FUTURELAB+

BIOMED

Behind the Scenes of Scientific Breakthroughs

The Human Genome Project

Developed in partnership with:

Discovery Education and Ignited

In this Lesson Plan:

Print the **Teacher Section** →

Print the **Student Section** →

This document is separated into two sections, For Teachers [T] *and* Student Resources [S]*, which can be printed independently.*

Select the appropriate printer icon above to print either section in its entirety.

Follow the tips below in the Range field of your Print panel to print single pages or page ranges:

Single Pages (use a comma): T3, T6

Page Range (use a hyphen): T3–T6

Cover Image
This is a conceptual illustration of genetic engineering.

BIOMED / BEHIND THE SCENES OF SCIENTIFIC BREAKTHROUGHS

The Human Genome Project

DRIVING QUESTION

Will a better understanding of the human genome structure help us increase lifespan or even live forever?

OVERVIEW

The Human Genome Project, also called HGP, was led by scientists worldwide in the hope of identifying all genes in the human body. The HGP was filled with high expectations to determine the sequence of bases in our DNA and link these sequences to each chromosome to create a map of inherited traits including diseases. DNA sequencing and the work of the HGP has allowed scientists to link the sequence of nucleotides to their corresponding genes and identify genes linked to diseases. Now DNA sequencing is used for different purposes that include DNA profiling in forensics, understanding environmental changes and evolution, and diagnostics and treatments in medicine.

In this lesson, students will understand how DNA sequencing works. They will learn about the genome and the proteome, and understand the impact of modifying the DNA sequence on the protein function. Students will summarize their learning by creating a miniature biotechnology unit for a middle school science class.

ACTIVITY DURATION

Five class sessions
(45 minutes each)

ESSENTIAL QUESTIONS

Could we replace our old cells and live a thousand years?

Could we make genetic diseases completely disappear from Earth?

How can environmental factors affect our epigenome?

OBJECTIVES

Students will be able to:

Investigate the technique of gene sequencing and its industrial applications.

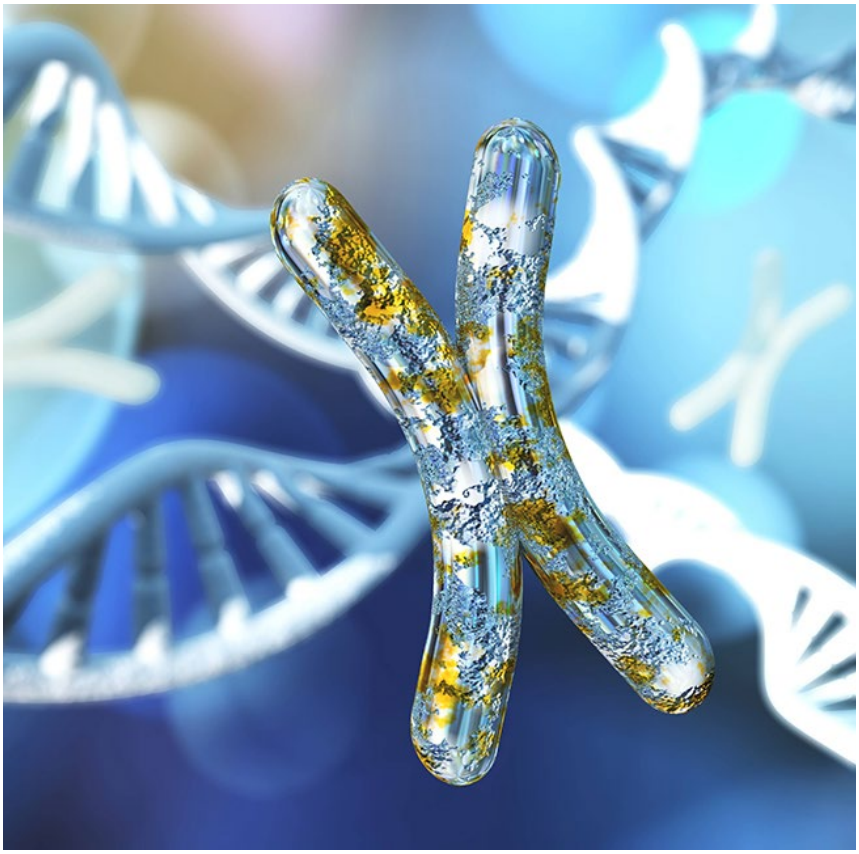
Examine the difference between the genome and the proteome.

Recognize the steps leading to the synthesis of proteins.

Study factors that link genes to longevity.

BACKGROUND INFORMATION

In this lesson, students will learn about the difference between the genome and the proteome. They will understand the purpose of genome sequencing and its industrial applications. It would be helpful if students have basic knowledge of genetics, knowing how DNA transcription and translation work.



