My research stemmed from my interest in transgenerational epigenetics. Specifically, I wished to learn how our lifestyles and environment will affect our children and our children's children. I find that Epigenetics research is consequential because it can give us a greater reason and purpose to live a healthier life and can also teach you more about the world around you. Many studies have been performed on animals to begin observing the effects of epigenetics. One study that I was particularly fascinated by was one that showed that within honey bees the worker bees and the queen bees are genetically identical. Although these bees have identical genotypes, their phenotypes are wildly different. The queen bee can be twice the size of the worker bees and they have very different physical forms and activities. While worker bees have a lifespan of weeks a queen bee can live for years.

This research into bees inspired me to create fiberglass bee wings. My main goals were to create a membrane structure within the wing and a honeycomb pattern. The wings were a multistep process and I did multiple tests beforehand to see how my materials worked. I began drawing out the wings, then I placed a piece of fiberglass on top and coated it in resin, next I coated pieces of yarn in the resin and placed them in a membrane pattern, this was left to cure overnight. The next thing I did was add another layer of fiberglass over the wings and use bubble wrap to vacuum bag the wings, this created a subtle honeycomb texture within the wings. The final step was to create a wearable harness out of a plaster mold of my back.

Iris D.
Colorado

The Morality Of Epigenetics

Iris D.

For most of my life I have been fascinated by the forces that shape our lives and personalities. I think this stems from a place of never really feeling like I know myself. As a kid, I took dozens of different quizzes and tests, like Myers Brigg and Enneagram, that are supposed to tell you who you are, but it was not enough for me to take the test -- I wanted everyone around me to also take them so that I could know not just how I worked but how they worked as well. I was fascinated by the difference I saw between myself and the people around me, especially my family. It was baffling to me that we could look so similar yet be such different types of people. It wasn't until my freshman year that I started to ponder these things on a more scientific level. When I was in 9th grade I took a fundamental biology class; it was the first time I had ever taken a science class devoted to the study of how humans work. I was instantly fascinated by everything we learned and I absolutely adored my teacher, but the concept that caught my attention the most was epigenetics. Epigenetics is the first clue towards answering my question of how people can look so similar, yet act in such diverse ways, and, as a credible scientific theory, provides tangible evidence rather than other unproven, pseudo-scientific explanations.

Our bodies are the product of our inherited genetic code. For as long as we have known about genetics, there has been an assumption that DNA is the only thing that is carried over into future generations. We knew that lifestyle can influence our health and personality, whether it be a heightened risk of cancer due to smoking or increased lifespan because of regular exercise and healthy eating. However, scientists recently discovered that our choices and experiences don't just impact our own lives, but also heavily influence future generations. The study of epigenetics helps us understand how lifestyle genetically impacts future generations of offspring, and provides the basis for an exploration on the implications and uses of that knowledge upon human society. The new information we have about epigenetics will force our society to consider essential questions about the release of new drugs and changes we need to make in terms of diet.

Epigenetics is a recent scientific discovery, brought about through a series of experiments. The first began in Overkalix, a small, rural town in the northernmost part of Sweden. In Overkalix, the quality of life depended greatly on the crop harvest which varied year to year. Often, harvests were considered average, or even excessive -- however, years marked with famine conditions contributed to significantly decreased nutrition among the village population. These are the years that Lars Olov Bygren, a preventative health and nutrition researcher, focused on in his research. Bygren had a long running interest in the lifelong impacts of nutrition and had once worked at the same institute in Norway as Anders Forsdahl, a physician and pioneer of public health research in Scandinavia. Forsdahl conducted a study in the far north of Norway and discovered that impoverished children who had lived through WWII were much more likely to suffer heart attacks as adults. Forsdahl's work prompted Bygren to think about—as he puts it—"early influences that give late replies."[1] In 1984, Bygren decided that Overkalix, where he can trace his ancestry back to 1475, was the perfect place to perform a study. His decision was based on the fact that there were detailed records of births, deaths, family lineages, and other details that were diligently recorded since the town's formation, in addition to a high degree of genetic isolation among the population. Bygren and his colleagues collected the pedigrees of 94 randomly selected people who had been born in Overkalix in 1905.

