differences. We will need a way to reconcile the differences between them to create the most accurate model possible. To do that, we need to figure out which *parts* of each group's model are best supported	

by evidence. That way, we can use the best "parts" of each to build a consensus model.	
To prepare for the gallery tour, pass out *"Picking the best model of human genetic variation"* and read it aloud with the class (noting that the questions will be the same for the model that is similar and the model that is different).	
Have students perform a gallery tour in their small groups, moving from table to table looking at each model. Have students then fill out the student sheet for a model that is different from theirs and one that is similar to their own.	Formative Assessment Opportunity: Go around the room and press students for their reasoning as they fill out these questions.
Allow each group to revise their model based on what they observed during the gallery tour.	
Hand out the student sheet entitled *"Creating a Consensus Model."* Have each group pick a spokesperson. Tell the spokespeople from each table to come to the front of the class to work together to draw a new consensus model on the front board.	Formative Assessment Opportunity: This is another opportunity to see if the students have the correct conceptions of within-, between-, and shared within-group variation.
Have all the students sit down and then have them discuss the following questions in their small groups: ● Do you agree or disagree with how the model represents the first finding? What makes you say that? ● Do you agree or disagree with how the model represents the second finding? What makes you say that? ● Do you agree or disagree with how the model represents the third finding? What makes you say that?	Formative Assessment Opportunity: Circulate the room and listen for accurate reasoning. For example, ask each group if the circles are the same size or different sizes, or whether the amount of overlap is appropriate.
Ask the class: does anyone think the model needs to be changed to better fit the data? If a student says yes, then ask them to come up to the front of the room and make the change. Then ask the class if they agree or disagree with the change and why. Do this once or twice at most.	

Then, explain to the students how scientists argue about what the best consensus model is for human genetic variation. Over the last century they have arrived at a consensus model, too. Project the consensus model on the board. Ask the students to think-pair-share in partners, discussing how their model differs from the scientific consensus model.	
Have students copy the scientific consensus model from the google slide deck into the box on their student sheet. Then, have students silently and independently review Robin's and Taylor's original models, compared to their new class consensus model. Point out to the class "Robin's and Taylor's models both look very different from the one we ended up with."	
Have students do a think-pair-share in response to the questions "why is Robin's model not the best fit for all the evidence?" and "why is Taylor's model not the best fit for all the evidence?"	
Have students complete the student sheet entitled *"I used to think… but now I think…"* as an exit ticket out the door. After students complete the final question on this activity, preview the challenge that will be happening in the next class – students will need to <u>individually</u> explain and argue for their ideas.	<u>Formative Assessment Opportunity</u>: If a student claims their thinking has not changed, then confirm this by comparing the model they made at the beginning of class to the model they made after Lesson 2. If their thinking has not actually changed, as evidenced in their models, then have the students explain what they have learned that reinforces their prior thinking.
Have students respond to today's lesson in their Reflection Journals. Post these questions for students to see:	<u>Journaling Note</u>: This journaling session is less about student feelings – in this lesson it is more of a reflection on how well the ideals and norms

1. How well are the classroom norms working? Do any need to be revised or changed to better help us reach the ideals? Ask students to indicate if they would prefer their thoughts stay only with the teacher or if they would be comfortable having the teacher share these thoughts anonymously with the class.	contributed to productive group work.

Teacher Reference Materials
N/A

Humane Genetics Lesson Plan 5: How Scientifically Accurate are Robin and Taylor's Claims about Genetic Variation?

Lesson Question: How Scientifically Accurate are Robin and Taylor's Claims about Genetic Variation?
Big Idea: We can support an argument with evidence that most genetic variation occurs within racial groups and there is very little genetic variation between racial groups.
Epistemic Idea: We can use the Reasoning with Evidence Checklist questions to critique arguments and point out where there may be reasoning errors.
Overview: Lesson 5 is the summative assessment for Chapter 1, concluding our investigation into human genetic *variation*, before Chapter 2 invites students to investigate *causation* of observed differences in complex traits. Students will form argument lines to engage in academically productive discourse and refine their thinking about human genetic variation. As part of this discourse they will identify when and how their critiques connect to the Reasoning with Evidence checklist questions (introduced in Lesson 3). Then, students will craft their own argument about what they think.

Objectives
• Synthesize and demonstrate understanding of between-group variation and within-group variation by correctly critiquing each character's claims using evidence about human genetic variation from in previous lessons.
• Apply understanding of the Reasoning with Evidence Checklist questions we have so far:
  ○ Misinterpretation
  ○ Cherry picking

 *Approximately two 45-minute class periods*

 **NGSS Alignment**

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts

Engaging in argument from evidence Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions. Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.	**LS3.B: Variation of Traits** Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus, the variation and distribution of traits observed depends on both genetic and environmental factors.	**Patterns** Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Key Terms

ancestry
between-group variation
DNA
ethnicity
genes
genome
ideals
norms
race
shared within-group variations
within-group variation

Preparation

- Have the Classroom Norms chart posted somewhere where all students can easily see it.
- Have the Reasoning with Evidence Checklist posted somewhere where all students can easily see it.
- Review students' Reflection Journal entries from the end of Lesson 4 in preparation for facilitating a check-in conversation about the Classroom Norms. Be prepared to update the norms on the chart based on student ideas and feedback.

Materials

MATERIALS	QTY

Blue, Red, and Purple Markers	2 sets / table
Lesson 3 slide deck (to refer back to)	1 per teacher

Click here for Lesson 5 Slide Deck
https://docs.google.com/presentation/d/10TkSh1lFK2BYLlrSbd9okiQ0MiJGRAHWcXVQdReNi4/edit?usp=sharing

Procedure

TASK	NOTES & MATERIALS
Before students enter the classroom have Taylor and Robin's claims written on the board along with the focus question: *How scientifically accurate are Robin and Taylor's claims about genetic variation?* • Taylor's claim: "Individuals of the same race differ from each other genetically, but people from different racial groups don't really differ at all in their genes." • Robin's claim: "Most genetic differences must be between different races. The genetic differences between individuals of the same race are too small to matter."	*Do this ahead of class.*
Lead a discussion based on feedback you received from student journals from the previous lesson. This discussion should focus primarily on how well the ideals and norms are working and if any norms need to be modified, added, or removed. **If using a chart or poster of the classroom norms, update it with any relevant points from this discussion.**	Attending to Norms: Use student feedback from the journals to drive this discussion, but make sure to *only use responses from students who have given their express permission.*
Hand out the student materials entitled *"Conclusion to Human Genetic Variation Segment."* Remind students that today's lesson is about accurately defending claims as an individual. Students will need to make their own decisions about the most accurate interpretation of data and use evidence to support their reasoning. Remind students that scientists describe human variation in two major ways: variation *within* groups and variation *between* groups. Have students turn and	Formative Assessment Opportunity: Walk around the room and check for understanding.

talk with their partners and discuss their thoughts on the question: Which part of each character's claim has to do with between-group variation and which part has to do with within-group variation?	
Have each student read Taylor and Robin's claims on this student sheet and ask them to underline in blue the parts in each claim that refer to within-group variation and underline the parts that refer to between-group variation in red. This is a silent and independent activity.	Materials: Blue and red markers.
Ask a few students to come to the front board to underline the appropriate parts of each character's claim in the correct color. Then, you should make any corrections to these underlines. Explain your reasoning behind your decision.	
Tell students that now that we're clear on how Robin and Taylor see within- and between-group variation, let's see how their claims stack up to evidence. So, we're going to do the underlining again, except this time with scientific evidence. Have each small group read through the six evidence summary statements in their student materials together. As they read, ask them to underline: - red: all information about between group variation, - blue: all information about within group variation, - purple: all information that discusses both forms of variation.	Materials: Blue, red, and purple markers
Next, the class will use an "argument line" with Taylor's claim that *individuals of the same race differ from each other genetically*. Use the Lesson 3 slide deck (which shows the Reasoning with Evidence Checklist) displayed for the class. Tell students, "Now that we have broken down the evidence into within-and between-group segments,	Attending to Norms: Prior to having students discuss their ideas, call attention again to the ideals and norms. Specifically: 1) point out ways to critique ideas rather than people. Remind students to use statements like "I disagree with *the idea* that…" rather

let's use it for real. I want each of you to decide if the evidence *supports*, *rejects*, or *neither supports or rejects* the characters' claims using the evidence we just worked with. Be ready to justify your stance with the evidence we just went through." Here are the instructional steps:

1. Tell the students they must create a line representing whether they think the evidence *supports* (left side of the room), *rejects* (right side of the room), or *does not support or reject* the claim (middle of the room).
2. Have students move to their chosen section of the line.
3. Conduct a brief review of the norms and how they can be applied during this activity (see note to the right).
4. Have students turn and talk with the person next to them why they are there. They need to explain the *evidence* and the *reasoning* connecting their evidence to their choice.
5. Tell the students that you will "cold call" on one person in each section of the line to share the reasoning connecting their evidence to their section choice.
6. You and student peers may respond, using talk moves (see note to the right) to further clarify arguments.

The first time you get to Step 6 of the above procedure, be the first to ask a question of the student you cold called on, so that you can model asking questions based on the Reasoning with Evidence Checklist (up on the slide).

Then explicitly tell students you will be stepping back, and that they should be ready to ask questions of their peers.

If they are getting stuck, just encourage them not to worry about the Checklist, and ask the questions that are on their minds. As they do, help them see the

than "I think you are wrong because…" The better option is to revoice the actual idea, rather than just the person who said it.

2) be open to changing our minds based on evidence. Remind students that when they disagree, they should ask others to say more about their thinking so they can understand better. Revoicing the idea can help ensure they were understood.

Note: Consider using the following talk moves to scaffold step five:

"So, let me see if I've got what you're saying. Are you saying…?"
"What's your evidence?"
"How did you arrive at that conclusion?"
"Who can add onto the idea that (insert student name) is building?"

Note: Use the following vignette to get an idea of the kinds of questions you can model asking, and of how to link students' own questions to the Reasoning with Evidence Checklist:

natural connections between their own authentic questions and any of the Checklist questions. Repeat this procedure for each section of the argument line (supports, rejects, does not support or reject).	A student is standing on the "rejects the claim" side of the room for Taylor's claim that *individuals of the same race differ from each other genetically.* You "cold call" on this student to explain their position on the line. The student says "I think the evidence rejects this claim because there is less variation as you go farther away from Africa. So for some races, like European or Asian ones, there isn't much difference between individuals of the same race." You respond "That's an interesting idea. We did see evidence that there is less variation as you go farther away from Africa. But, I'm thinking about Checklist question 2. It asks about cherry picking. Did we include all the relevant evidence? So I'll ask you: what about the data we saw on Evidence Card 3? Does that also back up your claim?" You give the student time to respond, and tell students that next time they should be ready with some questions.

	The idea isn't to repeat the Checklist questions verbatim, but to use them to get ideas.
Give students a moment to reflect on how they saw the ideals and norms being used well in the discussion. Then have them share these thoughts with a partner, and then call on several students to share their observations. Encourage students to name classmates who demonstrated these well if possible. i.e. "I heard (student name) do this…" Then repeat this process but for ideals or norms that could be demonstrated more. Do NOT have students name their classmates in this step.	Attending to Norms: Use this as an opportunity to point out which norms are being followed well, how following these norms benefits the discussion, and how to improve at following other norms. This gives students a chance to improve right away instead of waiting until after the discussion.
When finished, perform another argument line for Taylor's claim that *people from different racial groups don't really differ at all in their genes*.	
Ask students to record their answer to the question: What was right or wrong with the claim that *individuals of the same race differ from each other genetically, but people from different racial groups don't differ at all in their genes*?	Note: they can talk with other students to answer this question.
When finished, perform another argument line for Robin's claim that *most genetic differences must be between different races*.	
When finished, perform another argument line for Robin's claim that *the genetic differences between individuals of the same race are too small to matter*.	Note: You may need to redirect conversation if it becomes completely dominated by not knowing what Robin means by "too small to matter." Keep in mind that in the coming lessons (6-9) students will explore causation and for now we only know about how much variation there is - not whether it is the most likely cause of differences in traits.

Have students return to their seats. Hand out the student sheet entitled "*Critiquing Their Claims*." Have students quietly and independently explain in writing their argument about the extent to which Robin and Taylor's claims are correct or incorrect.	<u>Summative Assessment Opportunity</u>: this portion of the lesson is the chapter-level assessment so the students should do it quietly and independently and submit it to you before they leave. Look for students to argue that Robin's claims about between- and within-group variation are both incorrect. Look for students to argue that Taylor's claim about between-group variation is wrong but his claim about within-group variation is correct. ● When arguing that Robin or Taylor have made an incorrect claim about between group variation look for students to support this claim with any of the following evidence: o Human groups share similar sets of alleles, but they differ in the proportion of people who have each allele. o Compared to people from the same race, you find only a small amount of extra genetic differences when you compare the variable DNA of people from

	different races (5%). ● When arguing that Robin has made an incorrect claim about within group variation look for students to support this claim with the following evidence: o Most genetic differences in the human genome are found between individuals of the same ancestral group (95%). ● When arguing that Taylor has made a correct claim about within group variation look for students to support this claim with any of the following evidence: o Most genetic differences in the human genome are found between individuals of the same ancestral group (95%). ● For each claim/evidence combination look for correct or logical reasoning.
Have students read *"Robin and Taylor Discuss What They've Learned."* Have students independently write how Robin's thinking and Taylor's thinking have changed since their original claims as well as what they learned about reasoning with evidence.	

When students finish, have them briefly discuss with a partner what they wrote. Instruct them to change their answer if they hear anything from their partner that changes their thinking.	
Have students refer back to their student sheet *"Representation in STEM and the NFL"* from Lesson 1. You should also project the slide with the Completed Anchoring Phenomenon Graph. Have students once again write the pattern they observe in the graph.	
When students are done writing, re-state the pattern observed in the graph for the class. Then mention that despite all the work we've done so far, we still can't explain what *causes* this pattern.	
Frame the transition we will make in the next lesson for students: "This whole time we've been talking about genetic variation but not the effects of this variation, and whether this can explain the pattern we see with STEM and the NFL. This is what we will investigate in the next lesson." Then have students answer the final question on the student sheet *"Robin and Taylor Discuss What They've Learned."*	Note: Do ***not*** have students share what they think are the causal explanations yet. This ensures that Robin (in the next lesson) should be the first to voice (inaccurately) the idea of a causal link between the small amount of between group difference and disparities in the NFL and STEM.
Have students respond to today's lesson in their Reflection Journals. Post these questions for students to see: 1. How did this lesson make you feel? (This could be related to what you talked about with your classmates and teacher, what you read for the lesson, and/or what you did during the lesson.) 2. Is there anything related to this lesson you think students should know about or talk about? Ask students to indicate if they would prefer their thoughts stay only with the teacher or if they would be comfortable having the teacher share these thoughts anonymously with the class.	Note: Remind students of the various parts of the lesson they could reflect on - how they felt during the evidence line, their reactions to what other students said, how their thinking about Robin or Taylor's claims have changed, etc.

Teacher Reference Materials
N/A

CHAPTER 2: ***What is the best explanation (genes or environment) for observed differences between racial groups?***

Chapter 2 Big Idea

Environment is most likely a better explanation for racial disparities than genes because there is evidence that racial groups experience different environments, and when environments change, differences between races also change.

Humane Genetics Lesson Plan 6: Are genes the only thing that can cause variation in complex human traits?

Lesson Question: Are genes the only thing that can cause variation in complex human traits?
Big Idea: An accurate causal model of human trait variation shows that the environment has a large effect, genetic factors a small effect, and unknown factors a moderate to large effect on human trait variation *within a group*.
Overview: Chapter 1 explored the flaws in Robin's and Taylor's understandings of genetic *variation* by examining evidence that shows how much races actually differ genetically. Chapter 2 will explore the flaws in Robin's and Taylor's understandings of genetic *causation*. Thus, Lesson 6 introduces a new debate or disagreement between the characters regarding the causal role of nature (genes) versus nurture (environment) in the shaping of human intelligence and athletic ability, even just within a group. Lesson 6 is designed to move students from a simple model of genetic causation, such as a single gene model, to a more complex polygenic model, where many more genes (typically hundreds or thousands) each have a much smaller influence on human traits. To accomplish this goal, students are introduced to evidence cards that report on actual scientific studies of complex traits like skin color, IQ test scores, and educational attainment. Students are then asked to evaluate whether a single gene model can explain these three traits. Information in the evidence cards suggest that this model is too simple. Once students have realized that a single gene model is inappropriate, they are asked to revise this model and develop a new one to explain all three of these complex traits. The goal for students is to create the simplest possible model that does the best job of explaining all of the data in the evidence cards. Students engage in a gallery tour to facilitate the model revision and development process. At the end of this lesson, students will have constructed an understanding of polygenic causation. Then, this process is repeated, and the polygenic model will be further critiqued and revised with new evidence cards that help students to develop a multifactorial model including

polygenic factors and environmental factors. The ideas developed in this lesson are then integrated into Lesson 7, where students will shift from examining Robin and Taylor's within-group claims about causation, to their between-group claims about causation. In Lesson 7, students will learn how evidence of important differences in environment between racial groups strongly suggests that the environment likely causes any differences we observe between groups.

