Log Book

**Timetable:**

February 1st to 8th: Find out what is gene editing, what types of gene editing there are and find out how they work. Find out more info about the main type of gene editing (the one that is used more and the one which is more accurate.)

February 9th to 19th: Find out

- How is it going to change the world of medical treatment?

- Diseases that have been treated by this (experimental treatment and outcome)

- What are the side effects/ is it dangerous. (pros and cons)

February 20th to 28th: Find out

- Make a DNA model

- If gene editing is ethical?

- What do experts say about it?

March 1st to 15th

- What do people that have been treated by gene editing say?

- And finish my opinion/conclusion

* Shoot the video
* Edit

March 16th to 18th: Upload my information to CYSF. Make changes if I have to.

**Background Information:**

Site: <https://www.genome.gov/about-genomics/policy-issues/what-is-Genome-Editing>

Before I submitted my proposal form I looked at this website. I found out what gene editing is. Gene editing is a way scientists edit or modify the DNA of an organism. Using gene-editing we can change many traits which are physical or non-physical. For example, we can change what colour our eyes are or remove or treat diseases. Gene editing is like talking scissors and cutting a strand of DNA in a specific stop. Then scientists can insert a DNA template or let the DNA bases at the end where it got cut repair themselves making the DNA strand shorter eliminating the strand which was affecting the body in a way. There are many types of gene editing like Talens but CRISPR is the one people are focusing on now. CRISPR is becoming revolutionary as many things and people have been treated by this.

**Testable Question/ Purpose:** The testable question for my research project is How does gene editing works and how can it cure/treat diseases. The purpose of my project is to see if gene editing is the new way to treat diseases and cure genetic diseases. To see if we can make humanity better and take a step into the future of medical treatment

**Topics To research:**

* What is gene or genome editing? (I came up with this so I could get an in-depth understanding of what it is)
* What types of gene editing are there? ( I need to know what types there are just in case CRISPR isn’t a good way to edit and to know what attempts at gene editing there was)
* How does it work? ( I need to know how they worked so I could make a model and show in real life how they would work and to know the steps the proteins take to achieve gene editing)
* What are the benefits of gene editing? ( to see if it’s a good way of treating diseases and to see how good it is)
* How is it going to change the world of medical treatment? ( I came up with this to answer my hypothesis and to know more about gene editing)
* Diseases that have been treated by this (experimental treatment and outcome)
* What are the side effects/ is it dangerous. ( I came up with this so it can back up the main question and to see if it’s harmful and why.
* Is it ethical? ( I came up with this to see if it follows the guidelines)
* What do experts say about it? (To see what opinions the creators and experts of gene editing have to say about this topic
* What do people that have been treated by gene editing say. ( I came up with this to see peoples opinion

I choose these topics because these topics will find out if gene editing is a good way to treat diseases and to find out how the whole thing works. It will help me understand the Info better and will conclude if gene editing is good or bad.

**Hypothesis:**

 I think gene editing is the new way to treat certain diseases in organisms. The genetic information encoded in the DNA is responsible for the morphology and physiology of an organism. If we could modify DNA, we can change how cells perform or how the human body functions. This technology could strengthen our systems to fight off hereditary diseases like cystic fibrosis, type 1 Diabetes Mellitus and cancers. Intervening the immune response system could help treat acquired diseases like AIDS. By altering the DNA in the germ cells (before birth) genetic defects can be prevented at the embryonic stage. Gene editing can also be used for breeding animals, creating non-allergic food, eradicating pests, etc.

Although genome editing looks like a promising method of treatment, it has some disadvantages like deleting good genes, unpredictable outcomes. Many question how ethical is it to alter germline cells or alter traits. With deeper research and Code of ethics, gene editing can be the future of treatment.

