Genomics—Decoding the Language of Life

Objectives

Students will:

- Make connections between genomes, genes, and traits.
- Explore why/how genetic mutations can result in potentially harmful effects on human health.
- Explain how genetic sequencing can provide us with important information about human history and health.
- Explore what bioinformatic databases can reveal through genomic sequencing outputs.
- Understand that genomics can be used to help solve the world's biggest problems in the fields of epidemiology, agriculture, medicine, and environmental science.

OVERVIEW

We are excited that you are planning to view the Virtual Field Trip with We are excited that you are planning to view the Virtual Field Trip with your class. In these activities, students will learn about the intersection of biology and technology. Genomic techniques reveal important information that is helpful in many fields of study, including medicine, disease, agriculture, and environmental science that we were able to explore in the chapters of the video.

During this Virtual Field Trip, students will

- explore how sequencing a genome reveals the "code" of a living organism and how mutations can severely disrupt the way the code is interpreted by the cellular machinery of an organism.
- see how bioinformatics helps us to organize and interpret the information provided by sequencing techniques, and what we can learn about ourselves and our world from this.
- explore some of the amazing genomic breakthroughs made in recent years as well as the potential that these breakthroughs have to solve global medical, economic, and health-related problems and answer questions about the history and future of living things.

MATERIALS

- Fictional Genomes Student Handout
- Spiral bound index cards—1 set per student
- Markers—1 per student
- PTC paper strips
- Control paper strips
- PTC—What does it say about me? Student Handout

- Adventures in Genomics: Breakthrough Summary Sheet Student Handout
- Comic Book Planning Sheet Student Handout
- Comic Book Frames Student Handout
- Student devices (iPad, laptop) with internet connection

KEY VOCABULARY

- **DNA:** the hereditary material in humans and almost all other organisms.
- **gene:** the basic physical and functional unit of heredity. Genes are made up of DNA.
- **trait:** a specific characteristic of an individual that is determined by the interaction with the environment with genes.
- **genome:** the entire set of genetic instructions found in a cell.
- **genomics:** the study of the entire genome of an organism.
- **genomic sequencing:** the process of determining the entirety, or nearly the entirety, of the DNA sequence of an organism's genome at a single time.
- **bioinformatics:** a field that develops methods and software tools for understanding biological data, in particular when the data sets are large and complex.

BEFORE ACTIVITY

Before your students begin the Virtual Field Trip, students will review and interpret the connection between DNA, mutations, genes, and the genome to introduce the importance of genomics, a field of science that uses biology and technology to crack the code of life.

Teacher Prep: *Make copies of the Fictional Genome sheets A–F for students (reference page). There should be four copies of each genome sheet for a class of 24. Provide spiral bound index cards and markers so that each student will have one of each.*

Divide students into six sequencing groups (A–F), and give each group the correct sheet containing a series of letters that represents the genome of a fictional organism. Students should work together to "sequence the genome" and find a phrase hidden in the letters. The instructor should check in with each group and give hints if needed.

Once all groups have discovered their phrase, they will form four new groups of six students each, consisting of one member of the original groups, A–F. Each group member will be given a pack of spiral-bound index cards, and they will write the phrase they sequenced on the first card without sharing it with any other group members.

Each member will then pass their spiral index cards to the person to their left. A timer set at 60 seconds will

begin, and each person will draw a picture that represents the phrase written on the first card they received. When the time is up, cards will be passed to the next person to the left, and that person writes the phrase they believe the picture represents on the next card. This continues every 60 seconds until the cards return to the member who wrote the original sequenced phrase. Students will take turns revealing the changes the phrase went through by reading new phrases and showing the pictures that were drawn and comparing it to the original phrase that was sequenced.

Ask students to return to the whole group and show them the video clip "Why do we want to know about genomes?" Ask students to think about a connection between the opening activity and genomics. Discuss what the activity and miscommunication between students may represent in relation to genes and traits. Allow students to share their ideas with the whole group.

Students should understand that the differences in the phrases and pictures represent mutations in the DNA or in the cellular machinery that produces proteins, and that detecting these mutations in the sequencing process can help treat diseases, discover changes in pathogens, identify species, and learn more about genetic differences and similarities between organisms and individuals.

POST ACTIVITIES

Before You Begin—Teachers

Teachers should order PTC paper and Control paper strips prior to this activity. This can easily be ordered through biological supply companies, such as Carolina Biological, or it can be ordered on Amazon. The teacher should be sure to check shipping times to ensure that they arrive prior to the activity.