Objectives

- Construct understanding of a polygenic model of inheritance by using evidence from scientific studies exploring the polygenic basis of intelligence, skin color, and educational attainment to critique and then revise a Mendelian model of causation for complex human traits.
- Construct their understanding of a multifactorial model of inheritance by using evidence from scientific studies exploring the genetic and environmental causes of complex traits to further critique and revise their model of causation for complex human traits.

 *Approximately three 45-minute class periods*

NGSS Alignment

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.	**LS3.B: Variation of Traits** Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus, the variation and distribution of traits observed depends on both genetic and environmental factors.	**Cause and effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Key Terms

ancestry
between-group variation
DNA
environment
ethnicity
genes
genome
ideals
malleable
multifactorial
norms
polygenic
race
shared within-group variation
trait
within-group variation

Preparation

- Have the Classroom Norms chart posted somewhere where all students can easily see it.

Materials

MATERIALS	QTY
Colored Pencils	1 set / table
Butcher Paper	1 sheet / table
Markers	1 set / table

Click here for Lesson 6 Slide Deck
https://docs.google.com/presentation/d/1t9FLy9RvAEXRqx3BxrQ8yiBmaFwNPeyU1niPe39Jbuo/edit?usp=drive_link

Procedure

TASK	NOTES & MATERIALS
Remind students that we still can't explain the pattern we noticed in our anchoring phenomenon because we don't yet know what *causes* this difference.	
Hand out student sheet entitled *"Robin and Taylor's Disagreement Part 3."* Read this out loud as a class. As the reading occurs you can ask students to underline statements where a character is talking about genetic *variation* and to circle statements where they are talking about genetic *causation*. You may note for the class that both Robin and Taylor talk about "intelligence" and "athleticism" as if the first is the only thing you need for a STEM career and the second is the only thing you need for an NFL career. You might invite a few students to share reasons those ideas are not true. Point out that while it is certainly not the whole, nuanced picture, it's a way to simplify the argument, especially when it comes to determining if genes have anything to do with it.	Note: You can use this activity as an assessment if you also ask students to underline statements about between- and within-group variation in different colors.
Ask the class to look at the statements they underlined. Then, turn and talk with a neighbor and discuss the following questions: ● To what extent do Taylor and Robin agree or disagree about how much humans differ	Note: Research suggests that White people in US society rely upon a combination of factors to explain complex traits, such as free-will, the environment, and

genetically? What evidence do you have to support your claim? Ask the class to look at the statements they circled. Then, engage them in a think-pair-share for the following questions: ● To what extent do Taylor and Robin agree or disagree about what causes humans to differ? What evidence do you have to support your claim?	genes. These studies have also found that only 1/5th of adults rely exclusively on genes alone to explain traits. However, research also suggests that White people are more likely to use genes to explain the traits they associate with Black people than the traits they associate with White people. Use this opportunity to circulate around the room to understand how your students think about the genetic causes of complex human traits. For more on the research, see: ● Jayaratne, T. E., Gelman, S. A., Feldbaum, M., Sheldon, J. P., Petty, E. M., & Kardia, S. L. R. (2009). The perennial debate: Nature, nurture, or choice? Black and White Americans' explanations for individual differences. Review of General Psychology, 13(1), 24–33. ● Morning, A., Brückner, H., & Nelson, A. (2019). Socially Desirable Reporting and the Expression of Biological Concepts of Race. Du Bois Review: Social Science Research on Race, 1–17.
In small table groups, have the students discuss whether they agree or disagree with the new claims made by Taylor and Robin and why. While this is occurring, write the focus question on the front board: ● Are genes the only thing that can cause variation in complex human traits? Tell the students that the purpose of the lesson is to answer this question. Robin and Taylor noted that there is more genetic variation within groups than between them, so we are first going to explore the answer to this question *within* a group - that is, what causes complex trait variation between individuals within a group? To determine which claim is more accurate, we need to look at how strong of an influence genetic and environmental factors have on complex human traits like academic ability and athletic ability.	
Then, in small groups, have students brainstorm what comes to mind when they think of genetics or Gregor Mendel. Have groups pick a spokesperson to briefly share out to the rest of the class.	
Hand out the student sheet entitled *"Mendel's Simple Model."* Have students read independently until they reach the first question on the student sheet.	

When you get to the section that asks the students, "What are some traits that you have learned about that you think are well explained by Mendel's Simple Model?", have the students discuss in small groups, and then lead a whole class brainstorm. At the end of the brainstorm, tell the kids that the vast majority of human traits are not explained well by Mendel's simple model. Tell students: Because Mendel's simple model does not explain most human traits very well, we will review some more evidence, critique, and then revise this model.	Note: There is a common misconception that some observable human traits are determined by a single gene when they are actually not. For example, eye color, widow's peak, hitchhiker's thumb, and the ability to roll one's tongue are actually influenced by multiple genes, the environment, and/or the interaction between the two. For further info, see this website.
Hand out the *"Procedure for Evaluating Evidence about the Genetic Causes of Traits."* Have each small group read through the instructions on their own. Then, you will need to briefly summarize the instructions/procedure in your own words.	
Instructional Steps for Model Revision	
Step 1: Create Expert Groups. Have students count off by three. Have all of the ones meet at one table, the twos at another table, and the threes at another table. You will probably need two tables for each group.	
Tell each group that they will become experts on the information in their card and they will need to be able to teach other students about the information in their card once they are mixed with students from other groups. Have the students who were "ones" read the first evidence card. Have the students who were "twos" read the second evidence card. Have the students who were "threes" read the third evidence card. Expert groups should be prepared to discuss: 1. What the trait on their card is 2. Whether one or many genes influence it 3. How much of the differences between people can be attributed to genes	

<table>
<tr><td>4. What other factors might influence the trait</td><td></td></tr>
<tr><td>Ask the students at each table to evaluate whether Mendel's simple model can fully explain the data in their evidence card (project or draw this model on the front board). Have all of the students in each group write down their answers to this question in the appropriate box.</td><td rowspan="2">Formative Assessment Opportunity: Circle around to the groups and probe their thinking about what could be added to each model. Ask the students to explain the specific information in each card that is addressed by each change they make to the model.</td></tr>
<tr><td>Ask the expert groups to write down what could be changed or added to Mendel's simple model to make it better explain their specific evidence card.</td></tr>
<tr><td>Step 2: Create Jigsaw groups. Have students meet in triads that include students from all three groups.</td><td>Materials: Put butcher paper out at each table.</td></tr>
<tr><td>Use the listening triads routine to scaffold how students share their expert knowledge. One person is the talker, the next is the questioner, and the third is the notetaker.

The talker shares their expert knowledge about their evidence card. They should explain to their group:
1. What the trait on their card is
2. Whether one or many genes influence it
3. How much of the differences between people can be attributed to genes
4. What other factors might influence the trait

The questioner should raise questions about what the talker is saying.

On a piece of butcher paper at each jigsaw group, the notetaker should record what the talker said and what the questioner asked.

Have students rotate through each role as they share their expert knowledge for each evidence card. The first person who shares their knowledge is the first talker. Then, they become the questioner for the second evidence card and the notetaker for the third card.</td><td>Formative Assessment Opportunity: Circulate around the room and ask groups the following questions:

● What common causal factors influence each of these traits?
● What changes are you planning to make to Mendel's model?
● How do these changes make your model better?</td></tr>
</table>

Project the student sheet *"Model Revision"* on the front board and hand out the student sheet "*Options for Changing the Model*." As groups finish, go around the room and show them how they can revise their model by talking through the options on this sheet.	
Tell each group to come up with a consensus model that explains the data in all three evidence cards. Ask them to draw it on the butcher paper at their table and justify, in writing, how this model does a better job of explaining all three traits than Mendel's model. Point to the model revision student materials on the front board to show students how this task should be recorded on the butcher paper.	Note: As students are building consensus models, you can mediate group disagreements by pointing out which Reasoning with Evidence Checklist question the disagreement is about. For example, if two students disagree about the size of the arrow from genes to trait relative to the arrow from other unknown causes to trait, point out that they are disagreeing about evidence interpretation (checklist question 1). Or, if students are disagreeing about the number of boxes or ovals that should be included, point out that they are disagreeing over checklist question 3. They need to determine if **all** of the available evidence supports including every single one of the boxes or ovals. Attending to Norms: Remind students to refer to the posted Classroom Norms chart. In particular, any norms under the ideal of "we critique ideas, not people" will be important during these conversations.
Tell each group to come up with a consensus model that explains the data in all three evidence cards. Ask them to draw it on the butcher paper at their table and justify, in writing, how this model does a	

better job of explaining all three traits than Mendel's model. Point to the model revision student materials on the front board to show students how this task should be recorded on the butcher paper.	
Step 3: Perform the gallery tour critique. Hand out the *"Gallery Tour Critique"* student sheet. Have students rotate between tables in their jigsaw groups to look at each model. Ask them to choose at least **three** out of the other groups' models to evaluate, using the data table on *"Gallery Tour Critique."*	
Have students return to their jigsaw group seats and ask them to arrive at a decision about which model was the best and why. Have each expert group pick a spokesperson to summarize their justification of the best model.	
Step 4: Create the class consensus model. Ask the spokespeople to come to the front of the room. Tell them their task is to come up with a model that they all agree upon. Have the students who are still sitting use this time to consider any changes they might want to make to revise their group-specific model based on what they saw during the gallery tour.	
Have one of the spokespeople present the model and their justification for it.	
Have a discussion with the class about what they might want to change about it. If a student suggests a change then press them for their reasoning and ask other students if they agree or disagree with this choice.	Formative Assessment Opportunity: Use this time to address any misconceptions students have about the model.
Once done, have students draw the consensus model in the appropriate location on the gallery tour critique student sheet. Let students know that next we will consider our updated model, and see if it holds up to another round of gathering new evidence.	

Hand out the student sheet entitled *"The Polygenic Model."* You will have them repeat the instructional process for model revision again – this time, revising the polygenic model. (Note: there are 2 evidence cards instead of 3 for this round of revision, so count students off by twos to begin). Then give students time to work through the rest of the evidence cards and repeat the model critiquing process.	
Have students read the student sheet entitled *"A Multifactorial Model"* in their small groups. Then, ask the students a question to probe their understanding of what the size of the arrows suggests about the relative causal influence of genes or the environment with regards to complex traits. For example: ● Does the multifactorial model in front of you suggest that genes or the environment have a bigger impact on complex traits? What makes you say that?	<u>Formative Assessment Opportunity</u>: Use this time to address any misconceptions students have about the model. If the consensus model differs from the multifactorial model provided in the student materials, guide students to understand where the errors in the class model are and how to fix them.
Have a discussion with the class about what they might want to change about it. If a student suggests a change then press them for their reasoning and ask other students if they agree or disagree with this choice.	
Hand out the student materials entitled *"Critiquing Robin and Taylor's Claims*." Tell the students to look over the evidence they have learned over the last few days, which is written on this sheet, and use it to critique both of the character's claims. Have the students write down their critiques of Robin and Taylor's claims in the appropriate location. This is the embedded formative assessment of the lesson.	<u>Formative Assessment Opportunity</u>: This final task allows you to assess students' ability to use evidence to critique inaccurate claims.

End class with this wondering: “We chose to focus on within-group differences first – and we saw these big arrows for ‘environment' and ‘unknown causes’ in our models. So we can see that, at least within a group, the environment and other unknown factors often matter more than genes. Typically genes have a small association with complex traits. But what about between groups? We already know genetic differences are small. But we don't know if environmental differences between racial groups are small or large. If the environments of Black and White people are really different in the United States, then this would mean it’s likely that the environment is causing disparities instead of genes. So, in our next lesson, we will examine the environments of racial groups in more detail.” Tell them this will be the focus of the next class period.	
Have students respond to today’s lesson in their Reflection Journals. Post these questions for students to see: 1. How did this lesson make you feel? (This could be related to what you talked about with your classmates and teacher, what you read for the lesson, and/or what you did during the lesson.) 2. Is there anything related to this lesson you think students should know about or talk about? 3. How well did you and your classmates use the classroom norms? Provide some examples? Ask students to indicate if they would prefer their thoughts stay only with the teacher or if they would be comfortable having the teacher share these thoughts anonymously with the class.	

Teacher Reference Materials

N/A

Humane Genetics Lesson Plan 7: How does the environment differ between races?

Lesson Question: How does the environment differ between races?
Big Idea: The ideal experiment for determining causation of differences in traits *between racial groups* cannot be ethically done in humans, but we do have evidence that environments differ between races in the US. When environments are more equal, disparities between racial groups are smaller.
Epistemic Idea: In addition to our existing Reasoning with Evidence Checklist items, we can also evaluate reasoning about evidence based on whether the claims stick to what is supported by the evidence, or if they extend beyond it ("overextending").
Overview: While Lesson 6 provided evidence that the environment has a bigger effect on complex human traits than genetics *within a group*, Lesson 7 provides evidence that the environment does in fact (historically and currently) differ in significant ways *between* Americans of different racial groups. After a brief refresher on the U.S. historical context, students make sense of evidence cards that provide evidence of environmental differences, as well as evidence that disparities can change if environments change. Finally, students are introduced to a new Checklist item that deals with claims that are too big and general for the evidence available to support them, and they practice applying it to new arguments from Robin and Taylor. Looking ahead, in Lesson 8 the evidence from this lesson will become part of students' final explanatory models explaining the Anchoring Phenomenon for the whole unit. Students will also draw on it in their final application task in Lesson 9, in which they are tasked with refuting an argument based in racial essentialism.
Objectives ● Use evidence to construct an understanding of multiple ways that average environments differ between Black and White Americans, and that when differences in environment are reduced, racial disparities also reduce. ● Construct and apply understanding of a new Reasoning with Evidence Checklist item: ○ Overextending
Approximately three 45-minute class periods

NGSS Alignment

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts

Analyzing and interpreting data Evaluate the impact of new data on a working explanation and/or model of a proposed process or system. **Engaging in argument from evidence** Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions.	**LS3.B: Variation of Traits** Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus, the variation and distribution of traits observed depends on both genetic and environmental factors.	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Key Terms

ancestry
between-group variation
bias
common garden experiment
DNA
environment
ethnicity
genes
genome
ideals
malleable
multifactorial
norms
polygenic
private alleles
race
redlining
segregation
shared within-group variation
trait
within-group variation

Preparation

- Have the Classroom Norms chart posted somewhere where all students can easily see it.

Materials

MATERIALS	QTY
Colored Pencils	1 set / table
Butcher Paper	1 sheet / table
Markers	1 set / table
Chart Paper with Classroom Consensus Model (displayed)	1 / class

Click here for Lesson 7 Slide Deck
https://docs.google.com/presentation/d/15T-XobLIVm8pWY9BnMAZw3HrIGVuCFPju1OYyH4TfXg/edit?usp=drive_link

Procedure

TASK	NOTES & MATERIALS
Remind the class that last time we met, we built models of what causes complex human traits *within a group*. Ask a volunteer or two to voice what they learned from this.	Listen for student responses similar to: - Many genes had some small effect. - But the environment and unknown causes had some pretty big arrows!
Tell students that, given this, it seems like we need to investigate the environment as much as we did genes to get a better idea of what's causing racial differences in STEM and the NFL. We saw that there are only small differences in genes between groups, but are there big or small differences in environment between groups? Post the following question on the board: - How does the environment differ between races?	
Walk through the first set of Lesson 7 slides using the speaker notes to facilitate a discussion about humans, our environments, and possible impacts on traits. Stop when you get to the slide with Robin and Taylor.	
Hand out Robin and Taylor's Disagreement Part 4 (student materials). Display the slide with the instructions. Have students work in pairs to read the dialogue, underline and highlight it according to the instructions, and discuss the questions below.	
Continue walking through the Lesson 7 slides, using the speaker notes to facilitate a discussion about the kinds of evidence we could expect to see if Taylor was right, or if Robin was right.	

