



FUTURELAB+

**BIOMED**

*Behind the Scenes of Scientific  
Breakthroughs*

# Cellular Aging

Developed in partnership with:  
Discovery Education and Ignited

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## Cover Image

This is a conceptual illustration of genetic engineering.

*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

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## BIOMED / BEHIND THE SCENES OF SCIENTIFIC BREAKTHROUGHS

# Cellular Aging

## DRIVING QUESTION

*Can science increase the longevity of a cell?*

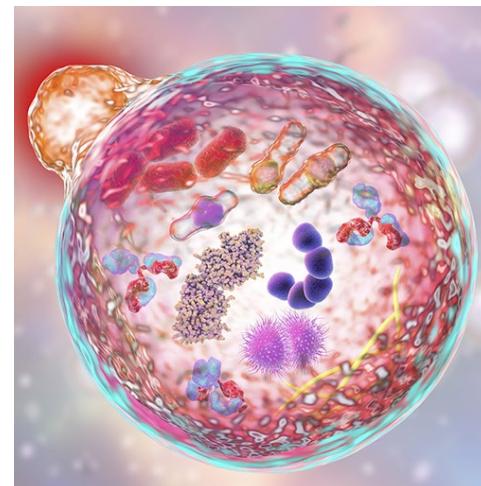
## OVERVIEW

Interest in scientific research of cellular aging has recently been featured in the news due to the 2016 Nobel Prize being awarded for autophagy. Autophagy is a process during which the cytoplasmic contents of cells that are damaged are destroyed by lysosomes. Through various studies, the relationship between autophagy and cellular aging was elucidated. Scientists have discovered other mechanisms that increase cellular aging, including telomere shortening, DNA methylation, and distortions in the cytoskeletal structure. In addition, lifestyle factors that affect the rate of these changes have also been studied. Advances in research on cellular aging have improved scientists' knowledge and the discovery of possible therapeutic targets to improve aging.

In this lesson, students will learn about the hallmarks of cellular aging through a **WebQuest** and reading of articles from scientific journals. Students will play the role of a biomedical researcher and bioinformatician. They will utilize their knowledge to ultimately produce an artifact depicting the various internal and external changes of cells as they age.

## ACTIVITY DURATION

Five class sessions  
(45 minutes each)



3D illustration showing fusion of lysosome with autophagosome containing microbes and molecules.

## ESSENTIAL QUESTIONS

*What are the consequences to the body as cells age?*

*How does the body recognize and eliminate cells that have aged and now behave abnormally?*

*Can cells become immortal?*

## OBJECTIVES

*Students will be able to:*

**Identify** the important characteristics that determine whether a cell has aged.

**Describe** the process of cell autophagy.

**Outline** regions of DNA and their roles.

**Explain** the significance of a chromosome's telomere.

**Gather** information from online research sources.

**Understand** the current research on cellular aging.



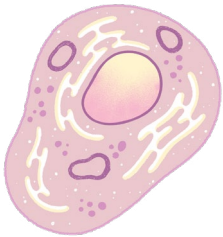
**BACKGROUND INFORMATION**

Students should have prior knowledge of the various organelles and the processes they are responsible for. They should also be familiar with protein synthesis, which involves transcription and translation. The cell cycle should be familiar as it will provide them with a point of reference for discussion.



3D illustration of telomeres located on the end caps of the chromosome.

Materials
Colored Pencils or Markers
Poster Paper
Glue or Tape
Ruler
Scissors
Hallmarks of Cellular Aging Presentation
Hallmarks of Cellular Aging Presentation Rubric
Biomedical Research Conference Capture Sheet
Henrietta Lacks Video Capture Sheet
Autophagy WebQuest Capture Sheet
DNA Regions Capture Sheet
Diseases and Lifestyle Factors of Cellular Aging Capture Sheet
Internal and External Changes in Cellular Aging Poster Project
Prevention of Protein Aggregation
Removal of Senescent Cells
Drugs That Extend Life In Mice
Young Blood Has Rejuvenating Properties
Rubric for Biotech Unit Challenge
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 research and present information on certain changes to DNA that occur in specific diseases, such as breast and prostate cancer or Alzheimer's. Students should regulate their opinions and be sensitive toward classmates who may have some personal experience with these diseases. Students will discuss ways in which lifestyle factors may not be necessarily considered a choice. It is important for students to be able to identify the social factors that may contribute to whether or not an individual is able to put one of the lifestyle changes into practice. This will emphasize to students the social justice issue of rights, or more so, the lack of the rights for some individuals to choose.

## CULTURALLY AND LINGUISTICALLY RESPONSIVE INSTRUCTION

During the activities in this lesson, students will brainstorm and create a program that would mitigate causes of cellular aging in certain ethnic or racial groups. Strategies used in this lesson are especially helpful for culturally diverse students as they allow for the use of non-volunteerism for prevention of unconscious bias in calling on students; they provide for thinking and reflection time in a safe space to answer questions; and they provide for peer support during discussions of complex materials. Students will understand the connection among DNA changes, cellular aging, and lifestyle choices. A lack of certain resources and how they may affect certain lifestyle choices will also be discussed.

## ADVANCING INCLUSIVE RESEARCH

Students will revisit the case of Henrietta Lacks, introduced in "Crowdsourcing Innovations in Biotech." Her contribution to science will be examined and the opportunity to highlight health disparities connected to mistrust. Addressing these connections will allow society to move toward the goal of spotlighting and addressing disparities and access.

## COMPUTATIONAL THINKING PRACTICES

In this lesson, students apply the computational thinking strategy of decomposing problems by breaking down what they learn about cellular aging to develop a presentation about the topic. They are responsible for presenting specific information about the causes of cellular aging, first by reviewing a model of cell senescence and identifying how their assigned causes affect cell senescence as an entire process. Students read research papers and analyze data to create a graph of the effect of lifestyle factors on cellular aging. Later students apply the strategy of finding patterns as they evaluate information from various research studies to use as supporting evidence for the creation of their programs. Students will take a large problem—DNA alterations—and break it down to develop a program focusing on the prevention of cellular aging.

## CONNECTIONS TO THE PRODUCT LIFE CYCLE

Students will take on the role of collaborative biomedical researchers and share their research with possible stakeholders. Students will discover how this role connects to the **commercialization** phase of the product life cycle.

## Have you ever wondered...

### *What happens to cells that are damaged in the body?*

The human body has a multitude of methods to ensure cells maintain homeostasis. Damaged cells are identified through a series of processes and eliminated through apoptosis or autophagy.

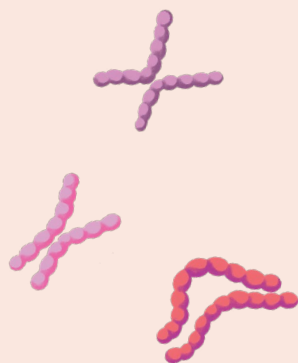
### *Are cellular components recycled?*

Most of the cells in the human body include organelles important for the function of the cell and subsequently the organism. Organelles are made during interphase in the cell cycle. Autophagy is the process that recycles components of cells when a cell has aged.

## MAKE CONNECTIONS!

### *How does this connect to the larger unit storyline?*

For students to be able to devise techniques that could prolong life, they need to have an understanding of the mechanisms that cause cellular aging. The identification of cell biomarkers involved in cellular aging could be used as possible targets of therapy.



### *How does this connect to careers?*

**Biomedical researchers** are important in investigating ways to improve how the human body works, particularly when diseased. Some of these scientists work to create medicines that can treat various chronic and infectious diseases. They can perform tests on various tissues or identify certain proteins active in a reaction. Biomedical researchers use various tools, such as microscopes, cell culturing, and gel electrophoresis. They often use their technical skills to analyze experimental data to determine which additional studies need to be conducted.

**Bioinformaticians** are very useful when there is a large amount of data to be analyzed. They often develop computational techniques that can be used to focus on a specific area of research. This results in the ability of scientists to look at data from the perspective of various related components. Bioinformaticians often utilize different concepts from mathematics, computer science, and biology.

### *How does this connect to our world?*

Research in factors that contribute to cellular aging and ultimately organism aging has always been a trend. Research in this area of science requires researchers who can think critically and make connections among the various aspects of a cell. Identification of the differences in the causes of cellular aging among various ethnic or gender groups can enhance the well-being of these groups that otherwise have shortened life spans.

# Day 1

## LEARNING OUTCOMES

Students will be able to:

**Identify** the important hallmarks that determine whether a cell has aged.



## CULTURALLY AND LINGUISTICALLY RESPONSIVE INSTRUCTION

Strategies used in this lesson are especially helpful for culturally diverse students as they allow for the use of non-volunteerism for prevention of unconscious bias in calling on students; they provide for thinking and reflection time in a safe space to answer questions; and they provide for peer support during discussions of complex materials.

# Procedure

**Teacher Note >** *This unit is heavy in developing perspectives and taking sides on topics that could be seen as controversial. Please exercise extreme care and preparation when presenting any potentially triggering topics. This unit is a quest for understanding the subtle nuances and multiple dimensions of the issues with a goal of ultimate understanding.*

## Optional Unit Launch Activity (30 minutes)

- 1 Launch students into the project and this unit by allowing them to take on the role of a team of scientists researching a scientific breakthrough in the field of aging and longevity.
- 2 Students will work in groups of four to five to learn more about the different roles and tasks that each team must complete. They will need to work collaboratively and communicate effectively in order to “breakout” within the time constraints.
- 3 Share the [Breakout EDU](#) link with students. Students will use clues to unlock each digital lock and discover more about the unit ahead.