Materials

- **32 Ping Pong Balls**
- **Large Clear Trash Bag**
- **10 Feet of Plastic Wrap**
- **Hot Glue or Super Glue**
- **Scissors**
- **Sharpie**
- **Poster Paper**
- **Tape**
- **Proteomics Video Capture Sheet**
- **Online Interactive: Transcribe and Translate a Gene Capture Sheet**
- **Gene Control Capture Sheet**
- **Create Your Own Mini Biotech Unit Capture Sheet**
- **Design Journal**

Pedagogical Framing

Instructional materials are designed to meet national education and industry standards to focus on in-demand skills needed across the full product development life cycle—from molecule to medicine—which will also expose students and educators to the breadth of education and career pathways across biotechnology.

Through this collection, educators are equipped with strategies to engage students from diverse racial, ethnic, and cultural groups, providing them with quality, equitable, and liberating educational experiences that validate and affirm student identity.

Units are designed to be problem-based and focus on workforce skill development to empower students with the knowledge and tools to be the change in reducing health disparities in communities.

SOCIAL-EMOTIONAL LEARNING

Students will work in groups on multiple activities from exploring DNA function to artificial intelligence. This requires all discussion participants to demonstrate empathy and practice social awareness. They are given numerous occasions during which they can make decisions to ensure self-management.

CULTURALLY AND LINGUISTICALLY RESPONSIVE INSTRUCTION

Students will work on the applications of the Human Genome Project (HGP) and consider who will benefit from it. This will encourage them to develop a connection to how this might or might not benefit their community. They will search for solutions for communities that lack resources and who have been historically disenfranchised or underrepresented in scientific research. Students also employ various responsive strategies to learn about the controversy of the project and to construct their own ideas in response. Students will contemplate how the HGP used traits or genes unique to a particular group.

COMPUTATIONAL THINKING PRACTICES

This lesson opens with students using a model to demonstrate how chromosomes prepare for cell division. On Day 2, students practice the computational thinking strategy of decomposition as they transcribe and translate genes in order to understand the connection between the genome and the proteome. Then they construct a flowchart that outlines the structure and process of protein synthesis. Students find patterns and analyze data in order to determine how environmental factors affect the gene expression.

CONNECTION TO THE PRODUCT LIFE CYCLE

The lesson addresses all the components of the Product Life Cycle, from DNA sequencing to the different applications involving proteome and artificial intelligence. This will give students the skills required to understand how biological structures can be manipulated and engineered to fulfill long desired human wishes to extend life infinitely and ultimately allow them to take part in one of the most industrially active quests by creating a method to slow aging.

Have you ever wondered…

How is the hydra phylum, a small animal living in freshwater, capable of avoiding aging and living forever?

The hydra phylum has been the target of extensive research because its cells do not age. The cause of death of the hydra is predators or disease, but the hydra's cells never seem to age and it still remains a mystery to this day.

How can mutation in the DNA sequence help with disease diagnosis?

DNA sequencing allows us to identify the sequence of bases (A, T, C, G) in a gene and therefore variants of that sequence help scientists link the gene segment to diseases.

What was the first virus to have its genome entirely sequenced?

The flu virus was the first to have its genome sequenced. In fact, it is made of RNA segments and had to be copied in order to produce the proteins.

MAKE CONNECTIONS!

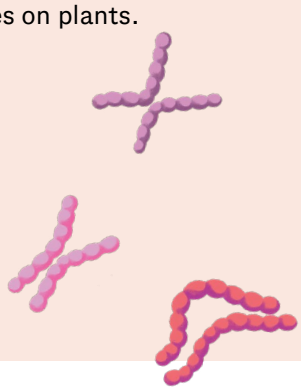
How does this connect to the larger unit storyline?

Progress in technologies has been the reason for an extended lifespan. Scientists have discovered that only two percent of the genome leads to the production of proteins. What do the other 98 percent do? Scientists have discovered that these segments of DNA could be involved in the regulation of proteins. Could this be the secret of a long life? Students will explore the DNA through sequencing of the genome and links to its proteome.

How does this connect to careers?

Bioinformaticians use programming to design models and organize data. Bioinformaticians are involved in sequencing the human genome and connecting it to known DNA sequences.

Geneticists will study the genes and link them to particular diseases to help find the best treatments for each patient. Geneticists can also study genes on plants.



How does this connect to our world?

There are large disparities when it comes to the treatment efficacy of approved drugs. Biotechnologies enable a better understanding of human genome variation and metabolism leading to personalized diagnostics that improve drug efficacy and reduce adverse effects. In the case of proteins being responsible for diseases, using technologies to alter the DNA function of these proteins is also leading to a better lifestyle and increased lifespan.

