Tech for Humanity Case Studies

Your Genes Say No

> *"But what *is* "natural"? I wonder. On one hand: variation, mutation, change, inconstancy, divisibility, flux. And on the other: constancy, permanence, indivisibility, fidelity. Bhed. Abhed. It should hardly surprise us that DNA, the molecule of contradictions, encodes an organism of contradictions. We seek constancy in heredity—and find its opposite: variation. Mutants are necessary to maintain the essence of our selves. Our genome has negotiated a fragile balance between counterpoised forces, pairing strand with opposing strand, mixing past and future, pitting memory against desire. It is the most human of all things that we possess. Its stewardship may be the ultimate test of knowledge and discernment for our species. "*
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> *— Siddhartha Mukherjee, The Gene: An Intimate History*

William was like many other boys. He liked sports, video games, going to the swimming pool, watching movies, reading spy novels, and dating girls. He had spent most of his youth just like any other child, dreaming about the future. From the time he was little until when he was a senior in high school, he wanted to be an engineer. He wanted to solve problems. In particular, he wanted to be a NASA engineer and develop technologies to explore space. He had known since he was a child that he himself could never be an astronaut. He could never board a Starship by Space X and travel to the Lunar colonies first built in 2030. He knew this because when he was only 5 years old, he had been identified as having a predisposition to Type 1 Diabetes (T1D) after a government mandated genetic test to enter public school. The tests were designed to help address and head off a broad array of medical issues prior to children entering school in the late 2020s.

A wave of student athlete heart failures during athletic events, rising concerns over Autism, Attention Deficit/Hyperactivity Disorder, and a bevy of other genetic abnormalities resulted in the national genetic testing act of 2027 which made it possible (but optional) for parents to get free testing for their children at any age. By 2031 New York State had begun to mandate that all children receive genetic testing. This allowed the state to budget health care and special needs expenses years in advance and lock in funding for schools and programs. Despite some push back within disability rights, and other communities the program began to spread to other states.

William's father, Oliver, a T1D himself, wanted to head off issues with T1D and saw promise in Tzield a vaccine that could delay the onset of T1D. When he was tested in 2031 prior to entering Kindergarten William's genetic tests indicated that he had variations of the HLA-DQA1 and HLA-DQ81 genes indicating a predisposition to T1D. William himself had not become diabetic, but his genetic predisposition to diabetes had imposed multiple restrictions on his life. He was prohibited

from joining the U.S. Military, he wasn't allowed to be a commercial truck driver, and he wasn't allowed to be a commercial pilot. All the restrictions associated with being a T1D applied to him as an individual predisposed to the disease.
The roots of genetic testing date back to the start of the Human Genome Project started in 1990 with the goal of mapping the entire human genome within 13 years. Working with thousands of scientists over a period of 13 years the first complete human genome was sequenced without gaps by 2002 at a cost of $2.7 billion. By 2023 a complete human genome could be sequenced in approximately 5 hours and cost less than $2,000. By the time of the national genetic testing act of 2027 a full human genome could be sequenced in about 2 hours and cost less than $1,000. When William had his genome sequenced in 2031 his full genome took 1 hour to sequence and cost $500. The trajectory of genetic testing for diseases of all kinds rapidly increased the efficiency of genetic testing and opened the process up to nearly everyone in the country.

The Genetic Testing Act combined with a revision to the 2001 Health Records Act in 2026 created the basis for an enormous training database for artificial intelligence algorithms. The 2028 Health Records Anonymization and Transparency Act paved the way for all patient records from providers to contribute to a national health information database. This database created a longitudinal national dataset that included a wealth of health data on millions of Americans over time. Health companies began to combine health records and genetics data over time to create new health care solutions tailored to individual patients. Yet the AIs could also be used by health insurance providers to set tailored rates based on individual predispositions to genetic diseases or other potential health risks.

Health AIs had been evolving since the early 2000s. IBM had released a health-related version of its Watson AI, but the AI was found to be extremely inaccurate. Despite early failures in health AIs the industry did not decline and continued to generate significant interest. Increasing research into bioinformatics over the intervening years began to foster an increasingly robust understanding of genetics and further informed AI model development. Yet concerns remained as to the efficacy of using AIs to influence individual futures.

Despite having a genetic predisposition to T1D, by the time William graduated from college he was still not diabetic. Yet because of his predisposition to a genetic disease his potential health insurance premiums were higher than those of others. As a result, when he would apply for jobs AI algorithms would search his health and criminal records and potential employers would either not offer him a position or would offer him a lower annual salary to offset his higher medical insurance premiums.

Unable to secure his dream job after graduating from college William went back to school to get a Master's degree and a Doctoral degree in mechanical engineering and astrophysics. He excelled at everything he did. When he went back on the market again after completing his degrees, he was again offered lower salaries by the private sector in an effort undertaken by firms to offset

his medical insurance premiums. Despite never developing a diabetes he was nonetheless continually penalized for having a genetic predisposition to the disease.

