FUTURELAB+

BIOMED

Behind the Scenes of Scientific Breakthroughs

Bioengineering of Organisms

Developed in partnership with:

Discovery Education and Ignited

In this Lesson Plan:

Print the **Teacher Section** →

Print the **Student Section** →

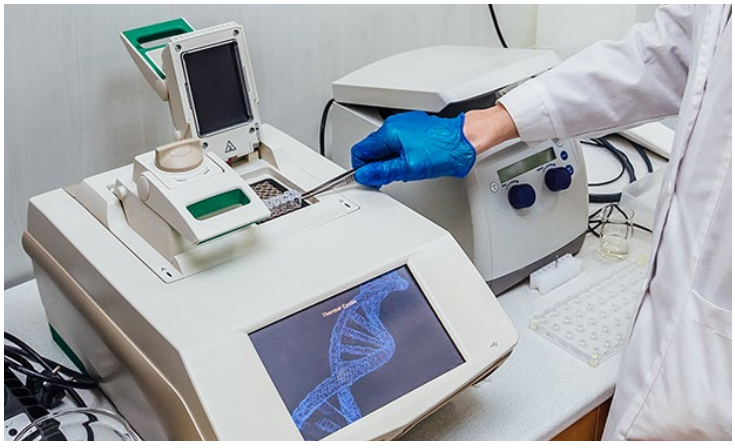


Image of a scientist with gloved hand putting DNA sample into real-time PCR-cycler.

—

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

Page Range (use a hyphen): T3–T6

BIOMED / BEHIND THE SCENES OF SCIENTIFIC BREAKTHROUGHS

Bioengineering of Organisms

DRIVING QUESTION

How are GMOs affecting society and evolution?

OVERVIEW

DNA alteration and modification has been used for many years to create stronger crop yields in agriculture and in research on animals in laboratory studies. Advanced technologies have impacted bioengineering and have broadened its applications.

In this lesson, students will review techniques that are used to create bioengineered organisms and genetic modification. They will understand the different ways in which viable animal products can be used to deliver drugs. They will study the limits and ethical restrictions associated with manipulating and altering human DNA.

ACTIVITY DURATION

Five class sessions
(45 minutes each)

ESSENTIAL QUESTIONS

How can we increase human lifespans using bioengineering?

How ethical is bioengineering for genetic modification?

Who may benefit from bioengineered organisms?

OBJECTIVES

Students will be able to:

Identify the applications of bioengineering.

Apply DNA editing to health issues.

Examine regulation and precautions linked to DNA editing.

Understand markers involved in aging.

Materials

- **Genes Modification Capture Sheet**
- **DNA Editing Rubric**
- **How to Slow Aging! Capture Sheet**
- **Increase Life Expectancy Poster Rubric**
- **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 examine the serious consequences of bioengineering living organisms. They will also work in groups to complete a final project based on information collected. The combination of important decision making and finding a solution to help others will enable them to develop integrity, responsibility, and empathy. Students use the social-emotional learning skills of social awareness and self-awareness to participate in discussions on bioengineering and its consequences.

CULTURALLY AND LINGUISTICALLY RESPONSIVE INSTRUCTION

Students will have many opportunities to work in groups and explore the possibilities and applications of bioengineering on humans and the environment. The lesson offers opportunities for creating empathetic, culturally and linguistically responsive instructional strategies to the exploration of bioengineering and its possible impact on communities of color. This lesson also points to the critical importance of having diverse backgrounds represented in artificial intelligence and biomedical engineering. Peer feedback provides support for culturally and linguistically diverse students' use of "standard English," while bridging the content from scholastic research to the reality of delivering complex, and controversial, information.

COMPUTATIONAL THINKING PRACTICES

In this lesson, students examine patterns in DNA modification techniques. They analyze data in order to understand how DNA modification is linked to genetically engineered organisms. Once students grasp the consequences of genetically-modified animals on our health and the environment, they apply the computational thinking strategy of decomposing problems to evaluate situations when DNA editing can be used for healthy purposes.