Day 1

LEARNING OUTCOMES

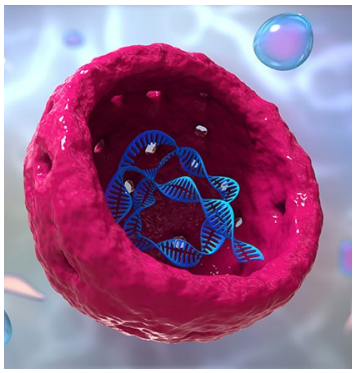
Students will be able to:

Model how DNA is packaged inside the nucleus of a cell.

Describe the purpose of the Human Genome Project and the social and medical applications that this information provides.

COMPUTATIONAL THINKING IN ACTION

In this activity, students use the computational thinking strategy of building models to show where DNA fits within a cell, how it is packaged, and what takes place ahead of cell division. They are given the option of exploring a 3D model to make further connections and deepen their understanding of genome structure and sequencing.



This image shows a 3D illustration of the nucleus of the eukaryotic cell.

Procedure

Teacher Note > *Students will model how DNA is packaged inside the nucleus of a cell and how the understanding of the structure of our genome led to the sequencing of our genes for the Human Genome Project.*

Whole Group (30 minutes)	
1	Ask students the following question: If you stretched the DNA in one cell all the way out, how long do you think it would be? Invite students to share their predictions. Our DNA would be about 2 meters in length! To demonstrate this, hold two meter sticks up.
2	Explain to students that they will work in a group of four to build a model of how DNA can be packaged so it can fit inside the nucleus of a cell.
3	Each group should have the following materials: 8 ping pong balls, clear trash bag, adhesive (hot glue or super glue), tape, and a sharpie.
4	Have each group assemble a nucleosome by connecting 8 ping pong balls in the arrangement of a double stack of four. Each ping pong ball represents a protein called a histone.
5	After all nucleosomes are constructed, the teacher should roll 10 feet of plastic wrap into a rope-like shape. This represents the DNA in the model.
6	One group will wrap their nucleosome with the DNA about 3–4 times. When they are finished, a second group will leave some space and use the plastic wrap to wrap their nucleosome. This will continue until all groups have wrapped the nucleosome in sequence. Tape or adhesive may be used to secure the plastic wrap (DNA) to the nucleosome.
7	To demonstrate how a chromosome forms to prepare for cell division (mitosis or meiosis), the groups will have to push and pull all the nucleosomes together to make a condensed arrangement of the DNA.
8	When the arrangement is condensed, place it in the clear trash bag. Fill half the bag with air before tying it closed.

Teacher Note > *Plastic bags, wraps, and films often cannot be recycled in your school recycling bins. You or your students may take these items to local retail stores where they collect plastic grocery bags for recycling.*

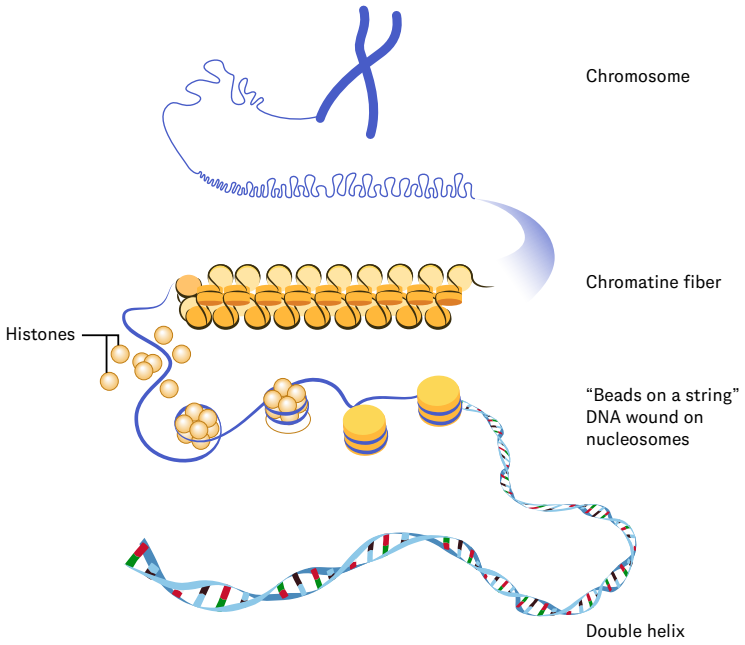
Continues next page >

Day 1

Continued

Procedure

9 To close the activity, display the following image for the students to examine.



Have students answer the following question with a *Pick a Stick*, or similar protocol.

