

BIOMEDICAL ENGINEERING LESSON PLAN

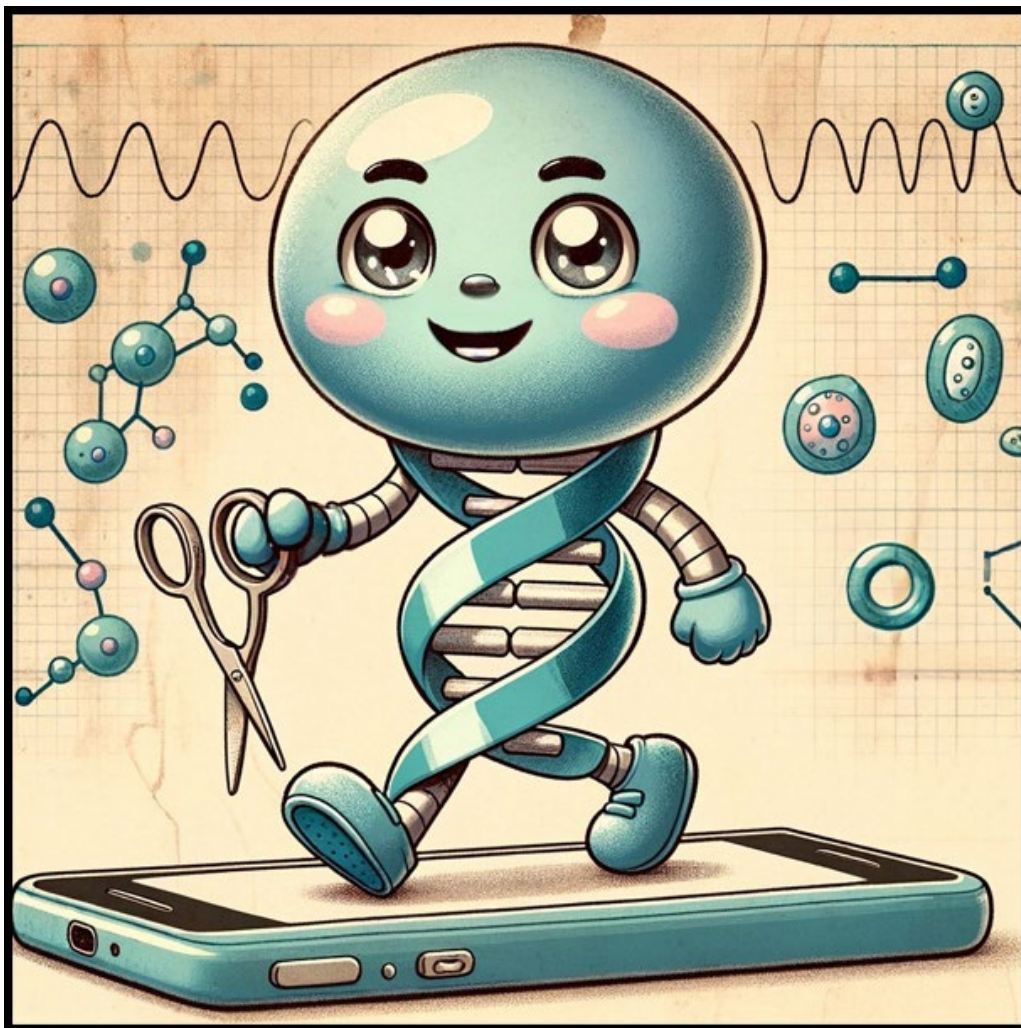


ADAPTABLE FOR GRADES 6-8

Can be adapted for two 90-minute plans or four 45-minute plans

GENETIC TELEPHONE:

A STORY-DRIVEN JOURNEY THROUGH THE WORLD OF DNA & GENE EDITING



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National Institute of
Biomedical Imaging
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BEAMS
Biomedical Engineering Adapted for Middle Schoolers

*Technologies to Shape
the Future of Health*

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Table of Contents

Genetic Telephone: A Story-Driven Journey Through the World of DNA & Gene Editing	3
Lesson Summary: DNA Mutations and CRISPR	3
Learning Objectives	6
DOC 2A: Story Rules	8
DOC 2B: Random Mutation Story Activity	14
DOC 2C: Student Handout for Story (Example 1)	17
DOC 2D: Student Handout for Story (Example 2)	18
DOC 3 – see slides for Lesson Plan 1: DNA Mutation.....	19
DOC 4 – see slides for Lesson Plan 2: CRISPR	19
DOC 5A: CRISPR Story Activity.....	19
DOC 5B: Student Handout for Story (Example 1).....	22
DOC 5C: Student Handout for Story (Example 2)	23
DOC 6: Quiz Activity	26
Sixth Grade Questions.....	26
Seventh and Eighth Grade Questions.....	28
DOC 7: Homework Assignment Questions and Rubrics.....	33
DOC 8: External Resources for Teachers and Students	35
DOC 9: Feedback from Teachers/Testimonials.....	36
Materials List.....	37

Genetic Telephone: A Story-Driven Journey Through the World of DNA & Gene Editing

Lesson Summary: DNA Mutations and CRISPR

Topic Area: DNA Mutations and CRISPR

Note: For background information about these topics, please refer to our compiled external resources ***DOC 8 External Resources for Teachers & Students***

Grade Levels: 6-8 (can be adapted to make activities more complex)

Duration: Two 90-minute blocks (can also be broken up into four 45-minute blocks)

Block 1: Random Mutation Story and Detailed Lesson on DNA Mutations

In the first 90-minute block, the lesson is focused on introducing students to the concept of DNA mutations and their significance in genetic variation. The students are engaged in a "Random Mutation Story" activity. In this activity, students are provided with a fictional story of a family experiencing "genetic mutations" leading to various traits and health conditions which affects the story's outcome. This narrative approach helps students grasp the real-world implications of DNA mutations and how they contribute to biodiversity and genetic diversity within populations. The story also highlighted the potential positive and negative outcomes of mutations.