Hand out the student sheet entitled *"Analysis Table,"* found in the Student Materials. Then, place one set of the three Lesson 7 evidence cards (found in the Student Materials for Lesson 7) at each table. As the student groups read each card, ask them to discuss each of the questions in the Analysis Table, and work together to decide how it should be answered. Ask them to then individually record their ideas, based on the group discussion, in their own copy of the Analysis Table. Circulate around the groups to see how students are doing. Use the key included below in this teacher guide (you may want to make some extra copies) to help any students who need support with additional examples.	<u>Attending to Norms:</u> Draw students' attention to the class norms chart again. Let them know that these evidence cards will present information about differences in environment that people are currently experiencing and that differ by race. They may relate to personal experiences that you and/or your classmates have had. Be especially attentive to the norms during these discussions to ensure all group members feel respected and supported. <u>Note</u>: The word "segregation" shows up in these evidence cards. Sometimes it refers to the era of segregation (*de jure* segregation) and sometimes it refers to modern segregation that is not sanctioned by law but occurs nonetheless (*de facto* segregation). Students don't need to know the terms *de jure* and *de facto*, but if they seem confused as to why housing segregation is present today when segregation is no longer legal, help them understand that segregation/separation of people by race can still happen even if it is not designed by law (although it can be designed through other means).

Display the slide that shows what the evidence would look like if it supported Taylor's claim. Use the speaker notes to summarize how the data we saw better supports this claim than Robin's claim.	
Display the slide "What would a fair scientific test of Robin's and Taylor's claims look like?" and use the speaker notes (linked in the "Teacher Reference Materials" at the end of this lesson) to walk students through this question by first starting with the ideal experiment - the common garden experiment. This lecture will then walk through what it would take to set up a similar experiment in humans - which would be unethical and impossible. Emphasize the following conclusions: ● Genes can only explain small differences in traits within a group (if all individuals within this group have the same environment) ● The environment can explain the average difference in traits between groups (and within a group if environments are unequal)	
Share with students: So we know that the perfect experiment – the common garden experiment – is impossible to do, so we'll never have the ideal evidence to fully distinguish the effect of genes from the effect of the environment in humans. So our data are *limited*. When we have limited data though, sometimes people still want to come to very big conclusions. We might come to bigger or broader conclusions that aren't *directly* supported by the evidence we have.	
Project the slides that start with "Overextending." Use the speaker notes to walk through them with the class. Highlight how really big, broad, generalized conclusions need a lot of evidence to support them,	<u>Note</u>: It's important for students to know that making predictions is not a bad thing! It's a key aspect of scientific thinking. However, they need

while smaller, more limited claims are a better match for more limited data. Highlight the difference between a *prediction* and a *conclusion*.	to be clearly labeled as predictions, *not* conclusions.
Project the slide with the updated Reasoning with Evidence Checklist. Then remind students: So, we were wondering what Robin and Taylor thought when they saw the same evidence. Keeping this idea of "overextending" in mind, let's take a look!	
Hand out the student sheet *"Robin and Taylor's Disagreement: Part 5."* Tell students that Robin and Taylor read the same Lesson 7 evidence cards that you just read. Let's see how they reacted! Have student volunteers read aloud (one for Robin, one for Taylor).	
Tell students that it's possible Robin and/or Taylor overextended – let's apply our new Checklist question and see. Advance to the first slide with Robin's argument on it. Use the speaker notes to model for students how you would identify Robin's first overextension. Use the speaker notes to model describing the kind of data Robin would need in order to back up this claim. Use the speaker notes to model how Robin could reduce the size of his claim, and/or relabel it as a prediction.	

Point out the next overextension that Robin makes. Have students form pairs, and then count off by twos. Pairs in the ones should think of data that could support the overextension. Pairs in the twos should think of ways to reduce the claim. Have a few pairs from the ones share out. Have a few pairs from the twos share out. Use the speaker notes to summarize the kind of data Robin would need to support this claim, and how Robin could reduce the size of his claim.	Formative Assessment Opportunity: Use the summary in the speaker notes to see how much students are picking up on the ways to correct overextensions, and how they would impact the strength of the character's arguments. Call on pairs to share (and press them to explain their thinking) until you see some strong connections with the takeaways you will summarize.
Then briefly point out Robin's third overextension. Give students a minute to turn and talk about why this is an overextension. Ask for a volunteer to explain their thinking. Use the speaker notes to summarize the kind of data Robin would need to support this claim, and how Robin could reduce the size of his claim.	
Have pairs quietly re-read Taylor's argument and see if they can find any overextensions. Have a few pairs share out - the class should identify the last sentence, as shown in the slides. Pairs in the ones should think of data that could support the overextension. Pairs in the twos should think of ways to reduce the claim.	Formative Assessment Opportunity: Use the summary in the speaker notes to see how much students are picking up on the ways to correct overextensions, and how they would impact the strength of the character's arguments. Call on pairs to share (and press them to explain their thinking) until you see some strong

Have a few pairs from the ones share out. Have a few pairs from the twos share out. Summarize that Taylor is making a prediction, but hasn't seen any evidence to support that *all* hiring discrimination would end, *nor* that it could happen within two years. Therefore, if he is reasoning with evidence well, he shouldn't state it like a conclusion.	connections with the takeaways you will summarize.
Point out that finding more data isn't always possible (even if we can describe what it would need to look like) – recall, for example, that the common garden experiment is impossible and unethical to do in humans. So any conclusions we draw about how much a human trait is explained by genes vs the environment will *always* have to be relatively small and limited (rather than big and generalized).	
Hand out the student sheet *"Robin and Taylor Reflect on What They've Learned."* Ask for student volunteers to read it aloud, one voicing Taylor and another Robin. Facilitate a brief whole-class discuss with these reflection questions: - What did Robin and Taylor learn about how to avoid overextensions? - How did they practice the ideal of *changing our minds based on new evidence (even when it's uncomfortable)?*	<u>Attending to Norms</u>: In particular, if your class has a norm similar to "If we change our mind, we share this with others, and why" ask students for examples of how Robin and/or Taylor practiced this norm.
As the lesson closes, have student volunteers summarize what we learned from the modeling in Lesson 6 and the evidence cards in Lesson 7 about the influence the environment is having on complex human traits.	

Use student contributions to arrive at the following summary: *The environment differs in substantial ways between races and disparities can change when the environment changes. So, what conclusion are we ready to draw about the causes of differences in who is in the NFL, and who is in STEM?*	
Have students respond to today's lesson in their Reflection Journals. Post these questions for students to see: 1. How did this lesson make you feel? (This could be related to what you talked about with your classmates and teacher, what you read for the lesson, and/or what you did during the lesson.) 2. Is there anything related to this lesson you think students should know about or talk about? Ask students to indicate if they would prefer their thoughts stay only with the teacher or if they would be comfortable having the teacher share these thoughts anonymously with the class.	Journaling Note: remind students that they are **not** graded on their answers (ideally, not graded at all for this) and that the feedback will not be shared with other students unless the student wants it to be shared.

Teacher Reference Materials

Lesson 7 - Speaker Notes for the Common Garden Experiment Slide Lecture
https://docs.google.com/document/d/1c2pXwaCDM712mWGpi5JHwgzJqPHsiM3QCTpb33_LQ7o/edit?tab=t.0

Humane Genetics Lesson Plan 8: Are Genetic Differences Between Races or Environmental Differences Between Races a Better Explanation for Racial Differences in the NFL or STEM (genes or environment)?

Lesson Question: Are Genetic Differences Between Races or Environmental Differences Between Races a Better Explanation for Racial Differences in the NFL or STEM (genes or environment)?
Big Idea: Genes can be a cause of variation within a group if all group members experience the same environment. But, because different races experience different environments, and because racial disparities change across environments, we should be skeptical of anyone who claims that racial disparities boil down to genes alone.
Overview: This lesson requires students to integrate their knowledge from Chapters 1 and 2. Students will have the chance to construct a model of their own explanation for the Anchoring Phenomenon of racial disparities in STEM and the NFL. They will begin individually, then work with a small group, and finally work towards a whole class final consensus model.
Objectives • Synthesize and demonstrate understanding from across the unit to develop models will reflect that genes are a better explanation for variation within racial groups than they are for variation between racial groups and that the environment is likely a better explanation than genetics for variation within and between groups.
 *Approximately three 45-minute class periods*

NGSS Alignment

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts

Developing and using models Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. **Engaging in argument from evidence** Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.	**LS3.B: Variation of Traits** Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus, the variation and distribution of traits observed depends on both genetic and environmental factors.	**Cause and effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Key Terms

ancestry
between-group variation
bias
common garden experiment
DNA
environment
ethnicity
genes
genome
ideals
malleable
multifactorial
norms
polygenic
private alleles
race
redlining
segregation
shared within-group variation
trait
within-group variation

Preparation

- Have the Classroom Norms chart posted somewhere where all students can easily see it.

Materials

MATERIALS	QTY
Butcher Paper	Class Set
Markers	Class Set

Click here for Lesson 8 Slide Deck
https://docs.google.com/presentation/d/1gs2hldrbUol4oFByD8jTSkK4csO66q1wU_XDx1L9mFc/edit?usp=sharing

Procedure

TASK	NOTES & MATERIALS
Remind students that we recently saw how environments differ on average between races, and that disparities between groups in society are reduced when the environments between those groups become more equal. We also learned at the beginning of this unit about the very large amount of genetic difference within and incredibly small amount of genetic difference between different racial groups. Ask the class: *Are we finally ready to answer our opening question about representation in the NFL and STEM?*	Note: Giving students an example from the last set of Evidence Cards could help refresh them about how environments can differ. A good example would be highlighting how standardized test score gaps between Black students and White students shrank when there was less disparity in social and economic environmental factors. You could also project the visual from your chosen card for students to see.
Have students get out their *"Representation in STEM and the NFL"* student sheet from Lesson 1. (You might also consider projecting the Anchoring Phenomenon Completed Graph for students to see.) They should individually review what they wrote for the explanation for the pattern in the graph. Then with an elbow partner, they should take turns describing what new information we now have that could help us explain the phenomenon.	Materials: Re-hand out each students' completed *"Representation in STEM and the NFL"* sheets from Lesson 1.
Tell students that the goal of today's lesson is to create models that will finally help us explain the anchoring phenomenon from Lesson 1. Hand out the student sheet entitled *"Making Your Final Models"* (in the student materials).	Materials: ● the data table from Lesson 3 about genetic variation ● the models created in Lesson 6 about multifactorial inheritance ● the data table from Lesson 7 about differing environments

	• You should also have the evidence cards from these three lessons available in case students want to refer to them for more information. Note: If you collected these resources at the end of previous lessons, have them in piles ready to hand out to students.
Tell students they will use everything they have learned over the course of this unit to make a set of three final models. First, students should work individually to draw their own ideas for the three models.	Formative Assessment Opportunity: Circulate while students are creating their models. Listen for any inaccurate statements and intervene to suggest specific pieces of evidence that you think students have overlooked. Press students to explain which evidence card(s) back up the way they are drawing their models.
Next, students will work in small groups to draw their models large on butcher paper. Project the Checking Models slide to help students with deciding how to make their group drawing.	Materials: 1 large piece of butcher paper per small group Markers Attending to Norms: Remind students of the norms the class constructed (especially any norms related to the ideal of critiquing ideas, not people) as appropriate.
Perform a Gallery Tour and have students complete the *"Picking the Best Model"* part of their student sheets.	
Organize students into 3 large groups.	Materials: Whiteboard, chalk board, or butcher paper/chart paper

Have them work together to draw a new ***consensus*** model on chart paper or butcher paper. Instruct students to provide evidence from previous lessons for each element of the model.	Markers Formative Assessment Opportunity: This is another opportunity to see if the students have the correct conceptions of genes, environment, and other possible influences on career outcome, as well as the degree of magnitude of each.
Once all 3 groups have completed their consensus models, ask them to briefly present them to the class. (The groups that don't go first can just point to any differences in their model to the first one). Ask students if anyone disagrees with any part of the model. If students answer yes, ask them to justify. Do this a few times at most. When you're satisfied consensus is reached, have students copy down their final consensus model into the box on the student sheet.	Formative Assessment Opportunity: Observe the Ideal Consensus Model in the teacher materials below. Circulate to monitor student progress relative to this ideal model. Specifically, observe the final trait students are choosing for their models. If students are choosing "intelligence" or "athleticism" for their models, question if this ultimately helps explain the anchoring phenomenon. Guide them toward an understanding of why "Career Outcome" is probably a better final trait for their model because it is the ultimate outcome - athleticism and intelligence are only proximal factors.
Project Robin and Taylor's models (slide 2) of between-group variation. Remind students that while their models show within- *and* between-group variation, they should only compare Robin's and Taylor's to their between-group models. With a partner, have students discuss how they would rank Robin's, Taylor's, and the consensus models from most accurate to least accurate. They should justify why they ranked them this way.	Note: Student groups should be able to come to a decision and justification fairly quickly by this point; there is no need for the justification to be fully complete as long as it's clear they can articulate some key reasons that Robin's and Taylor's models are less accurate, and that Robin's is more inaccurate than Taylor's.

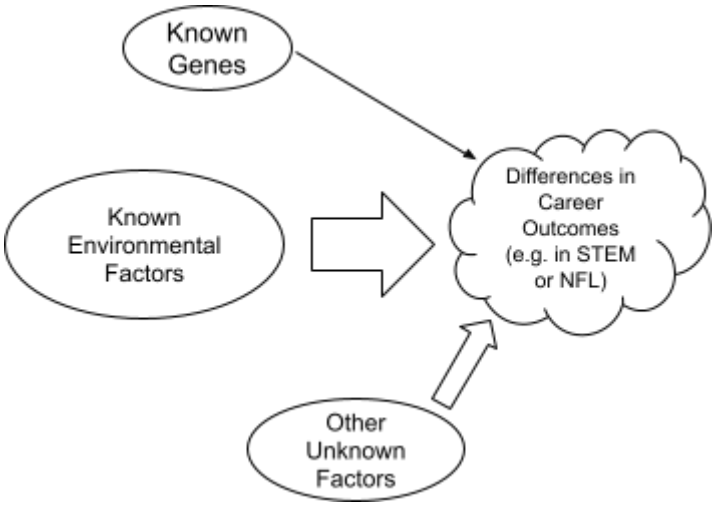
When students finish, call on a group to state their ranking and provide justification. Call on another group to describe whether they agree or disagree with the first group's justification. Repeat for another group or two if needed until the class has agreed on a ranking and justification.	
Poll the class about which models they ranked as most accurate. Call on several students to explain an element of the most accurate model that makes it more accurate than the other two.	Formative Assessment Opportunity: Use this poll to assess student comprehension. If the class as a whole has not identified the consensus model as the most accurate model, guide them to that understanding.
Hand out the student sheet entitled, *"Robin and Taylor Realize They Now Agree."* Have students read it quietly and independently. Have students underline anything in the reading that **connects** to the models they have made. Have students circle anything that **extends** their thinking about their model. Have students put a question mark next to anything that **challenges** something about the models they have created.	
Have students respond to today's lesson in their Reflection Journals. Post these questions for students to see: 1. How did this lesson make you feel? (This could be related to what you talked about with your classmates and teacher, what you read for the lesson, and/or what you did during the lesson.) 2. Is there anything related to this lesson you think students should know about or talk about? Ask students to indicate if they would prefer their thoughts stay only with the teacher or if they would be comfortable having the teacher share these thoughts anonymously with the class.	

Teacher Reference Materials

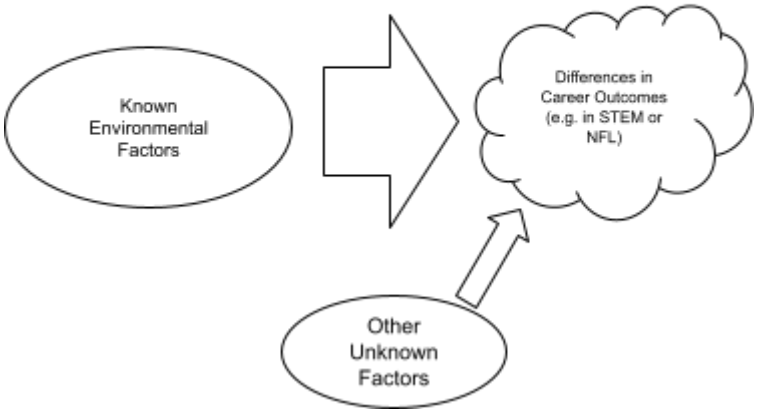
Ideal Consensus Models

For teacher reference only – do not share with students.