CONNECTION TO THE PRODUCT LIFE CYCLE

The lesson addresses the **discover** phase of the product life cycle by allowing students to step into the roles of an artificial intelligence engineer and a biomedical engineer. Important steps in the production of bioengineered organisms answering serious ethical questions, which students will actively attempt, researching industrial applications, and building a model to increase life expectancy based on data collected.

Have you ever wondered…

What are GMOs?

GMO stands for genetically modified organisms. GMOs are living things that have had their genetic codes altered in one way or another. GMOs can take many forms. For example, a commonly used medicine that comes from a GMO source is insulin. It is used to treat diabetes. GMOs allow scientists to make changes to plants and animals in a more specific way and in a shorter amount of time than traditional breeding methods.

What is a concern with GMOs?

One of the main issues with GMOs is that they have been accused of triggering allergies. Contamination of non-GMO corn with GMO corn containing a pest-repelling protein called Cry9C may have caused an allergic reaction in one Taco Bell customer in 2000. It was not possible to prove a concrete connection between the protein and the allergic reaction, but many believe this protein is the underlying culprit. It turns out there is no evidence that GMOs of any kind are any more or less allergenic than their non-modified counterparts. Additionally, further technology development might even allow us to eradicate common allergens in our food.

How can we modify cells to increase lifespan?

Certain cells are known to be associated with tissue damage and aging. Tweaking those particular cells could help us live longer. Somatic cells have a limited life span. These cells are involved in an animal's growth, metabolism, and behavior. In contrast, reproductive germline cells continue from one generation to the next. A study by the National Institute of Aging found that certain genetic mutations known to extend the lifespan of the *C. elegans* roundworm induced somatic cells to express two genes typically only active in germline cells. Usually, germline cells live longer than somatic cells. This is due in part because they are more stable and better able to resist stress. In the study, the transformed somatic cells allowed the roundworms to live much longer than usual.

MAKE CONNECTIONS!

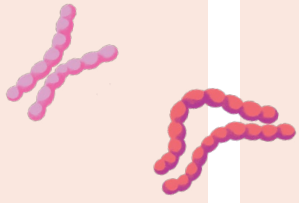
How does this connect to the larger unit storyline?

DNA has long been the subject of changes and modifications. However, scientists are now able to alter DNA molecules to remove the part that is not of interest or creating a health problem and change it with a segment of DNA of their choice. Applications include agriculture, pharmaceutical, and health.

How does this connect to careers?

Artificial intelligence engineers study computer languages and transpose them to develop new algorithms and methods, and build models with health applications.

Biomedical engineers develop new equipment or methods to improve human health.



How does this connect to our world?

Some diseases arise from old age. With the use of bioengineering and new techniques, these diseases can be pushed back and appear much later in life. Bioengineering could also improve health conditions and the overwell wellbeing of older individuals.

Day 1

Procedure

LEARNING OUTCOMES

Students will be able to:

Understand DNA modification techniques.

Link DNA modification to genetically engineered organisms.

Individual Work (20 minutes)

1 Provide students with the *Genes Modification Capture Sheet*.

2 Introduce DNA modification techniques by instructing students to watch a video: *How to Make a Genetically Modified Plant* (10:26). Use *Pause and Play* at strategic intervals to have students jot down notes while they watch the video.

3 Ask students to complete *Genes Modification Capture Sheet* using what they learned in the video.

Whole Group (15 minutes)

1 Ask the class what GMO foods they think they have eaten. Allow students to draw quick simple sketches of the foods. Then, introduce examples of GMO foods:

- salmon—grows more quickly and uses less feed
- potatoes—modified to resist insects and pests
- soybeans—used for livestock and making soybean oil
- apples—developed to resist browning after being cut
- corn—modified to resist pests or tolerate herbicide
- papaya—By the 1990s, ringspot virus disease had almost wiped out Hawaii's papaya crop. A GMO papaya, named the Rainbow papaya, was developed to resist ringspot virus.

Use *Three Truths and One Lie* to allow students to think about the amount of GMO crops that are being used.

