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Genetic Engineering and the Potential Effects on Evolution

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by Akemi Hamai

Introduction

Imagine a world without disease; no cancer, no zika fever, and no malaria. Just a decade ago, there was not a way to effectively eradicate these and other harmful diseases from the human population. There were many advances in treatment but no real solution to stopping infections, until now. There are still some limitations, but there have been huge advances in technology that make it possible to start combating these diseases. Humans have been trying to alter and control the organisms that we interact with for thousands of years by selectively breeding naturally-occurring variations of crop plants. Whatever variation we preferred, we would choose those plants or animals to reproduce, passing on those favored characteristics. Now we do not have to be limited by what nature presents us. We can even select characteristics that we desire that come from different species. These new technologies offer huge promise of creating stronger, more disease-resistant crops, eliminating genetic diseases like Huntington's, cancer, deafness, and stopping mosquito borne illnesses, like malaria, dengue fever and zika fever.[1] What are the ethical and moral implications of using these new technologies, and how will these genetic modifications affect the course of evolution on populations in the future?

Objective

The purpose of this unit is to teach students about new advances in genetic engineering and how these advances might affect the evolutionary process. Students will do some research and reading about different organisms that are currently being engineered, have academic discussions and write an argumentative paper making a claim for or against using these technologies based on the evidence gained from their research. This unit is aimed towards 8th grade students that range from a second-grade reading level to a college-age reading level.

Rationale

Although the basic mechanism of how evolution works has not changed very much in the past century since Darwin, the field of genetics has exploded. What we understand about how genes work and are regulated is growing every day, and with this new knowledge comes new technologies. Just like electronic technology developing at a rapid pace, the implications and regulations about using genetic technology are lagging behind. Middle school students are not known for their impulse control and long-range planning and often make questionable decisions at the spur of the moment. Students love all the new gadgets and toys and are often the early adopters of whatever new device that comes out on the market. They find new ways to use these devices but never question if they should. It is like they have found new powers, but with them should come new responsibilities. Putting limitations on new technology is marginally discussed and even if parents/teachers try to put controls, the students always seem to find a way to work around them. The same can be said for these new advances in genetic engineering, but instead of students, it is the scientists who are using these technologies without always considering the consequences. The discussions about whether we should do certain things are happening after the fact. I want to expose my students to what these new technologies in genetics are and to show them the great potential to ease suffering and make life more convenient for humans while getting them to understand the implications for the future. Following the Common Core and Next Generation Science Standards, I want students to be able to grapple with the ethical ramifications and to make an argument for how the technology should be used or not. They will be the generation that could potentially benefit from these technologies but will also have to help shape the policies around their usage. My students often struggle with writing and having academic discussions, and through this unit, the students will gain the skills to do both.

Some states and school districts may have different standards around teaching evolution than the NGSS, and it may even be controversial. In my state and district, this is not the case, but I will sometimes have students who question or say they do not believe in evolution. I tell them that I am not trying to change their beliefs; I am just presenting the science, and they can make their own choices. I also mention that faith does not require evidence but science does; all I am doing is presenting the evidence that science has validated for accepting evolution.

One other note, because the technology discussed in this unit is so new, things are changing rapidly and may be different by the time you view this unit; some federal laws and regulations may be in place by 2017.

Background

Darwin, Evolution and Natural Selection

The students need to have an understanding of how evolution works to be able to determine whether or not genetically-engineered organisms will affect populations in the future. Therefore, I added some information about basic evolution. Charles Darwin first explained how species evolved in 1859 and suggested the mechanism that he called natural selection. His theory changed the field of biology and explained how we had so many different species on Earth. He also made the connection between evolution and heredity, although he

did not understand how heredity worked, and he had no knowledge of genes.[2] He realized that there had to be variations within a species; these variations had to not harm the chance of the individual organism's survival so they could reproduce, and the variation had to be able to be passed on from one generation to the next. If the variation was beneficial to the organism's survival, then it was more likely to be passed on and was called an adaptation. These adaptations accumulated over time and could even lead to speciation if the environment changed. Darwin did not understand how adaptations and traits were passed on; he just understood that they had to pass from parent to offspring. He called this process natural selection. Natural selection is a process that creates adaptations, and for this process to work, three things need to be involved. The first factor is variation, where within a species there are slight differences. For the second factor, some of these variations need to be caused by random, naturally-occurring mutations (changes in the genes) that can be inherited or passed down from parent to offspring. The last factor is that these variations must increase the chance of the organism surviving and reproducing so it can pass on these mutations.[3] In the years following Darwin's most famous book, knowledge about genes and inheritance increased and continues to expand today at an even more rapid pace.

Mendel, Genes, and Inheritance

In 1865, an Austrian monk, Gregor Mendel, identified the discrete units of heredity with his pea plant experiments.[4] His work was not distributed widely at that time, and it took until the early 1900's for his work to be rediscovered and promoted by William Bateson, a biologist at Cambridge, who coined the word genetics to mean the study of heredity and variation.[5] Wilhelm Johanssen, a botanist, coined the word gene, although neither he nor Bateson knew what a gene was. They understood the function of a gene but not the chemical or physical nature of it.[6] It would take almost another half century for the physical structure of a gene to be discovered and for the chemical composition of deoxyribonucleic acid (DNA) and base pairs, A-T and G-C, to be unveiled by Watson, Crick, Wilkins, and Franklin. This discovery propelled the scientific understanding of genes and ultimately led to humans trying to alter, disrupt, and control them.