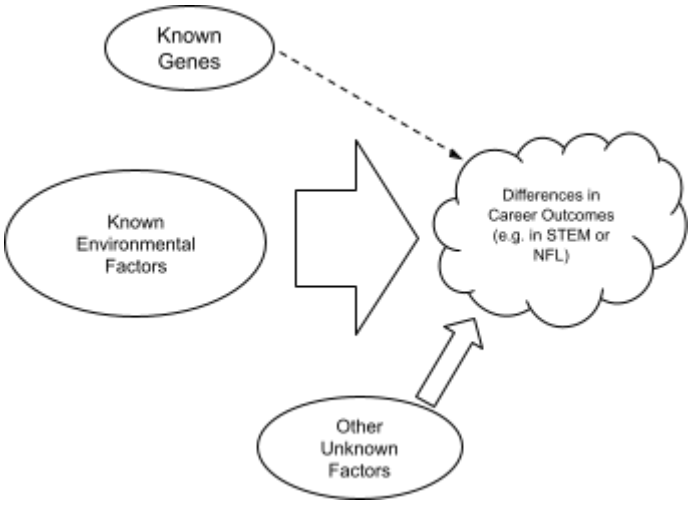
Within-group models for Black or White should look close to the following:



Between-group models should look close to the following:



Note that students may at first suggest a *less accurate* model that includes a dotted line from known genes to career differences similar to the following:



But if you press them for evidence, students should be able to build consensus around the idea that even though there is some evidence that genes may play a small role *within* groups, there is **no** evidence that they do *between* groups. Therefore, there are no **known** genes that could influence differences in career outcomes. If students bring up that we can't do the common garden experiment on people, and therefore can't completely rule out that some as-yet-to-be-discovered gene(s) could play a role, you can note that this could be a small part of the "other unknown factors" element of the model. So not including any arrow for "known genes" is the most defensible option.

Final Model Scoring Guide

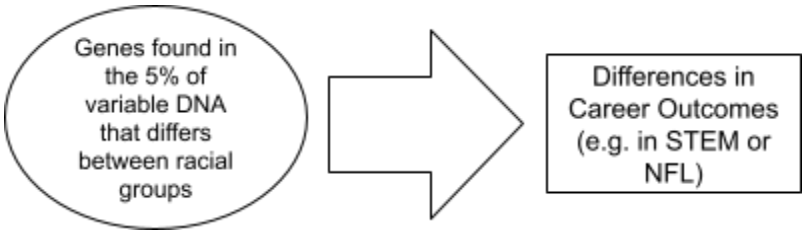
Look for the following in student responses.

- All three models should show career outcome as a malleable trait.
- All three models should include large arrows for both Environmental factors and other unknown factors.
- For both within-group models, genes should be present, but only as a very thin arrow.
- Students may vary in how they represent the environment for White within-group compared to Black within-group. For example, they may include Racism as a separate component, or part of Environment for Black only. This is ok, however, you may want to probe students' understanding and press them to think about how racism could potentially affect and often advantage White individuals.
- For the between-group models, some students may include a tentative dotted line for genes, and others may not include genes at all. Either could be argued for, so pay attention to how students justify their models (there are no evidence cards that show a definite role for genes in between-group differences).
- No students should include any solid arrow for genes at all in their between-group

model.

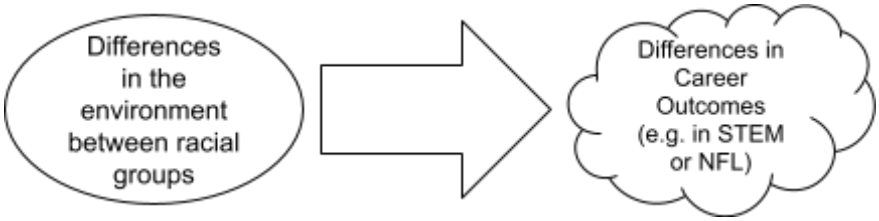
Robin's Model

Between Group



Taylor's Model

Between Group



Humane Genetics Lesson Plan 9: How can we use what we know to critique misinformation about racial disparities?

Lesson Question: How can we use what we know to critique misinformation about racial disparities?
Big Idea: Misinformation about racial disparities can be refuted with scientific evidence.
Epistemic Idea: We can use our Reasoning with Evidence Checklist to critique arguments and point out where there may be reasoning errors.
Overview: In this final application task, students encounter an opinion post that refers to published studies discussed in a popular science article. The person argues that "disparities (in intelligence) between racial groups are inherent and genetic; there is no point in implementing policies to try to reduce this disparity." Students use their knowledge from the entire unit, including their Reasoning with Evidence Checklist, to critique this flawed argument and write a counter-argument.
Objectives • Use evidence from throughout the unit to critique a racial essentialist argument and write a counter-argument. • Use and apply our Reasoning with Evidence Checklist questions to critique arguments and point out where there may be reasoning errors.
 *Approximately two 45-minute class periods*

NGSS Alignment

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing explanations Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. **Engaging in argument from evidence** Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions. Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.	**LS3.B: Variation of Traits** Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus, the variation and distribution of traits observed depends on both genetic and environmental factors.	**Patterns** Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. **Cause and effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Key Terms

ancestry
between-group variation
bias
common garden experiment
DNA
environment
ethnicity
genes
genome
ideals
malleable
multifactorial
norms
polygenic
private alleles
race
redlining
segregation
shared within-group variation
trait
within-group variation

Preparation

- Have the Classroom Norms chart posted somewhere where all students can easily see it.

Materials

MATERIALS	QTY
All Evidence Cards (located at the end of this document)	1 set per pair of students
Orange highlighter	1 per student
Blue highlighter	1 per student
Green highlighter	1 per student

Click here for Lesson 9 Slide Deck
https://docs.google.com/presentation/d/17SCCl3IYqW5b2D22HT3VsX7Q9Nijbk_L3ulzLl_BBc0/edit?usp=sharing

Procedure

TASK	NOTES & MATERIALS
Have students recall that Robin and Taylor just learned that the environment is a better explanation than genetics for disparities we see between racial groups. However, not everyone knows this information. Hand out "*Robin and Taylor Apply What They've Learned"* and have students read it in pairs.	Note: Robin and Taylor note the existence of "racist policies" in their conversation. If students question what this means or refers to, remind them that they've seen examples in the last set of evidence cards, e.g. segregation. You may want to explain that regardless of intent or belief of the policy creator, policies are racist if they perpetuate racism and racial inequalities.
Share that now we will have an opportunity to see how well we can use what we've learned to critique inaccurate claims about race and genetics. Note that Taylor says "people use their understanding - or misunderstanding - of science to make a lot of decisions."	Attending to Equity: Pay attention to student emotional states throughout this lesson. Even now that they should have the knowledge to combat them, encountering negative stereotypes (however inaccurate) has the potential to bring up strong feelings in students. Engage students as necessary to help them feel safe, process what they are feeling, and take a break as necessary.
Hand out a copy of the Lesson 9 student materials to each student. You may choose to project the process slide with the instructions for the whole activity.	Materials: - All Evidence Cards (located at the end of this document) - 3 colors of highlighters (orange, blue, and green are suggested in the student materials, but other colors

Hand out a full set of all the evidence cards from this unit (Lessons 3, 6, and 7) and an orange, blue, and green highlighter to each table pair.	may be used). Underlining with markers or colored pencils would also work.
Before getting into the activity, let students know that if they encounter people making harmful and inaccurate claims in their own lives that they may feel motivated to respond. Tell them they need to be very careful as they consider if this is something they feel comfortable doing or not. Have a brief discussion about this with students, focusing on the following elements: - Reflect with students and elicit their thoughts about how challenging (but important) it was to have some of these conversations in class. - Remind students that our behavioral norms enabled us to have productive conversations. However, many people outside of this classroom do not follow these norms in conversations. So having these conversations elsewhere will not be the same as having them in this classroom. Ask students to consider with a partner ways that having conversations with people outside of the classroom can differ from conversations inside a classroom (see the second note to the right). - Tell students they may feel the desire to respond to these types of statements. With a partner, ask them to think of times and places that might be conducive to productive conversations? What are times that would *not* be good to have these conversations? Have a few students share their ideas with the class. - Tell students that if they choose to engage in these conversations outside of the classroom, they should be aware of their own comfort level and safety and consider when to stop a conversation. Let them know they should stop if they feel unsafe	Note: Check into school policies about students responding to online posts during school hours or from school accounts so you can share this information with students. **The goal of this activity is ***not* to encourage students to engage in online debates.** The goal is to present inaccurate ideas to students in a medium through which they are likely to encounter them in the real world, and then for students to think through how to critique those ideas. Remind students of this as often as necessary. Note: Ways conversations outside a classroom differ from those inside a classroom: - Not everyone has been exposed to or knows the same information. - There is no teacher present to monitor student safety. - People have not agreed on norms for behavior. Attending to Equity: You may want to emphasize that students of color do not have any special "responsibility" to engage in these conversations, lead these conversations, or help White students with these conversations, especially as potential negative personal and emotional impacts

for any reason or if they feel the conversation is becoming about them personally instead of about ideas. - Remind students that they are not crafting a response today that you expect them to use in <u>everyday conversation</u>. Instead, tell students what you want them to do in <u>class</u> today is to reflect on how to make a scientific argument that critiques the claims from the online user using the evidence they've learned in this unit.	can be much greater than for White students.
Project the process slide with the instructions for the whole activity and go over the plan for the whole lesson with students. Then have them complete steps 1a and 1b: 1. On your own: Read "Intelligence and DNA," which is an excerpt adapted from a popular science article. a. On your own: Underline the 3 key findings discussed in the article. b. With a partner: Turn and talk to take turns explaining what each means in your own words.	
Bring the class together to complete step 1c: c. **With your class:** Be prepared to share yours and your partner's ideas about the 3 main findings to help your class make sure they understand the article. Use the speaker notes in the slides to guide the discussion. After hearing pairs share out, decide whether you need to walk through the findings in the paper with the class to ensure understanding.	<u>Note</u>: It is very important that students correctly understand what the article is saying, otherwise they will struggle to understand how User1 is misinterpreting it in the next part of the lesson. This could lead to backfire, and students finding user1's incorrect statements too convincing. <u>Note</u>: If your class periods are 45 minutes, this is a likely class period break. You may want to advance to the last slide and have students

	complete the suggested Exit Ticket to check understanding.
Students should continue to follow the instructions on the student sheet. You may choose to project the process slide with the instructions for the whole activity.	Formative Assessment Opportunity: Circulate as students are highlighting to check to make sure they are highlighting the correct kinds of statements. Use the provided key to guide you. Some answers will vary, but redirect students if their highlighting choices seem incorrect and they can't explain them correctly. Identifying incorrect claims should still be a learning opportunity for students. Note: It may be very surprising to students to realize that the "Intelligence and DNA" article didn't say anything about race at all. Throughout this unit, we have been focused on the question of differences by race, and user1 is also focused on this. But, the article actually did not address this. As you circulate, probe students to see if they have realized this. You may want to share that most genetic studies do not focus on race. Attending to Norms: Remind students that they should be using evidence from this unit to critique AnonymousUser1's claims. If partners disagree about the accuracy of any of AnonymousUser1's claims, point out any norms your class constructed related to the ideals of "we critique ideas, not people" and "we are open to changing our

	minds based on evidence" to help students navigate these disagreements.
Individually, students should write their argument that critiques the post. - Remind students that they should critique specific claims from the post and use evidence in their critiques. - Encourage them to use the optional **sentence stems** (project this slide) if they find them helpful.	Note: Because students were not explicitly taught how to cite evidence in this unit, you may simply instruct them to use *the number of the evidence card* as their source unless students are familiar with citing evidence in a more specific format.
When students finish, collect their arguments to review them and provide feedback (see assessment opportunity note to the right).	Summative Assessment Opportunity : Use the ideal response provided below as a guide for providing feedback. Any claims students make should be supported by evidence from the unit, and the corresponding evidence card should be noted. Note that some students may choose to address the policy implications suggested by AnonymousUser1 (e.g. " because none of the scientific evidence used to support this person's claim holds up, I don't think their argument about policy holds up either.") and others may stick strictly to the science. Either is OK and this should not affect scoring. Additionally, the ideal response is just that – ideal. It is comprehensive and responds to all the errors in User1's claims and reasoning. Student responses do not need to be comprehensive, but they should be able to critique and refute multiple claims and multiple aspects of User1's reasoning. If they focus on a few but do it well, that is

	strong evidence that they have achieved the unit's learning goals.
After responses have been scored for your own and any research purposes, you may choose to have students review the Ideal Response provided below in the Teacher Guide and compare it with their own work. You may also discuss with students that while this activity was focused on critiquing the claims made by User1 in their post, the final models we developed in Lesson 8 to answer our question about racial disparities serve as a counter-argument. Not only does User1 make a flawed argument for genetic causes, we as a class developed a strong alternative – our final models.	
Have students add an entry to their Reflection Journal. *This post will be slightly different in that it should be a reflection about the whole unit, not just this lesson*. Have students reflect on what has changed for them over the course of this unit. Present these questions to students to get them thinking, but tell them they do not need to respond to all of them: 1. How has your *knowledge* changed over the course of this unit? 2. How has your *thinking* changed over the course of this unit? 3. How have your *feelings* about this topic changed over the course of this unit?	

Teacher Reference Materials

Sample Student Claims Tables:

With a partner: Did AnonymousUser1 make any claims about the ***amount of between-group difference*** **between racial groups**?

- If so, write those orange highlighted or underlined claims here.

- Then, note any evidence from evidence cards that you could use to help critique these claims.
- Use the format (L_: Card _) to refer to specific evidence cards.

Claim(s)	Evidence card(s) that contradict this claim
"Since human races clearly differ dramatically in physical traits such as skin color, which have a clear genetic basis, it is reasonable to conclude that we also differ in the genes that affect our cognitive traits. Therefore, it makes sense that White people would have more of these genes and Black people would have fewer of these genes."	L3: All Cards

With a partner: Did AnonymousUser1 make any claims about ***between group differences being mostly caused by genes***?

- If so, write those blue highlighted or underlined claims here.
- Then, note any evidence from evidence cards that you could use to help critique these claims.
- Use the format (L_: Card _) to refer to specific evidence cards.

Claim(s)	Evidence card(s) that contradict this claim
"These genes must explain racial differences in academic achievement."	L7: Cards 1 and 2

With a partner: Did AnonymousUser1 make any claims about ***intelligence being fixed***?

- If so, write those green highlighted or underlined claims here.
- Then, note any evidence from evidence cards that you could use to help critique these claims.
- Use the format (L_: Card _) to refer to specific evidence cards.

Claim(s)	**Evidence card(s) that contradict this claim**
"...racial bias is largely non-existent now. That means that since we still see disparities in IQ, these must be due mainly to genetics rather than environmental influences. It seems that IQ is relatively fixed, and can't change."	L6: Set A: Cards 2 and 3 L6: Set B: Card 2 L7: Cards 1, 2, and 3

Sample student work:

Critiquing an Argument with Our Reasoning with Evidence Checklist	
Error from Checklist	**Critiques**
Misinterpretation	Actual data: "researchers looked for genetic differences between people with average IQs (around 100) and people with very high IQs (around 170). They found genetic variations between these groups that explained 33% of the reason a person was in the high IQ group." Misinterpretation: "people with certain genetic variants have 33% higher IQs than people without those variants"; this person misinterprets what the 33% is actually referring to.
Cherry-picking	Not included: the researchers noted that alleles explained only 4.8% of the variation in IQ scores in the study, and the rest was the result of unknown causes.

	Not supporting: the researchers noted that alleles explained only 4.8% of the variation in IQ scores in the study, and the rest was the result of unknown causes.
Overextending	Since human races clearly differ dramatically in physical traits such as skin color, which have a clear genetic basis, it is reasonable to conclude that we also differ in our cognitive traits. Therefore, it makes sense that White people would have more of these genes and Black people would have fewer of these genes. (Evidence is only that individuals vary in these genes, not by race.) This means multiple studies are showing that genes can explain intelligence differences between people, and therefore between races as well. (Between-race differences were not included at all in the available evidence.) Historical societal impacts like segregation have ended, meaning racial bias is largely non-existent now. That means that since we still see disparities in IQ, these must be due mainly to genetics rather than environmental influences. It seems that IQ is relatively fixed, and can't change. (Certain forms of segregation have ended, but it does not follow that bias is non-existent now. Nor does it follow that disparities would necessarily have anything to do with genetics.)

Sample Ideal Student Argument:
Highlight = focused on the Reasoning with Evidence Checklist

I disagree that genetics is likely the main cause of differences between racial groups in complex traits like IQ. In fact, differences in the social environment are likely to be the main cause of these differences. This person's argument is missing important evidence, and has multiple reasoning errors.