**Teacher Note >** *This activity introduces the unit project and leads into sharing the [Design Journal](#) with students. If you are unable to complete the optional Unit Launch Activity, ensure that you still share the [Design Journal](#) for students to complete as they move through the unit. Let students know that for their final project, they will research a scientific breakthrough, create a short video, and make an interactive job board at the end of the unit. Throughout the unit, students will answer questions in their [Design Journal](#) and connect their everyday learning to their culminating collaborative project.*

## Whole Group (15 minutes)

- 1 Ask students the question: *Can a cell live forever (be immortal)?* Use a [Turn and Talk](#) discussion protocol for them to discuss the answer.
- 2 Use [Stand and Share](#) to ask students about ideas on how this might happen.

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# Day 1

Continued

## Procedure

- 
- 3 Let students know that they will be working through a scientific paper together. Explain that throughout the next few lessons they will play the role of a biomedical researcher. These types of scientists must do extensive research to have a good understanding of a particular topic and this research includes reading many scientific papers.

**Teacher Note >** Ask students if they remember when they discussed Henrietta Lacks in a previous unit. If time permits, the video also provides examples of research and medical advances that have been performed using HeLa cells. The [Henrietta Lacks Video Capture Sheet](#), including questions related to the video, can be used.

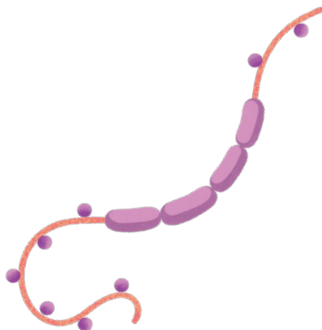
- 
- 4 If necessary, show the [HeLa Cells video](#) (4:27) and use [Pause and Play](#) for students to complete the [Henrietta Lacks Video Capture Sheet](#).

- 
- 5 Provide students with the [Hallmarks of Cellular Aging Presentation](#) guideline page. Let students know that in the next activity, they will role play a team of biomedical researchers who are studying a topic related to aging in cells. Once they have a clear understanding of their topics, they will create short presentations to share the information they have learned with the other teams at a mock biomedical research conference. Each group will be assigned one particular characteristic of aging cells to research.

### COMPUTATIONAL THINKING IN ACTION

Students use the strategy of decomposition as they read information and break down what they learned to develop a presentation about the characteristics of aging cells. They will consider their roles as biomedical researchers who are presenting to colleagues to gain a deeper understanding of the process of cell autophagy.

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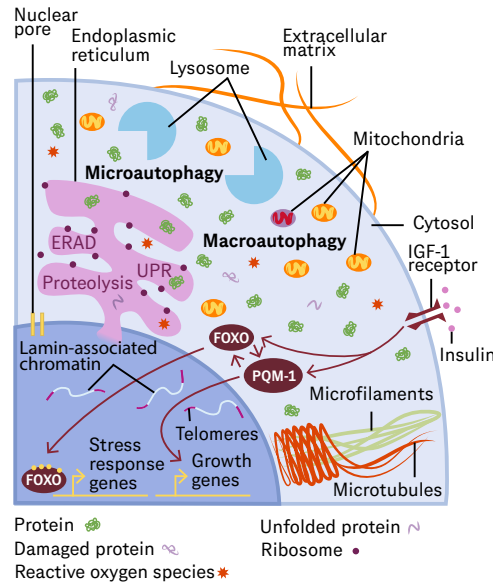
# Day 1

Continued

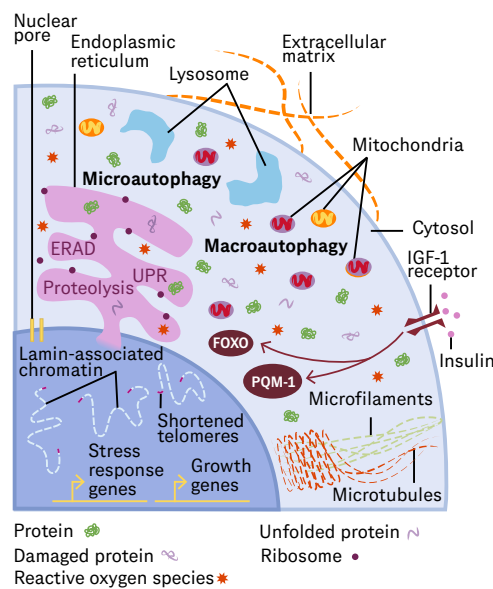
## Procedure

- 6 Show students the figure of a young and old cell (from the [journal article](#)). One way aging cells can be identified is by comparing and contrasting images of young and old cells.

### Young Cell



### Old Cell



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# Day 1

Continued

## COMPUTATIONAL THINKING IN ACTION

By comparing biomarkers in young and aging cells, students are using the computational thinking strategy of finding patterns. This helps students understand the changes in cells over time and recognize why aging cells would behave abnormally.

## INDUSTRY AND CAREER CONNECTION

Emphasize to students that a major soft skill needed for biomedical researchers is an openness to learn and a good attention span. Students will have to understand and be able to explain their assigned topics and so should be open to learn anything they will come across (even if it is unfamiliar). Students will also need to listen to several other students explain their topics. As a result, students should maintain a good attention span to focus and learn.

# Procedure

- 7 Students refer to this image on their presentation guideline page. Set a timer for three to four minutes. Their job is to compare the images and determine as many biomarkers of an aging cell as they can.
- 8 Display the image on the front screen. Use a *Pick a Stick* calling strategy (or similar random calling procedure) for students to come forward and point out on the image the differences they discovered until all of these have been identified: (Prompt as needed to get as many answers as possible.)  
  
A: misshapen lysosome, less mitochondria, more damaged proteins, more macroautophagy, expression of stress response and growth genes turned off due to missing molecules, more reactive oxygen species, damaged microfilaments, damaged microtubules, etc.
- 9 Review what must be included in the *Hallmarks of Cellular Aging Presentation* and review the *Hallmarks of Cellular Aging Rubric* with students.

## Small Group (30 minutes)

- 1 Have students form groups of three or four. Assign each group a separate topic, including Transcriptional Regulation, Nuclear Trafficking and Organization, Protein Translation, Proteostasis, Mitochondrial function, Cell Membrane, and Extracellular Matrix.
- 2 Remind students that they will be doing a *Jigsaw* style presentation and that group members will be presenting to a separate, other small group, so all group members need to have a clear understanding of the information they have been assigned.
- 3 Tell students to refer to the background information from the previous activity to help with understanding their assigned topic.
- 4 Monitor student progress throughout the work period by circulating and answering any questions about pronunciation of complex words, etc.
- 5 Students should have the last 10 minutes to practice their presentations within their groups in preparation for presenting in the next class session.

## Day 2

### LEARNING OUTCOMES

Students will be able to:

**Describe** the process of cell autophagy.

**Differentiate** among characteristics of cell aging.

## Procedure

### Whole Group (3 minutes)

**Teacher Note >** Remind students that they will spend the first 15 minutes of class sharing their research from the previous session with other 'biomedical researchers.' Let them know that this type of sharing is a part of the product cycle of a medicine, during the commercial phase. During this time, scientists share the results with possible stakeholders so that they may gain more knowledge on the product. Ensure that someone in the group is assigned the role of timing each presentation so that each student has ample and equitable time to share.

Tell students to go back into their groups from the last session. Give each student a copy of the [Biomedical Research Conference Capture Sheet](#). Have students include information from each of the researcher's presentations using this capture sheet.

### Small Group (15 minutes)

- 1 Have one member of each group form another group (the number of groups will be determined by the number of topics chosen for students to research). Then, another member of each group forms another group. Repeat until groups are made up of students who have all become an expert on a different topic, as in a [Jigsaw](#) activity.
- 2 Give each group member two minutes to share their research with the other members of the group.
- 3 Remind students to review the guidelines in the rubric.
- 4 Monitor as students share their research, ensuring students are using the [Biomedical Research Conference Capture Sheet](#) to write their notes.

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# Day 2

*Continued*

## Procedure

**Whole Group (4 minutes)**

- 1 Display the following data for students:

A	Inhibits CS —	Induces CS +	B	Under in CS ↓	Over in CS ↑
Adipose tissue			Adipose tissue		
Adrenal gland			Adrenal gland		
Blood			Blood		
Blood vessel			Blood vessel		*
Brain			Brain	*	*
Breast			Breast		
Colon			Colon	*	*
Esophagus			Esophagus		
Heart			Heart		*
Liver			Liver		
Lung			Lung	*	*
Muscle			Muscle		*
Nerve			Nerve	*	
Ovary			Ovary	*	
Pancreas			Pancreas		
Pituitary			Pituitary		
Prostate			Prostate		*
Salivary gland			Salivary gland		*
Skin			Skin		
Small intestine			Small intestine		
Spleen			Spleen		
Stomach			Stomach		
Testis			Testis		
Thyroid			Thyroid		*
Uterus			Uterus	*	*
Vagina			Vagina		

**COMPUTATIONAL THINKING IN ACTION**

Students examine information from a database developed by bioinformaticians to find patterns in the deterioration of a cell as it ages. Throughout this lesson, students learn that bioinformaticians develop systems, databases, and methodologies to collect and analyze data for clinical or research purposes. They are responsible for applying information technology and computer science in a biomedical context.