Have students consider what items used in the class model are represented in the illustration and structures of a cell.

a. Ping pong ball = histone

b. Stacked ping pong balls = nucleosome

c. Plastic wrap = DNA wound on nucleosomes

d. Tightly packed histones = Chromatin fiber

e. Trash bag = nuclear envelope (not pictured)

10 Q: Do you think it would be easier to access the genes found on the DNA before or after the formation of the chromatin fiber? Explain.

A: Genes would be more easily accessible for gene expression before the closely packed arrangement of the nucleosomes into the chromatin.

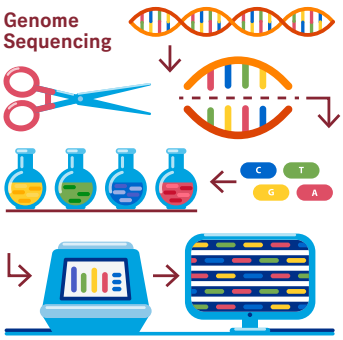
Continues next page >

Day 1

Continued

Procedure

11	If students need additional time to master this concept, have them watch this 3D animation: *3D Animations—DNA Molecule: How DNA is Packaged (Basic)—CSHL DNA Learning Center* (1:30).



Small Group (15 minutes)	
1	Explain to students that they will be introduced to *Lessons from the Human Genome Project* (7:27) by watching a video.
2	Determine prior knowledge by asking students to share what they know about the Human Genome Project.
3	Explain that students are going to watch the video *Lessons from the Human Genome Project* with a partner and they will be responsible for constructing a list of "10 Things I Didn't Know" about the Human Genome Project while watching the video. They can pause the video to construct the list.
4	To close the activity, have students share their lists with two other groups to construct *25 Things You Didn't Know* about the Human Genome Project on a sheet of poster paper. Their lists should not have any repeated information. Each sheet of poster paper can be hung on a wall for the students to view.

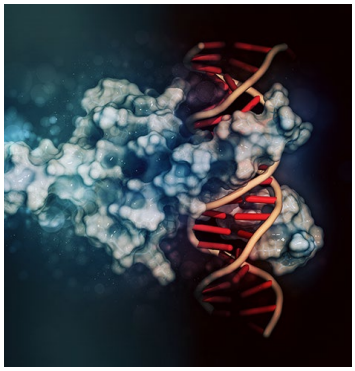
Day 2

LEARNING OUTCOMES

Students will be able to:

Compare and **contrast** the genome and the proteome.

Transcribe and **translate** genes to determine the protein produced.



This image shows a 3D illustration of a DNA ladder model surrounded by semi-transparent protein surfaces.

Procedure

Teacher Note > *On Day 1, students learned about the genome. Today they will explore the link between the genome and the proteome.*

Whole Group (15 minutes)

1 Start the class by posing the question: *What is the difference between genome and proteome?* Allow students to *Raise a Righteous Hand* to answer.

A: The genome is the set of genes of an organism and the proteome is the set of proteins of an organism.

2 Distribute the *Proteomics Video Capture Sheet* to each student. Have them read each description before they watch the video. While watching the video: *Proteomics: Proteins At Work* (4:30) students should determine if the description belongs to the proteome or genome. When the video is complete, have students compare their answers with a partner before reviewing the correct answers with the class.

3 Close the activity by having students answer the following questions on a note card.

a. Q: What are the main targets of drugs?

A: Proteins

b. Q: How can proteins in the blood help with diagnosis of disease?

A: Unusual proteins, called biomarkers, are released in the blood when a person is afflicted with a disease and the discovery of markers for each disease associated with specific DNA sequences can help develop more efficient drugs.

Continues next page >

Day 2

Continued

Procedure

INDUSTRY AND CAREER CONNECTION

In this activity, students will be tasked with using a bioinformatician's soft skills of teamwork and problem-solving as they explore how cells "read" the information in a DNA sequence to build a protein.

Small Group (30 minutes)

1. Explain that students are going to work with a partner to transcribe and translate three genes to understand the connection between the genome and the proteome. Distribute the *Online Interactive: Transcribe and Translate a Gene Capture Sheet* to each student. Read the directions and have the students complete the interactive together.

2. To close the activity and assess what students have learned, have them construct an illustrated flowchart of protein synthesis. The flowchart must include the following criteria:

   a. Description of the role of each structure: ribosome, nucleus, mRNA, gene, DNA, tRNA, codon, and amino acids

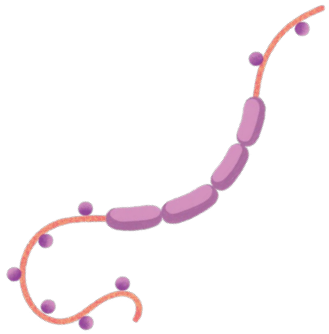
   b. Description of each process: translation and transcription

   c. Location of each process: translation and transcription

   d. A gene sequence must be used as an example: CGACATGACTAGTCTGGGATC

COMPUTATIONAL THINKING IN ACTION

Students abstract information and develop algorithms as they identify core components from their learning to create a flowchart of the protein synthesis process.