Most importantly, this person is making claims about race, when the article they use as evidence makes no claims about race at all (overextending). This person claims that "Since human races clearly differ dramatically in physical traits such as skin color, which have a clear genetic basis, it is reasonable to conclude that we also differ in our cognitive traits." This just isn't what the data show. First of all, there is more variation within groups than between groups. 95% of the total amount of genetic differences between humans are between individuals of the same ancestry. Only 5% of the total amount of genetic differences between humans are between people from different ancestries (L3 Card 3). And only 23.4% of skin color differences are explained by genes, while 76.6% is attributed to unknown causes (L6 Set A Card 1). So the idea that races would be very different in a trait like intelligence because we observe differences in skin tone is not supported by the evidence.

It doesn't follow that just because one physical trait can be partially explained by genes that a complex trait like intelligence can be – in saying this, they have overextended beyond what the data actually show (overextending). This person claims that "genes must explain racial differences in academic achievement." But it seems they cherry-picked the data (cherry picking). They didn't mention that the study in the article also showed that which alleles a person has can only explain up to 4.8% of the variance in IQ scores – the other 95.2% of the variance in IQ scores result from other unknown causes (L6 Set A Card 2). It's the same story if you look at educational attainment instead of IQ. Which alleles someone has explained only 11% of the differences in educational attainment between individuals. This means that the other 89% of the differences in educational attainment observed between people have nothing to do with genes (L6 Set A Card 3). Furthermore, they completely misinterpreted the data when they said "33% of someone's IQ is due to genes" (misinterpretation). That study actually only looked at what explains why someone was in a very-high IQ group.

Finally, this person also claimed that because disparities have stayed the same even when there have been big environmental changes, like desegregation, the environment must not play a big role. We know IQ can change – studies that have tracked IQ scores over time have found that IQ test scores are rising steadily over time. Scientists think

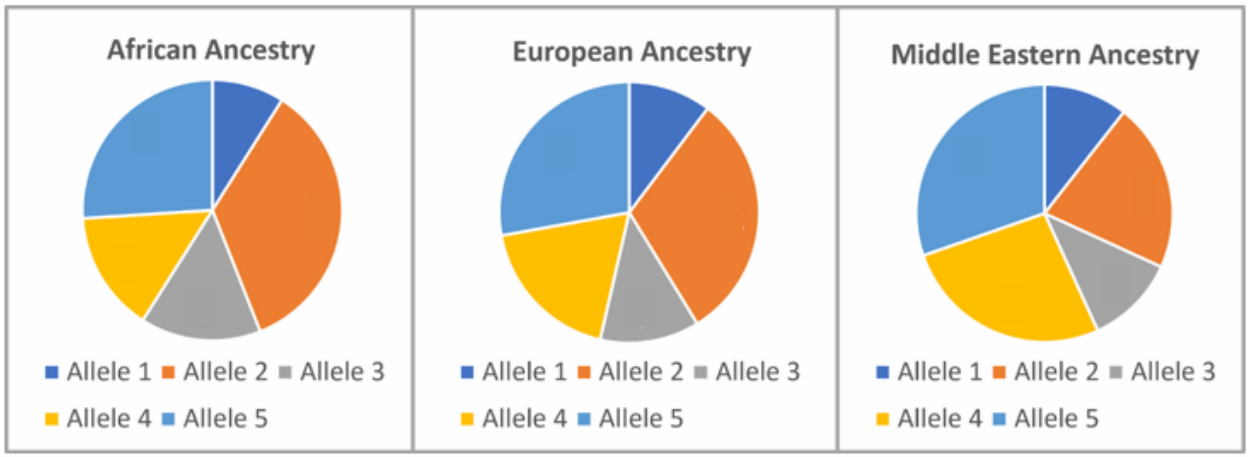
that this increase is caused by modifications in nutrition, health, quality of education, etc. (L6 Set B Card 2). And sadly, desegregation was not the end of environmental differences between races. Racist policies allowed housing and school segregation to live on to this day. Racial "achievement gaps" vary greatly by location, ranging from nearly no gap in some places to very large gaps in others. Gaps were largest in areas where there was more housing segregation, school segregation, and income inequality between Black and White Americans. In areas of the country where segregation and income inequality were lower, the gaps were drastically smaller (L7 Card 1).

Because this person makes so many reasoning errors, I don't think their conclusions about policy implications hold up either. This makes me skeptical about claims regarding social policy that are rooted in unscientific beliefs about the differences between and within race or ancestry groups.

All Evidence Cards

Lesson 3, Card 1: *ACTUAL Allele Percentages by Ancestry Group*

These are actual data from a study on the human genome. Each pie-chart represents the different sequences of DNA, called alleles, that can be found at identical locations in the human genome in different individuals. While this data is from one single location (called D6S474) the same pattern tends to be found, on average, in all variable DNA. When this spot in the human genome is studied, five different alleles are found, which we have labeled with colors. There is a dark-blue allele, an orange allele, a gray allele, a yellow allele, and a light-blue allele. The size of the slices in each pie chart represents how many people in each group have each allele. For example, the orange allele at this spot in the DNA is most common in Africans. Numerically, 35% of people of African ancestry have the orange allele. About 33% of people of European ancestry also have the orange allele. However, fewer than 25% of people of Middle Eastern ancestry have the orange allele.



Notice that individuals from the same group have different alleles from each other at the same point in their DNA. This is true in each group. Notice also that people from different groups tend to have the same kinds of alleles at identical points in their DNA. But, the amount of people in each group who have a certain kind of allele varies from group to group. For example, look at the yellow allele. Around 15% of people of African ancestry and people of European ancestry have the yellow allele. But, 25% of people of Middle-Eastern ancestry have it. In summary, people from different groups have the same alleles, but the proportion of people in each group with a particular allele varies from group to group.

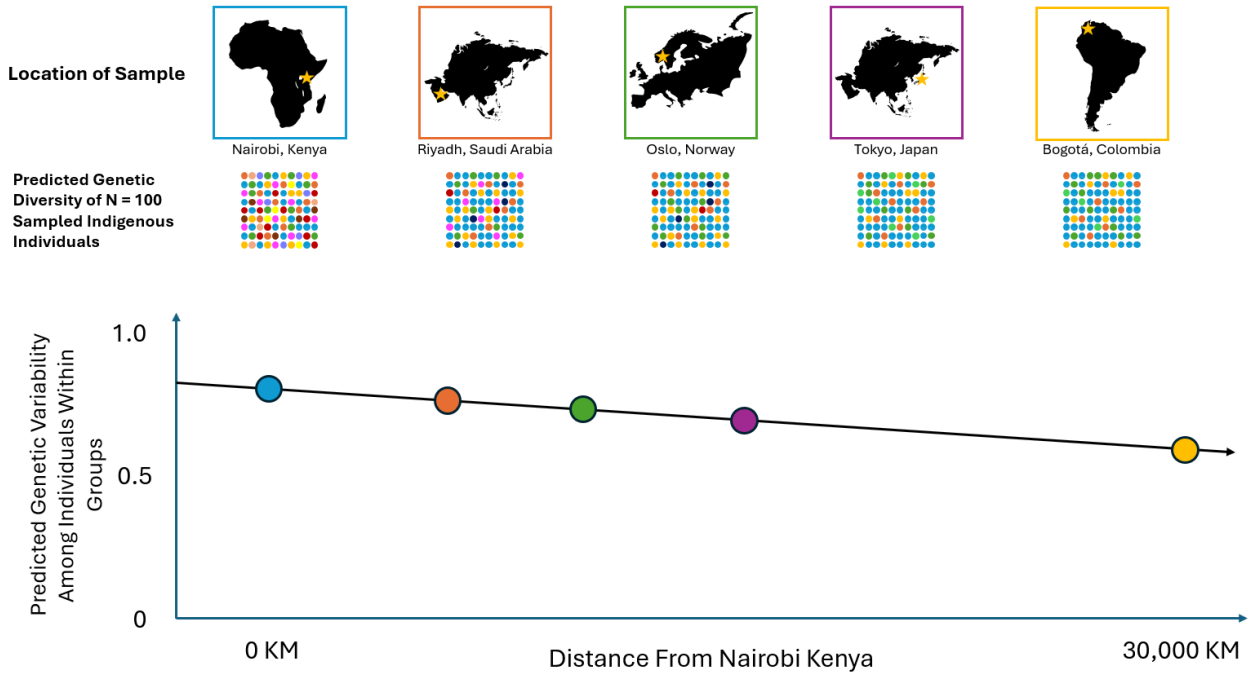
Links to references on back of card.

Link to article: https://pmc.ncbi.nlm.nih.gov/articles/PMC3531797/
Rosenberg, N. A. (2011). A population-genetic perspective on the similarities and differences among worldwide human populations. *Human Biology*, *83*(6), 659–684. https://doi.org/10.3378/027.083.0601

Link to article: https://journals.plos.org/plosgenetics/article?id=10.1371/journal.pgen.0010070
Rosenberg, N. A., Mahajan, S., Ramachandran, S., Zhao, C., Pritchard, J. K., & Feldman, M. W. (2005). Clines, clusters, and the effect of study design on the inference of Human Population Structure. *PLoS Genetics*, *1*(6). https://doi.org/10.1371/journal.pgen.0010070

Lesson 3, Card 2: *ACTUAL Map of Genetic Variation by Ancestry Group*

Below is the *ACTUAL* predicted amount of genetic variation among individuals with ancestry in Kenya, Saudi Arabia, Norway, Japan, or Columbia. The amount of genetic variation within each of these groups is represented through the amount of differently colored dots. Where you see more colors there is more genetic variation (alleles). Where you see fewer colors there is less genetic variation (alleles). For example, look at the colored dots found in people of Kenyan ancestry. You can see that there are a lot of differently colored dots. This means that there are a lot of different alleles found within people of Kenyan ancestry. So, people of Kenyan ancestry are not genetically identical. Now look at the dots in Colombia. People of Colombian ancestry also exhibit genetic variability because there are different colored dots within Colombia. All of the dot colors found in Colombia are also found in Kenya. No matter where you look there are usually a variety of colored dots. However, the amount of colors declines as you move further away from Kenya. You can see this pattern in the line graph.



What does this data mean? There is no continent on Earth where we find that all of the people are genetically identical- there is always a wide variety of alleles in every population. The widest variety of alleles is found in people of African ancestry. As you move away from Africa, the amount of genetic variability in each population decreases, as seen in the graph above. In summary, there is a lot of genetic variability within any ancestral group of humans, and all human groups share many of the same kinds of alleles.

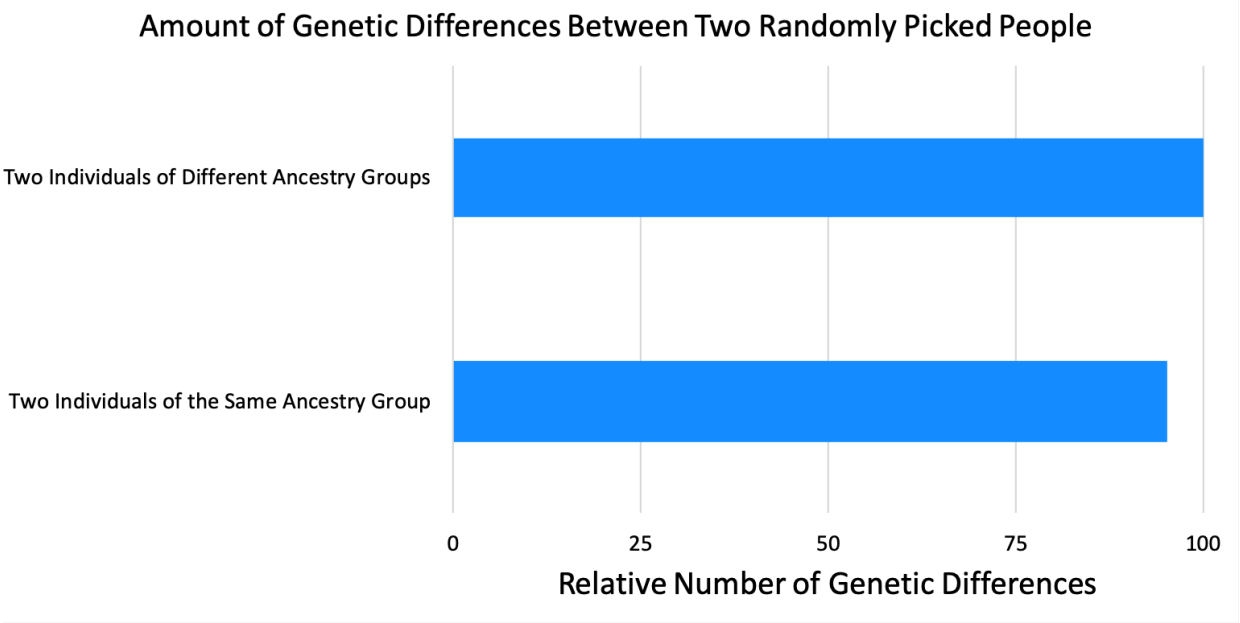
Links to reference on back of card.

Link to article: https://doi.org/10.3378/027.083.0601

Rosenberg, N. A. (2011). A population-genetic perspective on the similarities and differences among worldwide human populations. *Human Biology*, *83*(6), 659–684. https://doi.org/10.3378/027.083.0601

Lesson 3, Card 3: ***Genetic Differences Between Individuals of Same and Different Groups***

The graph below shows actual data from a study on the human genome. 0.1% of our DNA makes us different from other people. This means that one DNA base pair out of every 1,000 will be different between any two individuals. How much of that difference is between people from different races? Look at the graph below. The bar graph on the top shows the amount of genetic differences between two randomly chosen individuals of different ancestry groups. The bar below it shows how many genetic differences in the variable DNA exist between two randomly picked individuals of the same ancestry group. Notice that the top bar is only slightly larger than the bottom bar. This means that when we compare individuals of two different ancestry groups, they are only slightly more genetically different in the variable DNA than two individuals of the same ancestry group.



What does this data mean? Only 5% of the total amount of genetic differences between humans are between people from different ancestries. 95% of the total amount of genetic differences between humans are between individuals of the same ancestry. This means that if two people of the same ancestry group have 100 differences in their variable DNA, then we would expect two people of different ancestry groups to have on average about 105 differences in their DNA.

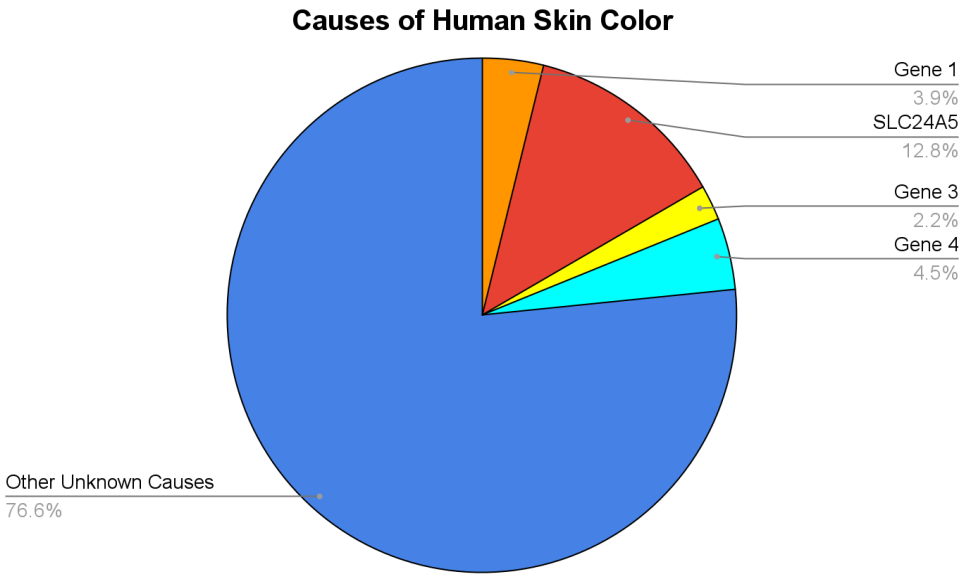
Links to reference on back of card.

Link to article: https://doi.org/10.3378/027.083.0601

Rosenberg, N. A. (2011). A population-genetic perspective on the similarities and differences among worldwide human populations. *Human Biology*, *83*(6), 659–684. https://doi.org/10.3378/027.083.0601

Lesson 6, Set A, Evidence Card 1: Causes of Skin Color

Genes that are associated with making skin darker or lighter are shared by populations around the globe. Studies have found four places in the human genome that are estimated to account for 23.4% of skin color differences between people. Each of the alleles at these genes associated with skin color are found in every human population at varying amounts. The question that these data answer is how much of the difference is caused by genes. The pie chart shows that 76.6% of the skin color differences have unknown causes. But, 23.4% of skin color differences have a known association with these four genes.