Activity 1: An Inherited Taste

To help students experience what genomics can help us learn about ourselves and our history through our genes, in this activity, students will explore the TAS2R38 gene.

To begin the activity, ask students to share what they know about how their sense of taste works and what might be the consequences if they somehow lost their sense of taste. Allow students to share their answers with the class. Explain that in this activity, they will first test their sense of taste, and that the results may reveal some things about themselves that they were not aware of.

Give each student a strip of control paper. Ask the students to hold on to the paper and wait for further instructions as they are passed on. Ask students to taste the control paper and report their results. Students should say that it simply tastes like paper. They can throw away the strip when they are finished tasting it.

Next, give each student a strip of PTC paper and ask students to taste this strip of paper and report their results. Some of the students should report that they taste nothing and that it is the same as the first paper strip, and some of the students should report a nasty bitter taste. Ask students to discuss what they think has happened to these poor students that are in need of a drink.

Reveal to students that the second strip has been treated with a harmless chemical called phenylthiocarbamide—PTC. Ask students why they think only some of the class could detect this bitter taste?

Students should guess that the ability to taste PTC is a genetic trait and the ones who only tasted regular paper do not have this trait.

Ask students to find a partner. Give each pair a copy of the "**PTC—What does it say about me?**" Student Sheet. Tell the class that they will be exploring some of the things that genomics has helped us to learn about this trait and us as humans.

Student pairs should work through the activity, following the instructions and using the links provided.

Once students are finished, give student pairs time to share their CER results with other pairs or with the whole class to assess what students have learned about the power of genomics to help people.

Activity 2: Adventures in Genomics: The Comic

As students learned in the Virtual Field Trip, genomic breakthroughs have impacted what we know about many areas of study including medicine, agriculture, environmental science, and epidemiology.

Ask students to get into pairs or small groups of three and go to "Adventures in Genomics" on their student devices. Explain to students that their task is to scroll through the list of genomic breakthroughs and choose one that interests them, or the instructor may assign them. No two groups should choose or be assigned the same genomic breakthrough.

Give each pair or group a copy of the **Adventures in Genomics Breakthrough Summary Sheet**. Tell students that their job is to view the video and record information from the video on their summary sheet. After viewing, group members should discuss their answers to the reflection questions at the end of the sheet and record these as well.

Students will then work together to create a one-shot issue of the comic series "**Adventures in Genomics**" that tells the story of their genomic breakthrough in a graphic and entertaining way.

Explain to students that they can create their comic on paper (using the **Comic Book Frames sheets**) or they can do this digitally using free online tools such as Canva, Pixton, or Storyboard That.

Before they create their comic, ask students to complete a copy of the **Comic Book Planning Sheet**. This will give them a space to use what they've learned in the breakthrough video to identify characters and plan their storyline.

Once students have finished their Comic Book Planning Sheet, they should use the supplies available (Comic Book Frames sheet, pencils, colored pencils, markers, student devices—iPad or laptop—with the digital comic-book-making tool of their choice) to work together and create their comic.

If time allows, students may present their comics to the whole group, or comics can be displayed (on laptops or iPads if they are digital) around the classroom for students to read and learn about other breakthroughs in genomics.

Cut into strips and give each group or pair only their assigned genome

GENOME A	sdfaoijefitsdsfjsoijvraindconskdingdfaondfdfslkscatsadlfkaoicjskanwejandsdlfjoivondogsdfiaonocaoj	**Phrase:** It's raining cats and dogs
GENOME B	sdvjaosinsstickzdkflnsdsfkaslkanddlknasdonvstonessdkflnavosdmaysdkvnsodnbreakserjobbsdfnmysdonaoinvasovnbodjsnessadfknoisn	**Phrase:** Sticks and stones may break my bones
GENOME C	sdfaaonoadcfifadsfnaoincteenadsnfoainoicxfklminutesdfgnasodnooffansefoafndaoiadfoame	**Phrase:** Fifteen minutes of fame
GENOME D	dlkfjaoslikeasdfnasofjafjasdfljslfafishasdljfaosdfjoincssoutsdfkjasodifnoicoisofejanoawaterasklfnaoiwwskdoics	**Phrase:** Like a fish out of water
GENOME E	afjaosidfjthedsofinaeoinfaearlyadfhajdfaibirddalskjaoiaoidnacatchadesaslefjaognatheaofnaoiwormdk	**Phrase:** The early bird catches the worm
GENOME F	adfkahadndmondskoeydalfnhaiojfaoddoesasdnfaoinfanotdoafaoignaogrowesssaoidonadofnaiotreesaoneia	**Phrase:** Money does not grow on trees

ADVENTURES IN GENOMICS: BREAKTHROUGH SUMMARY SHEET

What field of science is your genomics breakthrough in? (Epidemiology, evolutionary biology, agriculture, etc.)