After four years of research, it became clear that the "early influences that give late replies" began much earlier than Bygren had expected -- in the subjects' grandparents. The data showed that the grandsons of men who experienced a feast season during pre-puberty (when sperm cells

[1] Epstein, D., & Epstein, D. (2015, December 16). How an 1836 Famine Altered the Genes of Children Born Decades Later.

are maturing) died on average 6 years earlier than the grandsons of men who had experienced a famine season during pre-puberty, often of diabetes. When a statistical model that controlled socioeconomic variables (individuals of lower status historically experience more disease and a decreased lifespan) was applied to the experiment, the difference in lifespan increased to 32 years.[2] Bygren had found proof that the experiences of grandfathers were being passed down to their grandsons, a discovery that contradicted the contemporary idea of genetic inheritance which stated that only inherited DNA is passed down, while experiences die with the individual. Bygren's experiment revealed that something other than DNA was being passed down through the generations, but he was unable to release his research for over 10 years due to criticism from the scientific community. "It took many years, and we submitted to many journals," Bygren says. Scientists who reviewed (and rejected) the paper for publication did not quibble with the statistics. Rather, they said: "it's impossible," Bygren recalls. "The results cannot be."[3]

Bygren decided he needed more proof of his discoveries before anyone would believe him. In 2000, he contacted Marcus Pembrey, a clinical geneticist who had conducted studies on children who were missing part of the DNA sequence from chromosome 15. The notable information that came out of this study was not that the deletion caused a disease, but rather that the disease depended on the parent where the missing DNA originated. Children with the deletion on the chromosome inherited from their father experienced Prader-Willi syndrome, which causes insatiable hunger and obesity. Conversely, children with the deletion on the chromosome inherited from their mother experienced Angelman Syndrome, a severe mental impairment characterized by the inability to speak, walk, move, or balance well. [4] The DNA sequences of the children who experienced Prader-Willi syndrome and Angelman Syndrome were identical, yet there was clearly a difference between them. The DNA sequence contained a record of the parent that it came from; once again, a mysterious mechanism was moving between generations.

Bygren and Pembrey decided to work together to create a two pronged attack to further research if life experiences could be transmitted across generations. In the first approach, the team used England's Avon Longitudinal Study of Parents and Children (ALSPAC), which tracks the health and development of thousands of children starting in-utero. They looked at 5,451 fathers who had been or still were smokers, 166 of which had smoked just before puberty when their sperm, which transmits genetic material, was forming. The sons of these 166 men turned out to be fatter than the sons of men who didn't smoke until after sperm production.[5] Once again, certain experiences (or toxins) in one's life seemed to have left some sort of hereditary record. For the second prong of the project, they decided to return to Overkalix and expand the collection of data to include both men and women from a wider pool of birth years. They found that the granddaughters of women who had lived through a famine period when they were either in the womb or infants (when the fetus's eggs were forming) had a greatly increased risk of early death. Interestingly, granddaughters of women who were undernourished when their eggs were forming and grandsons of men who were over-nourished as their sperm were forming were at greater risk

[2] Epstein, D., & Epstein, D. (2015, December 16). How an 1836 Famine Altered the Genes of Children Born Decades Later.

[3] Epstein, D., & Epstein, D. (2015, December 16). How an 1836 Famine Altered the Genes of Children Born Decades Later.

[4] Epstein, D., & Epstein, D. (2015, December 16). How an 1836 Famine Altered the Genes of Children Born Decades Later.

[5] Epstein, D., & Epstein, D. (2015, December 16). How an 1836 Famine Altered the Genes of Children Born Decades Later.

as well. The information that Pembrey and Bygren collected from these experiments served to reaffirm and provide more evidence for their belief that there was a mechanism other than classical genetics that determined what would be passed down through generations.