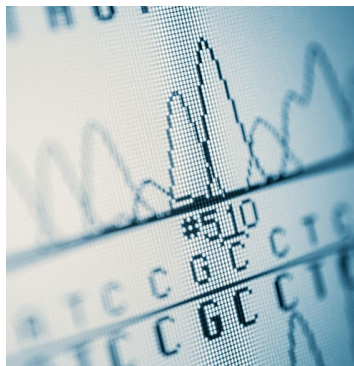
Explain to students that they are looking at an example of one of the computational techniques that allow scientists to look at the effect of several factors on various processes. The people who create and interpret these techniques are called bioinformaticians. This database is known as CellAge, and includes all of the genes with known associations with cellular senescence (CS on the displayed diagram), the deterioration of a cell as it ages.

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## Day 2

Continued



### INDUSTRY AND CAREER CONNECTION

Emphasize to students that a major soft skill needed in bioinformaticians is being detail-oriented and a technical skill includes being a fast learner. During the WebQuest, students will have to read the information given to answer the questions. As there is a lot of information, closely paying attention to the readings and identifying the specific information necessary to answer the question will be integral for this assignment. Students will have 15 minutes to read and learn about the topic of autophagy. They will then be responsible for answering questions so they will need to be able to gather the main concepts from the readings. Being a fast learner also includes identifying ways in which an individual best learns in a short time period.

## Procedure

- 2 In this session, students will learn about autophagy. Have them make an educated guess as to what the word “autophagy” means (auto- self; phagy: eating). Tell students that bioinformaticians can create a computational tool to identify how autophagy affects various genes or molecules in the cell or more generally to observe the effect of various processes on cellular aging.
- 3 Let students know that this database would be important to use and review during the product cycle of medicine. Researchers can find out information on how a certain gene or drug target interacts with other genes and/or processes.
- 4 Q: Ask students why they think this would be a good starting point?  
A: Other scientists have previously studied some of these genes and so repeat studies would not necessarily have to be performed. This information can help save scientists time when planning their future experiments.
- 5 Let students know that they will review data using bioinformatics during the WebQuest.
- 6 Provide students with the [Autophagy WebQuest Capture Sheet](#).

### Individual (15 minutes)

Monitor students as they work. Note the most common misconceptions and/or challenges students have with completing the WebQuest.

### Whole Group (8 minutes)

- 1 Using the questions each group created from [Hallmarks of Cellular Aging Presentation](#), review at least one question from each group, including a mixture of multiple choice and short answer questions. They can use the notes from [Autophagy WebQuest Capture Sheet](#) and the notes from the biomedical research meeting.

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## Day 2

*Continued*

## Procedure

- 
- 2 Add student questions and review questions to an online platform (Kahoot, Quizizz and/or Quizlet Live) that allows students to answer multiple choice and short answer questions. This gives the opportunity to conduct a formative check for understanding and class discussion. Include the questions from the autophagy WebQuest:
- 
- a. Which of the following are included in the process of autophagy? Select all that apply. Correct answers are indicated by orange font.
- parts of cell digested by lysosomes
  - organellar remodeling
  - translation inhibition
  - activated when your body is under stress
  - telomere placement on chromosomes
- 
- b. Q: What is the connection between autophagy and aging?
- A: As cells age, they need to keep clean from damaged proteins/ organelles, etc. In newer cells, autophagy occurs to clean out and clear out any damaged proteins, organelles, or protein aggregates. This ensures there is a new raw material for a healthy cell.
- 



## Day 3

## Procedure

### LEARNING OUTCOMES

Students will be able to:

**Outline** regions of DNA and their roles in cell aging.

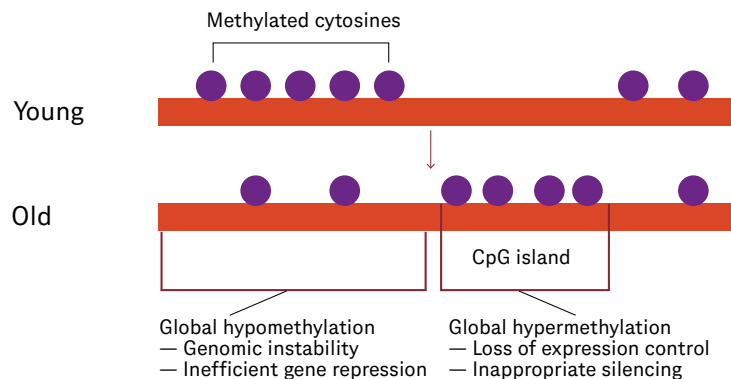
**Explain** the significance of a chromosome's telomere.

**Gather** information from online resources to understand current research on DNA's effect on cellular aging.

**Teacher Note >** Throughout this lesson, various models will be used to help students understand regions of DNA and their role in aging. Be sure to give students time to draw the significant portions of the model, including labels. Prior to explaining the model, have students attempt to describe the model by calling on volunteers. Choose to model note-taking styles, such as *Cornell* or bullet points as you lecture. For students who require accommodations, you may want to provide a partially filled out, or fill in the blank, *Cornell* notes form. In addition, this lesson is filled with advanced vocabulary so it would be helpful to provide a glossary of key terms that includes visuals to review before and during this lesson.

### Whole Group (15 minutes)

- 1 Give students the *DNA Regions Capture Sheet*.
- 2 Tell students that in this class session they will be learning about the various regions of DNA and their roles in cell aging. Let students know that this is an example of the information required during the discovery phase of the product life cycle. During this phase, scientists determine how particular information could be used as a target for a possible drug.
- 3 Let them know that in this class session they will listen to a lecture and take notes using the *Cornell* or bullet point styles.
- 4 Tell students to refer to the figure on the capture sheet as you explain it.

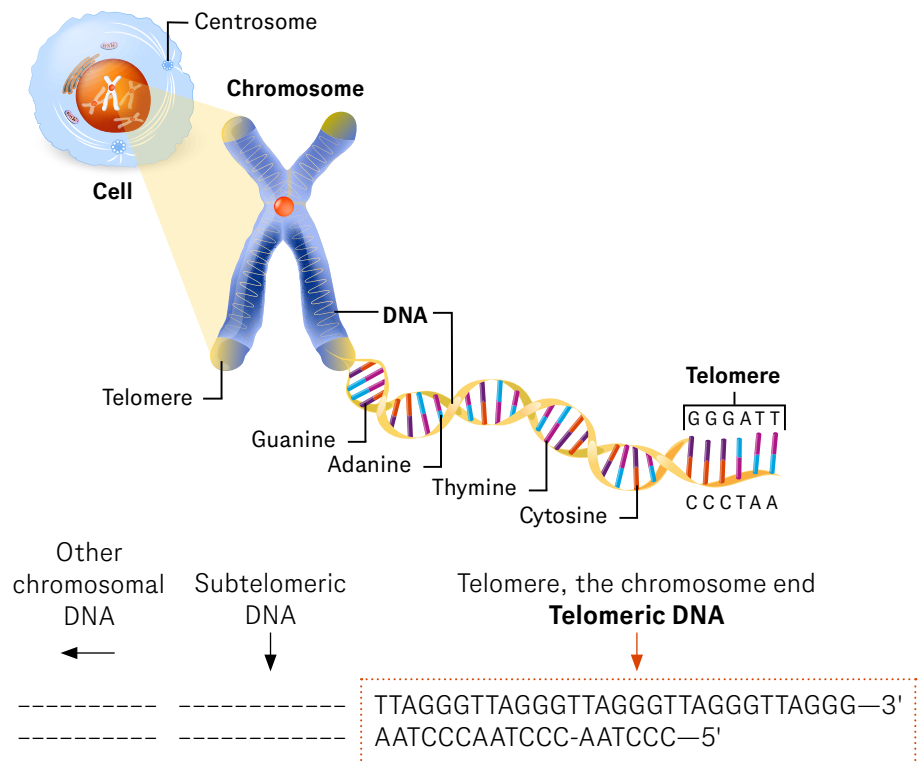


- a. Mammalian transcription factors possess DNA recognition elements containing CpG-rich motifs as well as GC-rich binding sites. DNA methylation can obstruct or eliminate their ability to act on many important regulatory sites.
- b. Young DNA Strand Characteristics -Methylated regions everywhere except CpG island

*Continues next page >*

**Day 3***Continued***Procedure**

- c. As the cell ages, the DNA strand experiences hypomethylation (less methylation) in places.
- d. Let students know that both hypomethylation and hypermethylation affect gene expression (hypo- gene expressed; hyper- gene not expressed “silenced”).

**Telomere**

- e. Telomeres are made up of a combination of DNA and protein and are found at the end of chromosomes.
- f. Presence prevents the shortening of DNA (naturally occurs at each round of DNA replication).
- g. Affects aging—when telomere length reaches a critical limit, the cell undergoes senescence and/or apoptosis.
- h. Lifestyle factors can speed up the shortening of telomeres due to DNA damage and can contribute to the health and longevity of an individual.