CRISPR-Cas 9 Technology

The students do not need to know the complicated biochemistry for 8th grade. All they need to understand is that it is a new, powerful technology that it is changing the field of genetic engineering. CRISPR-Cas9 is a new technology that offers many promises in genetic engineering but also many ethical challenges. CRISPR stands for Clustered Regularly Interspaced Short Palindromic Repeats, and Cas9 refers to a CRISPR associated protein 9.[7] It uses a cell's own genetic repair and replication system to cut and paste selected genes into cells. CRISPR-Cas9 was first discovered in bacterial cells that used this mechanism to cut viral DNA and insert it into their own genome. Incorporating the viral DNA into its own genome gave the bacteria an advantage because it would easily recognize the invading virus DNA the next time and be able to defend itself.[8] Scientists have been able to copy this mechanism and use it to insert or edit specific genes in a wide variety of organisms. The Cas9 protein uses RNA as a guide to cut the targeted gene in a specific place and then uses the cell's replication system to insert the desired gene if one is needed; otherwise, it just edits the gene out.[9] Scientists realized the potential of this technology to be able to recognize faulty or flawed genes and started thinking about the possibilities. Additionally, CRISPR was inexpensive compared to the current technologies used for gene editing, costing as little as $30 compared to $5000 for early technologies.[10] CRISPR could also work in other animals besides the traditional mouse and fruit fly models, and there have been dozens of CRISPR-altered organisms already created.[11] The technology is so successful that there are even people who are using it from their kitchens, garages, and sheds. You can even buy CRISPR DIY kits, take CRISPR workshops, and for

around $1000 start your own lab to make glow-in-the-dark plants or red-colored yeast.[12] This accessibility raises some concerns that the technology is too accessible, inexpensive, and may be used for unethical and destructive purposes either deliberately or by mistake. Since there are no regulations limiting people from doing this at home, what happens if someone accidentally or intentionally makes a super organism and releases it? Luckily, right now the technology is so new that you would have to have more sophisticated knowledge and equipment to actually engineer a pathogen. A molecular biologist from Lawrence Berkeley National Laboratory states, ". . . it would be easier to just go to Chipotle and get the pathogen itself."[13]

Another concern and hope for CRISPR technology is that it can be used to make gene drives. A gene drive is where you can manipulate the genes so they are forced into the population and does not follow the standard inheritance pattern normally found with sexual reproduction. In other words, you can ensure that the gene is passed on to the next generation.[14] This possibility has huge implications because whichever gene that humans want to be expressed can be forced into a population and can be copied and passed down through the next generations. In fast-reproducing organisms like bacteria, insects, and mice, you could eliminate or add certain traits fairly quickly or even drive that population into extinction. It could potentially get rid of pests or diseases or make plants hardier and livestock disease-resistant. There is so much potential, but there are also so many unknowns.

One other issue is that the technology is so new that users cannot always control where the CRISPR-Cas9 makes its cuts. When this happens, it is called "off-target" and CRISPR-Cas9 cuts into a different location, which could lead to potential problems since editing an off-target site in a gene means we are not controlling anything and could be creating something we do not want.[15] What if the genome is damaged and that damage is passed on to future generations? For example, what if it causes cancer cells to accelerate growth? Scientists are considering making reversal gene drives or "kill switches" which are like an undo or delete function in a word-processing program, but there is now federal law stating that these mechanisms must be in place before experimenting. A new document published in June 2016 by the National Academies Press (NAP) and put together by the National Academy of Sciences has made some recommendations about gene drive research, but none of these recommendations have become federal law or made into regulations.[16] There are some alarming risks with this new technology but also some potentially huge rewards, and we have to make sure there are safeguards in place while using this powerful technology. The questions posed on page 12 of the NAP document sums up the major concerns and issues of gene drive technology:

> Will the applications of gene drives be safe? Will they be effective? Will they have unintended consequences for the environment and public health? Do we know enough to release gene-drive modified organisms into the wild? Is using a gene drive to suppress or eliminate a pest species a good idea? What can scientists do to reduce risks to humans, other organisms, and the environment? How do we decide where gene-drive modified organisms might get released? What should governments do? Who gets to decide?"

Genetically Modified Organisms

Humans have evolved like all other organisms on the planet, but we are unique in that we can actively manipulate the world around us and engineer the future with our capacity to develop new technologies. We started out by tilling the land and domesticating animals so we could stay in one place and not be dependent on whatever our environment threw at us. From there, we could select the plants and animals that we wanted and propagate their seeds or breed more offspring through artificial selection. It took many generations using this basic technique, and we developed bigger and stronger crops and livestock. This ability to change the physical traits of crops and livestock happened in a relatively short period of time, a few thousand years, compared to the time it takes for organisms to evolve naturally which can take millions of years.[17] Along the way, we created technologies to irrigate crops and fight pests so we could convert larger portions of land for agriculture, and our population grew exponentially. We did not understand the mechanisms behind these changes, but we knew that we could use them in our favor. Now, it is common to find genetically modified foods on the shelves of our grocery store, and for some crops, it is more likely that we can get a modified form than not.[18] There has been some controversy surrounding genetically modified organisms, sometimes called "Frankenfoods," because they are sometimes made with genes from other species. There is concern that these foods will cause new allergies, develop resistance to herbicides, accidentally be released into the wild population, and spread disease.[19] On top of these concerns, there are some political concerns about giant chemical companies like Monsanto and Dow, that create, patent, and own these modified organisms. Also, there are questions about whether products that contain GMOs should be labeled so consumers know what they are buying. The upside of GMOs is that we can increase crop yields, make them more resistant to diseases/pests, make crops more drought tolerant, and create new medicines.[20] The obvious benefits of GMOs are that we could feed more people because of the higher crop yields, use less water to grow crops which are extremely important in countries like Africa and Australia and in the state of California that has been plagued by drought, and potentially develop some life-saving medicines. Currently scientists are trying to genetically engineer apples to carry a vaccine for pneumonia, and people who ate the apples also would get the vaccination.[21]