**Materials:**

**DNA Model-**

* Beads (4 colours. Small and big)
* Metal wire
* Sticks ( to hold up DNA model)
* Straws (4 colours)

**Cas9 model -**

* Cotton
* Red coloured beads (to represent RNA)

**Conclusion -**

To conclude my hypothesis was correct. I think gene editing is the new way to treat certain diseases in organisms because it is effective at getting rid of the disease and we can use gene editing in many ways. Scientists have used gene editing in humans already to cure sickle cell anemia and many more diseases. The opportunities are endless as CRISPR is evolving from just removing specific genome strands to changing the base pairs in seconds. With this technology right around the corner, I think more people have to invest into this research because this could be the new treatment for diseases. Genetic engineering will change everything. 3000 genetic diseases are caused by single-base mutations and with CRISPR Cas9 gene editing we can cure those genetic diseases. Even though gene editing might seem very dangerous if done correctly and by following the code of ethics we can edit genes with no harm. Scientists are exploring germ-line editing which will open up a whole new reality from us being immune to most diseases without getting genetically modified (Our parents get germ-line edited and the edited gene will pass on to us). But with that stretch come some obstacles. Germ-line editing is very dangerous as one mutation can bring serious illness or malfunction in the body. With this technology, we can proceed onwards and create a new way of life. We can eventually change our characteristics like physical appearances or how we behave. Thus gene editing is a great way of treatment for genetic diseases making life much better.

**Logbook entries:**

February 1st: I found out that I got selected for the CYSF. I wrote my Background Research

February 5th: I started to research what is gene editing.

* Data gathered: What is gene editing: It is a procedure that Scientists use to change the DNA of an organism. Gene editing involves changing, inserting, erasing and replacing DNA in the genome of an organism

February 7th: I found out which types of gene editing are the best way to edit genes and how they worked. I also researched the ways scientists change the DNA after they edit it. They can use ex-vivo and in-vivo. And I also found out which cells gene editing can be done on, germline cells and somatic cells.

* Data gathered: - What types of gene editing are there:

1. Restriction Enzymes: the Original Genome Editor

1 Gene editing started in the 1970s. [Restriction enzymes](https://www.nature.com/scitable/topicpage/restriction-enzymes-545) recognize specific patterns of nucleotide sequences and cut them like scissors. As a result, it houses a place for new DNA substances. Restriction enzymes are not used for gene editing these days, because they are restricted by the nucleotide patterns they identify, but still remain commonly used for molecular cloning.

2. Zinc Finger Nucleases (ZFNs): Increased Recognition Potential

When the world revolutionized with more technology and more needs people came back to the thought of gene editing as they need more things these proteins can read. Then the discovery of [zinc finger nucleases](https://www.cambridge.org/core/journals/quarterly-reviews-of-biophysics/article/discovery-of-zinc-fingers-and-their-development-for-practical-applications-in-gene-regulation-and-genome-manipulation/D25ADFAFC0F47D14E52E36BF5A27FCDE) (ZFN) in the 1980s tried to tackle this issue.

The ZFN is made of two parts: an engineered nuclease (Fokl) fused to zinc finger DNA-binding domains. The zinc-finger DNA-binding region identifies a 3-base pair site on DNA which can be combined to understand longer sequences of DNA. However, the specificity of the DNA sites increased. But ZFN was not perfect. Aside from the negativity, ZFNs showed a strong stand in the field of medicine. Scientists used ZFN mainly to impair CCR5 on human T-cells (a significant receptor for HIV) Using ZFN editing, scientists discovered that autologous CD4+ T-cells were safe to handle and were an invigorating potential for HIV treatment. Also, ZFN editing is used to edit tumour-infiltrating lymphocytes as a strategy for metastatic melanoma.

3. TALENs Gene Editing: Single Nucleotide Resolution

The new TALENS arose in 2011 as the need for gene editing became a reality. TALENs was an improvement over ZFN. [Transcription activator-like effector nucleases](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3547402/) (TALENs) are built like ZFNs. TALENS and ZNFs use the Fokl nuclease to understand DNA strands and require dimerization to work, but the DNA bonding is different. TALENs work by using transcription activator-like effectors (TALEs) and arrays that are in front of each other that have 33-35 amino acid repeats. The repetition in the amino acids makes single-nucleotide recognition which increases the targeting ability and understandability compared to ZFNs.

4. CRISPR (Cas9) Gene Editing: Genome Editing RevolutionizedCRISPR gene editing was initially discovered in 2012 by Professor Jennifer Doudna, a biochemist (University of California, Berkeley) and Professor Emmanuelle Charpentier, a microbiologist and a biochemist (Sorbonne University). They weren't the first to discover CRISPR but they were the first to describe the use of CRISPR to edit genomes. This incredible work led them to win the Nobel prize in chemistry last year. Jennifer Doudna was seeing how bacteria fights against viral infections. And she found out many bacteria have an adaptive immune system called CRISPR. In 2013, Feng Zhang explained how CRISPR can be used to edit eukaryotic DNA further.