Using evidence from their discoveries, Pembrey and Bygren proposed that epigenetic mechanisms were at work. Epigenetics literally means "above genes" and describes the process of genes being turned on and off by certain molecules that attach to them.[6] "The stunning implication of the ALSPAC smoking data and the Överkalix data was that some important epigenetic marks that impact human health might not get wiped clear between generations, but might actually be passed down for multiple generations along with genes."[7]

Due to our long lifespan, there are few studies about transgenerational epigenetic inheritance within humans, but studies being conducted on animals involving epigenetics may reveal some information that can be applied to humans as well. One such study was conducted at Duke University. Researchers took pregnant Agouti mice, who carry the agouti gene which gives them yellow fur and a propensity for obesity and diabetes, and fed them a diet heavy in vitamin B and methyl donors (a methyl molecule is a common epigenetic mark, so the diet provided methyl molecules which were able to attach to genes and turn them off). When the methyl molecule attached to the agouti gene and shut it off, it led to the pregnant agouti mice giving birth to healthy, brown offspring, instead of offspring with typical agouti mouse health problems.[8] Another experiment was conducted where a group of fruit flies were exposed to antibiotic geldanamycin and developed bristly growths around their eyes, leading to the development of these growths on future generations that had never been exposed to the antibiotic. A third animal study looked specifically at behavior instead of physical features. Researchers took the offspring of mother rats who had been bred to be nervous and not nurturing and put them with mother rats who were bred to be calm and nurturing. They found that these adopted rats grew up to be more resilient to stress and to be calm and nurturing to their own offspring. Nurturing in the first few weeks of life permanently turned genes on and off in the rats' brains.[9] This showed that epigenetics are not only heritable through generations, but can also be modified by experience and change genetic expression during the lifetime of the organism.

With this newfound knowledge about epigenetics and the various ways they can impact us and our offspring, it is essential to understand how can we utilize this information to improve human lives. The most radical way of positively impacting our lives is through medical research: there are many studies and clinical trials that are taking place on epigenetic therapies for a variety of conditions. Histone deacetylase inhibitors and DNA methyltransferase inhibitors have been at the forefront of these approaches.[10] The majority of clinical trials so far have been in cancer research. However, this is starting to change: early clinical trials have begun for an inhibitor of the sirtuin class of histone deacetylases that could help with the inherited neurodegenerative disease

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[6] Epstein, D., & Epstein, D. (2015, December 16). How an 1836 Famine Altered the Genes of Children Born Decades Later.

[7] Epstein, D., & Epstein, D. (2015, December 16). How an 1836 Famine Altered the Genes of Children Born Decades Later.

[8] Moore, D. S. (2017). *Developing genome: An introduction to behavioral epigenetics*. Oxford University Press.

[9] Carey, N. (2013). *The epigenetics revolution: How modern biology is rewriting our understanding of genetics, disease, and inheritance*. Columbia University Press.

[10] Carey, N. (2013). *The epigenetics revolution: How modern biology is rewriting our understanding of genetics, disease, and inheritance*. Columbia University Press, 308

Huntington's. The development of pharmaceuticals that inhibit more focused epigenetic enzymes was one of the biggest developments as of 2013.[11]

The issue with medications that interfere with the epigenetic process is our inability to know if they will also affect the normal reprogramming that naturally occurs during the production of germ cells. This means that the use of these drugs could result in physiological changes that do not just affect the person they are administered to, but also their offspring and their offspring's offspring. This risk factor may lead to an insistence of transgenerational studies before epigenetic drugs are released to the public. While this might seem like the safest approach to these new drugs, it also means abandoning people living with debilitating pain and illness while we wait for the results of the transgenerational studies to arrive, which would take at least a generation. This raises the question: do we as a society push forward on using drugs that would have positive effects in the short term but have unknown long term effects, or do we keep these drugs out of circulation until we know they are completely safe?