Day 3

LEARNING OUTCOMES

Students will be able to:

Describe how our epigenome can be affected by environmental factors.

Explore how methyl and acetyl tags can affect gene expression.

Procedure

Teacher Note > *On Day 2, students studied how proteins can be linked to different cell functions and can be used as markers of disease. Today they will explore how our epigenome can be affected by environmental factors, which affect the expression of our genes.*

Whole Group (10 minutes)

1 Begin the lesson by asking students to answer the following question with a partner. Invite students to share their answers with the class.

a. Q: How are identical twins formed?

A: Identical twins form when a single embryo splits into two.

b. Q: Do identical twins have the same genome?

A: Yes

c. Q: What are some environmental factors that could affect our genome?

A: Diet, physical activity, exposure to toxins

2 Explain to students that they will be watching a video that discusses our epigenome. Remind students that tightly packed DNA can prevent gene expression. If genes cannot be transcribed, then proteins cannot be synthesized. Play the following video: *The Epigenome at a Glance* (1:47).

Small Group (30 minutes)

1 Explain to students that they will complete an online interactive with a partner to explore the relationship between epigenetics and gene control. Distribute the *Gene Control Capture Sheet* to each student. Set the purpose of the activity by reading the background and objective. You may also want to model where to find the information icons and how to use the control knob on the interactive using the following link: *Gene Control*.

2 To close the activity, ask the students to develop a clever way, such as a jingle or mnemonic, to associate methyl with silencing genes (tightly compacted DNA) and acetyl with activating genes (loose DNA).

For example:

A: A for activate

Day 4

LEARNING OUTCOMES

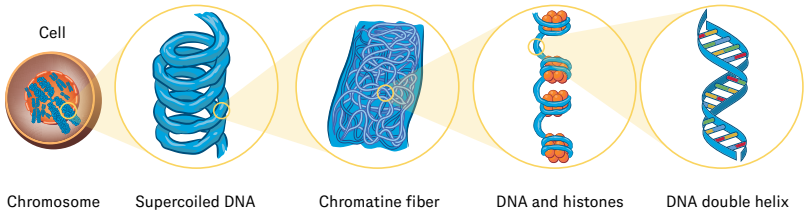
Students will be able to:

Inspect possible functions of unknown sequences of DNA.

Connect fragments of DNA that are still unknown with fragments of DNA that are known.

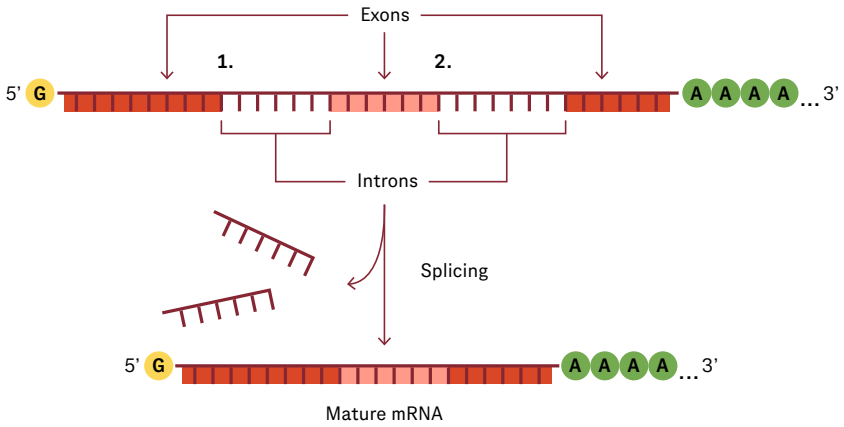
Procedure

Teacher Note > *On Day 3, students studied how DNA packaging and gene expression can be affected by environmental factors. Today they will investigate what is still unknown about the role of DNA sequences in human health and possibly longevity.*



Whole Group (20 minutes)

1 Introduce the topic of mRNA processing by displaying the following image. Have students develop a claim as to which part of the DNA is expressed into a protein. They need to provide evidence from the image to support their claims.



2 Ask students to make a prediction as to the purpose of introns if they are just spliced out of the mRNA. Share that current research suggests the functional roles of introns in various cellular processes are mRNA splicing, mRNA transport, and gene expression regulation. Introns may give some advantages as a mutational buffer in eukaryotic genomes protecting coding sequences from being affected by randomly occurring deleterious mutations. Introns occupy about 40%, on average, of the total length of genes, which means that most randomly occurring mutations will fall into intron regions, and do not affect protein sequences and functions.

