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THE DARK SIDE OF GENETICS: ANALYZING THE PREDISPOSITION TO MURDER

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THE DARK SIDE OF GENETICS: ANALYZING THE PREDISPOSITION TO MURDER

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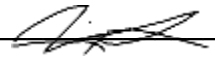

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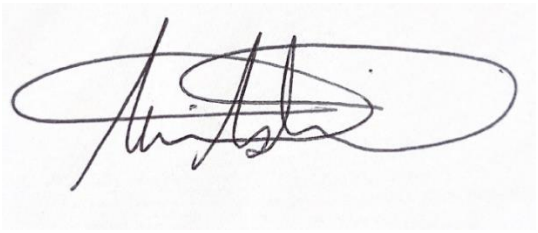

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ABSTRACT

Name: Isabella De Leon Major: Biology

The Dark Side of Genetics: Analyzing the Predisposition to Murder

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Violence is something we've all experienced to various degrees. Although murder is less common compared to other violent crimes, it nevertheless remains a devastating issue. It would be foolish to not allocate resources in search of a cure for murder. Modern genetics not only offers an answer, but a solution as well. What if we could identify murderers the day they were born? We have the technology to identify the genes (*MAOA* and *CDH13*) associated with murder, as well as the tools to edit them. There have been several movies and shows made regarding this theory, so why haven't we implemented it? Well, a major flaw remains. Our genes are not the only cause for murderous behavior and therefore cannot be used to predict violent behavior. Our behavior is a result of both environmental and genetic factors (nature and nurture). Additionally, the low activity *MAOA* variant associated with murder is present in 40% of the population. However, crime statistics state that the number of murderers in the United States is significantly less than 40%. This indicates that *MAOA* alone does not dictate murderous behavior. It would be both dangerous and ignorant to accept the belief that certain genes are linked to violent behavior.

INTRODUCTION

Violence has become a normalized phenomenon within the United States. Children and adolescents living in high-crime urban areas become psychologically desensitized from exposure to violence, which may decrease their immediate emotional distress but increases their propensity for violence (Ng-Mak et al., 2002). It's a vicious cycle that millions of individuals are currently enduring. In an effort to decrease violence, the United States has incarcerated so many individuals and that is has one of the largest incarceration rates compared to other developed countries (Widra & Herring, 2021). This is particularly interesting considering that the U.S. does not have the largest violent crime rates but does have the largest prison populations (Widra & Herring, 2021). In 2021, there were 1,221,200 individuals incarcerated in the United States (Carson, 2022). In 2019, there were 710,800 individuals incarcerated due to violent crimes, making up roughly 58% of the incarcerated population (Carson, 2021). Although there are many individuals currently incarcerated, our communities do not seem to feel significantly safer. Alarmingly, 64% of individuals who have committed a violent crime will reoffend again (Recidivism among Federal Violent Offenders, 2019). Perhaps violence is an integral skill in prison and a difficult habit to break once released, however, that is outside the scope of this thesis. Not only does this raise questions about the effectiveness of prison, but also safety concerns.

Violent crime is defined as an offense that includes the use, attempted use, or threatened use of violence against a person or property (18 U.S. Code § 16 - Crime of Violence Defined, 2018). This includes robbery, sexual assault, rape, assault and murder (National Institute of Justice, 2014). There are varying degrees of murder which are differentiated by premeditation and result. First degree murder is premeditated and intentional (Second Degree Murder, 2019).

Second degree murder is not premeditated, but it is intentional (Second Degree Murder, 2019). Third degree murder is neither premeditated nor intentional (Second Degree Murder, 2019). Additionally, there is also voluntary and involuntary manslaughter (Carlson, 2014). Voluntary manslaughter is intentionally killing someone out of passion or due to provocation (Carlson, 2014). Involuntary manslaughter is unintentionally killing someone due to negligence (Carlson, 2014). The act of intentional killing raises questions regarding individuals who commit these heinous acts. Are violent crimes committed by violent individuals? Are these individuals predisposed to violence through their genetics? Perhaps the nature vs. nurture dichotomy is too simplistic, and we may need to investigate other factors such as epigenetics.