Lesson Plan Highlights:

- 1) Random Mutation Story Activity: Students play a variant of the telephone game but instead of modifying a phrase, each individual gets to modify a story. There are specific rules as to the modification each individual can make. When comparing the story before the modifications and after all the modifications, we will mimic how random mutations occur in the genome. Detailed info about this activity can be found in ***DOC 2A Story Rules*** and ***DOC 2B Random Mutation Story Activity***
- 2) Detailed Lesson on DNA Mutations: The lesson continues with a more in-depth session on DNA mutations. The teacher elaborates on the types of mutations (point mutations, insertions, deletions), their impact on genetic information, and how they can lead to variations in phenotypes. This session aims to provide a solid foundation for

understanding genetic diversity and its origins. The lesson plan and supplemental media for this activity can be found in **DOC 3: DNA Mutation Lesson slides**

Block 2: CRISPR Story and Evaluation Activity

The second 90-minute block centers on the revolutionary CRISPR-Cas9 gene-editing technology and its applications. The lesson incorporates a "CRISPR Story" activity to help students understand the potential of CRISPR in modifying genes and its ethical implications. The block concludes with an evaluation activity to assess students' comprehension and critical thinking skills.

Lesson Plan Highlights:

- 1) Introduction to CRISPR: The teacher introduces CRISPR-Cas9 technology, explaining its mechanism of action and how it allows precise gene editing. The lesson plan and supplemental media for this activity can be found in **DOC 4: CRISPR Lesson slides**
- 2) CRISPR Story Activity: Students play a game similar to the one played previously. However, this time, they can make specific changes with an end goal in sight. Additionally, this game can be further complicated based on the age range of the students by adding "good actors," or students who are CRISPR agents, and "bad actors," or students who are cancer agents (hurting the overall story). The lesson plan and supplemental media for this activity can be found in **DOC 5A: CRISPR Story Activity**
- 3) Individual Quiz & Group Kahoot: Each student will take an individual quiz to assess their knowledge retention of these sessions. Next, there is a group component where a Kahoot game is played in groups of 2-4 in which the students have to attempt to decipher the CRISPR mutation that was done. **DOC 6 Individual Quiz Bank & Kahoot Activity (link:**

<https://create.kahoot.it/details/83177af2-97d4-459b-8c74-1d8881d49621>)
- 4) Homework Assignment: Each student gets to pick one topic on this sheet of potential topics to write a research paper. They are allowed to use online resources as long as they cite them. **DOC 7 Homework Assignment**

Outcome:

By the end of these two blocks, students will gain a comprehensive understanding of DNA mutations, their role in genetic diversity, and the potential benefits associated with CRISPR-Cas9 technology. The combination of narrative-driven activities, detailed lessons, group discussions, and evaluation tasks ensured a holistic learning experience that deepened their understanding of these complex genetic concepts.

Note to the Teacher:

Utilize the narrative activities to engage students and the detailed lesson to build a

strong foundation for their understanding. Encourage active participation in discussions to foster critical thinking and open dialogue about the ethical dimensions of genetic manipulation.

Learning Objectives

<u>MS-LS3-1 Heredity: Inheritance and Variation of Traits</u>: LS3.A: Inheritance of Traits - Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits.	Students are taught this content in multimodal methodologies. Initially, they are doing a hands-on activity that shows how small changes to something can affect the larger result through the Random Mutation Story Activity. Then they are given more context and info through the lesson plan. Finally, they are tested on their knowledge via the individual quiz.
<u>MS-LS3-1 Heredity: Inheritance and Variation of Traits</u>: LS3.B: Variation of Traits - In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations. Though rare, mutations may result in changes to the structure and function of proteins. Some changes are beneficial, others harmful, and some neutral to the organism.	Students are taught this content in multimodal methodologies. Initially, they are doing a hands-on activity that shows how small changes to something can affect the larger result through the Random Mutation Story Activity. Then they are given more context and info through the lesson plan. Finally, they are tested on their knowledge via the individual quiz.
<u>MS-LS4-5 Biological Evolution: Unity and Diversity</u>: Information about technologies that have changed the way humans influence the inheritance of desired traits in organisms. [Clarification Statement: Emphasis is on information from sources about the influence of humans on genetic outcomes in artificial selection (such as genetic modification, animal husbandry, gene therapy); and, on the impacts these technologies have on society as well as the technologies leading to these scientific discoveries.]	Our activity has a significant focus on CRISPR and the capabilities of this technology while also discussing the potential impacts of this technology on the broader society. This is covered by the CRISPR Story Activity and Lesson Plan. This content is also tested by the individual quiz and Kahoot.

<u>MS-ETS1-1</u>: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions	Students through the two hands-on activities are put directly on the ground floor of this problem and have to decide the pros and cons of conducting various changes and how it can affect the bigger picture and limit potential options for others later on in the activity. More specifically during the CRISPR activities, students will have to take into account positive and antagonistic factors that exist in the body such as cancer cells that do harmful mutations as opposed to beneficial improvements done using CRISPR.
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DOC 2A: Story Rules

Substitution Rule:

- Choose any word in the story and replace it with another word of your choice.
- Example: If the story says, "Alex walked to the park", you could change "walked" to "ran" so it reads "Alex ran to the park".
- Genetic Equivalent: Point Mutation - A single nucleotide in DNA is changed, replaced by another nucleotide.

Deletion Rule:

- Remove any word or phrase from the story.
- Example: "Alex walked to the park with his dog" could become "Alex walked to the park".
- Genetic Equivalent: Deletion Mutation - One or more nucleotides are removed from a gene or DNA sequence.

Insertion Rule:

- Add a word or phrase anywhere in the story.
- Example: "Alex walked to the park" could become "Alex excitedly walked to the park".
- Genetic Equivalent: Insertion Mutation - Extra nucleotides are added to a gene or DNA sequence.

Duplication Rule:

- Choose any word or phrase and repeat it immediately after itself.
- Example: "Alex walked very slowly to the park" could become "Alex walked very very slowly to the park".
- Genetic Equivalent: Duplication Mutation - A section of DNA is duplicated and both copies are retained.

Rearrangement Rule:

- Take any sentence or phrase and rearrange its words.

- Example: "Alex ate his sandwich" could become "His sandwich ate Alex".
- Genetic Equivalent: Inversion Mutation - A segment of DNA is reversed within the chromosome.

Combination Rule:

- Combine two adjacent words to create a new word or phrase.
- Example: "Alex walked to the big park" could become "Alex walked to the big park."
- Genetic Equivalent: Fusion Mutation - Two genes or DNA sequences are combined to form a single novel gene.