Continues next page >

Day 4

Continued

Procedure

3	Explain that students are going to watch the following video: *Just What is RNA Splicing?* (3:30). Challenge them to answer the following question after viewing the video: *It is estimated that there are 30,000 genes in the human genome and approximately 80,000 to 400,000 proteins in the human body. If one gene is transcribed and translated into one protein, why do we have so many more proteins compared to genes?* Have students construct their responses on note cards with a partner.

Small Group (25 minutes)

1	Explain to students that they will read and interpret a scientific article titled *The Mysterious 98%: Scientists Look to Shine Light on Our Dark Genome*.
2	Assign each student to one of the following expert groups below (*Jigsaw* strategy). Each expert group will be assigned a section of the *article* to summarize. • Importance of Genomic Grammar • Cellular Barcodes Reveal Regulatory Function • Deleting Sequences to Understand Their Role • Can Dark Matter DNA Treat Disease?
3	When expert groups have finished constructing their summaries, they should form a group of four. Each group must have one expert from each of the four sections of the article. Each expert will share his or her summary of the article.
4	To close the activity and determine individual student understanding, have students construct a one-sentence summary for each section of the article.

Teacher Note > *In order to ensure the summary is concise, you may use the dollar summary strategy in which students are told each word is worth 5 cents and the sentence cannot add up to more than one dollar.*

COMPUTATIONAL THINKING IN ACTION

By working together with their expert groups, students practice the computational thinking strategy of collecting data as they gather and review information. They abstract the most important elements in order to construct a summary and share out with classmates who covered different sections of the article.

Day 5

LEARNING OUTCOMES

Students will be able to:

Synthesize information about DNA packaging, protein synthesis, the Human Genome Project, proteomes, RNA processing, and epigenetics to create a mini biotechnology unit for a middle school science class.

Procedure

Teacher Note > *Remind students to update their Design Journal to capture how content learned in this lesson connects to the information they are investigating and to the creation of their final product.*

Whole Group (10 minutes)

1. Explain to students that they are going to create a miniaturized middle school biotechnology unit demonstrating what they learned in this lesson.

2. Ask students to brainstorm a list of features teachers usually include in a unit of study. Examples may include lectures, quizzes, hands-on activities, lab investigations, tests, etc.

3. Distribute the *Create Your Own Mini Biotech Unit Capture Sheet* and review the project criteria answering any questions students have.

4. Students will be responsible for creating a PowerPoint or Google Slides lecture. The lecture must be at least 7 slides that include the following topics:
   - **a.** Title slide
   - **b.** DNA packaging
   - **c.** Human Genome Project
   - **d.** Proteome
   - **e.** Protein synthesis
   - **f.** Epigenetics
   - **g.** RNA processing

5. Explain that students will also need to find a video on one of the topics and create a student capture sheet (as well as a teacher key) to assess student understanding.

6. Students will need to create a vocabulary activity covering 10 words and their definitions. Examples include quizlet, quizizz, and matching.

Continues next page >

Day 5

Continued

Procedure

COMPUTATIONAL THINKING IN ACTION

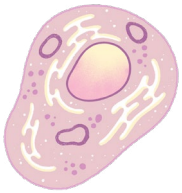
By creating questions to assess learning, students abstract the most relevant information from their mini-unit and consider the best way to gauge understanding. In taking this step through the testing phase, students have the opportunity to collect data and refine their project based on how well the content in their lessons met the learning objective.

7	Students will also develop a 20-question quiz (as well as a teacher key) that assesses student overall learning of the mini unit. The quiz must have at least one question about each of the topics covered in the lecture. Format of the assessment could include multiple choice, matching, labeling diagrams, and brief constructed responses.

Individual (35 minutes)

1	Students will work with a partner to create their miniature biotechnology unit. After reviewing the project criteria, have students determine how they will divide the work and create each part of the unit.
2	On the *Create Your Own Mini Biotech Unit Capture Sheet*, instruct students to write their names next to each part of the project for which they are responsible.
3	Students may need additional time outside of class to complete this summarizer.

Teacher Note > *Depending on your district's requirements for community service, students may be able to earn hours for delivering these lessons to younger students outside of school hours. Make sure to get administrative approval from your school as well as the school or program where the tutoring will occur.*



National Standards

Next Generation Science Standards

LS1.A: Structure and Function
Systems of specialized cells within organisms help them perform the essential functions of life. 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, which carry out most of the work of cells.

Science and Engineering Practices
Obtaining, evaluating, and communicating information
Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.

Crosscutting Concepts
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.

