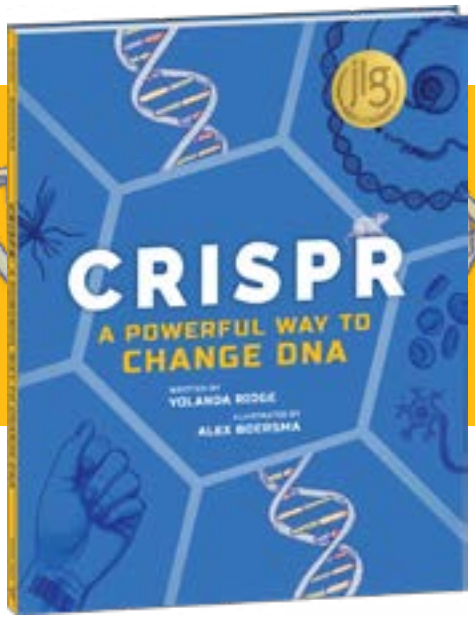

EDUCATOR GUIDE

CRISPR
A POWERFUL WAY TO CHANGE DNA
by Yoland Ridge
illustrated by Alex Boersma

GENRE:	middle grade non-fiction
THEMES:	CRISPR, genetic modification, discovery, genes, DNA, biology, technology, experiments, genetic engineering, future of science, ethics of science, GMO, disease control
SUITABLE FOR:	Grades 9+, Ages 14+
GUIDED READING LEVEL:	Fountas and Pinnell Z
LEXILE:	1180L
COMMON CORE STANDARDS:	W.8.1,1a,1b,1c,1d,1e,2,2a,2b,2c,2d,2e,2f,4,5,6,7,8,9b,10 RI.8.1,2,3,4,5,6,7,8,9,10 L.8.2,2a,2b,2c,3,3a,4,4a,4b,4c,4d,5,5b,6 SL.8.1,1a,1b,1c,1d, 2,3,4,5,6

SUMMARY:

CRISPR stands for clustered regularly interspaced short palindromic repeats. It's one of the most powerful ways we can shape the future. And it's poised to completely upend the way we think about science.

Yolanda Ridge makes this topic accessible to kids with introductory chapters covering the basics of DNA and genetic modification before showing them how this groundbreaking science could potentially:
• eliminate diseases like malaria and cancer,
• improve the stability of our food supply, and
• help to manage conservation efforts for threatened animals and environments.

But all of these possible advancements come with risks, the biggest being that the consequences are unknown. Chapters end with "Stop, Go, Yield" sections encouraging readers to consider the pros and cons of using CRISPR. "Cutting Questions" give readers the opportunity to further reflect on the ethics of the science.

CRISPR is a game changer. This important book, with detailed scientific illustrations, brings much needed clarity to a topic that will affect readers for generations to come.

Please remember that the suggested questions and activities within this educator guide are meant to serve as a starting point. Educators are encouraged to select items from each part of the guided inquiry process that work best for their style of teaching and will help them meet their goals when covering the topics in this book. Activities and prompts should be tweaked and/or reformatted to best fit your students, context, and community to ensure equity and inclusion.

BEFORE STARTING THE BOOK

This lesson plan uses guided inquiry as the foundation for its design, based on the HyperDoc model. For more information about guided inquiry and HyperDocs, click here. This lesson plan provides many options and approaches. Educators are encouraged to select items from each part of the guided inquiry process that work best for their style of teaching and will help them meet their goals when covering this topic.

PART A: ENGAGE

In order to effectively engage students with this book, it is important to introduce students to the topic in a way that will capture their interest and imagination. The following activities are designed to do just that!

VIDEO INTRODUCTION

Depending on the amount of time you have to teach this lesson, you can select a film from the following list that best suits your needs:

***Human Nature* documentary** (approximately 1.5 hours) A breakthrough called CRISPR has given us unprecedented control over the basic building blocks of life. It opens the door to curing diseases, reshaping the biosphere, and designing our own children. *Human Nature* is a provocative exploration of CRISPR's far-reaching implications, through the eyes of the scientists who discovered it, the families it's affecting, and the bioengineers who are testing its limits. How will this new ability change our relationship with nature? What will it mean for human evolution? To begin to answer these questions we must look back billions of years and then peer into an uncertain future.