He was eventually hired by the National Aeronautics and Space Administration. In tandem with its passage of the 2027 National Genetics Testing Act the U.S. government had passed legislation prohibiting discrimination in remuneration or hiring decisions for most non-military or flight restricted jobs for those with genetic predispositions to disease. He eventually secured his dream job working on space related projects and he never developed diabetes. Despite never becoming a T1D he continued to run into problems associated with his genetic predisposition to the disease over his lifetime. He was unable to secure affordable rates on life insurance and disability insurance. His car insurance company charged him a higher rate due to the potential of developing diabetes and correlations between diabetes and car accidents.

But what most hurt William was the inability to have natural children with his future wife. Together they discussed the possibility of having children without genetic engineering intervention but because of his predisposition to diabetes they decided to go to a genetic engineering fertility clinic. At this clinic they sequenced the genes of the sperm and eggs and were able to edit out genetic issues prior to implantation. While both recognized that the child they had was biologically theirs there was something odd about having to genetically modify their sperm and eggs to prevent all genetic predispositions to disease.

The story above is science fiction. It includes elements of biology, artificial intelligence, health sciences and insurance markets, discrimination, and more. This same story is a commonly told story in different forms within the science fiction community. One of the most famous tellings of this story arose in a 1997 movie titled *Gattaca* staring Ethan Hawke and Uma Thurman. The story tells the tale of a natural born child who is prohibited from the career of his choice based on his genes. His brother by contrast is a genetically engineered child who is given every opportunity. The tale explores the moral and ethical considerations associated with genetic engineering. The movie ends with Ethan Hawke's character achieving his goal of becoming an astronaut by deceiving the testing mechanisms after entering a deal with another person to use their blood and identity.

The question remains as to the realism of the story. This story is highly conservative in its assessment of genetic testing and its costs. Many gene sequencers can run dozens of sequences in parallel at the same time thereby lowering the cost associated with genetic testing for multiple individuals. The trajectory of gene sequencing has been astounding. The ability to sequence the human genome in a matter of hours is a reality. Discussions over using genetic testing and insurance or employment discrimination are well-worn paths of research within the global health community. The increasing use of AI in health care is similarly an area of increasing interest and concern for healthcare providers and patients alike. AI is already used in biomedical devices such as artificial pancreas systems, pacemakers, implantable defibrillators, biventricular pacemakers,

and more. AI is also being used in tandem with large models to identify disease or other issues in fields such as radiology.

As particular technologies advance, they often are integrated with other types of technology to create new realities that shape the way we view and interact with the world. Being able to engage with complex topics across a range of integrated concepts is key to heading off problems before they arise. Below are a series of questions that examine the various issues raised in the case example above.

Question 1:
The case study above sets up a scenario whereby the federal government makes it possible for anyone and everyone to have their genome sequenced. As the technology becomes increasingly affordable the relative cost of sequencing the genomes of every single patient in a medical practice is likely to move closer to reality. Information from such sequences might provide patients and their physicians with data that could lead to longer, healthier lives. Should the government consider providing or making gene sequencing available to the public as the relative costs go down? What are the benefits of knowing what your genes say about you and your health?

Question 2:
The case study above builds on the provision of access to gene sequencing with the requirement of gene sequencing by states. The logic behind this mandate is similar to the mandate for vaccinations. The State of New York in the case above is attempting to understand in advance the costs associated with its citizens and school programs as far in advance as possible so that it can plan our resources and budgets to ensure that is best meets the needs of its citizens. By knowing in advance the likely medical care and schooling costs for children it can make sure that it has enough teachers for special education programs hired and trained years in advance of them becoming necessary. Such information might allow for tailored educational practices that might better prepare students for lives with certain types of disease. It is also likely to prevent or mitigate potential death or illness such as genetic issues within a child's heart that might make it dangerous for them to play a particular sport. If it becomes cost effective what are some of the benefits and drawbacks of mandating genetic sequencing of citizens? Should states be allowed to require such tests for children to play certain sports such as football or basketball? Would genetic sequencing really allow schools or the state to plan and budget more effectively in advance? Is this a valid concern?

Question 3:
The United States began requiring digital health records shortly after the passage of the Digital Health Records Act of 2001. The data collected under this law often forms the basis for research on health-related issues within various regions and health systems. The data in these research studies is always anonymized. The data is often used to identify trends in health care and to plan

out health care investments and policies. Such data could also be useful as a training dataset for large health models used to train artificial intelligence. By combining health data from hospitals and practitioners these models could increase in accuracy and help patients to understand how their genes correlate to potential health outcomes. Yet the combination of data often removes the humanity in the relationship between the patient and the physician and turns the patient into a series of data points. These data points can drive patient and provider interactions. Should AI, data from practices, and genome data be combined? What are the potential consequences of such combinations? What are your thoughts on the use of data to drive health care decisions? Does it obviate the art of medicine in favor of sterile patient – physician interactions? Would you as a patient like a physician driven exclusively by data or to be more informed by the 'art of medicine?