Post the following statements on the board:

a. In 2018, GMO soybeans made up 94% of all soybeans planted.

b. Sugar beets are used to make granulated sugar. GMO sugar beets make up 50% of the sugar beets harvested.

c. In 2018, GMO cotton made up 94% of all cotton planted.

d. In 2018, 92% of corn planted was GMO corn.

Ask students to hold up fingers for the number to represent the statement that is a lie.

A: Statement 2 is the lie—99.9% of all sugar beets harvested in 2013 were GMO sugar beets.

Continues next page >

Day 1

Continued

Procedure

2	Ask the follow up questions: *Were any of you surprised by the GMO food examples? Why or why not?* Use a *Turn and Talk* for students to discuss their answers with a partner.
3	Discuss the following question with the class: *What is the difference between artificial selection and genetic modifications?* Use the *Snowball Fight Strategy* for students to write their responses and ask three or four students to read aloud the "snowball" they pick up. Question if they think the answers are correct or not and to explain their reasoning.

Teacher Note > *Students may inquire whether GMOs can be included in organic products; you may direct them to this United States Department of Agriculture (USDA) resource. Students may also have questions about regulation in the United States; you may direct them to this Food and Drug Administration (FDA) resource.*

Individual Work (10 minutes)

Have students reflect and answer questions in their **Design Journal**. This could be used as an Exit Ticket.

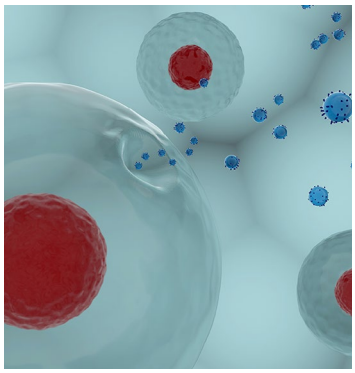
Day 2

LEARNING OUTCOMES

Students will be able to:

Investigate the impact of bioengineering on the environment.

Create a list of applications using bioengineering.



Procedure

Individual Work (10 minutes)

1 Display the image on page 5 of *Small Wonders, Endless Frontiers*.

2 Invite students to observe the image and ask:

- What do you notice?
- What do you wonder?
- How do you think nanotechnology, the study and application of extremely small things, relates to bioengineering?

3 Instruct students to read *New Virginia Tech Startup Seeks to Use Nano Capsules* about how nano-sized biological capsules are being created from cow's milk. As students read invite them to:

- circle ideas or facts that you already knew
- underline ideas or facts that are new learning for you
- place a star next to careers related to nanotechnology
- use a question mark to annotate questions you still have
- summarize the article by answer the question: *How could drinking a milkshake replace a vaccine shot?*
- predict what we might be learning next

4 Tell students to share out their summarizer with a partner and their ideas of what they might be learning next.

Teacher Note > *Some students may have difficulty with some of the words in the article. Provide definitions for challenging words, such as nanoscale, cardioprotective, hydrolyzing, and peptide. One potential answer to the summarizer question is that the milkshake could contain biological capsules made from milk that could carry lifesaving medicine that is particularly fragile.*

Whole Group (5 minutes)

1 Lead students into a discussion about exosomes and why they are more tolerated by patients than synthetic structures. Ask: *What is the great benefit of using exosomes to deliver drugs to a patient?*

Teacher Note > *Sometimes students have difficulty discussing, so you can use the sentence starters below and the Train or Pass it On discussion protocol. This could also be done in table groups to ensure that each student gets an opportunity to participate.*

Have one student pull a sentence starter from the envelope and read it aloud. That student should try to finish the sentence. If that student cannot finish the sentence, then he or she can pass it to another student who can finish the sentence. There are multiple correct ways to finish the sentence. This strategy helps to give students ideas about what to discuss.

Continues next page >

Day 2

Continued

Procedure

Sentence starters:
The alphaCT11 molecule has cardioprotective effects in mice that prevents the spread of cell death in heart muscle but...

Cardioprotective means...

Shuttling biomolecules and genetic material in the human body can be challenging because...

An example of a delivery envelope is...

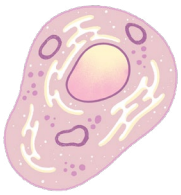
Milk generated by nursing mammals is used...