How CRISPR lets us edit our DNA (approximately 15 minutes) Geneticist Jennifer Doudna co-invented a groundbreaking new technology for editing genes, called CRISPR-Cas9. The tool allows scientists to make precise edits to DNA strands, which could lead to treatments for genetic diseases . . . but could also be used to create so-called designer babies. Doudna reviews how CRISPR-Cas9 works—and asks the scientific community to pause and discuss the ethics of this new tool.

PANORAMA on CRISPR (a BBC documentary) (approximately 30 minutes) Panorama released a documentary that contains high-quality content on CRISPR. It includes interviews with key scientists and explores active experiments.

If you don't have time in class to view these documentaries, you can have your students watch one of them in advance and answer questions using EdPuzzle. Ed Puzzle allows you to turn any video into a lesson and track student comprehension. You can reinforce accountability as you check if students are watching your videos, how many times they're watching each section, and if they're understanding the content. It also allows you to engage students by introducing students to self-paced learning with

interactive video lessons. It's easy to add your own voice narration and questions!

THE GREAT DEBATE OR THE SUPPORTED OPINION PIECE

Another great way to engage students in this topic is to have students debate and provide opinions about some of the issues raised by CRISPR prior to learning about it. If there is insufficient class time to debate these topics, you could have your students write, record, or film their personal opinions about one or more of the following prompts:

- living in a world where no one gets sick, not even pets
- producing enough food to feed everyone without damage to the environment
- genetically modifying foods now and in the future
- "curing" issues like myopia through genetics, even though we have existing treatments for it and other issues like it
- bringing back cloned extinct animals to roam the earth once more (like in *Jurassic Park*)
- wiping out an entire species (like mosquitos) given the harm they cause to humans
- eating beef or other animal products that have been created in a lab
- genetically engineering the sex of your child prior to birth, like John Legend and Chrissy Teigen did for their children John Legend and Chrissy Teigen
  Should you be allowed to choose the sex of your baby - A YouTube Video
- purchasing pets that have been genetically modified to live longer
- genetically modifying children to change their physical appearance (i.e. height, eye color, hair, etc.)
- genetically modifying our children to eliminate the potential of genetic illnesses.
- using animals in experiments that could lead to the elimination of diseases in humans

A FICTIONAL SHORT STORY (and a potential cross-curricular connection)

Stronger, Faster, and More Beautiful by Arwen Elys Dayton is a fictional novel set in our world, spanning the near to distant future, made up of six interconnected stories that ask how far we will go to remake ourselves into the perfect human specimens, and how hard that will push the definition of "human." This extraordinary work explores the amazing possibilities of genetic manipulation and life extension, as well as the ethical quandaries that will arise with these advances. The results range from the heavenly to the monstrous. Deeply thoughtful, poignant, horrifying, and action-packed, "Arwen Elys Dayton's *Stronger, Faster, and More Beautiful* is groundbreaking in both form and substance." —*Goodreads*

As an introduction to the topic of CRISPR, one of the short stories in this book could be read by, or to, students as a way to discuss the potential effects that genetic modification could have on humans, as well as the moral and ethical dilemmas that can come with it.

PART B: EXPLORE

Students will be encouraged to explore the chapters covered in this book through a gallery walk. Either virtually or in a classroom, teachers can set up a variety of questions, prompts, images, and resources for each of the topics covered in the book as previously listed in Part A of this lesson plan.

The gallery walk should be guided by a few central focus questions like the two provided below:

1. What are some of the ethical issues that the author raises about CRISPR?
2. What are some of the potential ways that CRISPR could change science, society, and the environment?

WHILE READING THE BOOK

The following questions are based upon the key information presented in each chapter. Teachers are encouraged to assign chapter readings and select questions as they see fit and to have students share their learning with their classmates in a variety of ways (i.e. a jigsaw, a think-pair-share, 4 corners, etc.).

