Lesson Plan: Gene Editing using CRISPR

Teacher-contributed lesson plan by Dr Sneha Bhogale, Pune, India.

As a **high school or undergraduate Biological Sciences** teacher, you can use this set of computer-based tools to teach about **CRISPR**: **C**lustered **R**egularly **I**nterspaced **S**hort **P**alindromic **R**epeats, a new **gene editing** technology that could enable certain species to adapt to the impacts of climate change.

This lesson plan includes resources that teach about gene editing using the **CRISPR-Cas 9 pathway** in bacteria. This pathway is a part of the adaptive immunity against phage infection in bacteria. It can be engineered to be used as a gene editing tool in living organisms. This lesson plan includes case studies that show how CRISPR gene editing technology can be used as a **climate adaptation strategy**.

Thus, the use of this lesson plan allows you to integrate the teaching of a climate science topic with a core topic in **Biological Sciences**.

Use this lesson plan to help your students find answers to:

- What is the function of CRISPR in bacteria? Describe the main components of the CRISPR-Cas9 system.
- Describe the two main DNA repair mechanisms in a cell.
- Explain how the CRISPR gene editing technique exploits the cell's DNA repair system to introduce targeted mutations.
- How can CRISPR gene editing help plant breeding programs to adapt to the effects of climate change? Elaborate using a suitable example.
- Discuss the use of CRISPR technology as a climate adaptation strategy to conserve coral reefs.

About the Lesson Plan

Grade Level: High School, Undergraduate

Discipline: Biological Sciences

Topic(s) in Discipline: Gene Editing, CRISPR, CRISPR-Cas9 Pathway, DNA Repair Mechanisms, Double Stranded Breaks (DSBs), Non-Homologous End Joining (NHEJ), Homologous Recombination (HR), Targeted Mutations, Nucleases

Climate Topic: Climate and the Biosphere, Climate Mitigation and Adaptation

Location: Global

Access: Online

Language(s): English

Approximate Time Required: 45-60 min

1 Contents

The reading can be accessed at:

https://med.stanford.edu/news/all-news/2018/04/crispr-used-to-genetically-edit-coral.html

4. Suggested questions/assignments for learning evaluation

- What is the function of CRISPR in bacteria? Describe the main components of the CRISPR-Cas9 system.
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2 Step-by-step User Guide

Here is a step-by-step guide to using this lesson plan in the classroom/laboratory. We have suggested these steps as a possible plan of action. You may customize the lesson plan according to your preferences and requirements.

1. Topic introduction and discussion

Begin with introducing what gene editing is and explain how it is different from genetic engineering- Gene editing, is a process in which DNA is inserted, deleted, modified or replaced at a specific site in the genome of a living organism. Genetic engineering, on the other hand randomly inserts or deletes genetic material to introduce mutations. In gene editing, nucleases/ molecular scissors are used which introduce a double stranded break (DSB) in the DNA at specific locations after which DNA repair mechanisms of the cell take over resulting in targeted mutations

(edits). Then, briefly discuss the commonly used nucleases- meganucleases, Zinc Finger Nucleases (ZFNs), transcription activator-like effector-based nucleases (TALENS) and CRISPR- that are used for gene editing. Emphasize that this lesson plan will focus on the CRISPR-Cas9 system of gene editing, as it is reported in recent times to be more efficient and effective than the others.

Use this animated video, 'Genome Editing with CRISPR-Cas9', narrated by Feng Zhang, McGovern Institute of Brain Research, MIT, to introduce the topic of gene editing using CRISPR-Cas9 system and to briefly describe the structural components of the CRISPR-Cas9 pathway.

This can be accessed at:

https://www.youtube.com/watch?v=2pp17E4E-O8

2. Extend understanding of the CRISPR-Cas9 pathway and CRISPR gene editing using an interactive visualization

Use the interactive visualization, 'CRISPR-Cas9 Mechanism & Application' by Howard Hughes Medical Institute (HHMI) BioInteractive, to enable your students to visualize how the CRISPR-Cas9 technology works at the molecular level and to explore its different components. Start by launching the 'interactive' component of the visualization tool. Navigate through the visualization to sequentially describe the gene-editing events of targeting and binding of the CRISPR-Cas9 complex to the target DNA, cleaving or breaking of the DNA at the target location and repairing of the DNA to introduce the desired mutation. Use the 'explore' button at every step to describe the different molecular components involved in the pathway.

Use the tab, 'How it's used' to view 20 short videos that explain how CRISPR gene editing technology can be used to achieve different results in its applications in science and industry.

This can be accessed at:

https://www.biointeractive.org/classroom-resources/crispr-cas-9-mechanism-applications

3. Discuss two case studies where CRISPR gene editing has been used as a climate adaptation strategy

Use the video, 'Gene editing yields tomatoes that flower and ripen weeks earlier' by Zachary Lippman, Cold Spring Harbor Laboratory (CSHL), to describe his use of CRISPR gene editing in two varieties of tomato plants to make them flower and ripen earlier than usual. Use the video to

explain how this approach is useful to obtain faster and higher yields of the tomato crop. Discuss, using the video how this will also enable plants to be grown in higher latitudes, thereby offsetting crop loss, if any, due to global warming. To enable better understanding of Dr Lippman's work, direct your students to listen to a CSHL Base Pairs podcast, link to which is available in the additional resources section of this lesson plan.