Pharmaceutical companies have not been keen on using drugs based on peptides because...

Exosomes can be used for targeted delivery...

The goal is to treat patients...

The benefit of using exosomes to deliver drugs is...



Small Groups (15 minutes)	
1	Ask students to form groups of five. Have each group find five applications of nanotechnology in bioengineering. With each application include an emerging "biotech career" related to nanotechnology.
2	Ask students to create a *Canva* page and add these applications and careers, as well as a sentence about the purpose of each of these applications.

Teacher Note > *Some students may not be able to get five applications finished in the allotted time. Allow these student groups to make a list of only three applications instead or be sure to make heterogeneous groups of students.*

Whole Groups (10 minutes)	
1	Ask each group to read its list of applications and careers to the rest of the class.
2	Lead students in a *Brainstorm* discussion about the precautions that would need to be taken regarding these applications for the environment.

Day 3

Procedure

LEARNING OUTCOMES

Students will be able to:

Identify lab risks when manipulating biomaterial.

Explore the consequence of genetically-modified animals on our health and the environment.

INDUSTRY AND CAREER CONNECTION

In this activity, students will take the vantage point of an artificial intelligence engineer by measuring the risk of working with hazardous equipment.

Whole Group (10 minutes)

1. Start the class by asking students to consider risks of working with human cells: *Can we get contaminated by harmful pathogens or even get cancer working with human cells?*
2. Ask students to read the following article about special precautions that need to be taken when working in a lab: *Handbook Health and Safety*.
3. Instruct students to write down three hazards from the text on a sheet of paper.

Small Group (15 minutes)

1. Ask students to form groups of five and exchange their papers with each other.
2. Instruct students to take on the role of an artificial intelligence engineer working in a lab, and find protection material for each of the hazards they listed using the link provided: *3 Biosafety Practices and Procedures.*
3. Ask students to give the paper back to the original writer after they complete the task.

Whole Group (10 minutes)

1. Lead students in a discussion, using the *Pick a Stick* protocol, by asking them the following: *Even if humans are protected in the lab, does that protect the environment when working with GMOs? What precautions apply to GMOs? Can we use animals for bioengineering? What are the impacts on the environment?*

Teacher Note > *Encourage students who want to learn more to also answer the following question: What happens to genetically-modified salmon? They can use the following link to help answer the question: Genetically Engineered Fish: The Future Of Food.*

Day 4

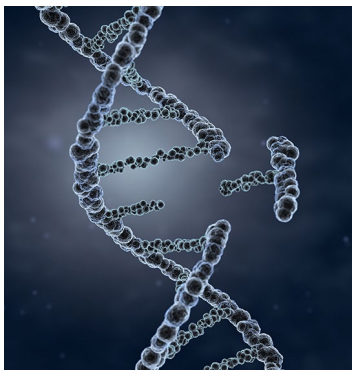
Procedure

LEARNING OUTCOMES

Students will be able to:

Assess ethical dilemmas of genetically modifying organisms.

Evaluate the situations when DNA editing can be used for healthy purposes.



Small Group (35 minutes)	
1	Ask students to form five groups and watch the video about DNA editing: *Watch* (5:31).
2	Have groups discuss what they watched by choosing to answer one question from below: • Could genetically-modified organisms pass their genes on to the next generation to change human evolution? • Who should access DNA editing in priority? • What are the risks of making an individual disease-resistant? • How could DNA editing threaten the environment?
3	Allow groups to discuss for a few minutes and write down their group answer on a piece of paper. Only one piece of paper per question and per group.
4	Collect all answers and shuffle the papers. Pick a student to come to the front and read each answer. Let all students guess what question the answer corresponds to. Doing so will enable groups to not only share their answers with the class, but also allow all students to touch on each of the concepts raised in the questions.
5	Give students the *DNA Editing Rubric*.
6	Without changing the groups, prompt each group to create a guide on *Canva* that would clarify restrictions and access to the use of DNA editing. Ask students to include information about all the following concepts: • Individual or species concerned • Informed consent • Research involving embryos • Consequences of a loss of chromosome or a fragment of it • Equal access: address disparities in access to healthcare and other interventions • Nontherapeutic use of DNA editing, such as glofish glowing under UV light • Enhancement purposes