Question 4: One of the issues raised in the case above are all the restrictions placed on someone with a predisposition to T1D. Yet all these same restrictions are already imposed on individuals with T1D. Even with modern biomedical devices such as the artificial pancreas system individuals with T1D cannot join the military, fly commercial planes, and be truck drivers. Laws and genes can be restricting. Yet what about when genes say no before they manifest into a disease or a condition? Should student athletes who have a potential for genetic issues with their heart be prevented from participating in certain sports? Should individuals predisposed to T1D be prevented from becoming pilots or astronauts? What if these predispositions are predicated on data derived from large models of data and analyzed by artificial intelligence? Should algorithms and data determine our fate based on probabilities of future health maladies residing in our genes?

Question 5: The case above discusses the resultant discrimination arising from gene sequencing. Private firms and insurance companies are in the business of maximizing revenue and minimizing costs. Firms regularly use data to direct business interactions across supply chains, investment decisions and more. An insurance company that has information indicating a potential client has or might have a medical condition is likely to result in that person being charged a different rate than other similar individuals. Similarly, because private firms must pay a large portion of their employee's health insurance premiums, they are also likely to bear part of the financial burden for bringing in an employee whose medical needs might result in a higher health insurance premium. In the case above firms solved the higher costs issue in different ways. First, they denied an offer without stating why to the individual seeking the position. This would be illegal under U.S. Federal Law which prohibits employment discrimination:

> *The EEOC is responsible for protecting you from one type of discrimination - employment discrimination because of your race, color, religion, sex (including pregnancy, gender identity, and sexual orientation), national origin, disability, age (age 40 or older), or genetic information.*

Identifying this type of discrimination is difficult. It is equally difficult to prove discrimination. The second type of discrimination used by employers in the case was differential pay between individuals with and without predispositions to genetic disease. Again, the Equal Employment Opportunity Commission (EEOC) would define paying someone differently based on their genetic information a form of discrimination. Although both types of discrimination are illegal. EEOC claims are not uncommon and annual claims of EEOC violations typically exceed 60,000 per year. Differential rates for health insurance are also prohibited under The Genetic Information Nondiscrimination Act of 2008. Title 1 states:

> *Prohibits a group health plan from requesting, requiring, or purchasing genetic information: (1) for underwriting purposes; or (2) with respect to any individual prior to such individual's enrollment in connection with such enrollment (provides that incidentally obtains such information is not a violation).*

Although these practices are illegal in health insurance and employment practice, they are not illegal in other forms of insurance such as life insurance. It is also important to note that the laws the prohibit these forms of discrimination while on the book are difficult to enforce and have the potential to be amended given sufficient lobbying by industry groups. Why is discrimination based on genetic information immoral and unethical? Should firms be able to discriminate to increase market efficiency? Does it surprise you that laws are already on the books to prevent genetic discrimination? Are there area where discrimination should be allowed?

Question 6: Are we more than our genes or are we simply the product of genetic outcomes? At the heart of this story William suffers because his genes end of defining him and making his life more difficult. But what if genes aren't the whole story but only part of the story that when combined with lifestyle decisions and a host of other actions changes the relative impact of genes on our lives? What if there are some genetic conditions that are immutable and likely to significantly impact the quality of life or ability to function in society? Have you had a genetic test? How would you feel about the data in that test being used in studies, to help identify health issues, or perhaps alter your rates for insurance?

> *"The desire to categorize humans along racial lines, and the impulse to superpose attributes such as intelligence (or criminality, creativity, or violence) on those lines, illustrates a general theme concerning genetics and categorization. Like the English novel, or the face, say, the human genome can be lumped and split in a million different ways. But whether to split or lump, to categorize or synthesize, is a choice. ... The narrower the definition of the heritable feature or the trait, the more likely we will find a genetic locus for that*

trait, and the more likely we will find that the trait will segregate within some human sub-population."