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## Day 3

Continued

### COMPUTATIONAL THINKING IN ACTION

*Drawing conclusions about the impact of lifestyle factors on telomeres is one way students apply the computational thinking strategy of abstraction. By identifying key scientific details, they can better understand the rate of telomere shortening and the importance of telomeres in human health and aging.*

## Procedure

- 5 Let students know that they will be reading a scientific paper about those lifestyle factors in groups, similar to Day 1.
- 6 Ask students what they believe to be lifestyle factors that can cause telomeres to shorten.
- 7 Let them know that they will work on researching information to present to the class. Tell them that they will either read about DNA methylation diseases or causes of telomere shortening.
- 8 Provide students with [Diseases and Lifestyle Factors of Cellular Aging Capture Sheet](#). Review the requirements and the rubric.
- 9 Tell students that they will be attending another conference, but this time they will be presenting their research as a group.
- 10 Let students know that you will provide a timer for students to help manage their time, which is an important skill of a biomedical researcher.

**Teacher Note >** *When explaining methylation, provide students with an analogy. For example, methyl groups can be likened to tagging something. Additionally, you can use a physical representation of a DNA strand, such as a pipe cleaner, and use beads as methyl groups. More beads or hypermethylation will prevent the expression of the protein. Fewer beads or hypomethylation will promote the expression of the protein.*

### Small Group (25 minutes)

- 1 Split students up into groups of four students.
- 2 Assign each group one of the topics: Aberrant Methylation in Cancer, Aberrant Methylation in Noncancerous Diseases, Smoking + Telomere Length, Obesity + Telomere Length, Exposure to harmful agents/nature of profession + telomere length, Stress + Telomere Length, Diet + Telomere Length.
- 3 Set a [timer](#) and project on the board so all students will be able to view it.
- 4 Monitor students as they work on the assignment.

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## Day 3

Continued

## Procedure

### Whole Group (5 minutes)

Spend the last few minutes of class having students record in their *Design Journal* and sharing the connections between what they are learning and their projects.

**Teacher Note >** *Because this lesson is especially content-rich, you may want to assign an Exit Ticket, such as Triangle-Square-Circle, as a formative assessment to gauge comprehension, identify any misconceptions, and determine areas that require further instruction/support.*



## Day 4

## Procedure

### LEARNING OUTCOMES

Students will be able to:

**Identify** examples of the causes and effects of changes in DNA on aging.

### COMPUTATIONAL THINKING IN ACTION

*In connecting with the the role of biomedical researchers, students practice the computational thinking strategy of abstraction as they refine the information they have researched and identify what should be included on their posters. They identify patterns in the the internal and external changes that take place during cellular aging, then decompose problems by providing prospective patients with at least one lifestyle change that has been proven to improve an aspect of cellular aging.*

#### Whole Group (25 minutes)

- 1 Remind students that they will be presenting the information they gathered during the last class at the conference on cellular aging.
- 2 Let students know that they are to take notes on each presentation, focusing on the description and its effect on cellular aging.
- 3 Give each student group four minutes to present. Let them know to only focus on presenting Parts A and B.

#### Whole Group (5 minutes)

- 1 Play the video on [Lifestyle Changes May Lengthen Telomeres, A Measure of Cell Aging](#). Stop at 3:02.
- 2 Emphasize to students the difference between causation and correlation. The scientists giving each group a lifestyle change and then observing results is an example of causation because only one variable was changed. Correlation includes a certain group having a certain characteristic, such as runners having longer telomeres. In this example, it is not known for certain that running causes individuals to have longer telomeres. There could be other factors at play, such as lung and heart health, age, or even gender. It is not until a controlled study is conducted with one variable changed, in this case running, that data can be collected to support or refute this claim.
- 3 Let students know that to review the information learned about cellular aging they will create a poster describing the internal and external changes in cells as they age. Tell them that biomedical researchers often have to take a lot of information that they have read or learned and synthesize it into the information related to their particular research.
- 4 Ask students if all lifestyle elements are choices. What are some elements that may not be a choice? Which communities or populations may be more apt to have a lack of choice associated with lifestyle?
- 5 Provide students with [Internal and External Changes in Cellular Aging Poster Project](#).

*Continues next page >*

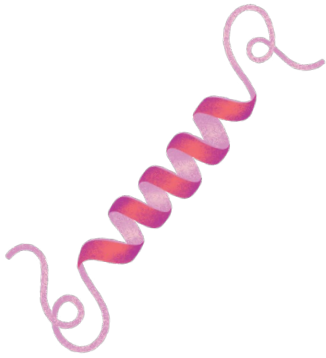
## Day 4

*Continued*

## Procedure

### Small Group (15 minutes)

- 1 Have students work on an assignment until the end of the class period.
- 2 Ensure that each group has assigned roles or parts to each group member.
- 3 Let students know that in this class session they will begin an assignment which they will complete tomorrow.
- 4 Let students know that they can continue working on the assignment for homework.





## Day 5

## Procedure

### LEARNING OUTCOMES

*Students will be able to:*

**Identify** examples of the correlation between differences in regions of DNA and telomeres and their roles in cell aging.

**Describe** the internal and external changes in cells as they age.

**Teacher Note >** *Provide students with the choice of creating a digital poster (i.e., [Canva](#), [Piktochart](#)) or paper poster.*

#### Whole Group (2 minutes)

- 1 Let students know that they will continue to work on the poster assignment from the last class.
- 2 Tell students to join together again with their same groups from the last class.

#### Small Group (10 minutes)

- 1 Let students know that they should be adding the final components of the assignment to the poster.
- 2 Walk around and ensure students are actively working. Also, note any particular areas in which students should improve and areas in which they are doing well.
- 3 Toward the end of the 10-minute time period, provide each group with a rubric.
- 4 Tell them to spend one minute and rate their progress on their assignment thus far.
- 5 Let students know the areas that you saw that are going well versus the areas in which they need to improve.

#### Small Group (20 minutes)

Let students know that they will now have 20 minutes to complete the assignment.

*Continues next page >*

## Day 5

Continued

### INDUSTRY AND CAREER CONNECTION

Emphasize to students that two major soft skills needed for biomedical researchers, one of which they should be practicing in this lesson, include organizational skills and the ability to set priorities. Students may want to spend time choosing colors or other artistic portions of their poster but should prioritize the rubric and components of the assignment. In addition, because of the required components, it would be important that students stay organized to not confuse external and internal changes of DNA as they relate to aging.

## Procedure

### Individual (13 minutes)

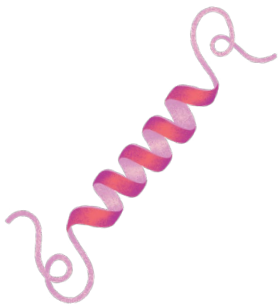
- 1 Walk around while students work. Note any misconceptions or challenges students have with a particular session.
- 2 Allow students to work for another 10 minutes of the class.
- 3 Have students complete a reflection of their work for the past two days. In one paragraph, tell them to respond to the questions: Rate your experience from 1–5, with 1 being not good and 5 being great. Explain your answer. Also, include how well you displayed the skills of a biomedical researcher.
- 4 Inform students that their posters are due next class.

**Teacher Note >** You may want to use a Google form for the reflection in #3 above. In addition, you may want to provide an opportunity for students to present their posters to the school and community and/or share them in an online forum. This could be a prime opportunity to engage families.

### Additional Resources:

*Explainer: What is autophagy?*

*How to kickstart self-cleaning mode in brain cells?*



# National Standards

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## Next Generation Science Standards

---

### LS1.A: Structure and Function

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.

---

### Science and Engineering Practices

#### Obtaining, evaluating, and communicating information

Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

---

### 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.

#### Structure and Function

Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.

#### Scale, Proportion, and Quantity

Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

---

## Career and Technical Education (CTE)

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### A3.1

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

---

### A5.1

Use the Internet and the World Wide Web to collect and share scientific information.

---

### A5.2

Use a variety of methods, including literature searches in libraries, computer databases, and online for gathering background information, making observations, and collecting and organizing data.

---

# Educator Resources

## BreakoutEDU Set-up and Answers

Students access the *digital breakout* and work together to solve the clues. The locks may be completed in ANY order. No one lock is required to unlock other locks.

### Word Lock

**Action:** Participants read the background article. They must determine the word that has been redacted from the background (aging). Participants spell the word **AGING**.

*Continues next page >*



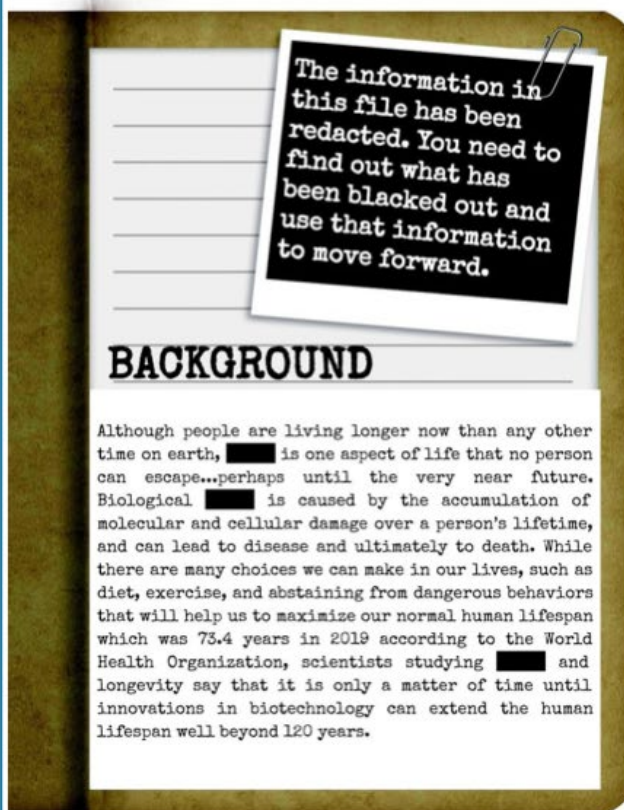
### Lock Setup

The information in this file has been redacted. You need to find out what has been blacked out and use that information to move forward.