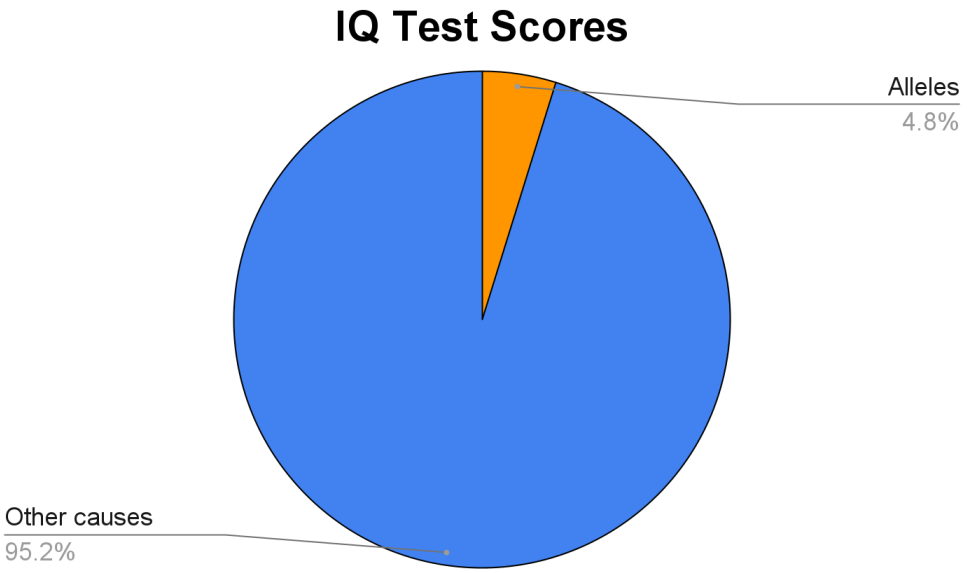
Link to article: https://doi.org/10.1126/science.aan8433

Crawford, N. G., Kelly, D. E., Hansen, M. E., Beltrame, M. H., Fan, S., Bowman, S. L., Jewett, E., Ranciaro, A., Thompson, S., Lo, Y., Pfeifer, S. P., Jensen, J. D., Campbell, M. C., Beggs, W., Hormozdiari, F., Mpoloka, S. W., Mokone, G. G., Nyambo, T., Meskel, D. W., … Tishkoff, S. A. (2017). Loci associated with skin pigmentation identified in African populations. Science, 358(6365). https://doi.org/10.1126/science.aan8433

Does Mendel's simple model fully explain these data? What makes you say that?

Lesson 6, Set A, Evidence Card 2: IQ Test Scores

Intelligence is a complex trait that is influenced by a large number of alleles. An IQ (intelligence quotient) test is designed to measure intelligence. Researchers have long debated how much of an individual's intelligence is captured by an IQ score. Nevertheless, previous studies have demonstrated that genes do have an influence on those aspects of intelligence measured by an IQ test. A recent study looked at the genetic contribution to IQ scores. The study involved 78,308 unrelated people of European descent, all of whom had taken an IQ test. Analysis of their DNA found 336 different alleles spread across 18 genes that influenced IQ score. These alleles explain up to 4.8% of the variance in IQ scores among the study subjects. The other 95.2% of the variance in IQ scores were a result of other unknown causes.



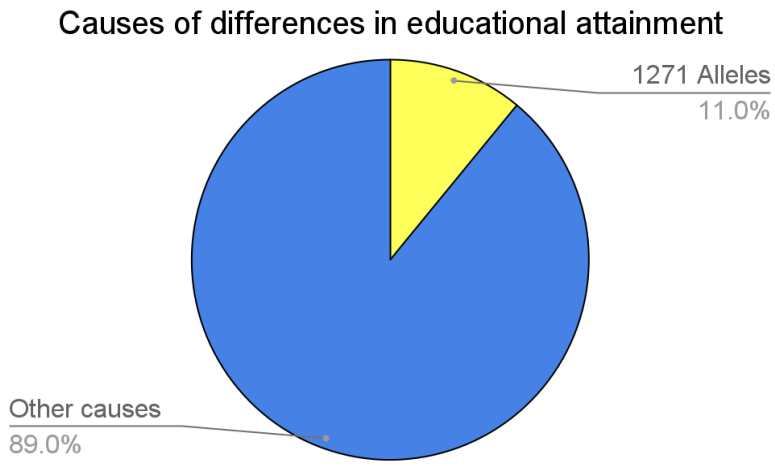
Link to article: https://doi.org/10.1038/ng.3869

Sniekers, S., Stringer, S., Watanabe, K., Jansen, P. R., Coleman, J. R., Krapohl, E., Taskesen, E., Hammerschlag, A. R., Okbay, A., Zabaneh, D., Amin, N., Breen, G., Cesarini, D., Chabris, C. F., Iacono, W. G., Ikram, M. A., Johannesson, M., Koellinger, P., Lee, J. J., … Posthuma, D. (2017). Genome-wide association meta-analysis of 78,308 individuals identifies new loci and genes influencing human intelligence. *Nature Genetics*, *49*(7), 1107–1112. https://doi.org/10.1038/ng.3869

Does Mendel's simple model fully explain this data? What makes you say that?

Lesson 6, Set A, Evidence Card 3: Educational attainment

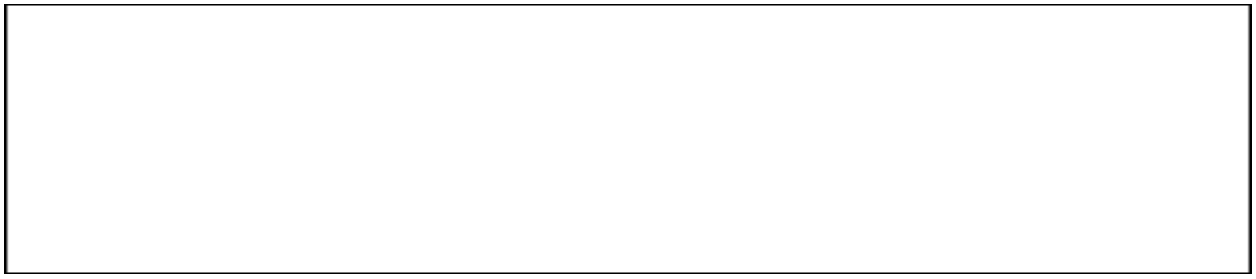
Educational attainment is the amount of formal education a person completes during their lifetime. For example, it is a measurement of the amount of time one has spent in school. Genetic differences between individuals are associated with some of the differences in educational attainment observed between individuals. But, how much? Recently, an international team of scientists published a large genetic study involving over 1.1 million people. They found 1,271 alleles located near 1,838 genes that were associated with how long people stay in school. Some of these alleles are involved with the development of neuron cells. However, each individual allele had only a very tiny effect on its own (less than 0.1% per allele). As a group, the 1,271 alleles together explained only 11% of the differences in educational attainment between individuals. This means that the other 89% of the differences in educational attainment observed between people have nothing to do with genes. However, some geneticists have recently argued that the association between these alleles and educational attainment may have nothing to do with academic ability. A study carried out in Iceland, for example, found that the allele combinations associated with higher educational attainment were more commonly found in men and women who delayed the age at which they had their first child. This means that these people had more time and money to educate themselves, which in turn means that their child inherits a more educationally enriched environment. So, the correlation between genes and educational attainment is real, but it might not have anything to do with academic ability. The figure below illustrates these findings.



Link to article: https://doi.org/10.1038/s41588-018-0147-3

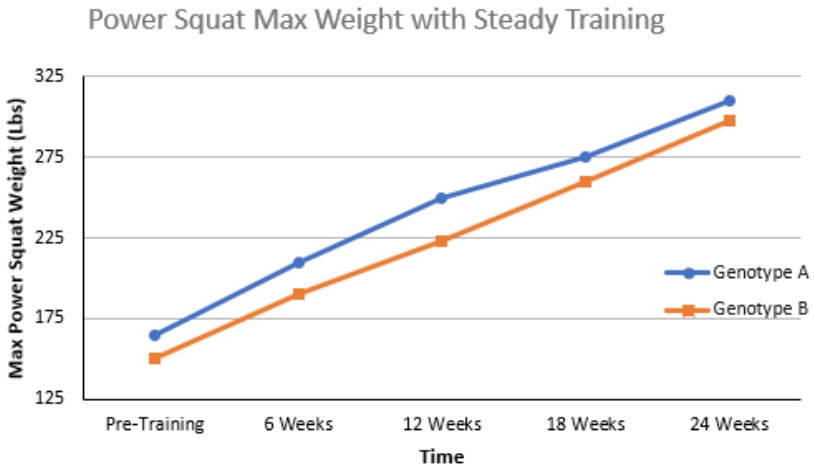
Lee, J. J., Wedow, R., Okbay, A., Kong, E., Maghzian, O., Zacher, M., Nguyen-Viet, T. A., Bowers, P., Sidorenko, J., Karlsson Linnér, R., Fontana, M. A., Kundu, T., Lee, C., Li, H., Li, R., Royer, R., Timshel, P. N., Walters, R. K., Willoughby, E. A., … Cesarini, D. (2018). Gene discovery and polygenic prediction from a genome-wide association study of educational attainment in 1.1 million individuals. Nature Genetics, 50(8), 1112–1121. https://doi.org/10.1038/s41588-018-0147-3

Does Mendel's simple model fully explain this data? What makes you say that?



Lesson 6, Set B, Evidence Card 1: Powerlifting

Your ability to lift weights has a genetic basis. There is a specific type of muscle fiber that is responsible for fast acting power. It is called a fast-twitch muscle fiber. There are two different genotypes of the ACTN3 gene that influence the power that a fast-twitch muscle fiber can exert. One genotype, called Genotype A, increases the amount of power the fiber can exert over a short period of time. The other genotype, called Genotype B, decreases the amount of power the fiber can exert over time. Even though power is influenced by these genotypes, you can still increase your power by eating well and training properly. Training and eating well will make each fast-twitch muscle cell bigger and increase the number of fast-twitch cells in your body. This means that your ability to lift weights can change over time, even though there is a genetic basis for this trait.



Links to articles:

https://doi.org/10.1038/sj.ejhg.5201964

Roth, S. M., Walsh, S., Liu, D., Metter, E. J., Ferrucci, L., & Hurley, B. F. (2008). The ACTN3 R577X nonsense allele is under-represented in elite-level strength athletes. *European Journal of Human Genetics*, *16*(3), 391-394.

https://doi.org/10.1086/377590

Yang, N., MacArthur, D. G., Gulbin, J. P., Hahn, A. G., Beggs, A. H., Easteal, S., & North, K. (2003). ACTN3 genotype is associated with human elite athletic performance. *The American Journal of human genetics*, *73*(3), 627-631.

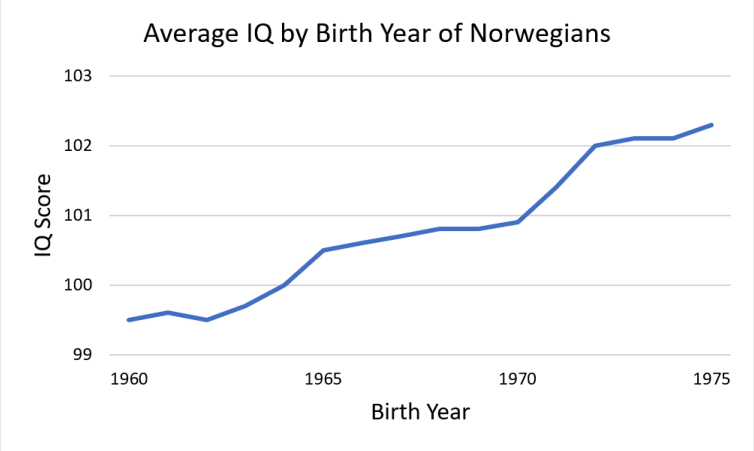
ncbi.nlm.nih.gov/pubmed/21912291

Wilson, J. M., Loenneke, J. P., Jo, E., Wilson, G. J., Zourdos, M. C., & Kim, J. S. (2012). The effects of endurance, strength, and power training on muscle fiber type shifting. *The Journal of Strength & Conditioning Research*, *26*(6), 1724-1729.

Does the polygenic model fully explain this data? What makes you say that?

Lesson 6, Set B, Evidence Card 2: IQ - Flynn Effect

In an earlier evidence card you learned that intelligence is a complex trait influenced by multiple factors. An IQ (intelligence quotient) test is designed to measure intelligence, although many scientists question whether it does. For example, scientists have long debated how much of an individual's intelligence is captured by an IQ score. Other scientists claim IQ tests are biased and unfair. Studies that have tracked IQ scores over time have found that IQ test scores are rising, indicating that intelligence can change. Even though genes make a very small contribution to IQ, scientists think that the increases in intelligence observable around the world are caused by modifications in nutrition, health, quality of education, and environmental stimulation. Furthermore, studies have found that your brain is like a muscle. Getting the right amount of sleep, eating nutritious food, and exerting effort in school can make your brain "muscle" stronger. Indeed, studies have found that when students learn that their intelligence can change, they tend to work harder and get better grades.



Note: IQ scores of populations have increased over time. The increase in IQ score over time is called the Flynn effect and has been extensively studied. A recent paper analyzed 285 studies involving 14,031 subjects that were conducted between the years 1951-2010. Each study in the analysis measured the magnitude of the Flynn effect. The combined analysis confirmed the Flynn effect, finding that IQ scores increased at a rate of approximately 3 points per decade. The scientists said Flynn effect is caused by environmental changes and cannot be explained by genes.

Link to article: https://doi.org/10.1073/pnas.1718793115

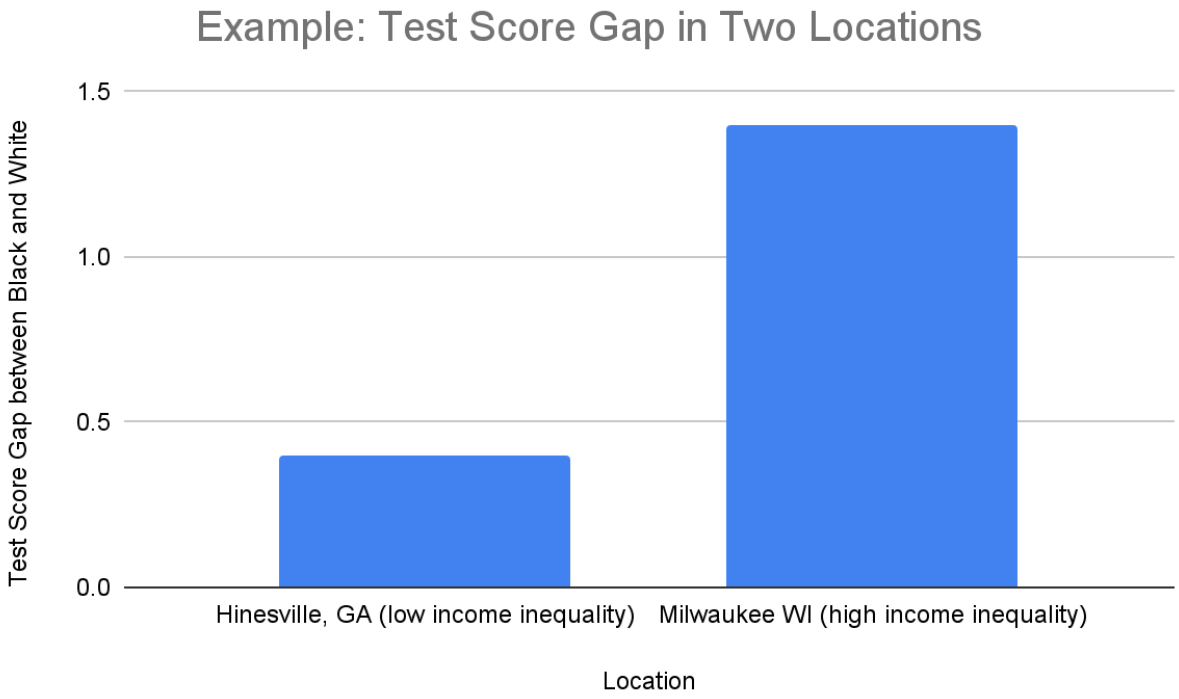
Bratsberg, B., & Rogeberg, O. (2018). Flynn effect and its reversal are both environmentally caused. *Proceedings of the National Academy of Sciences*, *115*(26), 6674-6678.