— Siddhartha Mukherjee, The Gene: An Intimate History

"Biological determinism is a blight on science. It implies that the way things are is the way they must be. [...] This position is wrong, both empirically and morally."
— John Horgan Author of the End of Science: Facing the Limits of Knowledge in the Twilight of the Scientific Age

Reflecting on your Genes Say No

There is little doubt the biological sciences have advanced in awesome ways over the last several decades. Progress in genetic sequencing have paralleled advances in computational power and reduced the time it takes to analyze an entire genome from years to months, to weeks, to days, and now to hours. Concurrently the costs associated with that analysis have plummeted. Researchers around the world are now able to probe the mysteries of our genetic code and unlock many of its secrets. Frequently the unlocking of secrets is aided by algorithms and data. The impact of algorithms and data on the future of health, work, insurance, and much more is yet to be fully written. There are no doubt boundless opportunities for positive changes that might help humans live healthier and more fulfilling lives. Yet as technologies advance and work in concert it is increasingly important to ask tough questions. It becomes necessary to examine the human impacts not on populations of people, but on individuals. In the story above William is affected by what his genes supposedly say about him. He is barred or delayed from achieving some of his dreams. Although his genes tell a story, that story is not fully written. It says what may happen, not what will happen. Genetics can and does provide insight into many aspects of biological life, yet it doesn't always provide the correct answers or tell us what to do with that information. The story becomes increasingly complicated as data on genes and their impact on human biology and behavior are mixed with algorithms often constructed and run in black boxes and trained on data that contains its own biases and issues.

A move towards biological (genetic) determinism has often been a shortcut that oversimplifies the reality of life and leads to challenges of equality and accountability. Determinism is by its very nature also extremely dehumanizing as it removes human agency and substitutes in numbers. Breaking these three issues down is the subject of the final pages below.

Equality: Siddhartha Mukherjee in the quote above rightly identifies the all-too-common human desire to categorize and segment populations off from one another. For thousands of years, we have separated one another into groups based on beliefs on skin color, religion, geography or

any other identifiable attribute. There is a tendency to ascribe to genetics a sterile, cold hard fact-based reality. This should be avoided. While genetic information can help identify issues as they arise or might help head of potential health/medical issues before they become too serious, they should not substitute for the human behind the genetic code being analyzed. This is akin to judging an entire forest by the health of a blade of grass somewhere in its midst. Sometimes the information can be very valuable, but it is not more valuable than the whole living organism. Individuals can no sooner change their genes than they can alter their place of birth, their skin color, or any number of other features that have been used to categorize them. Genes may not give every person biological equity, but it is important that genes are not a determining factor in equality of opportunity. William should not be discriminated against based on something beyond his control. Only where a true concern arises should issues of access be considered. And then these concerns should be discussed with the relevant individuals and communities of interest. While type one diabetics can and do occasionally lose consciousness due to fluctuations in their blood glucose, individuals predisposed to T1D but not yet diabetic have no such concerns. To close off certain opportunities to them, or to discriminate against individuals regardless of diagnoses or predisposition undermines the equality of individuals without reason and based on potentialities rather than realities. There will be an increasing temptation to discriminate based on genetic information. As algorithms and information on the genome continue to shed light on medical conditions rooted in genes it will become tempting to declare that someone with gene j or gene k should not do x or should not have opportunity y. Such justifications might be rooted in good intentions, but they do not facilitate equality and they remove the humanity of individuals.

Accountability: There are several key accountability issues associated with genes, AI, and medical care. As science continues to unravel the mysteries of genes there will be a temptation to identify initial or even secondary and substantiated findings as the declarative moment of understanding. The pressures to declare the functions and interactions of genes will increase as AI algorithms and big data training sets over time begin to highlight correlations between genes, diseases, traits, and other attributes of human biology. Accountability can occur through peer review processes, but that is only possible if everything from data collection, to processing, to analysis are transparent and replicable. Accountability is a critical component of science. Hiding behind patents, methods, or other obtuse frameworks while still reporting on findings is not acceptable. It is equally important to admit something was wrong or disproved as it was to find it in the first place. In the case of William, the fact that he has a predisposition to T1D does not equate to him getting T1D. identifying a correlation between a gene and a disease is not the same as a gene causing a the disease. Correlation does not equal causation. There are likely many intervening factors. The field of science and technologies studies has established sound frameworks for holding the scientific community accountable. Combining the oversight of different communities is likely to increase accountability.

Dehumanization: Perhaps the most significant aspect of the case is the dehumanization and removal of individual agency from William. He is more than the simply his genetic code. By constraining his life to a reading of his genes he is turned from an individual with hopes and desires for the future into a problem that must be addressed by the medical fields. He is a T1D patient in waiting. He may not have it yet, but his genes say he might, therefore we must treat him as a patient now. There is a tendency to think that humans are biological computer codes written and executed without interference from the operator. Yet this biologically deterministic view is simply not true. While genes influence the resultant biology and that influence can be great or small, the individual can in many instances impact running of his or her code. Through exercise, food consumption, education, and a number of factors, the individual has partial sway over the code they have been given. Even where genetic indicators are clear, and signs of disease are imminent the code should not substitute for the person. Doctors do not treat gene sequences; they treat human beings.