Some of these issues may have to do with marketing and education because 88% of scientists think GMOs are safe, while only 37% of consumers feel the same, and the American Association for the Advancement of Science (AAAS) and the American Medical Association (AMA) find no reason to label and stop the products from being used.[22][23] With the development of CRISPR, even more can be done to agriculture. The USDA recently approved a CRISPR altered mushroom that would take longer to brown and be viable on the shelf longer. CRISPR-Cas9 technology is also being used to create disease resistant wheat, corn, goats, vitamin-enriched oranges, and dehorned cattle.[24] The argument for these modifications is that they are actually less biologically disruptive than more traditional methods of modifying foods because they do not add new genetic material.[25] There are concerns, however, that there could be some off-target effects, meaning that the cut made during the CRISPR-Cas9 process is made in the wrong place and the gene that is modified is not the one intended. There are other crops being experimented on like soybeans, rice, and potatoes, and some skeptics think the big companies that produce GMOs like Monsanto will use CRISPR altered genes as a loophole around regulation and labeling since they are not genetically modified in the traditional sense. No one has determined whether or not CRISPR gene- edited organisms are the same as genetically modified organisms and therefore are unsure whether or not the regulations that apply for GMOs will apply to CRISPR engineered organisms. Again, there are concerns about these gene-edited organisms being released into the wild population, but scientists are also working on a "kill switch," a way for the gene to be programmed so it can be erased or deleted.[26] From our understanding of agriculture, genetics, and heredity, we were able to apply this

knowledge in order to change the human population.[27]

Eugenics and Designer Babies

In 1883, Francis Galton, Charles Darwin's cousin, proposed "positive Eugenics," or encouragement of the healthiest and "most-able" to reproduce in greater numbers. He wanted to copy the process of natural selection that his cousin observed in nature and agriculture and animal husbandry and apply it to the human race.[28] This idea carried over to the US but with a negative turn. In the early 1900s, the ideas of "social Darwinism" took root and created the modern Eugenics movement in America that rounded up "undesirables," loosely defined as people who were feeble-minded, deformed, alcoholic, homeless, poor, rebellious, or criminal, in order to institutionalize and sterilize them so they could not reproduce.[29] Over 60,000 Americans were sterilized in the early 1900's, many were not allowed to marry, and many were institutionalized.[30] This process was no longer about promoting the fittest but about eliminating the weak, and it was called negative eugenics. Galton wrestled with this new interpretation and weakly endorsed the idea from the UK. The criteria were ill-defined and were a ploy to stop immigration from Eastern and Southern Europe in an effort to promote the "Great Nordic Race" in the US.[31] Although these ideas may seem far-fetched, they had the backing of scientists at major institutions like Harvard, Princeton, Stanford, and Yale and the studies were well funded by the Carnegie Foundation, the Rockefeller Foundation, and the Harriman railroad funds.[32] The most famous eugenics case was of Carrie Buck who was brought up by her single mother, Emma Buck. Emma was poor and was thought to be a prostitute in order to make money. She was also thought to drink and may have contracted syphilis, and for these reasons, she was charged and found to be feebleminded and therefore institutionalized. Her daughter, Carrie, was a good student by her report card, but once Emma was institutionalized, things got worse for Carrie. She was placed in a foster home where she was raped by a relative of the foster parents and became pregnant. Her foster parents brought her back to court where she, too, was labeled as feebleminded and institutionalized and that's where her baby girl was born. The director of the institution, Albert Priddy, wanted to use Carrie as a test case to make sterilizations, based on eugenics, legal so he went to court to get the order. Witnesses were called to testify how the baby was also an "imbecile," although in truth she was developing at a normal rate. It was found that "three generations of imbeciles is enough," a quote by Supreme Court Justice, Oliver Wendell Holmes, who wrote the majority position, and Buck was ordered to be sterilized.[33] These ideas were adopted by Nazi Germany and used during WWII to exterminate millions of Jews, Gypsies, and gays in concentration camps.[34] From some horrendous experiments done in the concentration camps came a lot of knowledge about heredity and how genes work, and the field of genetics exploded through the rest of the century.