CHAPTER 1—JUMPING INTO GENETICS

1. Create a glossary of terms as you read. This can be interactive by attaching links of videos that explain these terms. For example use Book Creator or Google Slides.
2. What is the purpose of the genome? What analogy does the author use to describe the genome? (p. 4)
3. Are genomes the same between different people? Different species? (p. 4)
4. Where is the genome located in the cell and what are its components? (p. 4–5)
5. What do the letters of DNA stand for? How does DNA arrange itself? (p. 5)
6. The DNA alphabet is made up of 4 letters which represent nucleotides. Which nucleotides associate with each other and why is this important? (p. 6)
7. How many letters in the DNA code make a codon (or DNA word)? (p. 6)
8. How do these DNA codons arrange themselves to give the cell instructions? (p. 7)
9. What are genes used to make in a cell and how does this process work? (p. 8)
10. What is the importance of proteins in the body? (p. 8)
11. What is the difference in the alphabet between RNA and DNA? (p. 8)
12. Who is the father of genetics and what did he discover about genes and how they work? (p. 9)
13. Explain the difference between autosomes and sex chromosomes and why they mostly exist in pairs. (p. 10)
14. Research—The process called meiosis is briefly overviewed on page 11 of this book. Provide a more in-depth explanation of this process and explain how it makes eggs and sperm for sexual reproduction.

CHAPTER 2—REWRITING THE GENOME

1. According to the timeline, what was the major turning point for genetics and genetic engineering? Explain your choice. (p. 14–15)
2. What does the word CRISPR stand for? From a biological standpoint, what is the importance of CRISPR? How does this process work? (p. 16–17)
3. What is the importance of Cas-9? Where are the genes for these proteins located in the genome? How do the Cas proteins work? (p. 18)
4. What is the function of helicase and nuclease in the function of the CRISPR-Cas9 system? (p. 19)
5. What does it mean to “knock out” a gene? (p. 20)
6. Define the following terms: gRNA, template DNA, genetic engineering, transgenic, genetically modified organism. (p. 18–21)
7. Explain why it is critical to ensure that genetically modified DNA sequences are placed in the correct area of the genome and what would happen if these genes were placed in the wrong area of the genome. (p. 22)
8. Based on what you have read in this chapter, should genetic manipulation of human embryos be allowed to occur? Should genetic manipulation of animal embryos be allowed to occur? Why or why not? Be prepared to defend your position in a class discussion.

CHAPTER 3—BETTER BLOOD

1. Explain the benefits and drawbacks of mutations. (p. 24)
2. Define the term stem cell. How many types of cells could a stem cell potentially become? (p. 24–25)
3. What is sickle cell disease? Why is it advantageous to be a carrier of the trait, but not have the disorder? How does someone become a carrier or inherit the disorder? (p. 26–28)
4. Explain the difference between autosomal recessive and autosomal dominant traits. In the chart below, what are the probabilities of children inheriting the following genes if the following were to happen? (p. 28–29)

Parental Cross	Autosomal Dominant	Autosomal Recessive
♂TT x ♀TT		
♂Tt x ♀TT		
♂Tt x ♀Tt		
♂tt x ♀Tt		
♂tt x ♀tt		

The dominant trait is T and the recessive trait t. Remember that parents carry two copies of each gene which can be T or t.

Answers:

Parental Cross	Autosomal Dominant	Autosomal Recessive
♂TT x ♀TT	100% will exhibit the dominant trait	0% will have the recessive trait
♂Tt x ♀TT	100% will exhibit the dominant trait	0% will have the recessive trait
♂Tt x ♀Tt	75% will exhibit the dominant trait	25% will exhibit the recessive trait
♂tt x ♀Tt	50% will exhibit the dominant trait	50% will exhibit the recessive trait
♂tt x ♀tt	0% will exhibit the dominant trait	100 % will exhibit the recessive trait

5. What has been the traditional way to cure sickle cell anemia and what are the risks of using traditional treatment? (p. 30–31)
6. Why would CRISPR be a good way to cure sickle cell anemia? (p. 31)
7. Explain the difference between somatic cells and germline cells. Should CRISPR be used to genetically manipulate germline cells, somatic cells, none, or both? Debate and support your position. (p. 32–36)
8. Does CRISPR always target the intended area of DNA? What are some of the mistakes that can occur when using CRISPR? (p. 33)
9. What other types of diseases could CRISPR be used to treat? (p. 35)