Victims of violent crime are disproportionately minorities and individuals with a low socioeconomic status. Minority populations are disproportionately exposed to concentrated poverty, racism, limited educational opportunities, limited occupational opportunities, and other aspects of socioeconomic disadvantage contributing to violence (Sheats et al., 2018). Homicide is the leading cause of death for non-Hispanic black males from ages 1 – 44 (Sumner et al., 2015). Ultimately, young black individuals, compared to young white individuals, continue to be at a disproportionally higher risk for several forms of violence, leading to higher risks of both physical and mental harm (Sheats et al., 2018). A biopsychological analysis of violent crime may indicate how to reduce both the physical and mental effects of violent crime.

Violence not only affects individuals physically, but also mentally (Friborg et al., 2015). Exposure to violent events seems to affect individuals for long periods of time after the incident. Children who were physically abused are 54% more likely to develop depression and 32% more likely to become obese than those who were not abused (Sumner et al., 2015). Merely experiencing violence (physical, sexual, psychological) increases the risk of depression, post-

traumatic stress disorder, personality and conduct disorders, anxiety, sleep disorders, substance abuse, and suicide (Sumner et al., 2015). Exposure to violence can also lead to health problems later in life. Violence is associated with the development of major noncommunicable diseases such as cancer, cardiovascular disease, chronic lung disease, and diabetes (Sumner et al., 2015). It also increases the risk of harmful alcohol and tobacco use, physical inactivity, and obesity (Sumner et al., 2015). This further emphasizes the importance of analyzing the relationship between genetics and violent behavior. It could not only save lives but prolong them.

Unfortunately, violent crimes do not only affect the perpetrators and victims, but society as well. Community violence may scare individuals away from participating in neighborhood activities, lead to a decrease in business growth, and negatively affect the education of local children (CDC, 2022). In the United States, interpersonal violence has been linked to a decrease in economic growth and increase in inequality as certain populations are disproportionately affected by violence (Sumner et al., 2015). For example, homicide is the leading cause of death for non-Hispanic blacks (ages 1 through 44), but fifth leading cause of death for non-Hispanic whites in this age range (Sumner et al., 2015). Interpersonal violence is the leading cause of death in the United States among children, adolescents, and young adults (Sumner et al., 2015). There is also research which indicates that violent crimes may be influenced by changes in temperature. There seems to be an increase in violent crimes when individuals perceive the weather as being “hot” (Simister & Cooper, 2005). This is due to the human body generating adrenaline in response to excessive heat which keeps our body temperature within safe limits but may cause aggression as well (Simister & Cooper, 2005). Therefore, the effect of criminal activity goes beyond the victim and perpetrator. It affects the entire community, perhaps even

society as a whole. It is crucial that we better understand the relationship between genetics and criminal activity.

Are some individuals genetically predisposed to violence? Are there certain environments that are breeding these criminals? These questions spark conversations regarding the use of gene editing (ex. CRISPR) in an effort to decrease crime. However, the public seems to be divided, some favoring genetic determinism while others believe in complete free will. Genetic determinism states that our actions are pre-determined by our DNA, therefore diminishing free will (specific genotype always results in specific phenotype) (Resnik & Vorhaus, 2006). Regardless, it is extremely important to investigate the role of genes and criminal behavior, if not merely to better understand the psychology of criminals, then for public safety reasons as well. Misunderstanding and lack of knowledge is well understood to be a breeding ground for fear. This thesis will provide readers with the necessary scientific background to fully understand the influence of genetics on criminal activity. Additionally, if we try to better understand the psychology of criminals, perhaps we could prevent future crimes and ultimately decrease incarceration rates.

Ultimately, many people believe that *MAOA* and *CDH13* genes interact with environmental factors to create dangerous and violent individuals. Although they may increase the risk of violence in certain individuals through changes in brain chemistry, there is no exact combination of genetic and environmental factors which will create a murder. More specifically, there's no "recipe" or "checklist" which creates murderers. However, the spread of misinformation has fueled a growing fear among the public. It must be understood that we have autonomy over our genetics, and it should not be weaponized to discriminate against certain individuals. Additionally, it cannot be used to justify violent acts when processing individuals.