### Answer



### Lock Clue





# Educator Resources

## BreakoutEDU Set-up and Answers

*Continued*

### Color Lock

**Action:** Participants view the video. They must determine the organization from micro to macro levels (Cell–Tissue–Organ–Organ System–Organism) using the excerpts from the [Forbes article found here](#). Facilitators may wish to print the full text of the article, which can be found [here](#). Colors would be **Yellow–Red–Blue–Green–Purple** based on the information.

*Continues next page >*



### Lock Setup

Let's look at the latest longevity breakthroughs working on each of the five major levels of biological organization and what they each aim to accomplish. Organize the longevity breakthroughs on from micro to macro.

The files were dropped by another intern, so you may need to watch the video more than once to read the information and get it in the correct order and get them reorganized for the project leader.

Watch the video. You may pause and play or replay as many times as needed.

### Answer



### Lock Clue



# Educator Resources

## BreakoutEDU Set-up and Answers

Continued

### Number Lock

**Action:** Participants read the graph. Using the information given and noting that duplications should not occur:

- 2005–2010 Asia (70)
- 2005–2010 World (70)
- 2040–2045 Africa (70)
- 2015–2020 North America (80)
- 2025–2030 Europe (80)
- 2035–2040 Latin America & Caribbean (80)

Participants will then enter **7080** as the numeric code.



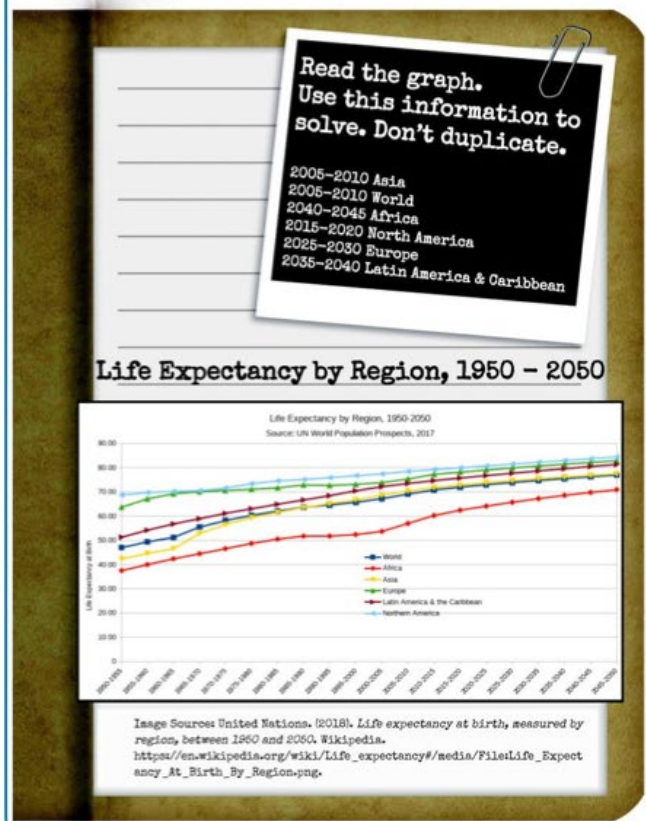
### Lock Setup

Read the graph. Use the information to solve. Do not duplicate.

### Answer



### Lock Clue



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**Henrietta Lacks Video Capture Sheet****ANSWER KEY****Do not share with students****Directions**

*Answer the questions below to prepare for the lab and record your data after completing the lab.*

1. Why do scientists need an immortal cell line?

Because they need to repeat the experiments over and over to test the effectiveness of certain drugs and techniques.

2. What was so special about the sample of cells?

Cells kept growing and growing.

3. What is the name of the cell line derived from Ms. Lacks?

HeLa Cells

4. What is the maximum number of times human cells can divide?

50 times

5. What is the name of the process in which cells “self-destruct”?

Apoptosis

6. Why is apoptosis useful?

It prevents the propagation of genetic errors or defects that occur after numerous rounds of cellular division.

7. What happens with apoptosis in cancer cells?

The signals for apoptosis are ignored; cells continue to divide and crowd out normal cells.

8. How many years passed from when cells were taken from Henrietta Lacks until her family was told?

20 years

9. List a few of the ways HeLa cells have been used to help scientists.

Polio vaccine, measles, mumps, HIV, Ebola, chromosomes are visible, first cells to be cloned, traveled to outer space, telomerase was discovered, common calorie-restricted HIV vaccine

**Autophagy WebQuest Capture Sheet****ANSWER KEY****Do not share with students****Directions**

*Answer the questions as you explore the websites.*

.....  
 Visit the [The National Center for Biotechnology Information website](#) and answer questions 1–3.  
 .....

1. What does the process of autophagy include?

Parts of eukaryotic cells are self-digested within the lysosome or vacuole; roles of autophagy include organellar remodeling, protein and organelle quality control, prevention of genotoxic stress, tumor suppression, pathogen elimination, regulation of immunity and inflammation, maternal DNA inheritance, metabolism, and cellular survival.

2. In what year was a Nobel Prize in Physiology awarded for Autophagy?

2016

3. What information about autophagy has been discovered?

Understanding how autophagy is regulated, what the core autophagy machinery looks like structurally and how it works, what autophagy is doing to keep us healthy (or in more rare circumstances, make us ill), and how we can manipulate autophagy pharmacologically or via lifestyle interventions to prevent and/or treat aging and many common diseases.

*Continues next page >*

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**Autophagy WebQuest Capture Sheet****ANSWER KEY****Do not share with students***Continued*

.....  
Visit the [The University of Maryland School of Medicine website](#) and answer questions 4–5.  
.....

4. What is autophagy?

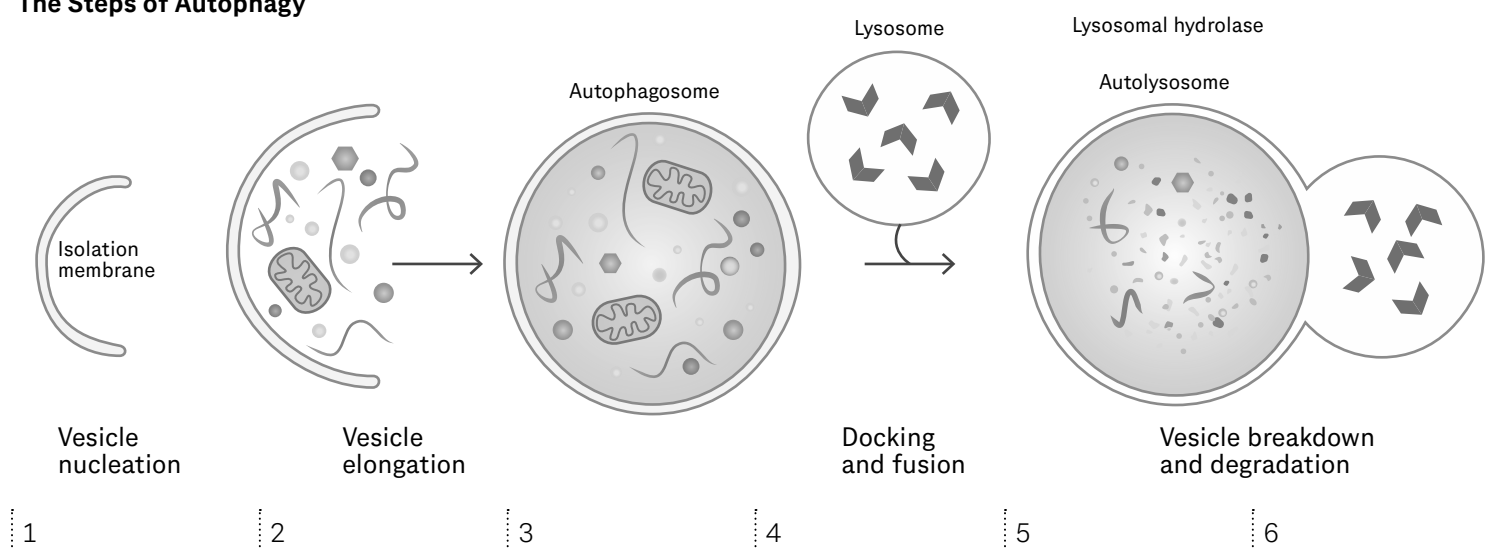
- Autophagy is a catabolic process mediating the turnover of bulk cytoplasmic constituents including organelles and protein aggregates in a lysosome-dependent manner. It protects organisms from a variety of diseases, including neurodegeneration, cancer, and aging.
- It is a cellular catabolic response originally developed in unicellular eukaryotes such as yeast to allow survival during the conditions of low nutrition.