Expansion Rule:

- Expand any sentence by repeating section numerous times.
- Example: "Alex walked to the park" could become "Alex walked walked walked walked to the park."
- Genetic Equivalent: Tandem Repeat Expansion - A sequence of DNA is repeated multiple times, leading to an expansion of that region.

Contraction Rule:

- Shorten any sentence by reducing a repeated part of the sentence.
- Example: "Alex walked walked to the park " could become "Alex walked to the park."
- Genetic Equivalent: Tandem Repeat Contraction - A repeated sequence of DNA is reduced in number.

Replacement Rule:

- Swap the positions of two sentences or phrases in the story.
- Example: If the story says "Alex walked to the park. He saw a bird." it could become "He saw a bird. Alex walked to the park."
- Genetic Equivalent: Translocation Mutation - A segment of DNA is moved from one chromosome to another.

Create a story or enter this prompt into an AI Large Language Model

"Create a short story based on the subject [SUBJECT] suitable for middle

school students. The story should be approximately [LENGTH] words long. Design the narrative in a way that allows for words or phrases to be easily switched, added, removed, or duplicated. Ensure that the changes made based on the provided list of words or phrases can alter the story's direction or outcome without drastically changing its core narrative. The story should be neutral in tone and contain multiple elements (like characters, actions, and settings) that can be modified without losing the overall context. The story should center around this topic [TOPIC]."

Where:

- [SUBJECT] can be replaced with any subject the user wants (e.g., "a school field trip", "a mysterious discovery in the backyard", "a talent show rehearsal").
- [LENGTH] can be replaced with the desired word count (e.g., "300", "500").
- [TOPIC] can be current events related to what students are interested in

CRISPR Story

Rules

Cancer Students (Objective: Keep or make the story worse)

Uncontrolled Growth Rule:

- Story: Add repetitive and unnecessary details to the story to make it confusing.
- Example: "Alex was sad. Alex was very sad. Alex was extremely sad."
- Biological Equivalent: Uncontrolled Cell Growth - Cancer cells grow and divide uncontrollably, leading to tumor formation.

Metastasis Rule:

- Story: Introduce a negative event or detail from one part of the story to another unrelated part.
- Example: "Alex lost his toy. Later, during dinner, his food tasted like the sadness of the lost toy."
- Biological Equivalent: Metastasis - Cancer cells spread from their original site to other parts of the body.

Avoid Repair Rule:

- Story: Introduce a problem in the story and avoid resolving it.

- Example: "Alex's bike broke, and he never tried to fix it."
- Biological Equivalent: DNA Repair Avoidance - Cancer cells often avoid the body's natural DNA repair mechanisms.

CRISPR Students (Objective: Improve or correct the story)

Targeted Editing Rule:

- Story: Identify a specific negative detail and replace it with a positive one.
- Example: Change "Alex was sad because he lost his toy" to "Alex was happy because he found his toy."
- Biological Equivalent: Specific Gene Targeting - CRISPR is used to target specific genes for editing.

Insertion Rule:

- Story: Add a positive event or detail to improve the story's outcome.
- Example: "Alex was feeling down, but then he received a surprise gift from his friend."
- Biological Equivalent: Gene Insertion - CRISPR can be used to insert beneficial genes into DNA.

Deletion Rule:

- Story: Remove a negative event or detail to enhance the story.
- Example: Remove "Alex's bike broke" from the story.
- Biological Equivalent: Gene Deletion - CRISPR can be used to remove harmful or unwanted genes from DNA.

Correction Rule:

- Story: Identify a mistake or inconsistency in the story and correct it.
- Example: Change "Alex was sad because he lost his toy, but he was holding it" to "Alex was happy because he found his toy and was holding it."
- Biological Equivalent: Gene Correction - CRISPR can be used to correct mutations or errors in DNA.

Create a story or enter this prompt into an AI Large Language Model

"Create a story based on the theme [THEME] that starts with a negative or challenging situation. The story should be approximately [LENGTH] words long. Design the narrative in a way that allows for words or phrases to be easily switched, added, removed, or duplicated to either worsen the situation (for the 'cancer' students) or improve it (for the 'CRISPR' students). The story's tone should start off as [INITIAL TONE: e.g., 'very negative' or 'slightly negative'] and should be [DIFFICULTY: e.g., 'easy', 'moderate', or 'hard'] to transition from a negative to a positive outcome. The story should center around this topic [TOPIC]."

Where:

- [THEME] can be replaced with any desired theme (e.g., "a school project gone wrong", "a lost pet", "a ruined birthday party").
- [LENGTH] can be replaced with the desired word count (e.g., "300", "500").
- [INITIAL TONE] determines how negative the story starts off. This can be set to "very negative" for a more challenging story or "slightly negative" for a milder starting point.
- [DIFFICULTY] determines how challenging it is to transition the story from bad to good. "Easy" means fewer changes are needed, "moderate" requires a balanced amount of changes, and "hard" means it's quite challenging to turn the story around.
- [TOPIC] can be current events related to what students are interested in.

ChatGPT example generated using prompt:

On a sunny afternoon, Emily decided to take her bike out for a ride around the neighborhood. The wind was gentle, and the birds were singing their melodious tunes. But as she pedaled faster, trying to feel the breeze against her face, disaster struck. A stray cat darted out from a bush, causing Emily to swerve abruptly. She lost her balance and tumbled off her bike, landing hard on the pavement.

The pain was immediate. Emily tried to stand up, but a sharp sting in her ankle made her wince. She looked down and saw that her ankle was swelling. Tears welled up in her eyes, not just from the pain, but from the realization that she might have sprained her ankle. The bike lay a few feet away, its front wheel still spinning.

A neighbor, Mrs. Thompson, who had been watering her plants, rushed over. "Oh dear, are you alright?" she asked, concern evident in her voice.

Emily tried to put on a brave face. "I think I sprained my ankle," she

replied, trying to hold back her tears.

Mrs. Thompson quickly fetched a cold pack from her house and wrapped it around Emily's ankle. "This should help with the swelling," she said. "But you should see a doctor."

Emily nodded, feeling a mix of gratitude and embarrassment. She had been so excited about her bike ride, and now she was sitting on the sidewalk, nursing a sprained ankle.

As the minutes ticked by, a few more neighbors gathered around, offering words of comfort and advice. Some suggested home remedies, while others shared their own tales of biking mishaps. Emily listened, feeling a bit overwhelmed.

Finally, her best friend, Sarah, arrived. She had seen the commotion from her window and had come running. "Oh, Emily," she exclaimed, "what happened?"

