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Exploring CRISPR-Cas9 in the High School Classroom Using Literature, Modeling, Lab Investigations, Projects, and Ethical Analysis

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ABE Master Teacher Fellowship Program

AMGEN Biotech Experience

Scientific Discovery for the Classroom

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Scientific Discovery for the Classroom

The projects designed by the 2024–25 ABE Master Teacher Fellows are a compilation of curricula and materials that are aligned with the Amgen Biotech Experience (ABE) and further support teachers and students in their biotechnology education. These projects were created over the course of a 1-year Fellowship in an area of each Fellow's own interest. Each is unique and can be adapted to fit the needs of your individual classroom. Objectives and goals are provided, along with expected outcomes. Projects can be used in conjunction with your current ABE curriculum or as an extension.

As a condition of the Fellowship, these classroom resources may be downloaded and used by other teachers for free. The projects are generally not edited or revised by the ABE Program Office for content, clarity, or language except to ensure safety protocols have been clearly included where appropriate.

We are grateful to the ABE Master Teacher Fellows for sharing their work with the ABE community. If you have questions about any of the project components, please reach out to us at ABEInfo@edc.org, and we will be happy to connect you with the author and provide any assistance needed.

AMGEN Biotech Experience

Scientific Discovery for the Classroom

Massachusetts

Exploring CRISPR-Cas9 in the High School Classroom Using Literature, Modeling, Lab Investigations, Projects, and Ethical Analysis

Objectives of Research: To create a comprehensive unit plan with lessons on CRISPR-Cas9 that engages students through dynamic content, procedural study, and epistemic assessment.

Introduction: CRISPR-Cas9 is a process discovered in bacterial cells that resulted in awarding the Nobel Prize to Jennifer Doudna and Emmanuelle Charpentier in 2020 for their 2012 *Science* paper. CRISPR stands for Clustered Regularly Interspaced Short Palindromic Repeats and is a natural prokaryotic defense mechanism used to protect the bacterial genomes from viral pathogens. CRISPR requires an associated Cas nuclease protein, a guide RNA, small nucleotide sequence of double stranded DNA from a pathogen, and a Protospacer Adjacent Motif (PAM).

The PAM sequence is a three-nucleotide DNA sequence that assists the Cas9 enzyme in identifying and binding to the correct target DNA site. CRISPR was found to provide adaptive immunity to bacterial cells. This natural process has developed into a scientific research technique over the past 10 years that has many implications for society. CRISPR has become part of the scientific lexicon in a short timeframe. As such, it is important that students understand this novel and widely applied technique. Using this module, CRISPR can be explored in the high school science classroom with a variety of content, procedural study, and epistemic assessments.

This CRISPR Unit contains nine lessons that include an introduction, paper modeling activities, visually appealing and content rich videos, curated LabXchange pathway, lab investigations and activities, ethical analysis with position paper, a mini-review paper, Amgen career exploration, and a final evaluation. This unit contains lessons for varying levels of high school students: AP Biology, biotechnology, and freshmen biology. This multimodal CRISPR unit addresses various student learning styles, levels, and languages. This can be achieved by using the lessons' images, paper modeling, text sets, simulations, lab investigations, ethical analysis, and research articles.

This project contains various resources that will enable educators to customize the lessons for the learners in their classrooms. It strongly utilizes scientific literacy, in both the reading and writing opportunities. Upon unit completion, a student survey will be administered to collect data and determine the effectiveness of the implemented CRISPR lessons.

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Student Learning Objectives

- Summarize the principle of CRISPR-Cas9
- Outline the basic steps of experimental CRISPR-Cas9; compare and contrast with genetic transformation
- Explore the current and future applications of CRISPR-Cas9
- Explore CRISPR using bioinformatics
- Evaluate CRISPR-Cas9 Case Studies: Identify the risks and benefits
- Determine and evaluate opinions concerning CRISPR use for genetic modification
- Explore career paths

Unit Lessons

1. Introduction
2. Modeling
3. Videos
4. LabXchange Pathway: Interactives, videos, simulations, and case study; discussion of findings
5. Lab Investigations & Activities
6. Ethics
7. Review Paper
8. Amgen Career Exploration
9. Final Evaluation

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Introduction Lesson

The purpose of this lesson is to determine students' prior knowledge about CRISPR.