Does the polygenic model fully explain this data? What makes you say that?

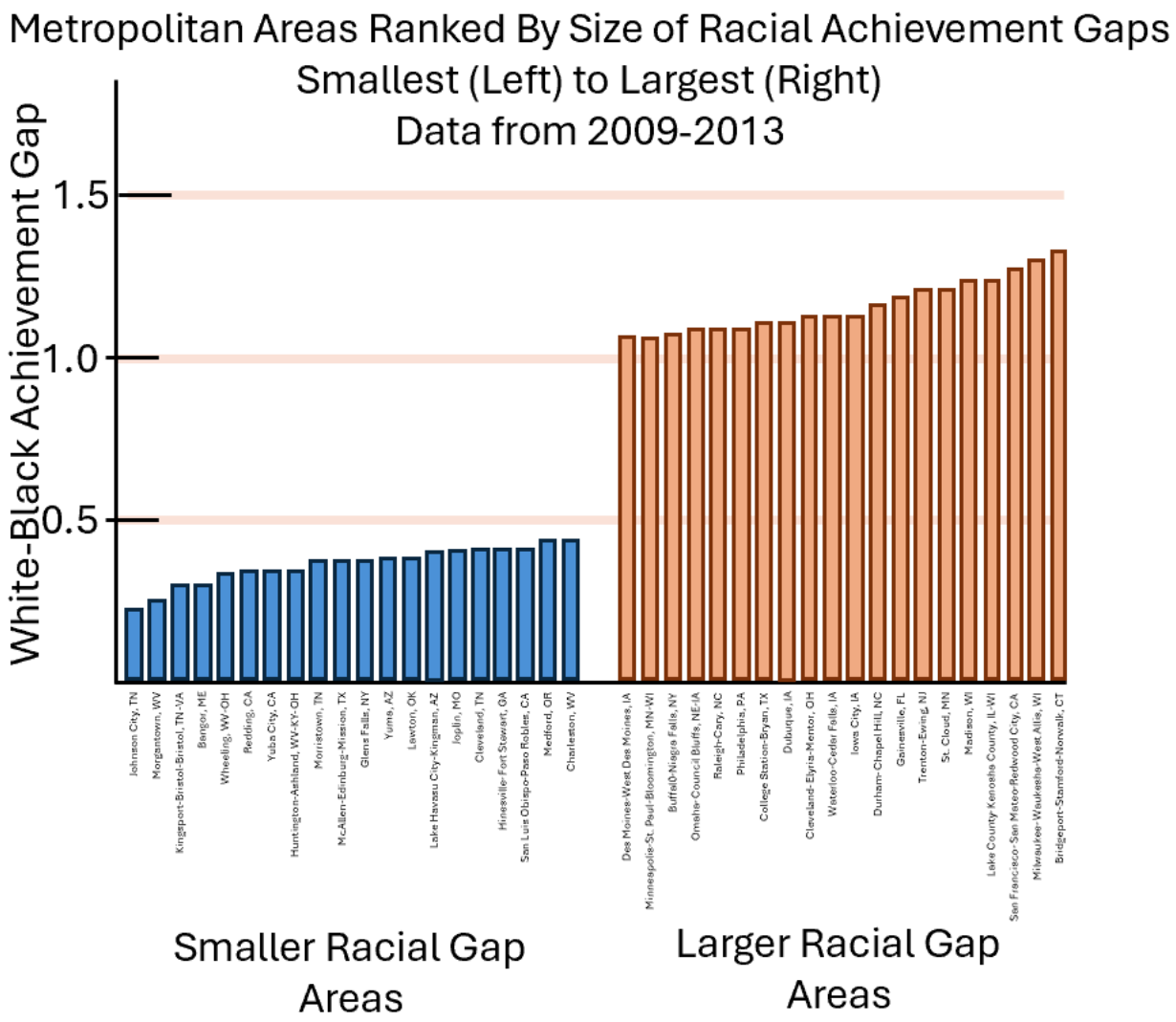
Lesson 7, Card 1: Standardized Test Score Gaps

In the United States, there is a test score gap between Black and White students, with Black students scoring lower on average than White students. A team of researchers was interested in the possible causes of this gap in scores. They measured the racial test score gaps in several hundred metropolitan areas and several thousand school districts in the United States. The team used the results of roughly 200 million standardized math and reading tests administered to public school students from 2009-2013.

They found that racial achievement gaps vary substantially, ranging from nearly no gap in some places to very large gaps in others. The racial achievement gaps were largest in areas where there was more housing segregation, school segregation, and income inequality between Black and White Americans. In areas of the country where segregation and income inequality were lower, the racial achievement gap in test scores was drastically smaller. Below is one example: in Hinesville, income inequality is smaller and the test score gap is also smaller compared to Milwaukee where income inequality is higher and test score gaps are bigger.



In the figure on the next page, you can see that there are large test score gaps in many locations, but there are also many locations with smaller test score gaps.

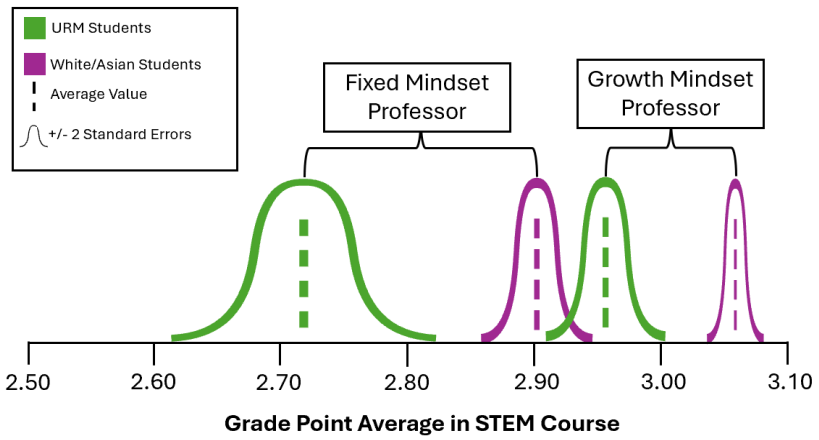


The cities on the right side of the figure above have large achievement gaps, and the researchers also found that they tended to have more segregation and income inequality than the cities on the left. In fact, they found that a total of 62% of the variability in test score differences between Black and White students who live in metropolitan areas was influenced by the amount of segregation and income inequality experienced by Black Americans. So, the different environments that White and Black Americans experience strongly contribute to differences in educational attainment between Black and White Americans.

Link to study: https://cepa.stanford.edu/content/geography-racialethnic-test-score-gaps
Reardon, S. F., Kalogrides, D., & Shores, K. (2019). The geography of racial/ethnic test score gaps. *American Journal of Sociology, 124*(4), 1164-1221.

Lesson 7, Card 2: Effect of Professor Mindsets on GPAs
Racial achievement gaps in STEM courses are greater in courses taught by professors who *believe* that STEM ability can't change.

In this study, researchers investigated how teacher beliefs affected their students. They also investigated if teacher beliefs affected students differently based on the student's racial or ethnic identity.



They compared students who are traditional underrepresented in science courses, so-called underrepresented racial minority (URM) students, to White and Asian American students. Research has shown that Black, Hispanic, and Native American students often face negative stereotypes about science ability, while White and Asian American students often do not. Therefore, the proportion of White and Asian American students tends to be higher in science courses as compared to the proportion of Black, Hispanic, or Native American students.

The researchers sampled 150 STEM professors and over 15,000 of their students. The classified students into the categories of White/Asian or URM based on each student's self-identified race, and then they measured whether the professors of these students believed that science and math ability was innate and unchangeable, which is called a fixed mindset, or whether it could change over time and grow, which is called a growth mindset. The researchers also measured the grade point average (GPA) of each student. The study found that there was a racial difference in GPA when comparing the average GPA of White and Asian students to Black, Hispanic, or Native American students. However, the classes that were taught by fixed mindset professors had greater racial differences in GPA than the classes taught by growth mindset professors. The racial gap was nearly twice as large in the classes taught by fixed mindset professors in comparison to classes taught by growth mindset professors. You can see this in the graph above because the distance between the green and purple bell curves for fixed mindset professors is nearly twice the distance observed between the green and purple bell curves for growth mindset professors.

This effect was so great that the GPA of Black, Hispanic, or Native American students who learned from teachers with a growth mindset was not significantly different from the GPA of White and Asian students who learned from fixed mindset teachers. You can see this in the purple and green bell curves that are of identical shape and size. Through analyses of course evaluations by the

students, researchers found that these results were linked to student motivation. Fixed mindset professors inspired less motivation in their students than growth mindset professors.

Link to study: https://advances.sciencemag.org/content/5/2/eaau4734

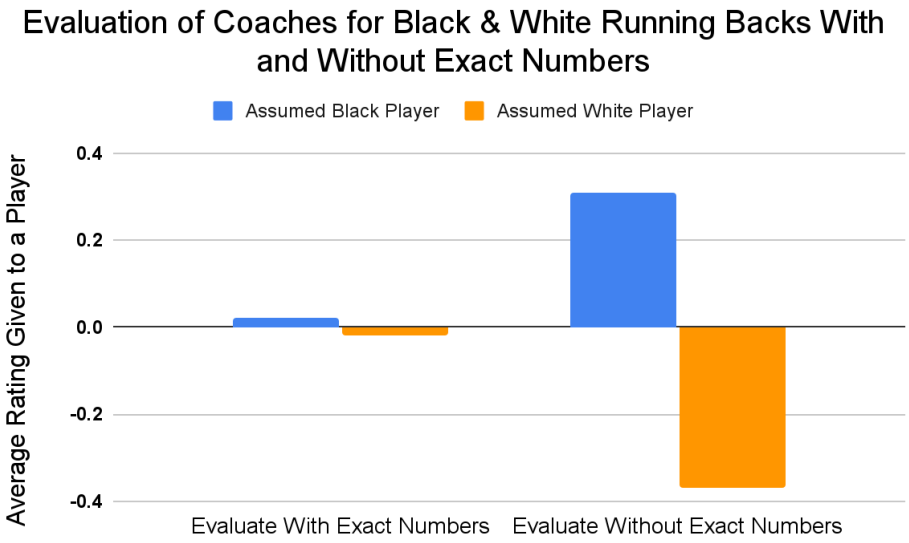
Lesson 7, Card 3: Effect of Race on College Football Recruiting

Researchers were interested to know how college football coaches evaluate prospective recruits of different races at the running back position. The running back position is a specific position that is overwhelmingly populated by Black athletes in D1 college football (the highest level of college football). In fact, it has become a stereotype that running backs are Black.

In this study, researchers got 47 full-time NCAA college football coaches together and asked them to evaluate prospective recruits. Coaches received player resumes, in-game statistics, and video highlight reels of prospective running backs. Even though the coaches watched a video, the researchers made sure the coaches couldn't tell if the athletes were actually Black or White. The coaches were then divided into two groups: one group was told they were evaluating a White player, whereas the other group got the statistics *of the exact same player* but the coaches were told that they were evaluating a Black player.

The researchers then looked for differences in how the coaches evaluated the exact same player depending on what they thought the player's race was. When the coaches looked at resumes with hard numbers, such as the exact time it took a player to run 40-yards, the two groups evaluated the players similarly – regardless of what they assumed the players' race to be. However, when the coaches were asked to look at a video (again, skin color could not be seen) of the *exact same player* but this time were asked to estimate the players' strength or speed, the coaches were far more likely to rate the exact same player better if they were told the player was Black.

This study highlights that coaches evaluate the skills of the exact same player differently based on the player's assumed race. Black players are seen more favorably for recruitment at the running back position by coaches, which could help explain their over-representation in the running back position.



Link: https://pubmed.ncbi.nlm.nih.gov/25559706/

Thomas, G., Good, J. J., & Gross, A. R. (2015). Racial athletic stereotype confirmation in college football recruiting. *The Journal of Social Psychology*, *155*(3), 238-254.

Comprehensive Robin and Taylor Narrative

Lesson 1

After students view the graph of the anchoring phenomenon and discuss what they think explains the pattern in the graph, they hear contrasting explanations from Robin and Taylor.

Robin and Taylor's Disagreement Part 1

Robin says: "Well yeah, that makes sense."

Taylor says: "Really? Why do you think it makes sense?"

Robin responds: "People of different races are very different in their genes. Black people have more of the genes that make them better athletes, and White people have more of the genes that make them smarter and better at science and math."

Taylor thinks that Robin is wrong, but he doesn't know what to say in response. Throughout this unit, you will help Taylor build an argument that refutes what Robin has claimed.

Students reflect on how they would respond to what Robin said.

Robin and Taylor's Disagreement Part 2

Here is how Taylor responds: Robin, that first thing you said about genetic differences between races can't be true. I just watched a documentary on the human genome, and it said that any two humans share 99.9% of their DNA. Humans only differ in 0.1% of their DNA. I think that means that people of the same race differ from each other genetically, but people from different racial groups don't really differ at all in their genes. So, there aren't really different racial groups – we're all just one race, the human race.

Here is how Robin responds: Yeah, I saw that show too, and it also said that humans share 98% of their DNA with chimpanzees, which means 2% of our DNA makes us different from chimps. So, the 0.1% of DNA that differs between humans matters. I think most of the genetic differences in our variable DNA must be between different races. The genetic differences between people of the same race are too small to matter.

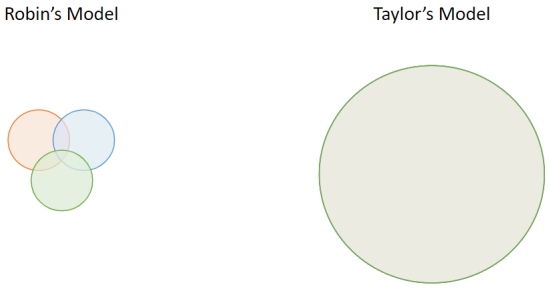
Basically, Taylor and Robin's argument boils down to these two claims:

- Taylor's claim: Individuals of the same race differ from each other genetically, but people from different racial groups don't really differ at all in their genes.

- Robin's claim: Most genetic differences must be between different races. The genetic differences between individuals of the same race are too small to matter.

Lesson 2

In lesson 2, students learn how to create models of Robin's and Taylor's claims. Those models look like this.



Lesson 3

In lesson 3, students review the evidence for the amount of genetic variation within and between human ancestry groups. Students also learn about misinterpreting and cherry picking, which are errors that people sometimes make when reasoning with evidence. They then hear how Robin and Taylor reasoned with the evidence in Lesson 3.

Robin and Taylor reviewed the same Lesson 3 Evidence Cards we just did.
Here are the arguments they made:

Taylor's argument:

Individuals of the same race differ from each other genetically, but people from different racial groups don't really differ at all in their genes. The reason I still think the evidence supports this is people of different ancestry groups share almost all the same alleles, but a variety of alleles are present within each group. The percent of alleles in each group might be slightly different, but there are almost always the same types of alleles found in each ancestry group. *Evidence card 1* shows that people of African, European, and Middle Eastern ancestry all had the same five alleles. *Evidence card 2* shows that the blue dots, representing alleles, are found in all the ancestry groups. Within each continent, there are lots of differently colored dots, meaning people within each group are not genetically identical. These two evidence cards each looked at a different type or set of genetic data that used different methods, and they both seem to tell the same story overall.

Robin's argument:

Most genetic differences must be between different races. The genetic differences between individuals of the same race are too small to matter. The reason I still think the evidence supports this is because people of different ancestry groups are genetically different from each other, as supported by evidence card 3. *Evidence card 3* shows that there are more genetic differences between two people of different races than there are between two people picked at random. So that means most of the genetic differences between people are in people of different ancestry

groups. Other evidence sets did not show as much of a distinction, but I think card 3 is the most convincing.

Lessons 4 and 5

Students then create a model of the actual evidence for human genetic variation in Lesson 4 and then evaluate the accuracy of Robin's and Taylor's original claims in Lesson 5. At the end of lesson 5, Robin and Taylor reflect on what they've learned:

Robin and Taylor Discuss What They've Learned

Recall that after seeing the same evidence cards we did in Lesson 3, Robin and Taylor stuck with their original claims and didn't change their arguments. But, like us, they also worked with their classmates to create a consensus model, applied the Checklist questions, and had to defend their thinking in an Argument Line. After doing all that, let's see what they said!