Emily recounted the unfortunate series of events, and Sarah listened sympathetically. "Don't worry," she said, "we'll get you back on your feet in no time."

With Sarah's help, Emily managed to stand up and hobble back to her house. The pain was still there, but with each step, she felt a bit stronger. She knew that with the support of her friends and family, she would recover and be back on her bike soon.

DOC 2B: Random Mutation Story Activity

Students play a variant of the telephone game but instead of modifying a phrase, each individual gets to modify a story. There are specific rules as to the modification each individual can make. When comparing the story before and after the modifications, we will mimic how random mutations occur in the genome. More details can be found in **DOC 2A - Story Rules**, along with a prompt for an AI Large Language Model to generate stories.

To Start:

- 1) Write or post all rules (see below) in a central area (whiteboard, smartboard, etc.)
- 2) Split students into teams of 4 to 5
- 3) Randomly give each student 2 - 3 rules (just the number) from the rule list (see below)
 - a) Do not give the genetic equivalents to the students
- 4) Hand out the generated story (example can be seen in **DOC 2C 'Example: TEAM Student Handout for Story 1'**) to each team. Only hand one paper copy to each team. If an electronic device with access to Word or Google Docs is available, use that instead and ensure that each student is assigned a specific color when making edits.
- 5) Explain the rules of the activity without reference to biology.
 - a) Decide on the first individual to start making changes.
 - b) During a student's turn, they can either choose to make a change or leave the text alone.
 - c) Students can make a change that follows one of the rules that they were given
 - d) In their turn, the student can only make one change.
 - e) Each turn should last around 30 seconds
 - f) Then they pass the story on to the next person.
- 6) Allow students to conduct the activity for 10 - 20 minutes. Set a specific time limit that all students are aware of.

- 7) At the end of the allotted time, each team presents what happened and what their thought process was when making changes.

Rule List

1.Substitution Rule:

- Choose any word in the story and replace it with another word of your choice.
- Example: If the story says, "Alex walked to the park", you could change "walked" to "ran" so it reads "Alex ran to the park".
- Genetic Equivalent: Point Mutation - A single nucleotide in DNA is changed and replaced by another nucleotide.

2.Deletion Rule:

- Remove any word or phrase from the story.
- Example: "Alex walked to the park with his dog" could become "Alex walked to the park".
- Genetic Equivalent: Deletion Mutation - One or more nucleotides are removed from a gene or DNA sequence.

3.Insertion Rule:

- Add a word or phrase anywhere in the story.
- Example: "Alex walked to the park" could become "Alex excitedly walked to the park".
- Genetic Equivalent: Insertion Mutation - Extra nucleotides are added to a gene or DNA sequence.

4.Duplication Rule:

- Choose any word or phrase and repeat it immediately after itself.
- Example: "Alex walked very quickly to the park" could become "Alex walked very very quickly to the park".
- Genetic Equivalent: Duplication Mutation - A section of DNA is duplicated and both copies are retained.

5.Rearrangement Rule:

- Take any sentence or phrase and rearrange its words.
- Example: "Alex ate his sandwich" could become "His sandwich ate Alex."
- Genetic Equivalent: Inversion Mutation - A segment of DNA is reversed within the chromosome.

6. Combination Rule:

- Combine two adjacent words to create a new word or phrase.
- Example: "Alex walked to the big park" could become "Alex walked to the big park".
- Genetic Equivalent: Fusion Mutation - Two genes or DNA sequences are combined to form a single novel gene.

7. Expansion Rule:

- Expand any sentence by repeating section numerous times.
- Example: "Alex walked to the park" could become "Alex walked walked walked walked to the park."
- Genetic Equivalent: Tandem Repeat Expansion - A sequence of DNA is repeated multiple times, leading to an expansion of that region.

8. Contraction Rule:

- Shorten any sentence by reducing a repeated part of the sentence.
- Example: "Alex walked walked to the park " could become "Alex walked to the park."
- Genetic Equivalent: Tandem Repeat Contraction - A repeated sequence of DNA is reduced in number.

9. Replacement Rule:

- Swap the positions of two sentences or phrases in the story.
- Example: If the story says "Alex walked to the park. He saw a bird." it could become "He saw a bird. Alex walked to the park."
- Genetic Equivalent: Translocation Mutation - A segment of DNA is moved from one chromosome to another.

DOC 2C: Student Handout for Story (Example 1)

Note: This story was generated using ChatGPT

Jamie had always dreamed of visiting France. The tales of its beautiful cities, historic landmarks, and delicious pastries had filled her imagination for years. So, when her school announced a week-long trip to Paris, she was the first to sign up.

The journey began with a long flight. Jamie sat next to her friend, Max, and they chatted excitedly about all the places they wanted to visit. The Eiffel Tower, Notre Dame, and the Louvre were at the top of their list. As the plane landed, the city's skyline came into view, and Jamie's heart raced with anticipation. Their first stop was the Eiffel Tower. As they approached the iconic structure, Jamie felt a mix of awe and excitement. They decided to take the stairs, counting each step as they ascended. At the top, the view was breathtaking. The city stretched out below them, with its winding streets and historic buildings.

Next, they visited Notre Dame. The grandeur of the cathedral left Jamie speechless. She marveled at the intricate stained-glass windows and the towering spires. Max, on the other hand, was more interested in the history of the place. He eagerly listened to the guide, absorbing every detail. The following day, they went to the Louvre. The museum was vast, and there was so much to see. Jamie was particularly excited to see the Mona Lisa. However, when they reached the room where the painting was displayed, they found it was being restored and wasn't on display. Jamie felt a pang of disappointment, but Max suggested they explore other parts of the museum.

As the days went by, they visited many other places - the Seine River, Montmartre, and the Champs-Élysées. They tried croissants, éclairs, and other French delicacies. Each day was new adventure. On their last day, they decided to visit a local market. The stalls were filled with fresh produce, cheeses, and handmade crafts. Jamie bought a beautiful scarf, while Max picked up some souvenirs for his family.

As they boarded the plane to return home, Jamie felt a mix of sadness and gratitude. The trip had been everything she had hoped for and more. She had made memories that would last a lifetime and had experienced the magic of France firsthand. Max turned to her and said, "This trip was amazing, wasn't it? I can't wait for our next adventure."

Jamie smiled and replied, "Me too, Max. Me too."