1. Provide scrap paper to student groups and write "CRISPR" on the whiteboard.
2. Ask students to think about CRISPR, discuss it with their lab group, and write all their thoughts down on the paper provided. To guide them, have them list what they know, think they know, and what they want to learn or do with CRISPR.
3. Have a full-class discussion with what students have written.
4. Collect the papers and redistribute them at the end of the unit for students to incorporate into their final reflection.

This activity will help determine the initial knowledge base to inform the teaching practice for this unit and assist with final reflection activity.

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CRISPR LabXchange Pathway 2025

Note: LabXchange lessons have been translated into many languages and thus can be accessed by all students.

Introduction Class with Discussion:

1. Gene Editing with CRISPR Image-Evaluate (Image). View and list the three key parts of the CRISPR Cas9 system.
2. CRISPR-Cas 9 Molecular Recording (Video). View and list five Thoughts, Questions, or Epiphanies (TQEs).
3. Genome Editing and CRISPR (PgED Video). View, list answers to questions and three TQEs.

Individual Pathway: Complete the pathway by performing each of the 11 lessons. Create one document that contains all your answers and post on Canvas when finished.

1. What is CRISPR Cas9? (Text). Read the text. List five things you learned from this text.
2. CRISPR Whiteboard lesson (Video). CRISPR-Based Diagnostic Tools: View, list, and describe the other Cas proteins.
3. CRISPR as Bacterial Defense System (Interactive). Perform interactive. List and explain three things about CRISPR, RNAs, and Cas9 proteins.
4. Mechanism CRISPR Cas9 Cleaves DNA (Interactive). Perform the interactive and list three things you learned.
5. CRISPR Cas9 Mechanism and Applications (Interactive). Perform the interactive and list three things you learned.
6. CRISPRa and CRISPRi (Image). Observe the image. What is Ca and Ci? Compare and contrast the two.
7. CRISPR: DNA's Text Editor (Video). Watch the whole video. List two things you learned.
8. CRISPR Cas9: Gene Therapy (Video). Watch the video. Explain how CRISPR-Cas9 gene editing technology can be used to precisely disrupt and modify specific genes.
9. CRISPR Cas9 has many different functions (Text). Read the text and link. List four uses for CRISPR technology.
10. Case Study: An Update on Genome Editor CRISPR Cas9- Friend or Foe? (Case Study). Read this case study. List two pros and two cons concerning CRISPR technology. List any TQEs.
11. CRISPR Question Set. Read and answer the questions. Take a screenshot and submit your score.

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Lab Investigations & Activities

Labs:

- **Modeling: CRISPR Origami Model** Edvotek #031. Three dimensional model activity with activation, gene editing, and gene knockout.
- **LabX CRISPR** (See explanation above) LabXchange supports 19 different languages.
- **MiniPCR: Chopped! Using CRISPR/CAS9 to cut DNA**. Students will use the CRISPR/Cas9 system in vitro to cut DNA in a test tube. By using different gRNAs, students will investigate how the Cas9 nuclease can be programmed to target specific DNA sequences. Takes a close-up look at the molecular machinery that makes the CRISPR/Cas9 System such a powerful genome editing tool.
- **Edvotek's CRISPR Codebreakers: Using CRISPR-CAS9 to Rewrite Genetics.** Explore cutting edge genetic engineering using CRIPSR-Cas9 to knock out a protein coding gene in classroom safe bacteria. Learn to design and screen gRNAs using base pairing rules, probability, and bioinformatics. #307
- **MiniPCR CRISPR Sickle Cell Anemia Therapy**: Students use a paper model to illustrate the genome editing process used in sickle cell patients.
- **Edvotek's Using CRISPR to treat Cystic Fibrosis**. Simulate the use of CRISPR-Cas9 to target a genetic mutation found in a patient suffering from Cystic Fibrosis. Develop an understanding of the gRNA design process, and use agarose gel electrophoresis to examine the prepared CRISPR treatment reaction products. #135 [Evaluate Gel Products]
- **HHMI Using CRISPR to Identify the Functions of Butterfly Genes** Freshmen biology students will use CRISPR-Cas9 to explore knock out butterfly genes to determine their function. First, students learn how CRISPR-Cas9 identifies and alters a target sequence in DNA. Second, they design their own CRISPR-Cas9 system to inactivate a butterfly gene and examine the resulting phenotype. The lab extension has students apply what they have learned to determine the function of a different gene. This activity can be used to review concepts of sequence complementarity, genotype-to-phenotype connections, and mutations.
- HHMI Biointeractive: This interactive activity explores how CRISPR-Cas9 technology works and the many ways in which scientists are using it in their research.
- **Compare and Contrast CRISPR with Genetic Transformation and RNAi**. Chart to compare the similarities and contrast the differences between CRISPR with Genetic Transformation, and CRISPR with RNAi. See template.
- **Explore career paths for Biotechnology.** Report via Canva presentation or mini poster. If poster, post on class walls or hallway lockers for all science students to examine. Use Amgen Rubric for evaluation.