CHAPTER 4—MUTANT MOSQUITOES

1. What is malaria and what are its symptoms? Who is most at risk? What areas of the world are affected and how many people die of this disease per day? (p. 38)
2. Explore—Read the scenario about Burkina Faso on pages 38–39 and read about gene drive technology on pages 42–48. Explain the ethics of gene drive organisms and some of the controversy on using these animals. What would need to happen to make it acceptable to use gene drive organisms?
3. How can CRISPR be used to eliminate malaria in mosquito populations? What are some of the difficulties surrounding using CRISPR to knock out the *FREP1* gene? (p. 41)
4. Make an argument for and against the use of gene drive technology to eliminate the following mosquito borne diseases (p.45):
   • West Nile • Yellow Fever • Malaria • Zika • Dengue Fever • Chikungunya

CHAPTER 5—CANCER CURED

1. What is cancer? (p. 52)
2. What happens to DNA that causes regular cells to become cancer cells? (p. 52)
3. Why is CRISPR potentially a good treatment for knocking out cancer cells? (p. 53)
4. How could CRISPR be used to knock out cancer cells? What DNA sequences could be targeted to eliminate cancer cells?
5. Extension–Scientists use mice to study cancer models and CRISPR cancer treatments. Discuss the ethics for and against using mice or other animals for the treatment of human disease. (p. 53 and p. 58)
6. How could CRISPR be used in immunotherapy to treat some types of cancer? (p. 54–56)
7. What are bioweapons and how could CRISPR be used to create these weapons? (p. 57)
8. How could CRISPR be used to stop the HIV viral cycle? (p. 59)
9. How does CRISPR-Cas9 cause cancer? How would we get it into human cells where it can edit the source of the disease? (p. 60)
10. Explore—Create an infographic or comic on how the following CRISPR-Cas9 gene delivery systems work: nanoparticles, attenuated viral vectors, light, electroshock (electroporation), micro-injection. Make sure that your work has clearly labeled images showing how these methods work and the benefits and drawbacks of the method for CRISPR-Cas9 gene delivery. (p. 60–61)
11. How could CRISPR be used to reduce the risks of certain types of familial cancers? (p. 63)
12. Explore–Do some research to see if other types of familial cancers would be good candidates for CRISPR based treatments. Justify your reasoning.

CHAPTER 6—PERFECT POTATOES

1. How has CRISPR been used to modify the foods we eat? What are some of the advantages and disadvantages of this technology? (p. 67)
2. Explore—Watch the video *Seed: the Untold Story* to better understand the impact of genetically modified foods on biodiversity, food security and economic stability.
3. Explain the difference between selective breeding and crossbreeding. (p. 67)
4. How can CRISPR be used to make safer, healthier foods? (p. 68–70)
5. What are some of the implications to biodiversity if GMO are introduced into the environment? (p. 71)

6. Should CRISPR modified food undergo the same labeling process as traditional genetically modified foods? Why or why not? (p. 72–78)
7. Based on what you have read in this chapter, should a technology like CRISPR-Cas9 be owned by any one person or corporation who discovers an existing biological process? (p. 69)

CHAPTER 7—HEALTHY HERDS

1. Should CRISPR-Cas 9 be used to modify animals to increase desired traits in animal husbandry like meat production, milk production, animal sexing, or disease resistance? (p. 80–81)
2. How can animal-bypassed meat be created? What are the benefits and drawbacks? (p. 87)

CHAPTER 8—DEATH DEFEATED

1. Explain how selective breeding can have a negative impact on purebred animals. Should CRISPR-Cas9 be used in purebred animals to prevent the onset of disease? (p. 90, 96, and 99)
2. How can CRISPR-Cas9 be used to revive extinct species? How would these revived species be different from the extinct species? What might the ecological impacts be if revived species were allowed to repopulate the Earth? (p. 91–95, p. 98)
3. How could CRISPR-Cas9 gene drive solutions be used to eliminate invasive species or prevent species from going extinct under changing environmental conditions? (p. 95 and p. 97)