In the late 1980s, the idea of manipulating the human population came back; this time it was to cure genetic diseases like Huntington's disease, blindness, and deafness. Instead of trying to cull out the weak, we focused on fixing the "weakness". Gene therapy technologies were created to alter the genes that caused these diseases with marginal successes, and they were very expensive.[35] Screening for Down syndrome and spina bifida through amniocentesis has been done for decades, but the technology has advanced much further. Along with these technologies came the power to choose characteristics of unborn children, which first happened around 1996 when a couple chose the sex of their child through IVF (in vitro fertilization). It is now possible to screen for breast cancer, autism, and cystic fibrosis related genes as well as choose the likelihood of your child's eye color or hair using a technique called PGD (pre-implantation genetic diagnosis).[36] More and more traits are being added, and it just might become a *Brave NewWorld,* a book by Aldous Huxley that describes embryos that are given certain traits that determines their caste in society. Although the technology does not exist now to create this dystopian society, we seem to be on our way, and this potential to

manipulate the genome brings up many ethical questions. Hopefully, we are past trying to create a "pure" race of humans, but what about trying to cure illnesses? Most people hope to have a healthy child, and if there were a way to ensure the health of a child, many people would take the opportunity. One concern of a bioethicist, Thomas H. Murray, is that if parents choose the traits of their child, they will have an expectation of how the child should turn out, and if the child does not meet that expectation, it could cause conflict in the relationship or within the individual.[37] This situation was predicted in the science fiction movie "Gattaca" where an engineered man can't face up to his failure and a non-engineered man is limited by his genes. There are also questions about what the criteria would be for determining which genes should be fixed. Who gets to make the decisions and who has access to these therapies still needs to be decided, and there have not been any regulations and laws that have set up the criteria. Disability rights activists also question the need to edit out genetic differences because the list is always expanding, and no one knows where to draw the line. Alcoholism and obesity are two conditions that have a genetic link as well as homosexuality. Would parents and doctors be allowed to "fix" these conditions? Also, some deaf people don't consider being deaf a disability and point out that accommodations made for disabled people have benefitted society, like closed captioning.[38] Along the same lines, some severely disabled people and their parents would not change even if they had the opportunity, and about 50%, when asked, ranked the quality of their life as good or excellent. They say that having the disability is what makes them who they are and that if they did not have the disability, then they would be a different person. They also point out people with disabilities remind others to be compassionate about differences among people, and if these disabilities are edited out of the human genome, then it might reduce compassion.[39]

On the other hand, there are some relatives of people with disabilities who would love the chance to change their situation. They see how the disability has affected their family and all the pain and suffering endured by their relatives. They also realize that they and/or their children may have the same genetic flaw. One person is Charles Sabine, whose brother John has Huntington's disease. Charles has the same gene and knows what his fate is. He says, "If there was a room somewhere where someone said, 'Look, you can go in there and have your DNA changed,' I would be there breaking the door down."[40]

CRISPR technology offers many promises of a disease-free future due to its low cost and its flexibility in many organisms. It can also target more than one gene at a time which makes it suited to work on more complex genetic conditions that are not controlled by just one gene. Human trials at the University of Pennsylvania have passed a federal biosafety and ethics panel and are awaiting approval from the FDA. They will target three types of cancer: myeloma, melanoma, and sarcoma.[41] How long will it take before other diseases are targeted, and will Charles Sabine get his wish before he, too, falls prey to Huntington's disease? Scientists are not only focusing on genetic diseases that affect humans but are also targeting vectors that spread disease like mosquitoes.

Mosquitoes and Disease

Most humans do not like mosquitoes and would happily get rid of them. There is good cause to dislike these little critters because they carry many pathogens that devastate human populations. There were 863,000 deaths and 243 million cases of malaria alone in 2008, and there are 50-100 million new infections of dengue fever every year and 25,000 deaths.[42] The cost to treat malaria is over 12 billion dollars per year, and now there is zika virus as an emerging mosquito borne pathogen.[43] The tools we have to combat these diseases are not very effective, and there are no vaccines or cures, only treatment. Mosquito nets, window screens, getting rid of standing water when possible, and chemical spraying of pesticides are the most common ways

on a large scale that we use to stop mosquitoes from biting humans. As you can see from the statistics above, these strategies are not working very well. The problem is that there are 3,500 species of mosquitoes, and they have a very rapid life cycle and a large reproductive capacity.[44] They have also lived on Earth for more than 100 million years and have been able to co-evolve with many species.[45] Mosquitoes only live from 2 weeks to a couple of months. In that short life-cycle, they need to feed, mate, and reproduce. The males do not bite humans, but the females do; the blood meal gives them an extra nutritional boost for their eggs.[46] This bite transfers the pathogen that the female mosquito is carrying into the human victim. Most of the time, just an itchy bump occurs from a reaction to the mosquito's saliva, but in many tropical areas, more serious diseases are transmitted, so getting rid of mosquitoes seems like a good idea. There have been some attempts to interrupt their reproductive cycle by releasing sterilized males into the wild population, but it is hard to separate the males from the females, and they are often damaged during transport. Plus, the modified males do not seem to be as reproductively competitive compared to their wild counterparts.[47] There have been attempts to introduce genetically modified males that carry a lethal gene that will get passed on to their female offspring, but this attempt only reduces the population, and resistance to the modified gene may build up.[48] Now many scientists are putting their bets on CRISPR-Cas9 technology to deliver the fatal blow. CRISPR-Cas9 can address many of the issues with the older technology because it will not weaken the males that are released, and they can create a gene-drive that will force a lethal gene into the population by commandeering the wild mosquitoes' genes and converting them to what the modified mosquito has. If the gene-drive works, it could potentially reduce the mosquito population to a point where they will not be able to infect many people or it could also potentially cause that species of mosquito to go extinct in the release area.[49] This method could be combined with some of the more conventional methods of controlling mosquitoes that would make the plan even more effective. Another benefit is that this approach may reduce the amount of chemical pesticide sprayed in the community, which has had some negative side effects. It is also so much cheaper and does not rely on the people in the community to remember to use or buy screens and nets. It seems like a viable solution, but there are still some worries about potential unintended consequences.