Systems and System Models
Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

Career and Technical Education (CTE)

A3.1
Define and describe the structure and function of DNA ribonucleic acid (RNA) and proteins, explain the consequences of DNA mutations on proteins.

Proteomics Video Capture Sheet

ANSWER KEY — **Do not share with students**

Directions
Complete the first question and read through the descriptions on the second question before watching the video. While watching the video Proteomics: Proteins At Work, determine if the description belongs to the proteome or genome, and mark in the appropriate column.

1. Before watching the video: Develop your own definition of a proteome.

The proteome is the entire set of proteins that is, or can be, expressed by a genome, cell, tissue, or organism at a certain time.

2. While watching the video: Determine if each description listed below matches proteome or genome.

Description	Proteome	Genome
Target of drugs	X	
In the nucleus		X
Made through RNA cell instruction	X	
Can predict drug response	X	
Collection of proteins	X	
Can predict nasty side effects		X
Can predict drug doses	X	
Thousands of proteins in the blood	X	

Description	Proteome	Genome
Markers of diseases	X	
Comes from DNA	X	
Made in the cytoplasm	X	
RNA synthesized from it		X
Composed of genes		X
Can predict drug responses and drug doses		X
Biomarkers	X	

Gene Control Capture Sheet

ANSWER KEY **Do not share with students**

Directions

Signals from the outside world can work through the epigenome to change a cell's gene expression.

Use the link: Gene Control to determine how sound affects the expression of the GFP gene.

1. Click on each information (i) icon to write a brief description of each of the following in the table below.

GFP gene	The GFP gene is a segment of DNA that contains the instructions for making Green Fluorescent Protein.
GFP mRNA	GFP mRNA is a single-stranded copy of the GFP gene in the form of messenger RNA (mRNA). Ribosomes read (translate) GFP mRNA to produce Green Fluorescent Protein.
Green fluorescent protein	In this experiment, GFP is a convenient readout of gene activity. Since DNA and genes are not visible even under a microscope, the amount of glowing GFP in the cell lets us know if the gene is inactive, highly active, or somewhere in between.
Histone	Histones are proteins that help organize DNA. A group of eight histone proteins come together to form a spool around which DNA wraps. Histone proteins have tails that stick out. Histone tails are often covered with chemical tags, affecting how they interact with DNA.
Methyl tag	Methyl tags most often silence genes, or keep them turned off.
Acetyl tag	Acetyl tags are usually found near active genes. Acetyl loosens the interaction between DNA and histones, allowing easier access to the DNA.

2. Toggle the "Labels Off/On'' button to see where each image is found in the protein synthesis process. When finished, remove the labels.

Continues next page >

Autophagy WebQuest Capture Sheet

ANSWER KEY **Do not share with students**

Continued

3. You will use the control knob to observe what happens to the mRNA and protein levels when you manipulate the epigenetic tags on the gene. Complete the table below with your observations.

	Clock Knob Position				
	12:00	3:00	5:00	7:00	10:00
Shape of DNA Loose, Coiled, Tightly Compacted	Loose	Loose	Loose	Tightly Compacted	Coiled
Level of mRNA Normal, Increased, Decreased, None	Normal	Normal	Increased	None	Decreased
Level of Protein Normal, Increased, Decreased, None	Normal	Normal	Increased	None	Decreased
Color of Cell 0 = No Green 1 = Normal 2 = Very Green	1	1	2	0	<1

4. Scroll down to *Gene Control and Cancer* to complete the table below.

Amount of Methyl	Gene Expression On or Off	Affect on Genes
Less Methyl	Genes On Expressed	1. Activation of genes that promote cell growth
		2. Chromosome instability
More Methyl	Genes Off Not Expressed	1. Keep cell growth in check
		2. Repair damaged DNA
		3. Initiate programmed cell death

FUTURELAB+

Proteomics Video Capture Sheet

Directions
Complete the first question and read through the descriptions on the second question before watching the video. While watching the video Proteomics: Proteins At Work, determine if the description belongs to the proteome or genome, and mark in the appropriate column.

1. *Before watching the video*: Develop your own definition of a proteome.

2. *While watching the video:* Determine if each description listed below matches proteome or genome.

Description	Proteome	Genome
Target of drugs		
In the nucleus		
Made through RNA cell instruction		
Can predict drug response		
Collection of proteins		
Can predict nasty side effects		
Can predict drug doses		
Thousands of proteins in the blood		

Description	Proteome	Genome
Markers of diseases		
Comes from DNA		
Made in the cytoplasm		
RNA synthesized from it		
Composed of genes		
Can predict drug responses and drug doses		
Biomarkers		

FUTURELAB+

Online Interactive: Transcribe and Translate a Gene Capture Sheet

Directions

Using the link Transcribe and Translate a Gene, watch the brief introduction video. The interactive will pause periodically to give you an opportunity to practice the two steps in building a protein; transcription and translation. When you have finished the interactive, you will have selected three genes to transcribe and translate into various proteins.