Teacher Note > *Assess students using the DNA Editing Rubric. This activity will likely take more than the allotted time so students may have to complete the guide for homework.*

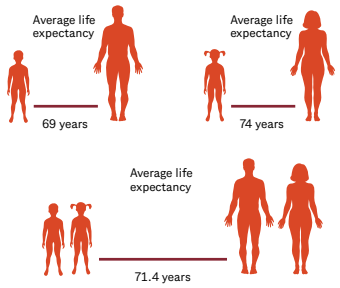
Day 5

LEARNING OUTCOMES

Students will be able to:

Combine the information of previous days to create a poster.

Examine the biomarkers of long-lived individuals to increase the lifespan of humans.



INDUSTRY AND CAREER CONNECTION

In this activity, students will take the vantage point of a biomedical engineer by modifying organisms using bioengineering and create new solutions to improve the quality of life of people aging.

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.*

Individual Work (10 minutes)

1 Ask students to partner and read the PMC article: *Understanding Ageing* and answer questions on the *How to Slow Aging! Capture Sheet*.

Teacher Note > *Walk through one or two questions on the capture sheet together with struggling students. You may want to print in a larger font, chunk text, and assign questions.*

Whole Group (5 minutes)

1 Answer all questions by reading them aloud to the class and allow time for students to correct any answers they did not get.

Small Group (30 minutes)

1 Give students the *Increase Life Expectancy Poster Rubric*.

2 In groups of four, ask students to create a poster on *Canva* with a possible solution to increase life expectancy using bioengineering, based on the article they read in the previous activity and information collected from previous days.

3 Tell students to add pictures, graphs, and comments and to include the following concepts:

- What cells, if any, should have their DNA edited and altered? Why?
- What are the processes in which cells are being modified?
- What are the diseases or tissue damage that are likely to disappear if the cells responsible for these damages are healthy?
- What is likely to improve?
- Who will benefit from it? What age range?
- What may be a consequence or consequences of using this bioengineering on our health and the environment?

Teacher Note > *Assess students using the Increase Life Expectancy Poster Rubric.*

National Standards

Next Generation Science Standards

ETS1.B
Developing Possible Solutions
When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

Science and Engineering Practices
Constructing an explanation
Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.

Crosscutting Concepts
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).

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.

Career and Technical Education (CTE)

A1.3
Recognize the role of innovation in creation of emerging biotechnology careers, including those in nanotechnology, biofuels, and forensics.

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.

Genes Modification Capture Sheet

ANSWER KEY **Do not share with students**

Directions
Write down at least three words or ideas related to each of the four bolded topics.

Traits Modified	**Plasmid Components**
Disease Resistance Gene Nutrition Herbicide Resistance Growth Properties	Promoter Origin of Replication ORI DNA for Desired Trait Antibiotic Resistance Gene
Gene Gun	**Tumor Inducing (Ti) Plasmid**
DNA is fired at the plant cell and hopefully lands in the nucleus Brute Force Strategy	Antibiotic Resistance ORI Virulence Promoter Virulence Genes Right and Left Borders Transfer DNA Tumor Genes Opine Break Down Genes 355 Promoter Gene Traits

How to Slow Aging! Capture Sheet

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

Directions
Respond to the questions as you read the article: Understanding Ageing: Biomedical and bioengineering approaches, the immunologic view.

1. What cells from the immune system are negatively impacted by aging?

L and T cells

2. What increases the risk of age-associated diseases?

Exposition to environmental factors

3. What is the origin of the term *senescence*?

A deterioration of the immune system

4. In elderly people, what aspect is correlated to health status?

A good immune system

5. What diseases are frequent in elderly people?

Infectious diseases, tumors, autoimmune phenomenon and inflammatory chronic diseases, such as atherosclerosis and Alzheimer's disease

6. What are the implications of chronic antigenic stress?

The onset of inflammatory diseases

7. What type of immunity appears to be the prevalent mechanism driving tissue damage associated with different age-related diseases?