Not many people think about the benefits of mosquitoes and why they might be useful to the ecosystem and other organisms. The males pollinate plants since they feed on nectar, and their eradication may negatively affect some flowering plants in particular areas. Mosquito larva is a food source for fish and turtles, and the mosquito fish, which is used to control mosquitoes, may be impacted. Many birds and bats also feed on the adults.[50] No one is sure how they fit into the food web and if removing them would have dire consequences. One entomologist predicts that the population of migratory songbirds in the tundra could drop by 50% because mosquitoes make such a large proportion of the available food although there is some disagreement.[51] It is also thought that caribou set their migration paths to avoid the swarms of mosquitoes, and this migration affects the Arctic Valley because the caribou are a major species in that area. Spiders, lizards, and frogs found elsewhere also prey on mosquitoes, although they also feed on other organisms.[52] There just really is great difficulty to know.

The newest technological advance, CRISPR-Cas9, is the most promising in terms of cost and ease of use, but there are very few regulations on how and when it can and should be used. It has the potential to wipe out species like mosquitoes that carry many pathogens to humans but with unknown consequences to the ecosystem.[53] It offers the promise of food security for all, but it brings back painful memories of Eugenics when blue eyed, blond haired traits were favored. Will diversity be genetically engineered out of the population? Will this change how and what we value about life? These and many other questions are still to be answered, and there are many decisions to make. The big question is no longer can we but should we?

Strategies and Activities

Recently my school has adopted a program called Constructing Meaning (CM) published by E.L. Achieve. The program is designed for long term English Language Learners and is applicable for any student not yet proficient in English. It helps teachers design scaffolds to make explicit the academic language demands of their content lessons. I have included these scaffolds in my resources section. My activities take place after the students have learned about evolution and natural selection. They have also learned about genetics and standard inheritance and about the structure of DNA. Without having this background knowledge it would be hard for them to access and understand the activities that follow.

Activity 1: Individual research, reading and note-taking

Before the students start their individual research they will have some instruction about the three topics so they know what they are and can make a more informed choice. The first activity that the students will do is some research about one of three topics: genetically modified organisms, designer babies and genetically engineered mosquitoes. I will let the students choose or gently nudge them to split the class into even groups. They will do some guided research on the internet and I will have a couple of readings on each topic at different reading levels. I have such a wide range of reading levels among my students so I have to provide more than one source for each topic. The articles will have the same basic information, they may have slightly different examples and the higher- level readings will go more in depth. All students will have a chance to learn about each other's articles in activity 3 and 4. They will take Cornell notes on their article(s), marking the text as necessary. These articles are annotated in the bibliography and are included in the resources section. I will give a short presentation on CRISPR-Cas 9 technology so they know the basics of how it works and also I will explain gene drives so they understand how it is different from standard Mendelian inheritance. Some diagrams are provided in the resources to help.

Activity 2: Partner sharing

After the students do some individual research they will partner up with someone who read the same article and have a discussion to share ideas about what they thought the article was about and what they thought were the most salient points. I will give them an "Academic Discussion" sheet I created for them that has sentence starters and response starters that will help them use phrases commonly found in academic discussions. I got this idea from an online class I took from Prof. Jeff Zwiers of Stanford University called Constructive Conversations. Before doing this activity you should make sure to model and have students practice using these phrases if this is the first time using the Academic Discussion sheet. The modeling and practice does not need to be about the content you are covering but can be on something more immediately accessible to the students.

Activity 3:Group Sharing

The partners from activity 2 will now join with other students in groups of about four that read a different article on the same topic to discuss what they understand from their articles. They can also bring in any other information that they gathered about their topic from their individual research. They may gain further insight to their topic and learn about the other articles' content without having to read it. It allows the students to learn from each other and to practice using academic language in a discussion and to prepare for the next activity.

Activity 4: Socratic Seminar

The students will now participate in a Socratic Seminar group by group. They have all had practice using the academic starters and responses and have had a chance to hear a few ideas and opinions about the topic. The students in the middle will have a larger discussion about whether the humans should genetically engineer organisms, what are the ethical considerations, and what they think are the potential effects on the evolution of populations. There also may be some discussion about gene drives and CRISPR-Cas9 technology specifically. The students sitting on the outside will not know the specifics about that particular topic but will have the same themes and questions. This gives the students a chance to hear more about genetic engineering and how it is being applied in a specific situation. The students on the outside will take notes about what they observe the students on the inside doing. I will have them focus on which arguments or evidence were stronger to try to get them to think more meta-cognitively about what makes a statement more effective. Make sure that they look for arguments that don't necessarily agree with their position because they will have to include that in their argumentative paper in Activity 5. They will be able to give feedback to the students that were in the middle so they know as well what other people understood from their discussion. This will be repeated two more times for the other groups.

Activity 5: Argumentative paper

The final activity is for the students to write an argument style paper using the information that they gathered from activities 1-4. I talked to the two of the six 8th grade humanities teachers at my school to align how I organize the paper to what they do in their classrooms. We also discussed potentially collaborating together on the writing portion of this unit which I am very excited about but have not worked out the details. I have included a scaffold of an outline of an argument style paper in the resources.

Resources for Students

I have included several articles about each topic and some have videos.