DOC 2D: Student Handout for Story (Example 2)

Note: This story was generated using ChatGPT

It was a short trip to New York City, and Alex had to visit his grandma in the hospital. He went on the trip and was ready to hear what the surgeon had to say.

“The surgery we will be performing on your grandma is for a hip replacement. The surgery should be completed and your grandma discharged within 24 hours,” the surgeon said.

And so, Alex took the first train out from Philadelphia.

The train conductor began to come around to collect tickets. Alex had put his ticket on his phone and carried a hard copy. Some of the train conductors were old-fashioned and preferred hard copies. This conductor punched the hard copy and went about his day.

As the final boarding call began, Alex overheard something strange from a group of students boarded with their teacher.

“I can’t wait to see the MET!”

“I’m excited to see the public library! It’s got such a cool interior.”

Seeing kids excited about museums and libraries was not what he expected for this generation. It was nice to hear them take an interest in things outside of school.

The train reached Weill Cornell Hospital at 5:00. The hip replacement surgery was completed at 8:00.

Alex spent the rest of the day with his grandma in the hospital and went back to Philadelphia afterwards.

DOC 3 – see slides for Lesson Plan 1: DNA Mutation

DOC 4 – see slides for Lesson Plan 2: CRISPR

DOC 5A: CRISPR Story Activity

Students play a game similar to the one played previously. However, this time, they can make specific changes with an end goal in sight. Additionally, this game can be further complicated based on the age range of the students by adding good actors - students who are CRISPR agents and students who are Cancer agents (hurting the overall story). More details can be found in **DOC 2A - Story Rules**, along with a prompt to generate stories.

To Start:

- 1) Write or post all rules (see below) in a central area (whiteboard, smartboard, etc.)
- 2) Split students into teams of 4 to 5
- 3) Randomly assign 1 - 2 students as Cancer students and the others as CRISPR students
- 4) Give each student their designated rules (just the number) from the rule list (see below)
 - a) Do not give the genetic equivalents to the students
- 5) Hand out the generated story (two examples can be seen in **DOC 5B 'Example 1: TEAM Student Handout for Story 2'** or **DOC 5C 'Example 2: TEAM Student Handout for Story 2'**) to each team. Only hand one paper copy to each team. If an electronic device with access to Word or Google Doc is available, use that instead and ensure that each student is assigned a specific color when making edits.
- 6) Explain the rules of the activity without reference to biology.
 - a) Decide on the first individual to start making changes.
 - b) During a student's turn they can either choose to make a change or leave the text alone.

- c) Students can make a change that follows one of the rules that they were given
 - d) In their turn, the student can only make one change.
 - e) Cancer students are trying to make the story worse whereas CRISPR students are trying to make the story better
- 7) Allow students to conduct the activity for 10 - 20 minutes. Set a specific time limit that all students are aware of.
 - 8) At the end of the allotted time, each team quickly presents what happened and what their thought process was when making changes.

Rules

Cancer Students (Objective: Keep or make the story worse)

Uncontrolled Growth Rule:

- Story: Add repetitive and unnecessary details to the story to make it confusing.
- Example: "Alex was sad. Alex was very sad. Alex was extremely sad."
- Biological Equivalent: Uncontrolled Cell Growth - Cancer cells grow and divide uncontrollably, leading to tumor formation.

Metastasis Rule:

- Story: Introduce a negative event or detail from one part of the story to another unrelated part.
- Example: "Alex lost his toy. Later, during dinner, his food tasted like the sadness of the lost toy."
- Biological Equivalent: Metastasis - Cancer cells spread from their original site to other parts of the body.

Avoid Repair Rule:

- Story: Introduce a problem in the story and avoid resolving it.
- Example: "Alex's bike broke, and he never tried to fix it."
- Biological Equivalent: DNA Repair Avoidance - Cancer cells often avoid the body's natural DNA repair mechanisms.

CRISPR Students (Objective: Improve or correct the story)

Targeted Editing Rule:

- Story: Identify a specific negative detail and replace it with a positive one.
- Example: Change "Alex was sad because he lost his toy" to "Alex was happy because he found his toy."
- Biological Equivalent: Specific Gene Targeting - CRISPR is used to target specific genes for editing.

Insertion Rule:

- Story: Add a positive event or detail to improve the story's outcome.
- Example: "Alex was feeling down, but then he received a surprise gift from his friend."
- Biological Equivalent: Gene Insertion - CRISPR can be used to insert beneficial genes into DNA.

Deletion Rule:

- Story: Remove a negative event or detail to enhance the story.
- Example: Remove "Alex's bike broke" from the story.
- Biological Equivalent: Gene Deletion - CRISPR can be used to remove harmful or unwanted genes from DNA.

Correction Rule:

- Story: Identify a mistake or inconsistency in the story and correct it.
- Example: Change "Alex was sad because he lost his toy, but he was holding it" to "Alex was happy because he found his toy and was holding it."
- Biological Equivalent: Gene Correction - CRISPR can be used to correct mutations or errors in DNA.

DOC 5B: Student Handout for Story (Example 1)

Note: This story was generated using ChatGPT

On a sunny afternoon, Emily decided to take her bike out for a ride around the neighborhood. The wind was gentle, and the birds were singing their melodious tunes. But as she pedaled faster, trying to feel the breeze against her face, disaster struck. A stray cat darted out from a bush, causing Emily to swerve abruptly. She lost her balance and tumbled off her bike, landing hard on the pavement.

The pain was immediate. Emily tried to stand up, but a sharp sting in her ankle made her wince. She looked down and saw that her ankle was swelling. Tears welled up in her eyes, not just from the pain, but from the realization that she might have sprained her ankle. The bike lay a few feet away, its front wheel still spinning.

A neighbor, Mrs. Thompson, who had been watering her plants, rushed over. "Oh dear, are you alright?" she asked, concern evident in her voice.

Emily tried to put on a brave face. "I think I sprained my ankle," she replied, trying to hold back her tears.

Mrs. Thompson quickly fetched a cold pack from her house and wrapped it around Emily's ankle. "This should help with the swelling," she said. "But you should see a doctor."

Emily nodded, feeling a mix of gratitude and embarrassment. She had been so excited about her bike ride, and now she was sitting on the sidewalk, nursing a sprained ankle.