Innate immunity

Continues next page >

How to Slow Aging! Capture Sheet

ANSWER KEY **Do not share with students**

Continued

8. What causes a decline in mitochondrial function?

Neuromuscular degenerative disease and other tissue dysfunction

9. What does inadequate micronutrient intake lead to?

Metabolic modification that has long term consequences, such as cancer (DNA damage), severe infection (immune dysfunction), and cognitive dysfunction and accelerated ageing (mitochondrial decay)

10. What does telomere length tell us about life expectancy?

Shorter telomeres directly correspond to shorter human life expectancy

11. What could be a way to increase life expectancy?

Prevent telomere shortening by transiently inducing the activity of telomerase

12. What cells are seen in greater numbers in the offspring of healthy centenarians?

B naïve lymphocytes

FUTURELAB+

Genes Modification Capture Sheet

Directions
Write down at least three words or ideas related to each of the four bolded topics.

Traits Modified	**Plasmid Components**
Gene Gun	**Tumor Inducing (Ti) Plasmid**

FUTURELAB+

DNA Editing Rubric

Score	4	3	2	1
Presentation and flow	DNA editing guide has great flow and all of the sections make sense together.	DNA editing guide has good flow and the majority of sections make sense together.	DNA editing guide has fine flow, but some sections do not make sense together.	DNA editing guide has poor flow and sections do not make sense together.
Content	Addresses all of the required concepts.	Addresses most of the required concepts.	Addresses half of the required concepts.	Addresses no required concepts.
Spelling and Grammar	There are very limited spelling and grammar mistakes.	There are minimal spelling and grammar mistakes.	There are a few spelling and grammar mistakes.	There are many spelling and grammar mistakes.
Final Score				

FUTURELAB+

How to Slow Aging! Capture Sheet

Directions
Respond to the questions as you read the article: Understanding Ageing: Biomedical and bioengineering approaches, the immunologic view.

1. What cells from the immune system are negatively impacted by aging?

2. What increases the risk of age-associated diseases?

3. What is the origin of the term *senescence*?

4. In elderly people, what aspect is correlated to health status?

5. What diseases are frequent in elderly people?

6. What are the implications of chronic antigenic stress?

7. What type of immunity appears to be the prevalent mechanism driving tissue damage associated with different age-related diseases?

Continues next page >

FUTURELAB+

How to Slow Aging! Capture Sheet

Continued

8. What causes a decline in mitochondrial function?

9. What does inadequate micronutrient intake lead to?

10. What does telomere length tell us about life expectancy?

11. What could be a way to increase life expectancy?

12. What cells are seen in greater numbers in the offspring of healthy centenarians?

FUTURELAB+

Increase Life Expectancy Poster Rubric

Score	4	3	2	1
Presentation and flow	Poster has great flow and all of the sections make sense together.	Poster has good flow and the majority of sections make sense together.	Poster has fine flow, but some sections do not make sense together.	Poster has poor flow and sections do not make sense together.
Content	Addresses all of the required concepts.	Addresses most of the required concepts.	Addresses half of the required concepts.	Addresses no required concepts.
Visuals	Includes both solid pictures and graphs.	Includes both pictures and graphs, but one may be slightly lacking.	Includes either pictures or graphs, but not both.	Includes no pictures or graphs.
Spelling and Grammar	There are very limited spelling and grammar mistakes.	There are minimal spelling and grammar mistakes.	There are a few spelling and grammar mistakes.	There are many spelling and grammar mistakes.
Final Score				

FUTURELAB+

References

Behrokh Mohajer Maghari and Ali M. Ardekani *Genetically Modified Foods and Social Concerns. Avicenna J Med Biotechnol.* July, 2011.

Genetic mutations transform cell type to prolong life in roundworm. National Institute on Aging. March, 2010.

GMO Crops, Animal Food, and Beyond. Fda.Gov. Children's Hospital of Philadelphia.

Xu, Charles. *Nothing to Sneeze at: the Allergenicity of GMOs* Science in the News. *Harvard University.* August, 2015.