In vivo gene therapy: This method involves directly introducing cells into the organism using a vector

Ex vivo gene therapy: In this technique, scientists harvest cells from the patient and return them to the patient after genetic modification.

Somatic cells in our body are non-heritable genes carrying cells that carry information for the functioning of a body. These do not pass on to the next generations. On the contrary, germline cells are inheritable genes that carry specific information and occur in the gametes.

February 8th: I choose CRISPR(Cas9) gene editing as the best way to edit genes and found out how it works.

* Data gathered: CRISPR: Crispr is actually a natural process in your body that is long functions as a bacterial immune system. This was initially found defending single-cell bacteria and archaea against invading viruses. CRisper uses 2 main components. The First is short sections of repetitive DNA ( deoxyribonucleic acid) sequences called Clustered Regularly Interspaced Short Palindromic Repeats or simply CRISPR. The second part is Cas or CRISPR-associated proteins which cut DNA like scissors. When a virus invades a bacteria, Cas proteins cut out a segment of the viral DNA to insert into the bacterium CRISPR region, capturing a chemical snapshot of the infection. Those viral codes of DNA are then copied into short pieces of RNA (ribonucleic acid). This molecule plays many vital roles in our cells, but in the case of CRISPR, the RNA binds to the protein cell called Cas9. As a result, this acts as a guard for a celebrity on duty to find a specific person latching onto floating genetic material and searching for a match of the virus. If the virus invades again, it will recognize it immediately and the Cas9 destroys the viral DNA.

February 9th-12th: I researched on the topic of Base editing as people from Harvard found out it’s much more accurate than CRISPR. I found out it uses CRISPR capability of finding the DNA strand but instead of cutting the whole DNA strand, it uses a specific protein cell to change the bases in each individual DNA base.

* Data Gathered: Base editing uses the programable searching of the Cas9 cell, but instead of cutting the DNA, it directly changes it from one base to another without disrupting the rest of the cells and genes. You could think of CRISPR Cas9 like scissors while base editors are more like pencils and erasers. The first cytosine base editor (CBE), which chemically changes a cytosine–guanine (C–G) base pair to a thymine–adenine (T–A) base pair at a targeted genomic area, was made in 2016 by chemical biologists David Liu and Alexis Komor at Harvard University in Cambridge, Massachusetts. Another researcher in Davids laboratory, Nicole Gaudelli, made the first adenine base editor (ABE) in 2017. The adenine base editor chemically converts A–T to G–C base pairs. Alexis Kormor took advantage of a naturally occurring enzyme called APOBEC1. This enzyme, which is part of the cytidine deaminase family, chemically converts C to a U (uracil) then to a T that occurs in RNA. Komor combined APOBEC1 to a Cas9 nuclease that is unable to create DNA double-strand breaks. When the guide RNA directs the APOBEC1–Cas9 protein to the targeted DNA strand using CRISPR, the deaminase converts C to U. The cell’s DNA-repair system then fixes the resulting U–G mismatch by turning it into a U–A base pair, and then to a T–A pair.

February 15th-17th: Got the pros (the benefits) of gene editing. I found out it can also treat crops from invading pests and diseases. I researched on a woman named Victoria Gray who was treated by CRISPR gene editing to cure her genetic disease Sickel cell anemia. Also found about GMO which is genetically modified organisms or food.