Readings and Research on GMOs

"Genetically modified organisms (GMOs): Transgenic crops and recombinant DNA technology.
http://www.nature.com/scitable/topicpage/Genetically-Modified-Organisms-GMOs-Transgenic-Crops-and-732 grade level and above

"Frequently asked questions on genetically modified foods"
http://www.who.int/foodsafety/areas_work/food-technology/faq-genetically-modified-food/en/ grade level resource

"GMO's – Pros and Cons." http://ireport.cnn.com/docs/DOC-957532 below grade level reading

"Genetically Modified Organism" http://encyclopedia.kids.net.au/page/gm/GMO grade level resource

"GMO Information" http://www.kidsrighttoknow.com/gmos/ below grade level resource

Readings and Research on Designer Babies

“How Much Can We Decide About Baby’s Genes?” http://abcnews.go.com/Health/OnCallPlusBreastCancerNews/story?id=5278365&page=1 grade level reading

“Should You Edit Your Children’s Genes?” http://www.nature.com/news/should-you-edit-your-children-s-genes-1.19432 grade level reading

“Designer Babies’ Debate Should Start, Scientist Say” http://www.bbc.com/news/health-30742774 below grade level

Readings and Research on Genetically Engineer Mosquitoes

“Genetically Modified Mosquitoes: What Could Possibly Go Wrong?” http://www.theatlantic.com/technology/archive/2016/04/genetically-modified-mosquitoes-zika/479793/ grade level and above

“What if mosquitoes went extinct?” http://science.howstuffworks.com/science-vs-myth/what-if/what-if-mosquitoes-went-extinct1.htm grade level readers

“Genetically Modified Mosquito Study in Florida to Halt Spread of Viruses Sparks Eco Debate” http://abcnews.go.com/Health/genetically-modified-mosquito-study-florida-halt-spread-viruses/story?id=38543361 video that will help low readers understand issues before reading

“Brazil Rolls Out GM Mosquito Farms” http://www.healthmap.org/site/diseasedaily/article/brazil-rolls-out-gm-mosquito-farms-71812 lower level reading

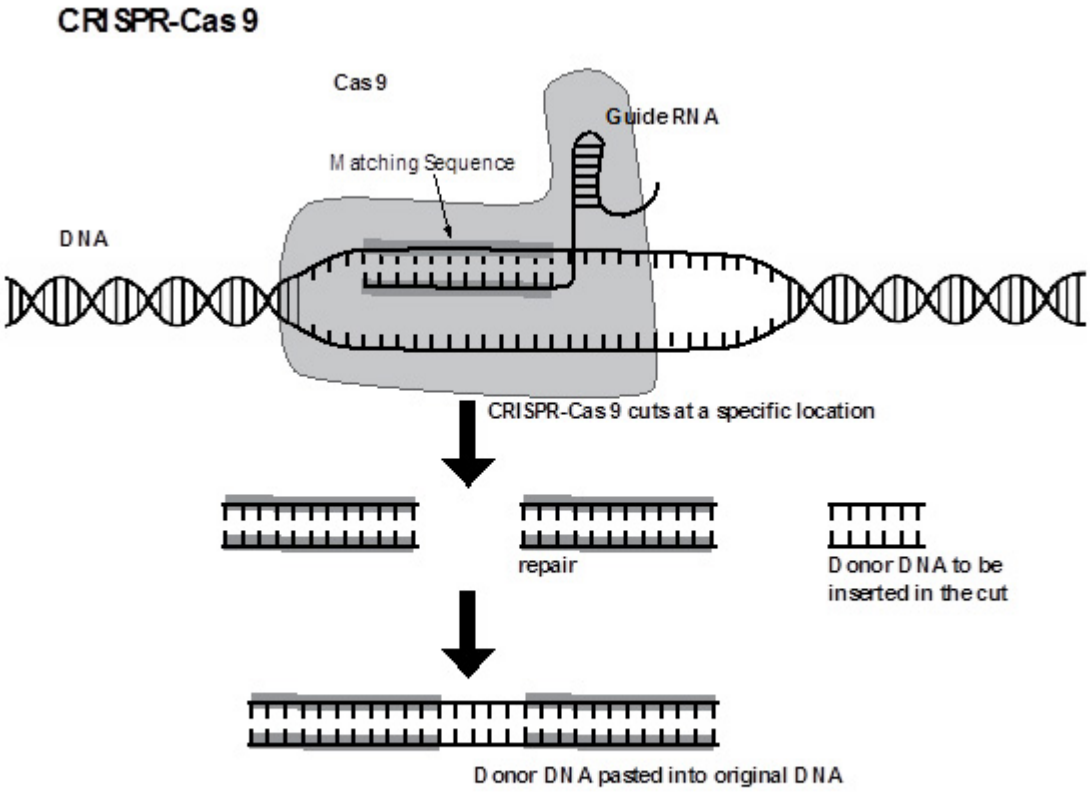
Resources for Teachers

CRISPR-Cas9 resources

“CRISPR, the Disruptor” http://www.nature.com/news/crispr-the-disruptor-1.17673

“How CRISPR Gene Editing Works http://science.howstuffworks.com/life/genetic/crispr-gene-editing.htm