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CRISPR Video List

1. What is CRISPR Gene Editing? 2017, Nova PBS, 1:35 minutes. Person talking about new technology that makes gene editing faster, cheaper, and easy to use.
2. Genetic Engineering will Change Everything Forever-CRISPR: By Kurtgesagt, 16:03 minutes. Six-part video that explains CRISPR, genetic modifications, possible end of disease, modified humans, and ethics. Long video, with good visuals, nice introduction for high school students. Shows some bias at the end.
3. CRISPR Explained: Mayo Clinic; 1:38 minutes. Explains CRISPR DNA editing with document editing; short.
4. Genome Editing: McGovern Institute; 4:12 minutes. Zhang of MIT and Broad Institute shows the applications for biomedical research and disease treatments. Video has good visuals high school students would enjoy.
5. CRISPR from Wired: Wired, 16:52 minutes. Long video with Sanjana explaining how CRISPR could be the key to eventually curing diseases like autism or cancer. Sanjana explains this concept to 5 different people; a 7 year-old, a 14 year-old, a college student, a grad student and a CRISPR expert. Video has explanation for 5 different levels of education; long conversation, lacks visuals.
6. CRISPR CF How Gene Editing Could Be Used for CF; From the Cystic Fibrosis Foundation, 3:03 minutes. Explains CRISPR and how it can be used to find a cure.
7. HHMI CF Mechanism and Treatment: HHMI explains mutations in the CFTR gene and how that knowledge can be used to develop a treatment; 2:30 minutes. Video has nice visuals, can use with CF Lab and extension for ABE's new *Exploring Precision Medicine* 7 chapters of lessons.
8. CRISPR Cas9 Explained: The Biggest revolution in gene editing The Guardian, 4:21 minutes; Doudna explains CRISPR and its ethics.
9. How CRISPR lets you edit DNA: Ted Ed, 5:28 minutes. Henle explores CRISPR technology and how it can be used to cure diseases

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Ethics

A. Designer Babies (Grades 9, 11, & 12)
    a. Choose three traits you would want your offspring to have (human or animal)
    b. Find the genes for these three traits and report: organism, chromosome location, and gene name.
    c. Based on findings, would you design this baby? Why or why not?
B. PG Ed CRISPR Lesson_Ethics_2025 (Grades 11 & 12)
    1. Use PGEd CRISPR Lesson template
    2. Learning Objective: Students will explain the mechanism of and question the ethics of CRISPR technology.
    3. Provide 3 articles on CRISPR.
    4. Use slides 7-15.
        a. 7- Genome editing to cure liver disease in mice
        b. 8-Layla Richardson; Immunotherapy(?)
        c. 9- Genome editing lead to solution for global shortage of organs
        d. 10- Should genome editing be used for reducing malaria?
        e. 13- Claims of editing twin girls
        f. 15- Summarize how CRISPR works: (1) A targeting system that finds the right place in the genome to cut; uses gRNA. (2) A component for making the actual cut to DNA; nuclease enzyme called Cas9.
    5. Case Studies Part 3
        a. Present four case study scenarios. Have groups choose one; write pro and con. Present to class. Four topics:
            i. Should genetically modified mosquitoes be released into the environment to combat Zika virus?
            ii. Should adults seek genome editing as a treatment for their liver disease?
            iii. Is it acceptable to edit the genome of human embryos to treat genetic diseases?
            iv. Is the use of genome editing for non-medical “enhancement” acceptable or not?
C. Summative: Position paper on CRISPR. Include personal reflection on what was learned in the unit lessons about CRISPR: what it is, how it works, applications, and ethics.