CHAPTER I: THE GENETICS OF HUMANS

Genetics is responsible for the development of every single cell in the body, directing the transformation from embryo to adult. Genetics is a broad term used to refer to the instruction manual for our body. The most basic unit of our genetics is a nucleotide, a chemical compound that is made up of a phosphate group, sugar, and a nitrogenous base (A, T, C, G, or U). DNA nucleotides have a deoxyribose sugar and A, **T**, C, or G. Meanwhile, RNA nucleotides have a ribose sugar and A, **U**, C, or G. Many nucleotides linked together are known as DNA or RNA. A DNA sequence that encodes a product is referred to as a gene. Many genes linked together with histones (positively charged proteins) create a specific conformation which results in a chromosome (Figure 1) (Lee et al., 2020). Each human has 23 pairs of chromosomes located in the nucleus of every single cell (Rushton, 2021). Two of these chromosomes (typically XX or XY) determine the sex of the individual, while the others are autosomal (Rushton, 2021). Chromosomes are inherited from our parents when the sperm (23 chromosomes) and egg (23 chromosomes) fuse to form a zygote (46 chromosomes, or 23 pairs of chromosomes). Male individuals inherit the Y chromosome from their father and X chromosome from their mother. Female individuals inherit an X chromosome from both their mother and father. Some individuals may have aneuploidy of their sex chromosomes (ex. XYY). There can also be aneuploidy of autosomal chromosomes (ex. Down Syndrome is characterized by three copies of chromosome 21, also known as trisomy 21).

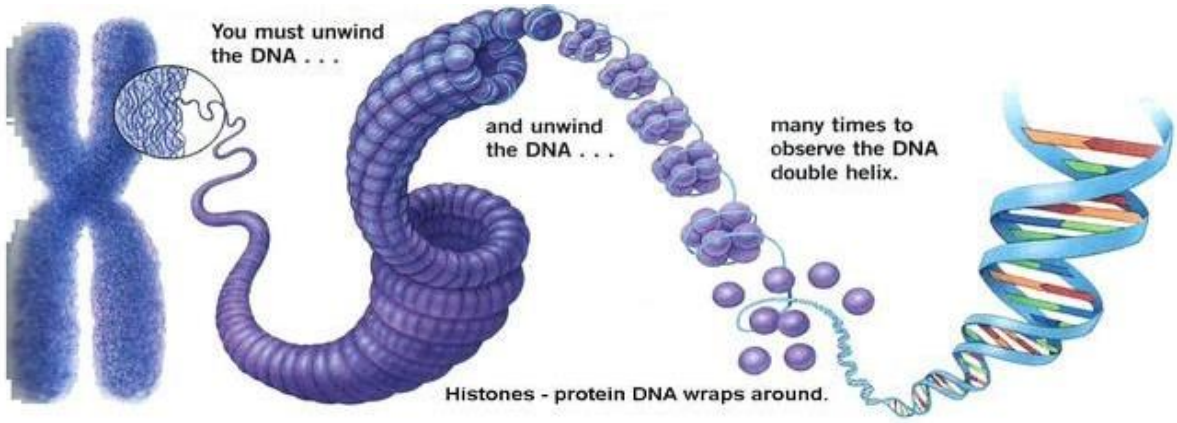

Figure 1: Chromosome Structure (Gibson 2021)

The majority of chromosomes are located in the nucleus of the cell, with the exception of mitochondrial chromosomes located in the mitochondria. DNA is transcribed into different types of RNA such as tRNA, rRNA, and mRNA. Once DNA is transcribed into mRNA it leaves the nucleus and enters the cytosol. The cytosol is a fluid filled space between the cell membrane and nucleus. Once in the cytosol, ribosomes will translate the mRNA into a polypeptide. Every three nucleotides are considered a codon, which codes for an amino acid. A polypeptide is a chain of amino acids. Polypeptides undergo posttranscriptional modification before ultimately becoming an active protein. These proteins can stay in the cell or get sent out to different parts of the body. Proteins perform many critical functions within the body. This includes the metabolism of neurotransmitters (Gordon & Greene, 2018).

Although we inherit our genetic material from our parents, this does not mean that it has always and will always stay the same. Epigenetics suggests that our ancestors' experiences led to gene expression changes that are still present generations later (Zimmet et al., 2018). This remains true even if individuals have a completely different lifestyle and environment than their earlier family members. Genetics can also change throughout an individual's lifetime. This

indicates that our own experience can shape our gene expression as well. DNA is constantly being replicated every time we make a new cell (DNA replication, n.d.). Essentially, DNA is the instruction manual for every single one of our cells. However, as new cells are created, mutations may arise that result in slight changes in the nucleotide sequence.