*Continues next page >*

**Autophagy WebQuest Capture Sheet****ANSWER KEY****Do not share with students***Continued*

5. Using the diagram below, describe the steps of autophagy. Include sequential steps written on the diagram.

Step	Description
1	A bilayer isolation membrane begins to form.
2	The double isolation membrane engulfs cytoplasmic material, including proteins, protein aggregates, and organelles such as mitochondria, ribosomes, and fragments of the ER.
3	The membrane forms a vesicle termed autophagosome.
4	Autophagosome eventually fuses with the lysosome.
5	An autolysosome is formed.
6	After fusion, the inner membrane is lysed and autophagic cargo is digested by the lysosomal proteases. This frees up amino acids, lipids, and nucleic acids which can be recycled as building blocks for new synthesis or used to provide energy to support cellular function.

*Continues next page >***The Steps of Autophagy**



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**Autophagy WebQuest Capture Sheet****ANSWER KEY****Do not share with students***Continued*

.....  
*Read the section titled “Autophagy” in the scientific journal:*  
*[The Cell Biology of Aging](#) and answer questions 6.*  
.....

6. How does autophagy play a role in ensuring a healthy cell?

Autophagic clearing of damaged proteins, protein aggregates, organelles, lipids, and other cargo is required to provide the new raw material for a healthy cell.

*Continues next page >*

**Autophagy WebQuest Capture Sheet****ANSWER KEY****Do not share with students***Continued**Use the content below to answer questions 7–8.*

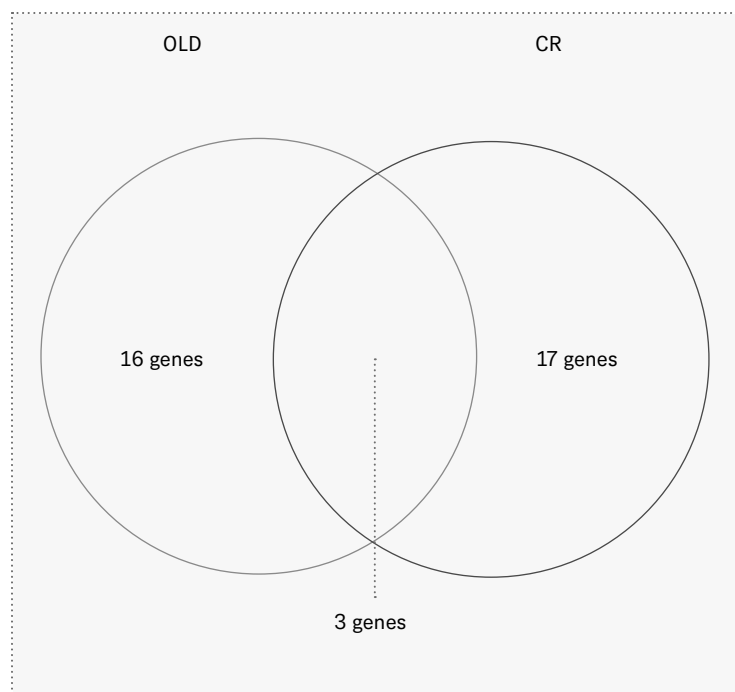
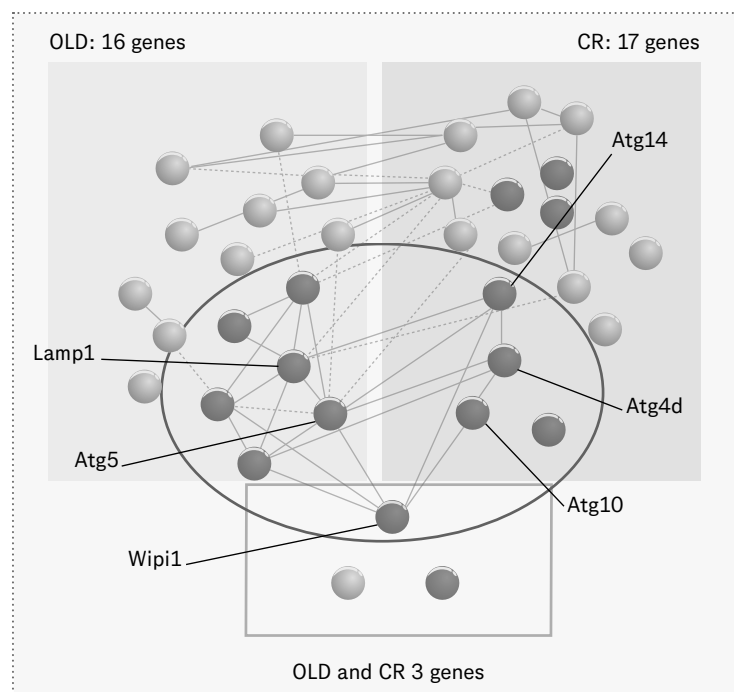
The images below are from the study titled, “Bioinformatics analysis of autophagy-lysosomal degradation in cardiac aging.” This study involved the use of a database that contained information on the expression of genes from old cells and calorie-restricted (CR) cells. In Part 2, the scientists used another database, STRING, which includes protein-to-protein interactions. They then grouped the information into a cluster or group of proteins that are involved in a certain process together. Genes that were found to be most common calorie-restricted in clusters, represented by solid lines, are shown in bold.

7. How many upregulated autophagy genes do the old cells and calorie-restricted (CR) cells have in common?

**Three**

8. Circle the genes that are involved in a cluster. Why should scientists focus on the genes that are most commonly included in a cluster?

**These proteins would be involved in a process occurring during autophagy. This data can be used to identify drug targets that can be used to affect the overall activity of autophagy.**

*Continues next page >***Upregulated Autophagic Genes:****Part 1****Part 2**

**Autophagy WebQuest Capture Sheet****ANSWER KEY****Do not share with students***Continued*

.....  
*Answer Review Questions 9–10.*  
.....

9. Which of the following are included in the process of autophagy? (Select all that apply)

- ☒ Parts of cell digested by lysosomes
- ☒ Organellar remodeling
- ☐ Translation inhibition
- ☒ Activated when your body is under stress
- ☐ Telomere placement on chromosomes

10. What is the connection between autophagy and aging?

As cells age, they need to keep clean from damaged proteins/organelles, etc. In newer cells, autophagy occurs to clean out and clear out any damaged proteins, organelles, or protein aggregates. This ensures there is new raw material for a healthy cell.

# FUTURELAB+

## Hallmarks of Cellular Aging Presentation

### Directions

You will play the role of an expert biomedical researcher in cell aging. You have been invited to a biomedical research conference and have been asked to share the latest research from your lab on the aging of cells.

You have been assigned one of the following topics:

- Transcriptional Regulation
- Nuclear Trafficking and Organization
- Protein Translation
- Proteostasis
- Mitochondrial Function
- Cell Membrane
- Extracellular Matrix

Your presentation must include:

- Ways in which new and old cells differ as shown in the figures below
- A description of the processes involved in the old cells that promote aging
- Identification of possible cell biomarkers (at least two) for aging
- Two questions about the topic:
  - One multiple choice and one short answer
  - Include correct answers and rationales
  - To be used in a future lesson

Please use the websites below in your research.

Background Information:

Transcriptional Regulation

Nuclear Trafficking and Organization

Proteostasis

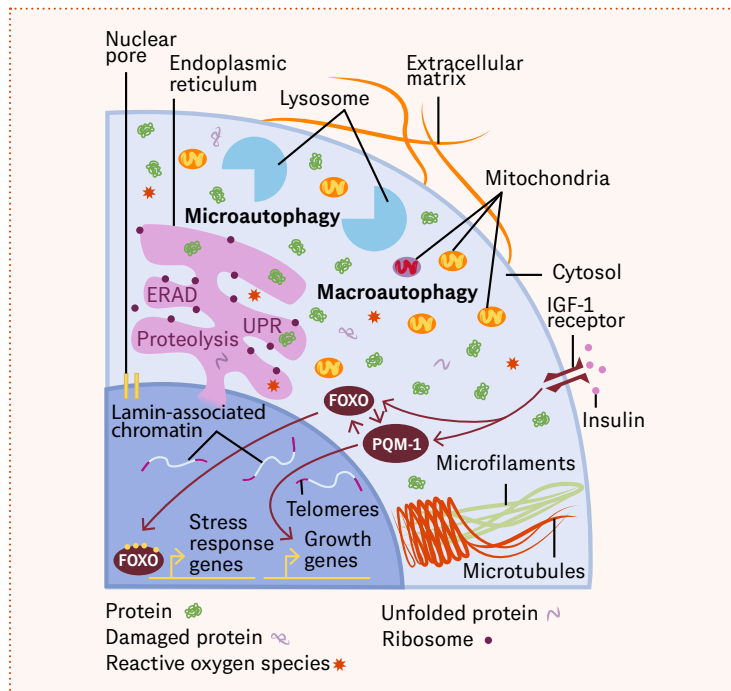
Protein Translation

Mitochondrial Function

Cell Membrane

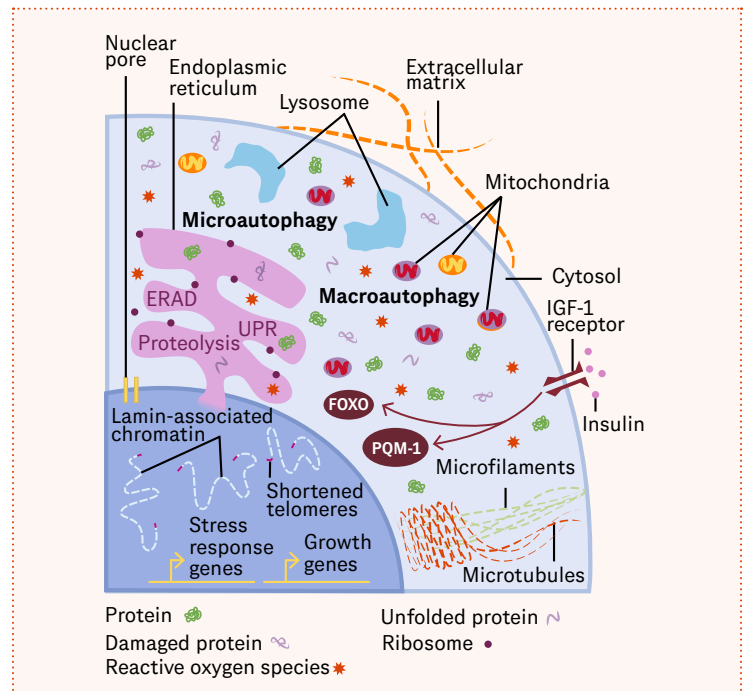
Extracellular Matrix

### Young Cell



Source: *The Cell Biology of Aging*

### Old Cell



Source: *The Cell Biology of Aging*

# FUTURELAB+

## Hallmarks of Cellular Aging Presentation Rubric

Score	4	3	2	1
<b>Description of aging characteristic</b>	The description of the aging characteristic was clearly outlined using the figure.	The description of the aging characteristic was outlined using the figure, although the student struggled.	The description of the aging characteristic was included, but the figure was not used.	The description of the aging characteristic was not outlined using the figure.
<b>Identification of Cell Biomarkers</b>	The student was able to identify at least two specific cell markers.	The student was able to identify cell markers, although they were not specific.	The student was able to identify one cell marker.	The student did not identify any cell markers.
<b>Biomedical Research Conference Presentation</b>	The presentation was succinct and the student was able to clearly describe the characteristics of cell aging.	The presentation was not succinct, but the student was able to clearly describe the characteristics of cell aging.	The presentation was lengthy and the student was not able to clearly describe the characteristics of cell aging.	The presentation was too short and the student was not able to clearly describe the characteristics of cell aging.
<b>Question Creation</b>	Two questions were created that were accurate, specific to the topic, and challenging.	Two questions were created that were specific and accurate to the topic, but not so challenging.	Only one question was created, which was accurate and specific to the topic.	Only one question was created but was not accurate, and/or no question was written.
<b>Final Score</b>				

# FUTURELAB+

## Biomedical Research Conference Capture Sheet

**Directions**

For each speaker identify:

- The difference between new and old cells  
(include a description with important molecules used)
- A possible biomarker
- A specific method to prevent or treat cell aging

Speaker	Topic
1	
2	
3	
4	
5	



# FUTURELAB+

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## Henrietta Lacks Video Capture Sheet

### Directions

*Complete the questions as you watch the video.*

1. Why do scientists need an immortal cell line?

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2. What was so special about the sample of cells?

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3. What is the name of the cell line derived from Ms. Lacks?

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4. What is the maximum number of times human cells can divide?

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5. What is the name of the process in which cells “self-destruct”?

---

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6. Why is apoptosis useful?

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7. What happens with apoptosis in cancer cells?

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8. How many years passed from when cells were taken from Henrietta Lacks until her family was told?

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9. List a few of the ways Ms. Lacks’ cells have been used to help scientists.

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### Directions

Visit the *The National Center for Biotechnology Information website* and answer questions 1–3.

3. What information about autophagy has been discovered?

2. In what year was a Nobel Prize in Physiology awarded for Autophagy?

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## Continued

4. What is autophagy?

*Continues next page >*

# FUTURELAB+

## Autophagy WebQuest Capture Sheet

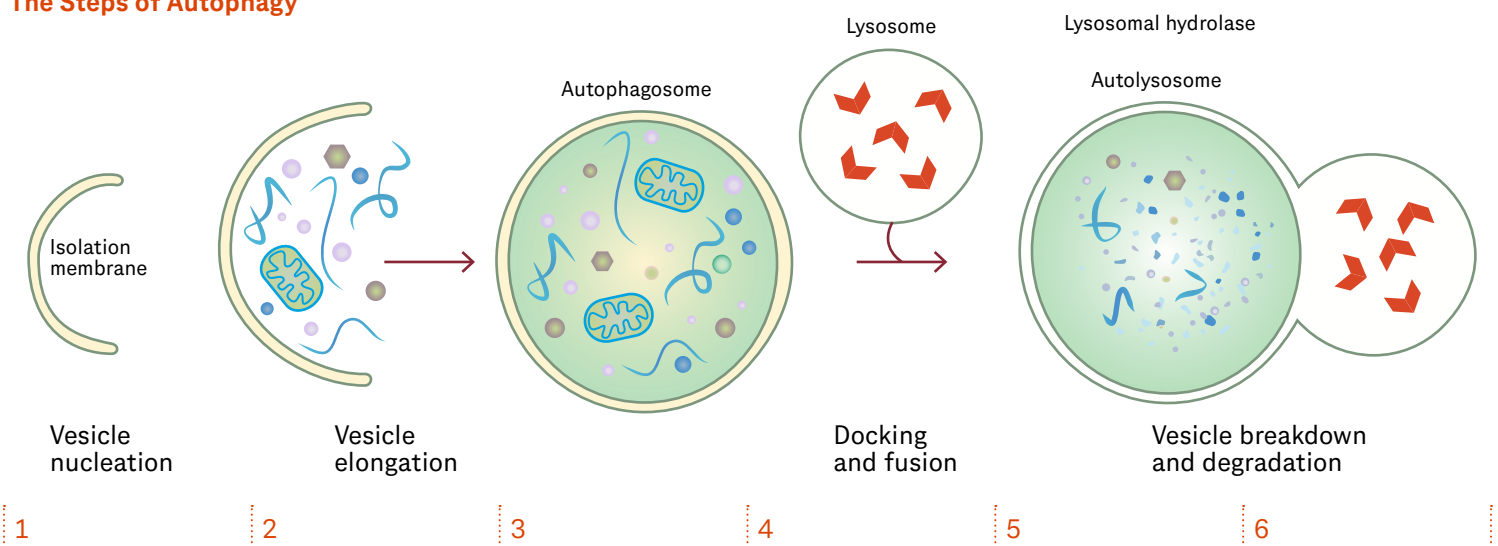
Continued

5. Using the diagram below, describe the steps of autophagy. Include sequential steps written on the diagram.

Step	Description
1	
2	
3	
4	
5	
6	

Continues next page >

### The Steps of Autophagy



## Continued

6. How does autophagy play a role in ensuring a healthy cell?

[illegible]

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# FUTURELAB+

## Autophagy WebQuest Capture Sheet

Continued

Use the content below to answer questions 7–8.

The images below are from the study titled, “Bioinformatics analysis of autophagy-lysosomal degradation in cardiac aging.” This study involved the use of a database that contained information on the expression of genes from old cells and calorie-restricted (CR) cells. In Part 2, the scientists used another database, STRING, which includes protein-to-protein interactions. They then grouped the information into a cluster or group of proteins that are involved in a certain process together. Genes that were found to be most common calorie-restricted in clusters, represented by solid lines, are shown in bold.

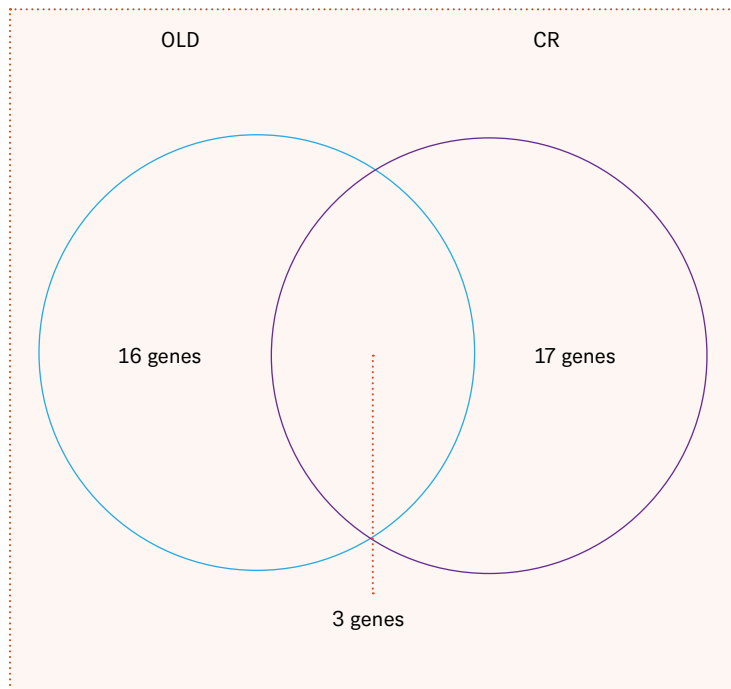
7. How many upregulated autophagy genes do the old cells and calorie-restricted (CR) cells have in common?