MiniReview Paper

Use the articles in the Bibliography below to create a mini-review paper on the mechanism, applications, and ethics of CRISPR Cas technology. See Review Paper Rubric, pp. 11–12.

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Career Exploration

Image by Gerd Altmann from Pixabay

1. Individually reflect on interests, education, values, skills, goals, talents, and vision.
2. Explore biotechnology career paths using Amgen project.
3. Create a Canva or mini poster. See Amgen Rubric, p. 14.
4. Possible visit from Amgen employee.

Findings/Evaluation

1. Create and implement lessons with biotechnology, AP Biology, and biology students.
2. Create and administer Google Form. Evaluate lessons through formative and summative assessments, and student feedback to determine if learning objectives were achieved.
3. Review and revise lessons as needed.

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Compare and Contrast CRISPR with Genetic Transformation and RNAi

Criteria	CRISPR	Genetic Transformation	RNAi
Cell Type(s)			
Molecular Players			
Molecular Size(s)			
Mechanism			
Applications			
Similarities: C vs GT			
Differences: C vs GT			
Similarities: C vs R			
Differences: C vs R			

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AP Biology Term 2 Project: CRISPR
(200 pts)

Due:_____

Project: Read the CRISPR research papers provided to you, due dates will be given for each of the papers. Write a review paper utilizing these papers with the title:

Mechanism and Applications of CRISPR

Format:

- MUST BE TYPED
- Include a cover sheet with the above title, the class, your name, my name, and the date
- No hard covers or plastic covers
- 12-point font, double spaced, with typical margins
- Late papers will be penalized by 10% reduction per day
- APA format

Grading: I expect the following:

A review paper incorporating the science of all the articles presented to you. This review must be a coherent and logical progression of ideas extracted from the articles. You may supplement the handouts with other science publications. All concepts and theories paraphrased by you must be cited correctly!! Text citations must be compatible with the source list. You must use (name, year) as the citation in the text directly after the idea. Do not quote from the article. A bibliography is required on the last page of the paper, with the following format:

Author's Last Name, First Initial, Middle Initial. (Year). Article title, *Journal Title*, *Volume* #(issue#), pp. page spread of the article.

Example: Carter, J. A. (2001). The RNAi revolution. *The Embo Journal, 3*(20), pp. 55–58.

Your audience for the paper is a biological scientist with little knowledge of this subject matter. Therefore, a format which propagates an in-depth and explanatory text, coupled to a free flowing of concepts, will receive full credit. Lack of depth, or lack of concept follow-up will not receive full credit.

If you need assistance, I will be happy to help you with the interpretation of the articles. I hope you enjoy the science contained in these papers. Certainly, the writing skills you practice here will be invaluable in college and throughout your careers.

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AP Biology Rubric: CRISPR Review Paper

(200 pts)