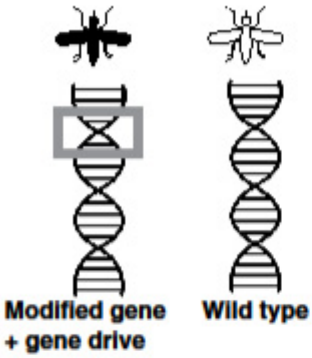
“FW: Thinking: Gene Drives: Saving Lives or Powering Extinctions?” http://shows.howstuffworks.com/fwthinking-show/gene-drives-video.htm video

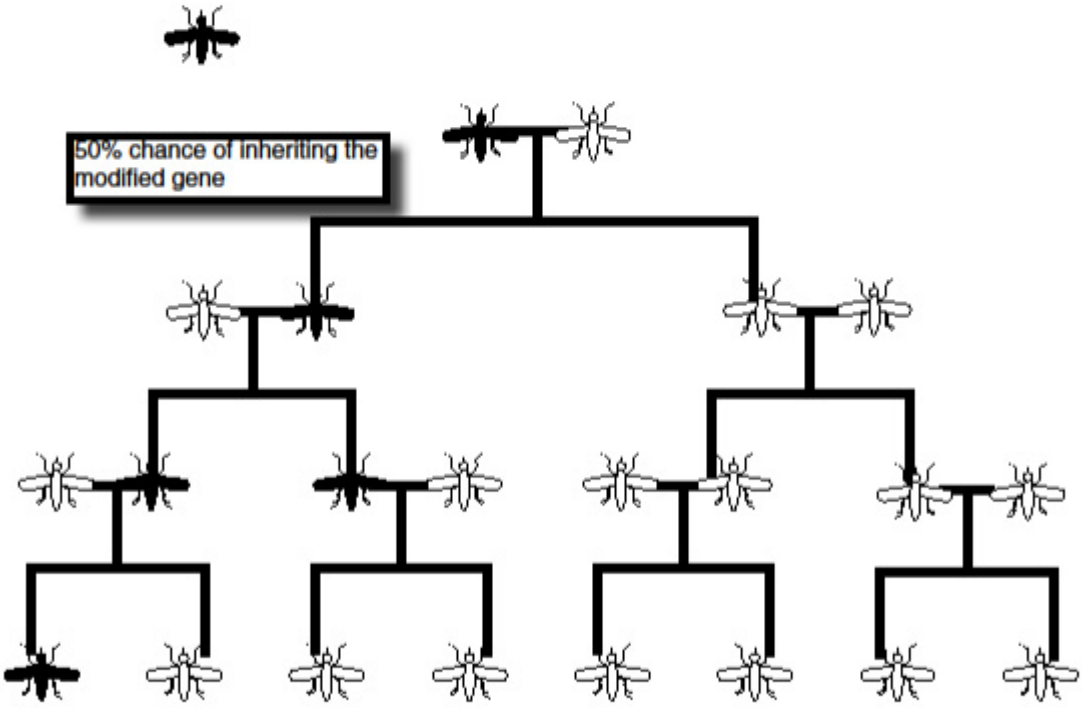


Modified DNA can now be inserted into organism where it will be copied during cell replication.

Image adapted from fulengen.com

Standard Inheritance
Each parent passes on one chromosome of a pair to its offspring.