As the minutes ticked by, a few more neighbors gathered around, offering words of comfort and advice. Some suggested home remedies, while others shared their own tales of biking mishaps. Emily listened, feeling a bit overwhelmed.

Finally, her best friend, Sarah, arrived. She had seen the commotion from her window and had come running. "Oh, Emily," she exclaimed, "what happened?"

Emily recounted the unfortunate series of events, and Sarah listened sympathetically. "Don't worry," she said, "we'll get you back on your feet in no time."

With Sarah's help, Emily managed to stand up and hobble back to her house. The pain was still there, but with each step, she felt a bit stronger. She knew that with the support of her friends and family, she would recover and be back on her bike soon.

DOC 5C: Student Handout for Story (Example 2)

Note: This story was generated using ChatGPT

SEGMENT 1: It was a short trip to New York City, and Alex had to visit his grandma in the hospital. He was not feeling great about the trip but was hopeful to hear what the surgeon had to say.

“The surgery should be quick. It’s common to get a hip fracture at her age. The surgery should be completed and your grandma discharged within 24 hours,” the surgeon said. And so, he took the first train out from Philadelphia.

SEGMENT 2: The train conductor began to come around to collect tickets. Alex had put his ticket on his phone. Some of the train conductors were old-fashioned and preferred hard copies. This conductor was upset that Alex did not have a hard copy, stating that the screenshot could serve as anyone’s ticket. Alex was forced to get off the train and scan his ticket at the booth for a hard copy. Unfortunately, this delay caused his first train to be missed, and he had to wait 3 hours for the next one.

SEGMENT 3: As the final boarding call began, Alex overheard something strange from a group of students boarded with their teacher.

“I can’t wait to see the White House!”

“I’m excited for the Lincoln Memorial! And the cherry blossoms are supposed to be at their peak!”

That was weird. Those kids must be taking some sort of group trip, maybe starting in New York and heading to D.C. after.

The train announcer came on.

“Train is leaving in two minutes for Washington, D.C., please have your tickets ready.”

This train was heading to D.C.!

SEGMENT 4: The train ride went poorly, with quite a few stops along the way. Alex managed to reach two hours behind schedule, and he was worried.

The surgery was delayed.

SEGMENT 5: After two days in the hospital, Alex’s grandma suffered a great deal of pain. The infection spread throughout the hip and Alex’s grandmother had to use a wheelchair for the rest of her life.

TEACHER COPY (potential changes that could be done to improve or worsen the story are highlighted and in brackets)

Option 1/2: It was a short trip to New York City, Alex had to visit his grandma in the hospital. He was [not feeling great about the trip] but was hopeful to hear what the surgeon had to say.

“The surgery should be [quick]. It’s common to get a hip fracture at her age. The surgery should be completed and your grandma discharged [within 24 hours,]” the surgeon said.

And so, he took the [first] train out from Philadelphia.

Option 1: The train conductor began to come around to collect tickets. Alex had put his ticket on his phone and carried a hard copy. Some of the train conductors were old-fashioned and preferred hard copies. This conductor punched the hard copy and went about his day.

Option 2: [The train conductor began to come around to collect tickets. Alex had put his ticket on his phone. Some of the train conductors were old-fashioned and preferred hard copies. This conductor was upset that Alex did not have a hard copy, stating that the screenshot could serve as anyone’s ticket. Alex was forced to get off the train and scan his ticket at the booth for a hard copy. Unfortunately, this delay caused his first train to be missed, and he had to wait 3 hours for the next one.]

Option 1: As the final boarding call began, Alex overheard something strange from a group of students boarded with their teacher.

“I can’t wait to see the MET!”

“I’m excited to see the public library! It’s got such a cool interior.”

Seeing kids excited about museums and libraries was not what he expected for this generation. It was nice to hear them take an interest in things outside of school.

Option 2: [As the final boarding call began, Alex overheard something strange from a group of students boarded with their teacher.]

[“I can’t wait to see the White House!”]

[“I’m excited for the Lincoln Memorial! And the cherry blossoms are supposed to be at their peak!”]

[That was weird. Those kids must be taking some sort of group trip, maybe starting in New York and heading to D.C. after.]

[The train announcer came on.]

["Train is leaving in two minutes for Washington, D.C., please have your tickets ready."]

[This train was heading to D.C.!]

Option 1: *Thankfully, there was still ten minutes to exit the station. Alex quickly got up and ran to the correct station. *

The train went smoothly, without stops. He managed to reach Weill Cornell Hospital at the perfect time.

Option 2: [The train ride went poorly, with quite a few stops along the way. Alex managed to reach two hours behind schedule and he was worried.]

[The surgery was delayed.]

Option 1: The surgery went smoothly.

All was well in the end, and he got to spend an extra day with his grandma. The surgery managed to go super smoothly, and his grandma was walking within two days!

Option 2: [After two days in the hospital, Alex's grandma suffered a great deal of pain. The infection spread throughout the hip and Alex's grandmother had to use a wheelchair for the rest of her life.]

Positive Ending to Option 2 (to demonstrate CRISPR at work): [Alex's grandmother was taken to another doctor after a month of the infection clearing. The doctor provided options for prosthetics.]

DOC 6: Quiz Activity

DNA Mutation & CRISPR Quiz - Kahoot Link - <https://create.kahoot.it/details/83177af2-97d4-459b-8c74-1d8881d49621>

Sixth Grade Questions

- 1) What is a mutation?
 - a) A type of superhero power
 - b) A change to the genetic code
 - c) A type of medicine
 - d) A type of cell
- 2) Which type of mutation involves the switching of adenine and guanine or cytosine and thymine?
 - a) Deletion
 - b) Insertion
 - c) Substitution
 - d) Translocation
- 3) What happens during a "frameshift" mutation?
 - a) Only one amino acid is affected.
 - b) The entire DNA sequence is deleted.
 - c) Every codon after the mutation is altered.
 - d) The DNA sequence remains unchanged.
- 4) Which mutation involves the complete reversal of one or more genes within a chromosome?
 - a) Duplication
 - b) Inversion
 - c) Large-scale insertion
 - d) Translocation
- 5) What can be a result of mutations?
 - a) All cells become unviable.
 - b) No change in the cell.
 - c) Creation of a new organism.
 - d) Immediate evolution of the species.
- 6) Which environmental factor can induce DNA mutations and may lead to cancer?