Click start to begin and answer questions 1–5.

Note: This interactive may not work properly when using Firefox. Try another browser if you encounter problems.

1. For what does each gene in a cell's DNA code?

2. Describe the process of transcription.

3. Describe the process of translation.

4. From what smaller units are proteins built?

5. Complete the flowchart.

DNA → _____ → _____

Continues next page >

FUTURELAB+

Online Interactive: Transcribe and Translate a Gene Capture Sheet

Continued

Choose one of the three genes and answer questions 6–19.

Step 1: Transcription

6. Describe what RNA polymerase does to DNA.

7. Transcribe the DNA into mRNA. Which bases pair together when building your mRNA?

8. What happens to the DNA strand once your RNA strand is made?

Step 2: Translation

9. Where does the mRNA go for translation?

10. How is the mRNA code read?

11. How many nucleotides make up 1 codon?

12. Each tRNA has its own _____ and a matching _____.

13. What does the ribosome look for on the mRNA in order to begin translation?

Continues next page >

FUTURELAB+

Online Interactive: Transcribe and Translate a Gene Capture Sheet

Continued

14. How many tRNA molecules can fit into the ribosome at once?

15. How many different tRNA molecules are there?

16. What determines the final shape of the protein?

17. Translate the mRNA into a protein.

18. The ribosome detaches from the mRNA when it reaches a _____ codon.

19. What protein did you build? What is its function?

Complete the steps with a new gene, then, answer question 20.

20. What protein did you build? What is its function?

Complete the steps with the last gene, then answer question 21.

21. What protein did you build? What is its function?

FUTURELAB+

Gene Control Capture Sheet

Directions
Use the link Gene Control to determine how sound affects the expression of the GFP gene and gain a better understanding of how signals from the outside world can work through the epigenome to change a cell's gene expression.

1. Click on each information (i) icon to write a brief description of each of the following in the table below.

GFP gene
GFP mRNA
Green fluorescent protein
Histone
Methyl tag
Acetyl tag

2. Toggle the "Labels Off/On'' button to see where each image is found in the protein synthesis process. When finished, remove the labels.

Continues next page >

FUTURELAB+

Gene Control Capture Sheet

Continued

3. You will use the control knob to observe what happens to the mRNA and protein levels when you manipulate the epigenetic tags on the gene. Complete the table below with your observations.

	Clock Knob Position				
	12:00	3:00	5:00	7:00	10:00
Shape of DNA Loose, Coiled, Tightly Compacted					
Level of mRNA Normal, Increased, Decreased, None					
Level of Protein Normal, Increased, Decreased, None					
Color of Cell 0 = No Green 1 = Normal 2 = Very Green					

4. Scroll down to *Gene Control and Cancer* to complete the table below.

Amount of Methyl	Gene Expression On or Off	Affect on Genes
Less Methyl		1.
		2.
More Methyl		1.
		2.
		3.

FUTURELAB+

Create Your Own Mini Biotech Unit Capture Sheet

Directions
Develop a miniature biotechnology unit for a middle school science class.

Project Criteria	Description	Who will complete this?
Lecture	The lecture must be at least seven slides that include the following topics: Title slide DNA packaging Human Genome Project Proteome Protein synthesis Epigenetics RNA processing	Slides 1. 2. 3. 4. 5. 6. 7.
Video	Find a video on one of the topics and create a student capture sheet (as well as a teacher key) to assess student understanding.	
Vocabulary Activity	Create a vocabulary activity covering ten words and their definitions.	
Quiz	Develop a 20-question quiz (as well as a teacher key) that assesses student overall learning of the mini unit. The quiz must have at least one question about each of the topics covered in the lecture. Format of the assessment could include multiple choice, matching, labeling diagrams, and brief constructed responses.	Questions 01–10 10–20

FUTURELAB+

References

Nina Bai and Dana Smith. *The Mysterious 98%: Scientists Look to Shine Light on Our Dark Genome.* University of California San Francisco. February 2, 2018.

An Introduction to the Human Genome. HMX Genetics. Harvard University. May 19 2017.

Sanger method of DNA sequencing, 3D animation with narration: CSHL DNA Learning Center. Cold Spring Harbor Laboratory. 2021.

Proteomics: Proteins At Work. NASA Video. April 24 2016.

Test a Protein's Activity. Genetic science learning center.

Is longevity determined by genetics? United States National Library of Medicine. September 18, 2020.

Stanford. *Introducing the Stanford Institute for Human-Centered Artificial Intelligence.* March 18, 2019.