What is the problem or question that the scientists in your video are trying to solve or answer?

What type(s) of genomic technologies are being used to help solve this problem or answer this question?

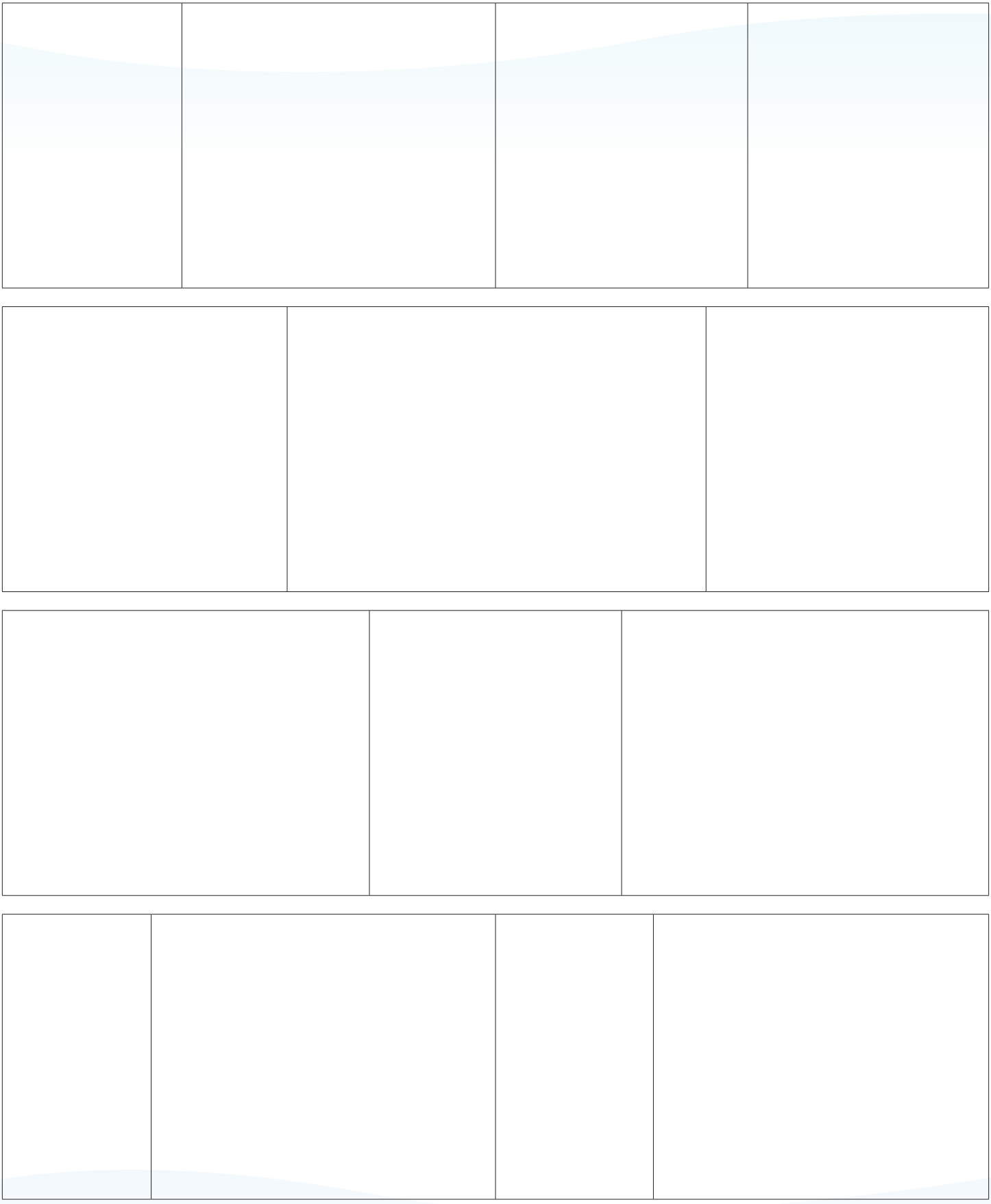
Do some research if you are not familiar with this technology. Summarize how it is being used in this specific genomic breakthrough.