* Researched Gathered: Can treat various genetic diseases like Albinism. Angelman syndrome, Ankylosing spondylitis, Apert syndrome, Charcot-Marie-Tooth disease, Congenital adrenal hyperplasia, Cystic fibrosis, Sickel cell anemia and much more.
* Gene editing can be used in the development of transgenic foods(genetically modified food),
* create model organisms for biomedical research.
* In 2020 there was a cattle named Cosmo that underwent CRISPR gene editing as an embryo in favour of giving birth to male offsprings. So that they could improve the efficiency of beef production because male cattle are more fuel-efficient at converting hay into beef. Cattle grown today contribute a lot of greenhouse gases to our atmosphere every day. By editing the cows to produce more male offsprings, we could get the same amount of beef with less cows which could reduce the amount of carbon footprint on the whole industry. To make this happen they used CRISPR to insert the SRY gene (the gene for male development) onto Cosmo’s 17th chromosome which is a non-sex chromosome. That means if he has calves that SRY gene on the 17th chromosome, they might develop male characteristics even if they don’t inherit the male Y chromosome.
* Sickle Cell Anemia: This is a cruel genetic disease that produces a defective form of hemoglobin (the protein needed for red blood cells to carry oxygen and deliver it to the body). The defective hemoglobin cells turn the blood cells into sickel shaped forms. These irregular cells block the bloodstream causing organ damage and sometimes extreme spikes of pain. Victoria Gray was diagnosed with sickel cell anemia when she was born. Sickle cell anemia is the most common inherited blood disorder and it’s hard to treat. Scientists know the exact cell change in their body which is a single A to T point mutation in both their copies of their hemoglobin gene. Many treatments are drugs and risky surgeries but for some patients, it’s still not enough to get this disease out of their body. Victoria Gray was exploring the possibility of a bone marrow transplant but her doctors suggested something else. She jumped up to the chance and became the first American who got treated with a gene-editing technique called CRISPR. CRISPR made the revolutionary arrize of treatment and know it’s working better than any doctor could have predicted. The genetically modified cells that the doctors injected into Victoria’s body appeared to be erasing almost every symptom of her disorder. She turned out perfectly fine after 2 years and was living a normal life with no pain and symptoms of Sickel cell anemia. Her red blood cells turned back to normal and she is now living a healthy life.

 For other treatment like some diseases which don’t pass on in the human gene pool, scientists edit stomatic cells so your future generation doesn’t inherit that genetic change.

February 18th-19th Got information about the CONS of gene editing and how a scientist edited an embryo of 2 babies before they were born to make them immune from HIV/AIDS. And also information about people who got treated for beta-thalassemia

* Research collected: Cons:
* Even though gene editing seems like the best treatment for genetic diseases and to grow more crops it comes with some side effects.
* CRISPR has been used for the treatment of many diseases, crops and etc but it also has been treated on babies too. He Jiankui isa Chinese scientist who edited the embryo in a woman before she gave birth. He edited a cell that made the babies immune to HIV becuase their father had AIDS. Later on, the woman gave birth to twins named Lulu and Nana. But Jiankui did this illegally with no consent from the Chinese government. He edited germline cell which is passed on to future generations. He Jiankui did an uncharted territory gene edit becuase CRISPR isn’t the best tool to edit genes. CRISPR can create a risk of an edit which can cause a mutation that will have side effects that we can’t predict. Becuase of this action Jiankui was sentenced to jail for 3 years and 3 million yuan or $ 589,882.50 in Canadian Currency

February 20th-25h: Found out the ethical issues of gene editing and how it can cause the extinction of certain species. Also, I found out the regulation people at the WHO committee and many other countries discussed on.

* Data gathered: Ethical Issues: Gene editing is a very controversial topic when it comes to the uses because there are two ways you can actually use it. One being somatic cell editing and the second being germline editing. Somatic cell editing is much safer because if genes had mutation we could fix them and they won't cause very dangerous threats to the patient. But when it comes to germline editing (editing sperm, eggs and embryos) it gets more dangerous as the person's life is at stake. Regulations:

After the world was shocked by the use of CRISPR on germline cells, many countries, WHO and certain scientific communities have come forward to create a line of control on its use. According to Jamie Metzl, a WHO member, (author of a book on genetic engineering), when we are talking about the life we need regulations at both national and international levels. We should create a balance between the need and misuse to set limitations and go step by step. WHO has put forward certain laws to control gene editing. Many countries have deemed germ cell editing as illegal.

William Hurlbut (Bioethicist, Physician) has an opinion that we need to carefully review the balance between nature and life, be respectful to it while regulating gene editing. It should be addressed to all diversities of humans without creating social problems and ecological imbalances.

