1 Genethics

Genes and their interactions with the environment are omnipresent in every aspect of society. The number of hairs on someone's head, a person's sexual characteristics, and deciding what to order at McDonald's (even if that decision is "eww, nothing"): genes. How a parent treats their child, how that child treats other kids at school, and how government leaders interact with one another: genes. Performance variation among professional athletes, an individual's susceptibility to Alzheimer's, and human skin color: genes. A worldwide viral pandemic, a mRNA vaccine, and pathogen drug resistance: genes. The imminent extinction of the Yangtze river dolphin, the invasion of non-native cheat grass to the American Southwest, and the resurrection of the wooly mammoth: genes.

Application of genetics to aspects of human society, such as those described in the complex scenarios above, is controversial. For some of the scenarios, simply the notion of genetic contribution is controversial. For others, the controversy comes from humans using knowledge of genetics to affect change. The scientifically literate that have been educated in principles of genetics (*cough cough* – ***you***) bear the responsibility of developing informed opinions on what is right and what is wrong (along with helping others avoid the traps of misinformation). In this final unit we will examine some of the current and past ways genetics integrates with society.

2 Why genethics matters: A case study of eugenics

From 1935-1945 the murders of over 10 million people in Eurasia was rationalized using principles of genetics. The Holocaust was founded upon the twisted idea that the genes of some people should cease to exist– a principle known as **eugenics**.

2.1 Origins of eugenics

The English scientist Francis Galton, Charles Darwin's first cousin, originally coined the term in 1883 (when Mendelian genetics was still unknown by science). The term "eugenics" predates "genetics". The term "eugenics" comes from the Greek "eu-" (good) and "-genos" (birth), and the idea proposed that society would benefit if people with "undesirable" traits ceased to reproduce and if people with "desirable" traits reproduced more. The traits of focus included intelligence, morality, and skin color. The idea was rooted in racism and bigotry from its onset; Galton was repulsed by other cultures during his world travels. Once the principles of heredity were re-discovered in the early 1900s, Galton and others were quick to apply it to their eugenics agenda.

The idea of eugenics may have began in Great Britain, but the United States is guilty of applying it to its people. In 1910 the Eugenics Record Office (ERO) was opened, which was a center supported by influential individuals and organizations including the Rockefeller, Kellogg, and Carnegie families. The center, led by biologist Charles Davenport, focused on promoting negative eugenics (which focuses on inhibiting the "unfit" from reproducing) and positive eugenics (which focuses on encouraging the "fit" to reproduce). The center played an integral role in the legalization of using undesirable traits to enforce non-consensual sterilization, marriage restrictions, and immigration controls in the United States.

Harry Laughlin, director of the ERO, published a book in 1922 called *Eugenical Sterilization in the United States*. By 1924, 15 states had laws allowing forced sterilizations. Here is a textual sample from one of these laws (slightly paraphrased from the Virginia Sterilization Act of 1924):

> *Whereas, human experience has demonstrated that heredity plays an important part in the transmission of sanity, idiocy, imbecility, epilepsy, and crime, now, therefore... whenever the superintendent of (list of hospitals) shall be of opinion that it is for the best interests of the patients and of society that any inmate of the institution under his care should be sexually sterilized, such superintendent is hereby authorized to perform the operation of sterilization on any such patient afflicted with hereditary forms of insanity that are recurrent, idiocy, imbecility, feeble-mindedness, or epilepsy.*

In 1927 these laws were put to the test, when a case called **Buck vs Bell** reached the Supreme Court of the United States. Carrie Buck, a 17 yr old foster child, had been institutionalized for being an unwed teenage mother (after having been raped by her foster brother). Carrie's daughter Vivian was taken from her at two months of age, and Carrie's mother was also institutionalized for "feeble-mindedness". Albert Priddy, a physician and proud supporter of eugenics, claimed that three generations of inherited feeblemindedness and low intelligence was sufficient evidence to support the sterilization of Carrie and Vivan. However, he had to prove that her infant daughter also exhibited signs of low intelligence. Although Vivian showed no evidence of "feeblemindedness", Priddy's hired social worker that observed the infant said that she was "peculiar" and "not quite normal". This led to the upholding of the law, allowing the forced sterilization of Carrie. "Three generations of imbecility is enough" read the official ruling. Vivian would go on to be an honors student in first grade before dying at age 8 in the same foster home where Carrie had been abused.