How will/might this breakthrough help humans locally or globally?

What are the next steps or questions that need to be answered or explored in this genomic breakthrough?

COMIC BOOK PLANNING SHEET

Notes	Frame 1	Frame 2	Notes
Notes	Frame 3	Frame 4	Notes
Notes	Frame 5	Frame 6	Notes
Notes	Frame 7	Frame 8	Notes



Now that you have determined if you are a "taster" or a "nontaster," it's time to learn what genomics has revealed to us about this trait…

Instructions: Go to the links and follow the instructions provided. Complete the reflection about what you have learned and what this information makes you wonder about "tasters" and "nontasters!"

PART 1: PTC the Genetics of Bitter Taste

LINK: https://learn.genetics.utah.edu/content/basics/ptc/

Section	What I Learned	What I Wonder
History (Introduction)		
PTC Gene		
Natural Selection at Work		
To Taste or Not to Taste		

PART 2: What does the PTC gene tell us about us?

LINK: https://med.stanford.edu/news/all-news/2003/02/bitter-or-sweet-stanford-research-spits-out-gene-linked-to-taste-sensation.html

What I Learned	What I Wonder

PART 3: Using Bioinformatics to learn about the PTC gene

Instructions:

1. Go to https://www.ncbi.nlm.nih.gov/
2. Click on “GENE” on the right side of the screen.
3. In the search bar at the top of the screen, type TAS2R38 and click search.
4. In the GENE box, click on **TAS2R38—taste 2 receptor member 38**.
5. Scroll down and answer the questions below:

What does this gene control? (See the “Summary” section)

What human chromosome is this gene found on?

6. Hit the BACK ARROW to go to the previous page.
7. In the “GENE” box, click the button labeled as “BLAST.”
8. This will take you to the “BLAST >> blast suite” page. Scroll down and click the blue “BLAST” button at the bottom left. (This may take up to a minute to load.)
9. When the BLAST page opens, scroll down to the Sequences Producing Significant Alignments table and choose “select columns” on the right side.
10. Select “Common name.” This will show the common names of the species that have the closest match to the human TAS2R38 gene.

What are the first three non-human species you find as you look down the list of common names of species that have the greatest percent identical score to the human TAS2R38 gene? (You can use the “Percent Identical” column to help you determine this.)

Which species has the closest gene sequence to ours? What percent of the sequence is identical to our own?

11. Go to: https://www.ncbi.nlm.nih.gov/genome/gdv/
12. Once you are in the Genome Data Viewer, you will see a tree showing relationships between taxa of living things.
13. Click on the dog in the tree. In the “search in genome” box, type in TAS2R38 "(the human PTC gene)". Click the magnifying glass to do a search.
14. When the browser loads, analyze the results.

Does the dog have the gene or do your results say "TAS2R38 returns no result"?

If the dog does have the gene, which chromosome is it found on?

15. Click the back arrow to return to the previous screen. Click on some other animals and repeat steps 13–14.

What are some other animals in the tree that also have this gene? List some below. What are some observations or inferences you can make about organisms that do have the "TAS2R38" gene and the organisms that do not?

Now that you have taken an in-depth look at the information that genomics has provided us about the ability to taste PTC, use what you have learned to complete the Claim, Evidence, and Reasoning (CER) activity summary below.

Prompt

Studies indicate that individuals with the "strong tasters" PTC gene variant were less likely to be smokers, indicating that people who find PTC bitter may be more likely than non-tasters to find the taste of cigarettes bitter and may be less likely to smoke.

Question: Could genomic sequencing potentially be used to help prevent people from smoking before they even start?

CLAIM	
EVIDENCE	
REASONING	

NATIONAL STANDARDS

Common Core State Standards ELA/Literacy

- RI.5.7 Draw on information from multiple print or digital sources, demonstrating the ability to answer a question quickly or to solve a problem efficiently.

NGSS Standards

- **HS-LS3-1 Heredity: Inheritance and Variation of Traits**
  Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.
- **HS-LS3-2 Heredity: Inheritance and Variation of Traits**
  Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.
- **HS-LS3-3 Heredity: Inheritance and Variation of Traits**
  Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.
- **HS-LS4-1 Biological Evolution: Unity and Diversity**
  Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.
- **HS-LS4-3 Biological Evolution: Unity and Diversity**
  Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.