- a) Drinking water
 - b) Listening to music
 - c) Exposure to certain chemicals
 - d) Reading books
- 7) Ultraviolet radiation from the sun can lead to which type of cancer?
- a) Lung cancer
 - b) Skin cancer
 - c) Brain cancer
 - d) Bone cancer
- 8) Which of the following is NOT a type of small-scale mutation?
- 1) Duplication
 - 2) Deletion
 - 3) Insertion
 - 4) Substitution
- 9) What is the main cause of evolution?
- a) Fast cell growth
 - b) Mutations over time
 - c) Exposure to loud noises
 - d) Eating certain foods
- 10) Which of the following best describes CRISPR?
- a) A type of virus
 - b) A method for editing genes
 - c) A type of bacteria
 - d) A mutation caused by radiation
- 11) Why is CRISPR considered revolutionary in the field of genetics?
- a) It can make people taller.
 - b) It allows precise editing of DNA.
 - c) It is a new type of plant.
 - d) It helps in faster cell division.
- 12) What is the potential application of CRISPR in relation to mutations?
- a) Increasing mutation rates
 - b) Creating new species
 - c) Correcting harmful mutations
 - d) Studying ancient DNA
- 13) How does exposure to certain chemicals influence DNA?

- a) They speed up DNA replication.
 - b) They can lead to mutations.
 - c) They make DNA glow in the dark.
 - d) They strengthen the DNA structure.
- 14) What does CRISPR stand for?
- a) Creative Replication In Simple Protein Reactions
 - b) Clustered Regularly Interspaced Short Palindromic Repeats
 - c) Cellular Response In Specialized Protein Reactions
 - d) Coded Repetition In Single Protein Replication
- 15) How might CRISPR be used in the future?
- a. To create superhuman abilities
 - b. To increase the lifespan of fruits
 - c. To correct genetic diseases before birth
 - d. To change the color of the sky

Seventh and Eighth Grade Questions

- 1) Which molecule is often referred to as the "blueprint of life"?
- e. RNA
 - f. ATP
 - g. DNA
 - h. Protein
- 2) In the structure of DNA, which base pairs with Adenine (A)?
- a. Guanine (G)
 - b. Cytosine (C)
 - c. Thymine (T)
 - d. Uracil (U)
- 3) What is the primary function of CRISPR in bacteria from which it was discovered?
- a. Energy production
 - b. Movement
 - c. Defense against viruses
 - d. Reproduction
- 4) Which type of mutation involves a change in a single nucleotide base pair in DNA?
- a. Point mutation
 - b. Deletion mutation
 - c. Inversion mutation

- d. Translocation mutation
- 5) How does CRISPR-Cas9 work?
- a. It enhances the mutation rate.
 - b. It acts as a molecular scissor to cut DNA.
 - c. It glues DNA fragments together.
 - d. It replicates DNA.
- 6) Which of the following can be a potential consequence of a harmful mutation in a gene?
- a. Enhanced strength
 - b. Glowing skin
 - c. Genetic disorders or diseases
 - d. Ability to fly
- 7) What role does the Cas9 protein play in the CRISPR system?
- a. It identifies the target DNA sequence.
 - b. It acts as a guide RNA.
 - c. It cuts the DNA at the target site.
 - d. It repairs the DNA after cutting.
- 8) Which environmental factor is known to cause mutations in DNA?
- a. Loud noises
 - b. Ultraviolet (UV) radiation
 - c. Cold temperatures
 - d. Oxygen
- 9) If a mutation occurs in a non-coding region of DNA, what is the likely outcome?
- a. It will always cause a disease.
 - b. It will change the color of the organism.
 - c. It might have no effect on the organism.
 - d. It will increase the lifespan of the organism.
- 10) Why is CRISPR technology considered a game-changer in genetic engineering?
- a. It allows for random mutations.
 - b. It enables precise and targeted modifications to DNA.
 - c. It can only be used in plants.
 - d. It makes organisms glow in the dark.
- 11) Which component of DNA provides the instructions for building proteins?
- a. Sugars
 - b. Phosphates

- c. Nucleotide bases
 - d. Hydrogen bonds
- 12) What is the main difference between DNA and RNA?
- a. DNA is double-stranded while RNA is single-stranded.
 - b. DNA contains sugars, while RNA does not.
 - c. RNA can replicate, but DNA cannot.
 - d. DNA is found in the cytoplasm, while RNA is in the nucleus.
- 13) Which of the following best describes the role of RNA in protein synthesis?
- a. It provides the energy for the process.
 - b. It acts as the blueprint for protein structure.
 - c. It carries the genetic information from DNA to the ribosome.
 - d. It repairs any mutations in the DNA.
- 14) If a segment of DNA has a sequence AATCGG, what would be the complementary RNA sequence?
- a. TTAGCC
 - b. UUAGCC
 - c. AATCGG
 - d. TTUCGG
- 15) What is the potential risk associated with using CRISPR technology in humans?
- a. It can lead to unintended genetic changes.
 - b. It can make humans photosynthetic.
 - c. It can cause an increase in height.
 - d. It can change eye color temporarily.
- 16) Which of the following mutations would likely have the most significant impact on a protein's function?
- a. A substitution at the last base of a gene.
 - b. A deletion causing a frameshift at the beginning of a gene.
 - c. A substitution in a non-coding region.
 - d. An insertion at the end of a gene.
- 17) Why are "guide RNAs" important in the CRISPR system?
- a. They provide energy for the process.
 - b. They determine where the Cas9 protein will cut the DNA.
 - c. They repair the DNA after it's cut.
 - d. They replicate the DNA segment.
- 18) Which of the following is NOT a potential application of CRISPR technology?

- a. Correcting genetic disorders in embryos.
 - b. Creating glow-in-the-dark plants.
 - c. Changing an adult's height.
 - d. Engineering crops to be more drought resistant.
- 19) What happens to a protein if a mutation occurs in the gene coding for it?
- a. The protein always degrades immediately.
 - b. The protein's function may change, or it may become nonfunctional.
 - c. The protein becomes more active.
 - d. The protein's size increases.
- 20) Which of the following best describes a gene?
- a. A type of protein.
 - b. An entire chromosome.
 - c. A segment of DNA that codes for a specific protein.
 - d. A cell's energy source.
- 21) Which of the following best describes the potential of CRISPR technology in medical science?
- a. To increase muscle mass in athletes
 - b. To correct genetic mutations linked to diseases
 - c. To enhance memory and intelligence
 - d. To change physical appearance, like eye color
- 22) How does a silent mutation differ from other mutations?
- a. It results in a change in the protein's function.
 - b. It causes a visible change in the organism.
 - c. It does not change the amino acid sequence of the protein.
 - d. It always leads to a disease.