Jennifer Doudna says that although CRISPR is relatively easy to use, it is very hard to do it well because it’s dangerous. She encourages scientists to engage with people in discussions about setting regulations and remove any distrust in science.

February 26th - 28th: I researched the accuracy of CRISPR gene editing and about designer babies. Scientists are hoping in a future where we can chase how our kids look like and with the help of CRISPR experts are saying this could become a reality. I also researched Gene drives after I saw a Ted Talk by Jennifer Doudna (one of the CEOs of CRISPR gene editing). I saw how gene drives dramatically increase the likelihood of survival of those edited genes by spreading quickly through generations and override natural selection.

* Research: Accuracy
* When editing genomes we may be able to edit them properly but we don’t know how our body will react. CRISPR gene editing is a very successful tool, but say there was a patient who got treated with CRISPR for sickle cell anemia, their genes could get mutations and some genomes could be deleted or could be inserted with a new strand which messes up the gene making the DNA strands ineffective thus resulting in the genome to shut down. This could be very dangerous as the genomes determine everything in our body and how we look. If the mutation changed our melanocortin gene (the gene that determines our skin colour), if we were white before our skin colour would change to yellow or tan or etc.

Further, CRISPR has treated many patients with genetic diseases but it’s not that accurate. It has shown that CRISPR fails 15% of the time in medical studies. At the University of Illinois, people found a failure in the Cas9 targeting system as the DNA strand which was cut didn’t detach from the DNA blocking it from the DNA to repair itself resulting in the genome shutting down.
* Designer Babies: CRISPR gene editing has opened the doors to create babies with desired characteristics physically and intellectually. The pioneer says that it is possible to design a baby but they haven’t reached there yet. There is no limitation as to where one has to stop using CRISPR.

March 1st: I started making my DNA model that shows how CRISPR works. I bought the equipment and planned everything out.

March 3rd: I finished my DNA model of the double helix strand of DNA using beads with the help of my mother. It came out well and I held it up with 2 sticks so I can show it.

March 7th: I made a Cas9 model which had a piece of guide RNA attached to it. I used a couple of cotton balls and my mom threaded them together then we attached a line or red beads to show the RNA in the middle. I also wrote my conclusion.

* What I wrote:

Conclusion: To conclude my hypothesis was correct. I think gene editing is the new way to treat certain diseases in organisms because it is effective at getting rid of the disease and we can use gene editing in many ways. Scientists have used gene editing in humans already to cure sickle cell anemia and many more diseases. The opportunities are endless as CRISPR is evolving from just removing specific genome strands to changing the base pairs in seconds. With this technology right around the corner, I think more people have to invest in this research because this could be the new treatment for diseases. Genetic engineering will change everything. 3000 genetic diseases are caused by single-base mutations and with CRISPR Cas9 gene editing we can cure those genetic diseases. Even though gene editing might seem very dangerous if done correctly and by following the code of ethics we can edit genes with no harm. Scientists are exploring germ-line editing which will open up a whole new reality from us being immune to most diseases without getting genetically modified (Our parents get germ-line edited and the edited gene will pass on to us). But with that stretch come some obstacles. Germ-line editing is very dangerous as one mutation can bring serious illness or malfunction in the body. With this technology, we can proceed onwards and create a new way of life. We can eventually change our characteristics like physical appearances or how we behave. Thus gene editing is a great way of treatment for genetic diseases making life much better.

March 12th: I started to record my presentation as I planned out how much time to talk about each topic. I recorded my introduction and my hypothesis.

March 13th: I recorded with the DNA model to add aesthetics so I recorded everything all over again. I recorded my introduction, hypothesis, what is gene editing, types of gene editing, how CRISPR works, base editing and benefits of gene editing? We set up a tripod and used my mom’s phone to record and edit the clips so far. I edited the video on iMovie and put the clips together. It was pretty fun to record everything so far. I have to do the cons, ethical issues, my opinions and conclusions tomorrow.

March 14th: I finished recording the disadvantages, ethical issues, regulations and the conclusion and started to edit the presentation.

March 15th: I started to upload my information to the CYSF website. I also edited my presentation fully.

March 16th: I shared my video to my friends to get their opinion. They said it was good so I carried on. I sent my teacher (Ms.Shoults) that I am done and she looked over my project. I finished uploading all my information and submitted everything.