CHAPTER 9—ENHANCED HUMANS

1. Why is it difficult to produce specific traits in humans? (p. 102)
2. Explain how CRISPR could revive eugenic principles in society. (p. 102)
3. Explore—Read "Speakers With Down Syndrome Go Before The United Nations: 'We Are The Canary In The Eugenics Coal Mine'" by Frank Camp or watch "I Am a Man With Down Syndrome and My Life is Worth Living"—Frank Stephens' Speech at the UN.
4. Should designer babies be allowed? With your understanding of evolution, what are the advantages and disadvantages of creating designer babies? (p. 102 and 107)
5. What is the current international consensus around the use of CRISPR technology? (p. 106–108)
6. How could CRISPR be used to create a new arms race? (p. 109–111)
7. If CRISPR-Cas9 introduced genes are entered into human germline cells, what are the potential long-term effects of these changes to the individual, society, and the environment? Should genetically modified people be allowed to have children, and be protected by the same human rights legislation in their country? (p. 109–111)

AFTER READING THE BOOK

PART C: EXPLAIN

Using evidence provided in the book, explain your responses to the following questions:

- Given the state of the world right now, what do you think is the single most important priority for using CRISPR technology?
- What is the most potentially dangerous aspect of CRISPR technology?
- Should there be laws in place to regulate the use of CRISPR technology? If so, what laws or consequences should exist?
- Do you think the use of CRISPR technology should be allowed on human embryos? Why or why not?
- When using CRISPR, are we "playing God" or simply using what we know to make the world better?

PART D: APPLY AND SHARE

In a poster, video, infographic, or podcast, respond to only one of the following personal connection questions:

- How could this technology improve your life or the life of a family member?
- Would you use CRISPR technology on your pet?
- Would you have wanted your parents to use CRISPR technology on you?
- Would you want to use CRISPR technology on your child?

Be sure to include details provided from the reading as well as further research from reputable sources.

PART E: REFLECT

Students should take some time to reflect on their learning and to determine what impact this book has had on their understanding of CRISPR and its future implications.

- What is one word that is reflective of what you have learned so far?
- Think back to the initial debates or your supported opinion piece. Based on what you now know after reading the book, has your opinion changed or remained the same? Justify your answer with evidence from the book.

PART F: EXTEND

The learning doesn't stop here! Students should be encouraged to extend their learning beyond this book and explore where, why, and how they think CRISPR will be used in the future. Here are some activities that students can engage in as an extension of their learning:

1. **Ask an expert—**Students can write to or attempt to engage with experts on social media or other platforms to ask questions about how they are currently using this technology, how they see this technology being used in the future, and what they feel are the benefits and dangers of using this technology.
2. **Make a creative film—**Students can make a movie that is fictional but correctly applies the use of CRISPR technology to show how CRISPR is being used in the future.
3. **Make a podcast—**Students can create a podcast that could be used to educate other students about CRISPR. This podcast might include an interview with someone currently in the field or include additional research from other reputable sources. The podcast could be made using the Anchor app.

4. **Host a town hall—**Students can have a town hall debate on whether CRISPR technology should be used in society from various stakeholder perspectives. For example, have students identify various stakeholders based on their reading from chapters in this book and have them represent that stakeholder's point of view in the class discussion.
5. **Write a short story—**Students can write a fictional short story, blog post, or comic that might have a utopian or dystopian take on the impact of CRISPR on future generations. However, the application of CRISPR must be accurate and/or possible. Using the Book Creator app is an easy way to do it!
6. **Create a physical or virtual gallery walk—**The book mentions various ways that CRISPR-Cas 9 is currently used or is being proposed to be used. Have students research and present other ways that CRISPR-Cas 9 is being or could be used to better humankind. In this activity, students should discuss in detail stakeholders, accessibility and costs, benefits and pitfalls to the individual and society, and the environmental impact of the use of CRISPR technology in this manner. Students can present their information in a Slidedeck or other format.