Taylor: I guess I was wrong to say that racial groups don't differ genetically at all. Clearly, they do differ a little because 4.3% of genetic differences occur between people of different groups. But, all human groups share similar sets of alleles in their variable DNA. The groups just differ in the proportion of people who possess certain alleles. So, it's still wrong to claim that people of different races are very different in their genes. And the other claims you made aren't right either, Robin. For example, we just learned that there are no alleles that every single person in one group has, but no one in another group has. We also learned that 95.7% of genetic differences occur between individuals of the same group. So the amount of genetic variation within each group is very large, and the amount of variation between racial groups is very low.

Robin: I can see what you are saying and I kind of agree, at least when it comes to everyday people and not elite athletes or scientists. I do agree that racial groups are not as genetically different as I thought they were. If 95.7% of human genetic differences happen among people of the same race but only 4.3% of variable DNA makes racial groups different, then yeah, racial groups are pretty similar in their genes. So yeah, there's more genetic difference *within* any given race than between races.

Taylor: Also, when I first reacted to all this evidence, I didn't change my mind right away. Even though most of the evidence supported my claim more than yours, my claim wasn't completely correct. And I only included some of the evidence in my original argument. I didn't bother to include *evidence card 3*. Maybe that was partially because in wanting to be right, I thought it would be easier to ignore the fact that 4.3% of genetic differences occur between people of different groups. But I really should have included *evidence card 3*, because it still is strong evidence against your original argument, Robin. It shows that *most* of the genetic differences occur between individuals of the same group.

Robin: Well you weren't the only one who didn't change their mind right away! I also tried to stick to my original claim at first. And I only included one piece of evidence – the one I found most convincing. Now I know that's "cherry picking," and it wouldn't be very convincing to a scientist. In science, including more of the evidence makes an argument stronger. I also misinterpreted what that evidence was even saying. That's why it's so important to get clear on within- vs. between-group differences when trying to answer this question!

Lesson 6

At the beginning of lesson 6, Robin and Taylor realize they still disagree about some things:

Robin and Taylor's Disagreement Part 3

Taylor: We just learned that the amount of genetic variation between racial groups is much smaller than the amount of genetic variation within a racial group. So, if there are genes that influence academic ability or athletic ability, then the alleles of those genes will be present in every group, just in different proportions.

Robin: I agree, which is why I think genes can still explain the differences in careers between White and Black people in STEM and the NFL. Maybe White people have more individuals who have the alleles that make them naturally good at science. Maybe Black people have proportionally more people who have the alleles that make them naturally good at sports. We know that there are small average genetic differences between Black people and White people. So maybe the 5% of the 0.1% of DNA that makes racial groups different is also the DNA that influences intelligence and athletic ability.

Taylor: Hold on, we don't even know how much impact genes have on traits like academic or athletic ability. I still think genes don't have anything to do with how smart you are or how good at sports you are. I think it's something else in our lives, like how you train or how you study or how you're raised, that affects your academic and athletic abilities.

Robin: I disagree – I think genes are the most important things that affect academics and athletics. Let's look at some evidence and find out.

Taylor: OK, but if we're going to look at evidence about the influence of genes on academic ability and athleticism, I think we should look at the influence of genes on traits *within* a group before we look at the influence *between* groups. That's because there's more genetic variation within a group, so if there's any influence from genes it's going to show up more within groups than between them. But, like I said before, I think we're going to find that genes don't have anything to do with traits like academic ability and athletic ability.

Robin: I agree that we should investigate how genes influence traits within a racial group first. But I disagree about what we're going to find. I think we're going to see that genes have the biggest influence on traits like academic or athletic ability within a group. And if we see a larger influence within a group then we can be pretty sure that genes impact differences between groups too.

Robin and Taylor are both making claims about the influence of genes and the environment on trait differences within groups and trait differences between groups. For now, let's focus on their within-group claims:

Taylor's Within-Group Claim: Variation in academic and athletic ability within a group is solely caused by environmental variation experienced by individuals within the group.

Robin's Within-Group Claim: Variation in academic and athletic ability within a group is solely caused by genetic variation within the group.

Lesson 7

After learning in Lesson 6 that genes have a much smaller influence than the environment on complex human traits within a group, Robin and Taylor still disagree at the beginning of Lesson 7 about the influence that genes and the environment have on differences between groups.

Robin and Taylor's Disagreement Part 4

Taylor: All that evidence showed us that environmental differences between individuals have a much bigger impact on complex human traits than genetic differences between individuals do. I was wrong to say that there is no impact from genes on those traits, but the impact is really small.

Robin: And I was wrong when I said that genetic variation within a group is the only thing that influences academic and athletic ability. We saw that the environment had a much larger influence on trait variation than genes did. But those studies were just looking at the impact of genes on differences between traits *within a group*. They didn't investigate what might be impacting differences in traits when we compare *different groups*.

Taylor: That's true. Because we saw that the environment has a really big impact on differences in traits within a group, if we investigate the environment I bet we'll find that it differs between races. I know from history class that during segregation, Black and White people were literally separated - they didn't live in the same places or go to the same schools. So I think that differences in the environment between racial groups are more likely the cause of racial disparities than genetic differences are.

Robin: But segregation was a long time ago. And even if genetic variation doesn't explain as much trait variation as I thought it did, I still don't think the environment can explain trait disparities between different races. Like, I've heard that there tends to be an "achievement gap" between White students and Black students on things like standardized tests. I doubt the environment can explain those gaps. Remember that 5% of the 0.1% of variable DNA exists between racial groups. I still think that between-group genetic differences are the only cause of disparities between racial groups.

Taylor's Between-Group Claim: I think it's much more likely that racial disparities in athletic and academic ability are due to differences in the environment and not genetic differences between groups. I think this because genetic variation between groups is small - only 5% of the 0.1% of variable DNA differs between groups. And I bet that the social environments that people of different races experience can be very different.

<u>Robin's Between-Group Claim</u>: I think that genetic variation between groups is the only cause of racial disparities in academic ability and athleticism. I think this because the 5% of the 0.1% of variable DNA that differs between racial groups explains the difference between groups.

After examining evidence about how the environment differs between racial groups, students learn about another reasoning error - overextending. They then evaluate if Robin and Taylor are doing any overextending when they reason with the evidence from Lesson 7.

Robin and Taylor's Disagreement Part 5

Robin and Taylor read the same Lesson 7 evidence cards that you just read.
Let's see how they reacted…

Robin: I saw in the evidence cards that the environment affects outcomes for people like in GPA or test scores. That makes sense. But people still completely control the environment they put themselves in. For example, in the study about standardized test scores, we learned that the income inequality in the place they live can impact their standardized test scores. But people can easily move to other places. So if people just chose to move to areas where schools are less segregated, then they would have better test scores.

Taylor: Well, I'm not sure people have total control of their environment. For example, look at the study about professor mindsets. That study showed that classes taught by professors with a growth mindset had smaller racial GPA gaps and students of all racial groups who had those professors had higher average GPAs. So the professor that students have can make a big impact on their grade. Individual students don't usually have a choice in the professor they are assigned, so I don't agree that people can control this. But if we made sure that colleges only hired professors with growth mindsets, then all GPA disparities between racial groups could be eliminated in just a couple of years.

Robin and Taylor Reflect on What They've Learned

Robin and Taylor have just critiqued each others' arguments for "overextending." After doing this activity, they reflected back on their previous arguments… let's see what they said:

Robin: Wow, I definitely made some mistakes! I realize now that some of the claims I was trying to make weren't supported by evidence. The evidence we looked at didn't say anything about choice, but I tried to apply my own idea about choice to explain the evidence anyway. What actually happened was I made a prediction, but I treated it like a conclusion. I was acting like my prediction was true when I didn't have evidence to support it – basically, I overextended my claim.

Taylor: Well, I didn't add in as many of my own ideas without evidence as you did, Robin, but in my concluding statement I did base a big claim on a pretty small amount of evidence. Maybe hiring only professors with growth mindsets would eliminate all grade disparities, and maybe it wouldn't, but we won't know *for sure* until someone studies it. I was making a large claim before I had a large enough amount of evidence to support it. In the future, I'll pay closer attention to what kinds of claims people are making. If they make claims that can't be directly supported by the data they're talking about, there's a good chance they're overextending.

Robin: So what about the claims we made at the beginning of this lesson - are those accurate? Earlier I said I was 100% certain that genetic variation between groups is the only cause of racial disparities in academic ability and athleticism. I see now that I don't have the evidence to support that claim. We saw evidence that racial groups experience different environments, like some groups being subjected to harmful stereotypes about ability or living in segregated areas with fewer resources. These different environments help explain differences in complex traits between races, which means I don't have evidence that genes are the only cause.

Taylor: Right, especially since racial disparities got a lot smaller when environments became more equal. Since no one has ever done a common garden experiment with humans, we can't conclusively answer the question about the impact of genes versus the environment on trait differences between racial groups. But we've seen that genetic differences between racial groups are small, only 5% of the 0.1% of variable DNA. And the impact of genes on complex human traits is also small. Plus, we've seen that environments can vary a lot between racial groups, and we know the impact of the environment on complex traits is relatively large.

Robin: Based on that evidence, I think we can be pretty confident that your earlier claim is accurate, Taylor. It's much more likely that racial disparities in athletic and academic ability are due to the environment and not genetic differences between groups.

Lesson 8

During Lesson 8, students construct models to explain the anchoring phenomenon. At the end of this lesson, Robin and Taylor return to reflect on everything they've learned:

Robin and Taylor Realize They Now Agree!

Taylor: Wow, this unit was intense! We've seen so much new evidence, like how genetically similar people in different racial categories are, how much genes vs. environment affects complex traits, and how people of different races experience different environments. Let's take a minute to reflect on it all – do we still disagree?

Robin: I think we actually pretty much agree now. Originally, I really got it wrong about just how big of a difference there is between the social environments of Black and White people. I see now that segregation made the environments of Black and White people different, and we can still see the effects of this today. And I feel bad that I didn't realize how harmful it can be to deny the impact that different environments have today. To sum up, my views have changed quite a bit since we started talking about this – I overestimated how important genes were for explaining STEM and NFL disparities, and underestimated how important the environment could be.

Taylor: Yeah, and I didn't account for the fact that genes can have some effect as long as the environment within a group is the same. Thinking back to the common garden experiment with plants, we learned that the height differences of plants that were all grown in the same type of soil only differed because of genetic differences between individual plants. But, if we compare a group of plants grown in nutrient-rich soil and a group grown in nutrient-poor soil, the average height difference between the groups was entirely environmental. It only had to do with the fact that some plants got good soil and some didn't.

Robin: Right, and for humans, the "soil" involves lots of different things, like school quality, housing segregation, and people's attitudes toward different racial groups. Since the environment we are born into impacts the opportunities we will have, our choices can be strongly influenced and limited by our environments.

Taylor: And some "soil" is better than other soil. The study about test score gaps showed that income inequality and segregation are kind of like bad soil because those two factors explain test score differences between White and Black students. And, stereotypes can also create different environments for Black and White people. When professors have negative stereotypes about the abilities of Black, Latino/a/x, and Native American students, grade disparities between those students and White and Asian students are much larger. Also, when Black and White football recruits have the same exact qualifications, people are more likely to be rated better for the running back position if they have a "Black sounding" name. If the environments of White and Black people are so different on average, then I bet there are many social things that make Black people more likely to go into sports or make White people more likely to go into STEM careers.

Lesson 9

To establish a need for students to evaluate the argument from AnonymousUser1, Robin and Taylor return at the beginning of Lesson 9:

Robin and Taylor Apply What They've Learned

Robin: We learned a lot in this unit, but I'm pretty sure lots of people still have misunderstandings about what causes the inequalities we see between racial categories. I should know since I originally thought some of these things were true. And I realize now that just because someone knows some science or refers to a study, it doesn't mean the conclusion they draw is necessarily accurate! It's still really common for them to have reasoning errors in how they use that science to support their claims.

Taylor: Now that we know the science, and know how to avoid these common reasoning errors, we can use that knowledge to argue against these kinds of racist claims.

Robin: I didn't realize it at the time, but those misunderstandings can too easily be used to support racist policies.

Taylor: Yeah, that worries me, because people use their understanding – or misunderstanding – of science to make a lot of decisions. If people believe the incorrect idea that "genes explain inequalities between racial groups," they will think there's nothing we can do to change these disparities to make the world a fairer place.

Robin: I found this post online last night that said pretty much exactly that. It's from a person who is talking about race and genetics, but they're saying a lot of things that we've just learned are false and given what we just learned, I was immediately skeptical. Take a look.

Taylor: Oh yeah this post is definitely incorrect. If someone I knew said this, I think I'd want to address it. I bet we could refute the claims in this post pretty well at this point too. We could use what we've learned to argue against these incorrect ideas. Let's keep our checklist handy so we can point out these errors wherever we see them.

Glossary of Terms

Term	Definition
Allele	One of two or more versions of a gene that occur in the same location on a chromosome.
Ancestry	A biological term to describe "an individual's relationship to other individuals in their genealogical history." Hubbard, A. R. (2017). Teaching Race (Bioculturally) Matters: A Visual Approach for College Biology Courses. *The American Biology Teacher*, *79*(7), 516–524.
Between Group Variation	The amount of *extra* variable DNA that differs *between* groups.
Bias	Unfairly favoring or being against a thing, a person, or a group
Common Garden Experiment	An experiment that estimates the impact of genes on an organism's traits. This experiment is done by randomly selecting offspring, taking them from their parents, and rearing them in an environment where their biological parents are not present. This allows researchers to estimate the genetic effect on a trait while controlling for the environment.
DNA	Hereditary material found in the nucleus that is made up of four chemical bases (adenine, guanine, cytosine, and thymine).
Environment	The physical, social, geographical, and/or economic conditions that a person, animal, or thing experiences.
Ethnicity	A culturally variable term describing a group of people who share or are perceived to share cultural features (e.g., language, dress, cuisine, etc.). Hubbard, A. R. (2017). Teaching Race (Bioculturally) Matters: A Visual Approach for College Biology Courses. *The American Biology Teacher*, *79*(7), 516–524.
Genes	A gene is the basic physical and functional unit of heredity. Genes are made up of DNA. Some genes act as instructions to make molecules called proteins. However, many genes do not code for proteins. In humans, genes vary in size from a few hundred DNA bases to more than 2 million bases.

Genome	All of an organism's DNA.
Ideals	A set of goals and standards to strive towards to better be able to think and behave like scientists.
Malleable	Able to be changed and/or adapted. i.e not unchangeable or fixed.
Multifactorial	Involving or dependent on multiple factors and/or causes
Norms	Norms are the socially agreed upon ways that we behave and interact with one another when working toward a common goal
Race	A culturally variable term describing a group of people who are perceived as sharing biological features (e.g., skin color, eye shape, hair texture, etc.). Hubbard, A. R. (2017). Teaching Race (Bioculturally) Matters: A Visual Approach for College Biology Courses. *The American Biology Teacher*, *79*(7), 516–524.
Redlining	Redlining refers to government and/or banking programs starting in the early 1900s which discriminated against particular racial groups in securing loans for home ownership. Areas were color coded to indicate "loan worthiness" and areas marked in red were the least worthy of receiving loans (hence the term redlining). Red areas were predominantly inhabited by black and minority residents. This severely limited minority people's ability to buy homes and start businesses which are major sources of wealth accumulation. This still has impacts on generational wealth today. *Mapping Inequality: Redlining in New Deal America* https://dsl.richmond.edu/panorama/redlining/#loc=5/39.1/-94.58&text=intro Jackson, C. (2021, August 17). *What is redlining?* The New York Times. Retrieved December 20, 2022, from https://www.nytimes.com/2021/08/17/realestate/what-is-redlining.html Jan, T. (2021, November 24). *Analysis | redlining was banned 50 years ago. it's still hurting minorities today.* The Washington Post. Retrieved December 20, 2022, from https://www.washingtonpost.com/news/wonk/wp/2018/03/28/redlining-was-banned-50-years-ago-its-still-hurting-minorities-today/
Segregation	Segregation is the practice of separating and restricting people to certain prescribed areas of residence or institutions (such as schools, restaurants, shops, etc.) based on factors such as race. While sometimes segregation is explicitly implemented through laws (de jure), de facto segregation can persist long after those laws are abolished. For

	instance, while racial segregation was legally banned in the USA in 1964, its effects can still be seen in school demographics. https://www.npr.org/2022/07/14/1111060299/school-segregation-report https://www.brookings.edu/essay/homeownership-racial-segregation-and-policies-for-racial-wealth-equity/
Shared Within Group Variation	The amount of variable DNA that is *shared* by two or more groups.
Traits	Characteristics or attributes of an organism that are expressed by genes and/or influenced by the environment. Traits are variable.
Variable DNA	The 0.1% of DNA that differs between humans.
Within Group Variation	The amount of genetic differences that occur *within* a single group.