8. Circle the genes that are involved in a cluster. Why should scientists focus on the genes that are most commonly included in a cluster?

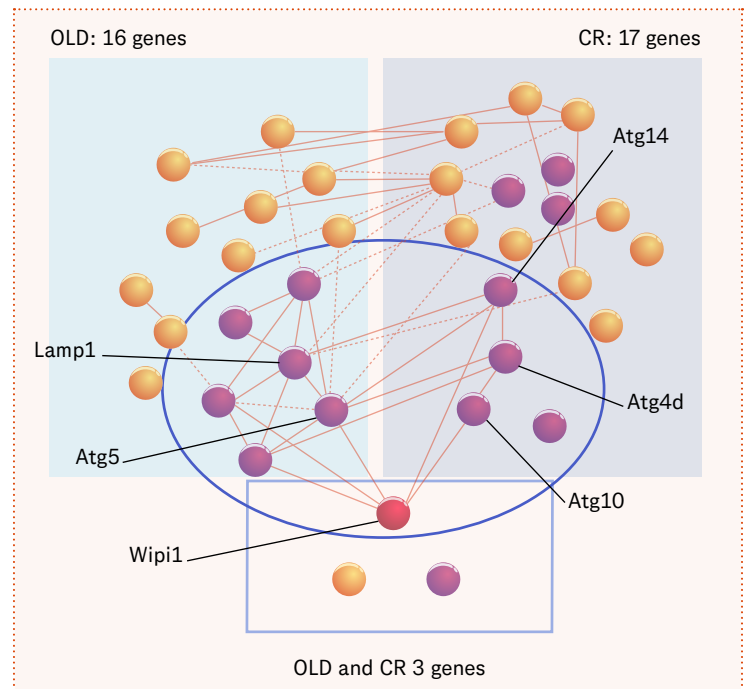
Continues next page >

### Upregulated Autophagic Genes:

#### Part 1



#### Part 2





**Autophagy WebQuest Capture Sheet**

*Continued*

.....  
*Answer Review Questions 9–10.*  
.....

9. Which of the following are included in the process of autophagy? (Select all that apply)

- ☐ Parts of cell digested by lysosomes
- ☐ Organellar remodeling
- ☐ Translation inhibition
- ☐ Activated when your body is under stress
- ☐ Telomere placement on chromosomes

10. What is the connection between autophagy and aging?

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[illegible]

# FUTU<sup>RE</sup>LAB+

## Diseases and Lifestyle Factors of Cellular Aging Capture Sheet

### Directions:

*Different regions of DNA can play a role in cellular aging. Your research group has been invited to speak at the annual Cellular Aging Conference. You will create a presentation that represents your recent research findings.*

*Your presentation must include:*

1. *A description of the topic, including a visual model*
2. *A graph showing data of some aspect of the topic*
3. *Identification of at least one social-justice challenge and relationship with the topic*

Here are a few resources that can be helpful:

*The role of DNA methylation on aging, rejuvenation, and age-related disease*

*Telomeres, Lifestyle, Cancer, and Aging*

*The Cell Biology of Aging—Chromosome and Telomere Regulation*

Write down your assigned topic here:

# FUTU<sup>RE</sup>LAB+

## Diseases and Lifestyle Factors of Cellular Aging Rubric

Score	4	3	2	1
<b>Components</b>	All required components are included.	Three of the four required components are included.	Two of the four required components are included.	One of the four required components is included.
<b>Presentation</b>	All group members play an equal role in the presentation and clearly understand the topic.	All groups members play an equal role in the presentation; most clearly understand the topic.	Most group members play an equal role in the presentation; most clearly understand the topic.	Only half of the members play an equal role in the presentation; only half clearly understand the topic.
<b>References</b>	Uses more than two references, which are specific.	Uses at least two references, which are more general.	Uses one reference, which is specific.	Uses one reference, which is more general.
<b>Final Score</b>				

# FUTU<sup>RE</sup>LAB+

## Internal and External Changes in Cellular Aging Poster Project

### Directions:

*You will review the information learned during the past few sessions by creating a poster describing your understanding of the internal and external changes that take place during cellular aging. You will then be tasked with providing prospective patients with at least one lifestyle change that has been proven to improve an aspect of cellular aging. You can use notes from the two biomedical researcher conferences, the Gallery Walk, and the Hallmarks of Cellular Aging Presentations for an example of the various changes that take place.*

*Your presentation must include:*

1. *A description of at least three external changes*
2. *A description of at least three internal changes*
3. *Introduction of DNA changes and their connections to cellular aging*
4. *A picture of each of the changes*
5. *Suggestion of one lifestyle change*
6. *An analogy for one external and one internal change*

*The analogy should include the cellular change, its effect on the cell, and a representation of the change and its effect on the cell.*

### Examples

Cellular Change	DNA methylation on certain CpG sites of genes
Effect on Cell	Methylation can silence the expression of certain genes, preventing the synthesis of proteins
Analogy	DNA methylation on certain CpG sites is like red stoplights in a certain part of town, preventing cars from continuing on their trips
Explanation	The red stoplights represent DNA methylation while the cars represent gene expression. The stoplights stops the cars, similar to how DNA methylation can stop gene expression.

### Resources:

*The Cellular Decision Between Apoptosis and Autophagy*

*The Cell Biology of Aging*

# FUTU<sup>3</sup>ELAB+

## Internal and External Changes in Cellular Aging Poster Rubric

Score	4	3	2	1
<b>Internal Changes</b>	A description of three internal changes and a specific picture is included for each change.	A description of three internal changes is included, but the picture chosen is not specific to the changes.	A description of two internal changes and a specific picture for each change is included.	A description of only one internal change and a picture related to the change is included.
<b>External Changes</b>	A description of three external changes and a specific picture is included for each change.	A description of three external changes is included, but the picture chosen is not specific to the changes.	A description of two external changes and a specific picture for each change is included.	A description of only one external change and a picture related to the change is included.
<b>Analogy</b>	One external and one internal analogy are included; they are creative and directly related to the changes and their subsequent effects.	One external and one internal analogy are included; they are directly related to the change and its subsequent effect, although not creative.	Only one external or one internal analogy is included.	No analogies are included.
<b>Lifestyle Change</b>	Lifestyle change is realistic, not generic, and related to cellular changes.	Lifestyle change is realistic and related to cellular changes, but generic.	Lifestyle change is unrealistic and generic.	Lifestyle change is not related to cellular changes.
<b>Final Score</b>				



# FUTU<sup>RE</sup>LAB+

## Rubric for Biotech Unit Challenge

### Behind the Scenes of Scientific Breakthroughs

Observable features of the student journal	Meets Expectations 8-10 points	Progressing 5-7 points	No Attempt 0 points
<b>1. Research</b>			
a. Journal shows that the student used learning from previous lessons as a foundation for the information in their interactive job board as well as additional research specific to their scientific breakthrough in longevity.			
<b>2. Defining the Problem</b>			
a. Identified the problem that needs to be addressed in the use of the scientific breakthrough as a treatment for aging.			
b. Demonstrated an understanding of how the presentation components can be used to convey information and attract diverse potential employees.			
<b>3. Brainstorming</b>			
a. Conveyed how the purpose and intent for each component of the presentation connected to one another and to the overall idea.			
<b>Final Score</b>			
<b>Grade</b>			

# FUTURELAB+

## Rubric for Biotech Unit Challenge: Biotech Careers in Longevity Project

### Behind the Scenes of Scientific Breakthroughs

Observable features of the student performance	Meets Expectations 8–10 points	Progressing 5–7 points	No Attempt 0 points
<b>1. Uses scientific knowledge to generate the design solution</b>			
a. Student used knowledge about cellular aging and genetic sequencing, as well as bioengineering technology, to convey information about their chosen scientific breakthrough.			
b. Student included information from research and data in presentation to convey a clear message to the target audience.			
c. Student included information from research and longevity scientific breakthrough briefing in the presentation to influence target audience and support a call for action.			
d. Student created an interactive job board that seeks to ensure equity in outreach and employment.			
<b>2. Describes criteria and constraints</b>			
a. Student described criteria (how does this design meet the challenge) and constraints (for example, how well does the interactive job board explain the role of each career in the overall testing and approval process) in the presentation.			

Continues next page >

# FUTU<sup>RE</sup>LAB+

## Rubric for Biotech Unit Challenge: Biotech Careers in Longevity Project

### Behind the Scenes of Scientific Breakthroughs

*Continued*

Observable features of the student performance	Meets Expectations 8–10 points	Progressing 5–7 points	No Attempt 0 points
<b>3. Evaluating potential solutions</b>			
a. Student used data and research to determine how the scientific breakthrough could lead to the extension of the human lifespan.			
b. Student determined their target population or demographic based on research and data and took into account racial or ethnic disparities in medicine and healthcare locally or globally.			
<b>4. Refining or optimizing the solutions</b>			
a. Student identified revisions that may be made to the campaign based on testing, peer feedback, and evidence from data collection.			
<b>Final Score</b>			
<b>Grade</b>			

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