A slightly less radical use of our knowledge on epigenetics is its application within the study of nutrition. We are in the midst of a global obesity epidemic that does not seem likely to change any time soon.[12] Even if our societies can begin to reduce the current obesity rate, we have already adversely affected the future generations. Bygren's study in Overkalix proved that the grandchildren of men who experienced a feast season just before puberty were more likely to have diabetes. The world contains entire generations of men who are experiencing these "feast season" conditions which will then be passed down through epigenetics to their grandsons. "There are now more obese than underweight adults in the world."[13] The study of epigenetics and obesity reduction is especially important when considering that obesity is greatly affected by socioeconomic status:

> "NHANES data for 2011-14 indicated that in homes where the head of household was a college graduate, 9.6 percent of children ages 2-19 had obesity, whereas in homes where the head of household was a high school graduate or less, 21.6 percent of children had obesity. Childhood obesity also varied by household income level, according to the same NHANES data. In low- and middle-income households, child obesity rates ranged between 18.9 percent and 19.9 percent. In higher-income households, 10.9 percent of children had obesity."[14]

These low income and low education children, specifically boys, are experiencing constant "feast" seasons which to increased health risks for themselves and their offspring. Not only are there differences between class and income, there are also striking racial and ethnic disparities: "Obesity rates are higher among Latino children (25.8%) and Black children (22.0%) than among White children (14.1%) and Asian children (11.0%). Latino boys (28.0%) and Black girls (25.1%) are most likely to have obesity."[15] Boys of color are much more likely to be obese at an early age, in other words to experience feast seasons as their sperm is developing. As Bygren discovered, this will lead to a shortened lifespan and more health risks for their offspring. An understanding of

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[11] Carey, N. (2013). *The epigenetics revolution: How modern biology is rewriting our understanding of genetics, disease, and inheritance*. Columbia University Press, 308

[12] Pelletier, K. R., & Weil, A. (2019). *Change your genes, change your life: Creating optimal health with the new science of epigenetics*. Origin Press.

[13] Pelletier, K. R., & Weil, A. (2019). *Change your genes, change your life: Creating optimal health with the new science of epigenetics*. Origin Press.

[14] Devitt, Michael. "New Report Shows U.S. Obesity Epidemic Continues to Worsen." *AAFP Home*, 15 Oct. 2018.

[15] "Childhood Obesity Trends." *The State of Obesity*.

epigenetics gives us scientific proof that the disadvantages that minority groups face now will have long term health effects on their children, perpetuating their marginalized status for future generations.

The increased obesity among at-risk communities is largely because of food giants like Nestle who are taking advantage of low-income individuals and peddling cheap filling food. Their impact is no longer just within the USA: "Sales of ultra-processed foods have more than doubled over the last decade — even spreading into developing countries".[16] A *New York Times* article written in 2017 discusses the impacts that Nestle is having on Brazil, controlling door-to-door vendors in the far flung reaches of the country and delivering large amounts of cheap packaged food to communities in Brazil. [17] This interference is not specific to Brazil: large corporations are upending traditional diets through packaged food all over the world. There are soaring rates of obesity in places that struggled with malnutrition only a generation ago. The knowledge we now have about epigenetics and our eating habits effects on our offspring makes it all the more important to fight back against these massive corporations to save our rapidly growing global population.

We have known for years that controlling your diet and eating healthy will have positive impacts on your health, but now we know that it will also have positive impacts on your future offspring. This discovery reveals that it is now more important than ever to lead a healthy lifestyle, eat well, exercise, and abstain from smoking and drug use -- if not for yourself, then for your children.

However, it is also important to understand that human development is not deterministic. Many experiences throughout life contribute to your phenotypes, and we cannot pin them all on childhood experiences. This is a double edged sword. On the one hand, it means that a parent's risky behaviors are not guaranteed to lead their children to a life of addiction and obesity, but on the other hand, it also means that even the most perfectly executed prenatal program of healthy habits cannot ensure smart, healthy, happy lives.

We can't change the actions of our ancestors, but it is imperative that the human race begins to take care of itself. After all, today's choices may have a paramount genetic impact on tomorrow's children. It is important to carefully weigh whether or not the short term benefits of medically interfering with epigenetics outweigh the unknown long term effects on future generations. We are entering a crossroads where we must decide whether to prioritize the wellbeing of our current population or the safety of our future one. It is important to think about how the negative impacts that we now know of are likely to be most common in minorities. The outcome of epigenetics, for now, remains uncertain.

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[17] Jacobs, Andrew, and Matt Richtel. "How Big Business Got Brazil Hooked on Junk Food." *The New York Times*, The New York Times, 16 Sept. 2017,

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