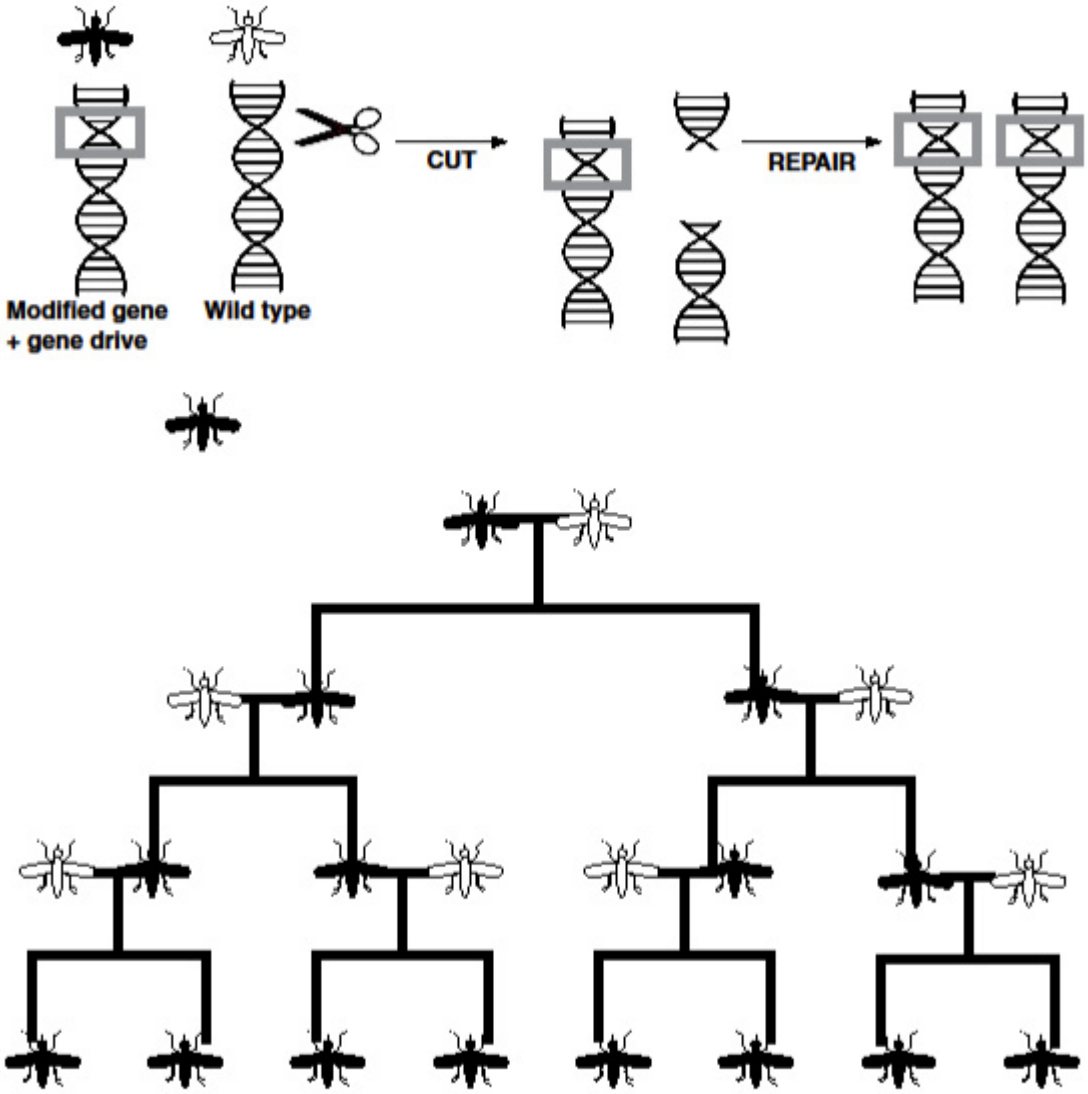


The modified fene spreads slowly through the population.

Image adapted from Nature 522, no. 7554 (2015).

GENE DRIVE INHERITANCE

The gene drive system cuts the partner chromosome, then the repair process copies the modification to the chromosome.



The modified gene sweeps rapidly through the population.

Image adapted from Nature 522, no. 7554 (2015).

Academic Discussion Starters and Responses

To deepen understanding:

What do you mean by . . .?

Say more about . . .

Can you elaborate on the . . .?

I understand the part about . . . but I want to know more about . . .

In other words, you are saying that . . .

A different way to say it . . .

To extend and build on an idea:

Can you give an example?

What is the strongest support for . . .?

For example,

In the text it said that . . .

One thing that illustrates this is . . .

Strong supporting evidence is . . .

To disagree with an idea:

How are the two ideas similar and different?

Which has the strongest evidence?

How does evidence for your argument compare to mine?

I see it a different way,

On the other hand, . . .

That's a valid point but . . .

Scaffold for Argument Paper

Prompt: _____

Claim (your position)

_____

_____

1st Argument (most general)

_____

_____

Evidence to support 1st Argument (can be paraphrased/quoted from text)

_____

_____

Elaborate (connect evidence to claim and explain)

_____

_____

2nd Argument (more specific)

_____

_____

Evidence

_____

_____

Elaborate

_____

_____

3rd Argument if necessary (most specific)

_____

_____

Evidence

_____

_____

Elaborate

_____

_____

1st Counterargument (Most likely argument against your claim)

_____

_____

Rebuttal (Explain why the counterargument may not be valid)

_____

_____

2nd Counterargument in necessary

_____

_____

Rebuttal

_____

_____

Conclusion (restate and paraphrase what you said before in your claim without repeating)

_____

_____

Sentence Starters for Argumentative Essay

Introduction: Write a hook that captures the reader's attention.

Have you ever thought about _____?

It has been said that _____.

Some people think _____.

Make your claim: Tell what your position is.

My position is _____.

My opinion is _____.

I think _____.

From my point of view _____.

Argument: Give your reason for making your claim.

Many experts claim _____.

According to _____.

This assertion is justified by _____.

Evidence: Provide evidence to support your argument. This can include statistics, expert opinion and examples.

Evidence can also be found in the article _____.

Another example can be found in _____.

To better understand my position, _____.

_____ proves that _____.

Elaborate: explain your evidence and how it supports your claim.

This example explains _____.

Furthermore, _____.

In addition, _____.

This confirms that _____.

Counterargument: main evidence against your position

Although some people think _____.

Others suggest _____.

_____ argues that _____.

Rebuttal: State why the opposition is wrong.

However, _____.

Nonetheless, _____.

Despite opposition, I am convinced that _____.

The point remains _____.

Conclusion: restate claim and summarize evidence

In closing, _____.

Finally, _____.

The facts clearly indicate _____.

It is essential to recognize _____.

There is little doubt

Adapted from E.L. Achieve

Appendix

From the Next Generation Science Standards

LS4-5 Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms.

LS4-4 Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individual's probability of surviving and reproducing in a specific environment.

California Common Core State Standards Connections:

ELA/Literacy –

RST.6–8.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions (MS-LS4-4),(MS-LS4-5)

RST.6–8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (MS-LS4-4)

WHST.6–8.8 Gather relevant information from multiple print and digital sources **(primary and secondary)**, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation. **CA** (MS-LS4-5)

WHST.6–8.9 Draw evidence from informational texts to support analysis, reflection, and research. (MS-LS4-4)

SL.8.1.a–d Engage effectively in a range of collaborative discussions (one-on-one, in groups, teacher-led) with diverse partners on grade 8 *topics, texts, and issues*, building on others' ideas and expressing their own clearly. (MS-LS4-4)

SL.8.4 Present claims and findings **(e.g., argument, narrative, response to literature presentations)**, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation

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