Open Ended Questions

What is DNA and why is it important for living organisms?

Describe in your own words how DNA acts like a blueprint for living things.

Imagine you find a mysterious strand of DNA. How might scientists determine which organism it belongs to?

What do you think might happen if there was a mistake or "typo" in the DNA sequence of an organism? How do you think mutations might play a role in the variety of species we see in nature?

If you could use CRISPR technology to make one change to a plant's DNA, what would you change and why?

Why do you think some mutations might be beneficial while others can be harmful? How do you think scientists discovered the structure and function of DNA?

CRISPR is often described as "genetic scissors." What do you think this means, and how might it be used to help people?

If you had the power to edit any organism's DNA using CRISPR, what ethical considerations do you think you'd need to keep in mind?

DOC 7: Homework Assignment Questions and Rubrics

Homework Questions (choose 1 for each student)

Imagine you are a scientist tasked with using CRISPR technology to solve a specific problem in agriculture: creating a tomato plant that can resist a common pest, the tomato hornworm.

1. Briefly describe what CRISPR is and how it might be used to address this problem.
2. Before you start editing the tomato plant's DNA, it's essential to define constraints to ensure the safety, effectiveness, and ethical considerations of your solution. List and explain at least five constraints you would set for this project. Consider factors like potential harm to the environment, the tomato plant's health, ethical concerns, and any unintended consequences.

Imagine you are part of a team of scientists aiming to use CRISPR technology to develop a type of rice that can grow in areas with very little water, helping address food shortages in arid regions.

1. Explain in your own words how CRISPR could potentially help achieve this goal.
2. Before making any changes to the rice plant's DNA, it's crucial to consider the broader implications of your actions. List and explain at least five constraints or considerations you would take into account for this project. Think about the ecosystem, the nutritional value of the modified rice, potential effects on local economies, and any other ethical or practical concerns.

Suppose you've been given the opportunity to work on a project using CRISPR to modify mosquitoes so they no longer transmit malaria, a disease that affects millions worldwide.

1. Describe how CRISPR might be utilized to prevent mosquitoes from transmitting malaria.
2. Before proceeding with the genetic modifications, it's essential to understand the potential challenges and limitations. Identify and explain at least five constraints or considerations for this project. Consider the impact on the mosquito population, potential effects on the ecosystem, the reaction of local communities, and any unforeseen consequences of altering a species' DNA.

Rubrics for Each Question

1. Description of CRISPR and its application (Total: 10 points)

Provides a clear and accurate description of CRISPR: 5 points

Explains how CRISPR might be used to address the tomato hornworm problem: 5 points

2. Constraints for the project (Total: 10 points)

Lists at least five constraints: 5 points (1 point for each constraint)

Provides a clear explanation for each constraint: 5 points (1 point for each explanation)

Total Possible Points: 20

DOC 8: External Resources for Teachers and Students

CRISPR-Cas Educational Website by Broad Institute: Provides an interactive introduction to CRISPR-Cas9 technology, its history, applications, and ethical considerations. [Link](#)

Learn Genetics - University of Utah: Offers a kid-friendly introduction to genetics and CRISPR through animations, videos, and interactive activities. [Link](#)

NOVA: CRISPR - Gene Editing and Beyond: NOVA's webpage on CRISPR includes videos, articles, and educational materials suitable for both teachers and students. [Link](#)

National Human Genome Research Institute (NHGRI): Provides a range of resources, including videos and fact sheets, to explain CRISPR and its impact on genetics and medicine. [Link](#)

Kurzgesagt – In a Nutshell: CRISPR-Cas9 Explained: A concise and engaging animated video explaining the basics of CRISPR technology. [Link](#)

TED-Ed: How CRISPR lets you edit DNA: A TED-Ed lesson on CRISPR's applications and implications, suitable for younger audiences. [Link](#)

Genome Editing with CRISPR-Cas9 - McGovern Institute: A comprehensive animation that breaks down the CRISPR-Cas9 process and its impact on genetics. [Link](#)

Bozeman Science - What is CRISPR?: A video that explains the basics of CRISPR-Cas9 gene editing, detailing how it works and its potential applications in modifying DNA. [Link](#)

DEFINITIONS – see document containing list of definitions

DOC 9: Feedback from Teachers/Testimonials

Testimonials Received from Teacher at:

Summerour Middle School, Norcross, Georgia,
Gwinnett County Del Valle High School, Del Valle,
Texas, Travis County

Random Mutation Story

"Activating the lesson with a relatable story will enhance student's interest in the lesson."

"This could lead to some fun stories especially if the rules aren't too constricting. It's essential that it's fun, otherwise it will be unrelatable."

CRISPR Story Activity

"Middle schoolers enjoy role -playing, which can significantly boost their engagement with the lesson."

Materials List

Block 1: Random Mutation Story and Detailed Lesson on DNA Mutation

Random Mutation Story Activity:

- Fictional story of a family experiencing genetic mutations (for reference).
- Paper and writing utensils for students to modify the story.
- DOC 2A Random Mutation Story Activity (Document detailing the activity). Detailed Lesson on DNA Mutation:
 - Presentation materials (e.g., projector, slides).
 - DOC 3: DNA Mutation Lesson (Document with lesson plan and supplemental media).

Block 2: CRISPR Story and Evaluation Activity

Introduction to CRISPR:

- Presentation materials (e.g., projector, slides).
- DOC 4: CRISPR Lesson (Document detailing the lesson). CRISPR Story Activity:
 - Game materials for the CRISPR activity.
 - Role cards with rules for students (e.g., CRISPR agents, Cancer agents).
 - DOC 5A: CRISPR Story Activity (Document detailing the activity). Individual Quiz & Group Kahoot:
 - Quiz sheets or digital devices for the individual quiz.
 - Devices with internet access for the Kahoot game.
 - DOC 6A Individual Quiz Bank & Kahoot Activity (Document with quiz questions and Kahoot link).

Homework Assignment:

- DOC 7 Homework Assignment (Document with potential topics for research paper).

Miscellaneous Resources

- DOC 8 External Resources for Teachers & Students (Document with additional resources).