Score	20	15	10	0
Level of CRISPR Understanding and Fluency	Evidence in response of full understanding of CRISPR; paper is fluent	Evidence in response of good understanding of CRISPR; most of paper fluent.	Evidence in response of basic understanding of CRISPR; some of paper fluent.	No evidence of understanding of CRISPR or fluency.
APA Paper Criteria: Typed, Proper Grammar, Format, Font, & Cover Sheet	Paper is typed, grammar, format, 12-point font, and appropriate cover sheet; All 5 criteria met.	Paper contains 4 out of 5 criteria.	Paper contains 3 out of 5 criteria.	Paper contains 0 to 2 out of 5 criteria.
Citations	Paper contains completely correct citations (96–100%).	Paper contains mostly correct citations (75–94%).	Paper contains some correct citations (60–74%)	Paper contains incorrect citations (0–59%).
Ahrens-Nicklas & Musunuru (2025)		Response reflects a complete synthesis of CRISPR.	Response reflects some synthesis of CRISPR.	Response reflects little to no synthesis of CRISPR.
Doudna & Charpentier (2014)		Response reflects a complete synthesis of CRISPR.	Response reflects some synthesis of CRISPR.	Response reflects little to no synthesis of CRISPR.
Fessl (2022)		Response reflects a complete synthesis of CRISPR.	Response reflects some synthesis of CRISPR.	Response reflects little to no synthesis of CRISPR.
Hall (2016)		Response reflects a complete synthesis of CRISPR.	Response reflects some synthesis of CRISPR.	Response reflects little to no synthesis of CRISPR.
Jinek et al. (2012)		Response reflects a complete synthesis of CRISPR.	Response reflects some synthesis of CRISPR.	Response reflects little to no synthesis of CRISPR.
Li et al. (2019)		Response reflects a complete synthesis of CRISPR.	Response reflects some synthesis of CRISPR.	Response reflects little to no synthesis of CRISPR.
Marraffini (2015)		Response reflects a complete synthesis of CRISPR.	Response reflects some synthesis of CRISPR.	Response reflects little to no synthesis of CRISPR.
Mestel (2017)		Response reflects a complete synthesis of CRISPR.	Response reflects some synthesis of CRISPR.	Response reflects little to no synthesis of CRISPR.
Voytas & Gao (2014)		Response reflects a complete synthesis of CRISPR.	Response reflects some synthesis of CRISPR.	Response reflects little to no synthesis of CRISPR.
Rubric			5-turned in	Not turned in

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Biotech Amgen Career Project

Your project is to research the Amgen Pharmaceutical Company and prepare a document (Canva or poster) which includes:

1. Your name(s) and title of project
2. Amgen:
    a. Company's name and logo
    b. Company History: Why and how did this company come about?
    c. Image of company
    d. What is the company's net worth and annual income?
    e. Is Amgen a private or publicly traded company?
    f. If public, what is their stock name and what is the current price per share?
3. Company products:
    a. Find and list three that are interesting or important to you.
    b. How are your three products produced? (What biotech techniques are used?)
    c. How much product is produced?
    d. How much does the product go for?
4. Company Employees
    a. Find two scientists involved, provide an image of each scientist.
    b. For each company position, provide a short description of the job, describe the education/experience required for the position, and define the salary range. Define a position that requires a:
        - PhD degree
        - Master's degree
        - BS degree
        - High School diploma
    c. For company executives, provide job description, experience required, degrees required, and salary ranges; CEO, CFO, CSO.
5. Reflection on the project:
    a. Think about your research into Amgen and the product you created.
    b. What did you learn?
    c. Did you find anything interesting that was not asked for?
    d. Is there a job position that looks interesting to you and why?
6. References

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Amgen Career Project Rubric

Criteria/Points	10	5	1
Names and Title		Full names and title provided.	Full names and title are not adequately provided
Amgen	All 6 criteria fully provided: name, logo, history, image, net worth, traded, and full stock information.	Some, 3–5 out of 6, criteria provided: name, logo, history, image, net worth, traded, or full stock information.	Only 1 or 2 out of 6 criteria provided: name, logo, history, image, net worth, traded, or full stock information
Products	All 3 products are fully detailed: names, production techniques, quantity, and price.	Some, 2–3 products, are detailed: names, production techniques, quantity, or price.	Only 1–2 products are detailed: names, production techniques, quantity, or price
Employees	All 6 criteria are fully detailed: 2 scientists, 4 different degrees, and executives.	3–5 of the six criteria are detailed: 2 scientists, 4 different degrees, or executives.	Only 1–2 of the six criteria are detailed: 2 scientists, 4 different degrees, or executives.
Reflection	All 3 criteria are fully met: learned, interesting, and job position.	Some, 2 out of 3 criteria, are met: learned, interesting, or job position.	Only 1 criterion is detailed adequately: learned, interesting, or job position.
References	References are fully provided for each section.	Some references are provided.	References are not adequately provided.
Total			**/55**

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