Eugenics was seen as a progressive movement during the early 1900s, and it was supported by many scientists and society leaders (including Theodore Roosevelt, Alexander Graham Bell, Hellen Keller, H.G. Wells, Winston Churchill, Francis Crick, James Watson, Kelly Miller, and Woodrow Wilson). In fact, eugenics was so prominent among geneticists that I'd say "eugenics" and "genetics" were almost synonymous during this time period (because almost everyone studying genetics had a vested interest in the eugenics movement). However, there were some that opposed the movement– including the man who coined the term "genetics" itself. William Bateson, who saw no evidence that traits such as mental defectiveness were Mendelian in nature, recognized that eugenics disproportionately targeted vulnerable groups of diverse identities. He also felt uneasy about the idea of applying basic principles learned in a controlled lab to the intricate, complex conditions found in society. He once stated:

> *"Genetics are not primarily concerned with the betterment of the human race or other applications, but with a problem of pure physiology, and I am a little afraid that the distinctness of our aims may be obscured. Alliances between pure and applied science are as dangerous as those of spiders, in which the fertilizing partner is apt to be absorbed"* - William Bateson

Thomas Hunt Morgan, the genetics pioneer who led major breakthroughs in discovering sex chromosomes, gene mapping, and recombination, was also disturbed by the eugenics movement. Despite working at the ERO at one point, Morgan later became an open critic of eugenics. He claimed that eugenicists failed to define their targeted traits (e.g., "feeble-mindedness", and without a definition the genetic basis of the traits was impossible to determine (how do you

find the genetic basis of something you can't even define?). Morgan argued that even if a trait persisted over many generations, it could be due to environmental conditions rather than genetic variation. He suggested that social reform, rather than genetic manipulation, would be more effective at changing behavioral traits in society.

Despite the opposition of these prominent geneticists, eugenics moved forward. By 1931, 30 states had sterilization laws. Numerous fairs promoted the principles of eugenics by having "Fitter Family Contests" where families could submit a a genealogical history of their families health and stand in front of judges where medical doctors would perform psychological and physical exams, the family with the highest "eugenic health" score receiving a trophy. Exhibits at fairs incited fears of miscegenation and "racial swamping" (where one race would spread and eventually displace another). The implementation of Compulsory Sterilization Laws in the United States led to the forced sterilization of at least 70,000 people from 1907–2008.

2.2 Nazi eugenics

While the eugenics movement was prominent in the United States, it also gained popularity in Germany where scientists and physicians were receiving literature sent to them by American eugenicists. Harry Laughlin was happy to share that his work had been applied in the 1935 Nuremberg Racial Hygiene laws, which made marriage and sexual intercourse between Jews and "Aryan" Germans. Laughlin, who was awarded an honorary doctorate by an institution after they purged Jews from their faculty, saw "common understanding of German and American scientists in the nature of eugenics." Adolf Hitler referred to *The Passing of the Great Race*, an American eugenics book, as his "bible". Hitler was quoted saying:

> "It is possible to a large extent to prevent unhealthy and severely handicapped beings from coming into the world. I have studied with interest the laws of several American states concerning prevention of reproduction by people whose progeny would, in all probability, be of no value or be injurious to the racial stock."

Inspired by the implementation of eugenics literature and practices in the United States, Hitler led the genocide of millions of people based on perceived traits. In his book *Mein Kampf* he states "The demand that defective people be prevented from propagating equally defective offspring is a demand of clearest reason and, if systematically executed, represents the most humane act of mankind." The term "Lebensunwertes Leben," meaning "life unworthy of life," was used to justify the systematic extermination of millions of people considered undesirable, including Jews, Romani people, disabled individuals, and others perceived as threats to the "purity of the Aryan race".

For the first 10 years of Hitler's tyranny, many eugenicists in the United States praised him. The superintendent of Virginia's Western State Hospital stated in a newspaper interview that "The Germans are beating us at our own game." Hitler and his Nazi scientist subordinates consulted American eugenicists about their practices of racial hygiene during this time. One eugenicist, after visiting Nazi Germany and seeing their eugenics in practice, said that "Everywhere I sensed that their opinions have been tremendously stimulated by American thought."

Although the majority of the United States eventually saw the horror of the Holocaust (causing the closure of the Eugenics Record Office in 1939), the objective of eugenics was not rooted out of society as a whole. Forced sterilizations continued throughout the 20th century. The

ramifications of the eugenics movement still haunt the United States. In 2023 the American Society of Human Genetics published a report titled "Facing Our History– Building an Equitable Future" where they apologized for the role former society leaders played in promoting the practice of eugenics.

2.3 Why eugenics is wrong: scientifically and morally

2.3.1 Scientifically wrong

Eugenics fails to recognize environmental influence on traits (phenotypic plasticity), gene-by-environment interactions (where an environment has a different phenotypic effect depending on the genotype), and gene-by-gene interactions (epistasis; polygenic traits). Many human traits are complex, and treating a complex trait as Mendelian (which is exactly what eugenics seeks to do) is an extremely flawed scientific approach that simply will not work.