The video can be accessed at:

https://www.youtube.com/watch?v=Jem3hP734uA

Use the reading, 'CRISPR used to genetically edit coral' by Hanae Armitage, Office of Communication, Stanford Medicine, to explain the proof-of-principle study published in PNAS by Phillip Cleves et al. (2018). Use this brief communication to explain how this work could allow researchers to use the CRISPR-Cas9 gene editing tool to identify and knock-out the coral genes responsible for coral bleaching due to ocean acidification. Discuss how this technique can thus be useful for coral conservation by building climate-resilient corals.

The reading can be accessed at:

https://med.stanford.edu/news/all-news/2018/04/crispr-used-to-genetically-edit-coral.html

4. Questions/Assignments

Use the tools and the concepts learned so far to discuss and determine answers to the following questions:

- What is the function of CRISPR in bacteria? Describe the main components of the CRISPR-Cas9 system.
- Describe the two main DNA repair mechanisms in a cell.
- Explain how the CRISPR gene editing technique exploits the cell's DNA repair system to introduce targeted mutations.
- How can CRISPR gene editing help plant breeding programs to adapt to the effects of climate change? Elaborate using a suitable example.
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3 Learning Outcomes

The tools in this lesson plan will enable students to:

- describe the CRISPR-Cas9 pathway of adaptive immunity in bacteria
- learn about DNA repair mechanisms in cells
- understand CRISPR gene editing technique to achieve targeted mutations in cells
- use of CRISPR gene editing in living organisms as a climate adaptation strategy

4 Additional Resources

If you or your students would like to explore the topic further, these additional resources will be useful.

1. Video micro-lecture; 'What is CRISPR?'

A video micro-lecture by Paul Andersen, Bozeman Science, that 'explains how the CRISPR/Cas immune system was identified in bacteria and how the CRISPR/Cas9 system was developed to edit genomes'.

This can be accessed at:

https://www.youtube.com/watch?v=MnYppmstxIs

2. Video; 'Biologist Explains One Concept in 5 Levels of Difficulty- CRISPR'

A video interview of several people by Biologist Neville Sanjana, New York University & The New York Genome Center on WIRED, to explain the significance of CRISPR technology as a gene editing tool in biomedical science.

This can be accessed at:

https://www.youtube.com/watch?v=sweN8d4_MUg

3. Reading and Embedded Podcast; 'CRISPR vs. climate change'

A news story by Andrea Alfano, Cold Spring Harbor Laboratory (CSHL), that talks about the application of CRISPR in agriculture. The embedded CSHL Base Pairs podcast,'10-CRISPR vs Climate Change' is an interview with previously referenced (Tool # 3) Professor Lippman 'about the threats climate change poses to agriculture and how CRISPR could help overcome them'.

This can be accessed at:

https://www.cshl.edu/crispr-vs-climate-change/

4. Reading; 'Why Gene Editing Is the Next Food Revolution'

An article by Eric Niiler, National Geographic, that describes why the use of CRISPR gene editing could be the next big step towards developing more nutritious, higher yielding, climate-resilient crops.

This can be accessed at:

https://www.nationalgeographic.com/environment/future-of-food/food-technology-gene-editing/

5. Reading; '10 ways CRISPR will revolutionize environmental science'

An article by Jenna Gallegos, Alliance for Science, Cornell University, that describes ways in which CRISPR could be used to mitigate and adapt to anthropogenically induced environmental changes.

This can be accessed at:

https://allianceforscience.cornell.edu/blog/2018/07/10-ways-crispr-will-revolutionize-environmental-science/

5 Credits/Copyrights

All the teaching tools in our collated list are owned by the corresponding creators/authors/organizations as listed on their websites. Please view the individual copyright and ownership details for each tool by following the individual links provided.
We have selected and analyzed the tools that align with the overall objective of our project and have provided the corresponding links. We do not claim ownership of or responsibility/liability for any of the listed tools.

1. Video; 'Genome Editing with CRISPR-Cas9'

Narrated by Feng Zhang, McGovern Institute of Brain Research, MIT.

2. Visualization; 'CRISPR-Cas9 Mechanism & Application'

By Howard Hughes Medical Institute (HHMI) BioInteractive.

3. Video; ‘Gene editing yields tomatoes that flower and ripen weeks earlier’

By Zachary Lippman, Cold Spring Harbor Laboratory (CSHL).

4. Reading; ‘CRISPR used to genetically edit coral’

By Hanae Armitage, Office of Communications, Stanford Medicine.

5. Additional Resources

Paul Andersen, Bozeman Science

Neville Sanjana, New York University and The New York Genome Center for WIRED

Andrea Alfano, Cold Spring Harbor Laboratory (CSHL)

Eric Niiler, National Geographic

Jenna Gallegos, Alliance for Science, Cornell University