2.3.2 Morally wrong

Eugenics targets oppressed groups (including minority, disabled, vulnerable, and poor), invokes harmful action on people without their consent (e.g., sterilization or death), and provides no clear definition as to what traits are "deleterious" to an individual or a population (and in many cases fails to define these traits at all).

2.4 A warning against the misuse of science and the importance of ethical principles

The twisted application of scientific principles by eugenicists highlights the dangerous consequences of unchecked power in the hands of those who harbor racist and bigoted ideologies. It demonstrates the need for ethical considerations when applying scientific knowledge to societal issues. The belief in racial superiority and the dehumanization of specific groups led to immense suffering and loss of life during the Holocaust. This historical lesson serves as a stark reminder that science must always be guided by ethical principles and a commitment to the well-being and dignity of all individuals.

Today, the legacy of the American Eugenics Movement and its link to the Holocaust serves as a warning against the misuse of scientific knowledge to justify discrimination and violence. It emphasizes the importance of rigorous ethical review in scientific research and the need for responsible dissemination of knowledge. Society must learn from this period in history and strive to ensure that scientific advancements are used to promote equality, justice, and the betterment of humanity, rather than to perpetuate prejudice and oppression. By learning from the mistakes of the past, we can build a more compassionate and inclusive future.

3 Including ethics in societal applications of genetics

Eugenics stands as a cautionary example of the potential dangers of applying genetics to society without ethical considerations. The historical misuse of eugenics, driven by racist and prejudiced ideologies, led to grave violations of human rights and immense suffering. However, it is crucial to recognize that ethical application of genetics can offer tremendous benefits to humans and

other organisms. Through responsible genetic research and interventions, we can revolutionize healthcare, agriculture, conservation, and forensic science, enhancing human well-being and environmental sustainability. To ensure that genetic tools are used ethically and responsibly, decisions on their approval and regulation should be made collaboratively by scientists, ethicists, policymakers, and informed individuals from diverse backgrounds. Open dialogue, rigorous ethical review, and transparent governance are essential to safeguard against the potential misuses of genetic technologies and to steer our society towards a future that embraces the immense promise of genetics while respecting the dignity and rights of all.

3.1 Genethics topics, corresponding literature, and case study

- **Prenatal Screening**
- Majumder_2021 `https://doi.org/10.1136/medethics-2019-105675`
  - Francine and Marcus are considering in vitro fertilization (IVF) to conceive a child due to difficulties with natural conception. They have financial means and access to preimplantation genetic testing (PGT), which allows them to screen embryos for genetic disorders before implantation. The couple is carriers for a genetic disease with mild health implications for their offspring. They face the decision of selecting embryos that are not carriers of the genetic condition, potentially ensuring a healthy child.
- **Personal Health Screening**
  - Bunnik_2020 `https://doi.org/10.1146/annurev-med-070119-114727`
  - Jacob has financial resources for genomic sequencing, and he purchases a genomic test indicating a predisposition to a hereditary disease that may/may not be treated by pharmaceutical and/or lifestyle changes.
- **Human Gene editing**
  - Almeida_2022 `https://doi.org/10.1057/s41599-022-01147-y`
  - Policymakers are considering whether to approve CRISPR-based gene editing technology to treat a debilitating genetic disease by modifying the nucleotide sequence of a gene.
- **Agricultural GMOs**
  - Zhu_2020 `https://doi.org/10.1038/s41580-020-00288-9`
  - Evanega_2022 `https://doi.org/10.1080/21645698.2022.2051243`
  - Agricultural policymakers are considering the adoption of genetically modified organisms (GMOs) to enhance crop production and address food security challenges.
- **Pest/Vector/Pathogen control**
  - Legros_2021 `https://doi.org/10.1111/eva.13285`
  - deGraeff_2021 `https://doi.org/10.1186/s12910-021-00588-5`
  - A region is grappling with a severe mosquito-borne disease outbreak, and policymakers propose using a CRISPR gene drive to push the mosquito population to extinction.
- **De-extinction**

  - Lean_2020 https://doi.org/10.1007/s10806-020-09839-8
  - Katz_2022 https://doi.org/10.1080/21550085.2022.2071550
  - Entrepreneurs are exploring the possibility of using genetic technology to bring back the woolly mammoth for ecological restoration purposes, such as populating a "Cenozoic Park".

- **Genetic Privacy**
  - Bonomi_2020 https://doi.org/10.1038/s41588-020-0651-0
  - A company offers direct-to-consumer genetic testing services, and individuals are faced with the decision of whether to share their genetic data for research purposes.

- **Genetic Ownership**
  - Klitzman_2022 https://doi.org/10.1016/j.tibtech.2022.02.009
  - A pharmaceutical company discovers a promising drug candidate based on the genetic material of an individual who unknowingly contributed to a biobank.