There are several types of mutations which differ in the degree to which they impact the protein created. Silent mutations will not influence the protein created. Essentially, the intended protein is still made despite the mutation. Silent mutations are point mutations (occur at a single nucleotide) when one base pair is exchanged for another but results in the same amino acid. For example, ACU codes for threonine but if a mutation results in the U changed to a C, it would still code for threonine (Figure 2).

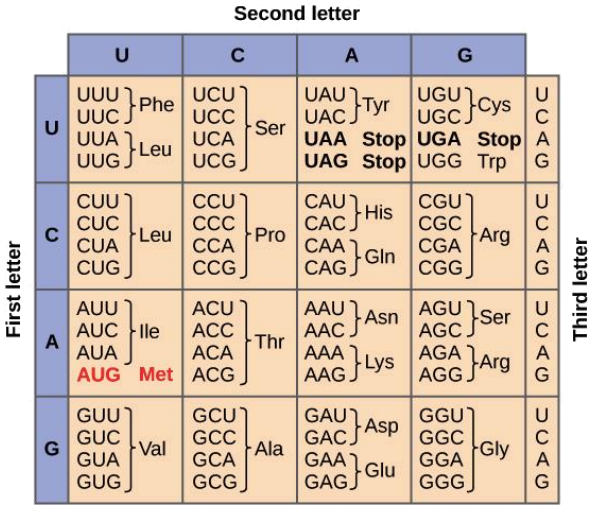

Figure 2: Codon Chart (Khan Academy, 2016)

Other point mutations include addition or deletion of a nucleotide (Biesecker, 2019) (Figure 3).

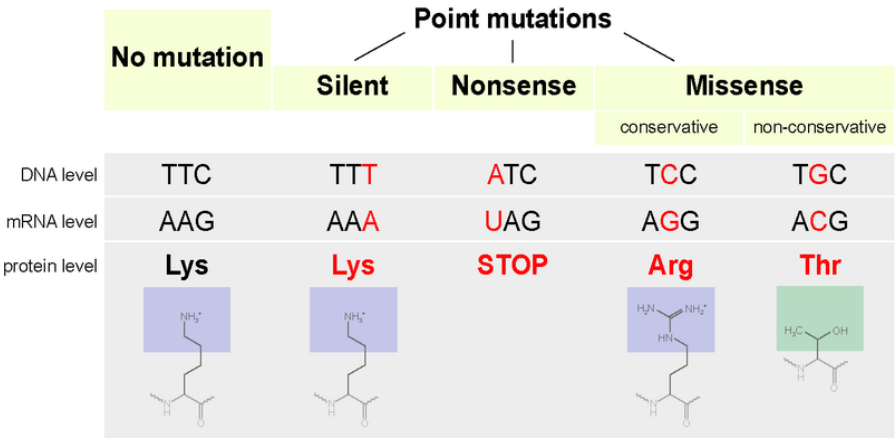

Figure 3: Types of Mutations (BD Editors, 2019)

These can either be missense mutations (if they code for a different amino acid) or nonsense mutations (code for a premature stop codon). Missense or nonsense mutations can be especially dangerous as they may result in a misshaped protein which cannot function properly. Some mutations can even be life-threatening, such as cancer-causing mutations (Rushton, 2021)

DNA is usually tightly wound around histones, which prevents other proteins from interacting with it. DNA can undergo posttranscriptional modification such as methylation or acetylation which effects access to the gene (Lee et al., 2020). More specifically, histone methylation decreases gene expression and is associated with transcriptional repression (Razin and Cedar, 1991). It's important to note that demethylation does the opposite of methylation, which means it increases gene expression. Meanwhile, histone acetylation increases gene expression (Lee et al., 2020). Deacetylation does the opposite of acetylation. Therefore, it decreases gene expression. After transcription occurs, RNA is cleaved into mRNA as the introns are removed (left in the nucleus) (Alberts et al., 2002). This further modifies the DNA and creates more combinations for the synthesis of proteins.

As mentioned before, we inherit our genes from our parents. However, genes and traits vary in their probability of being inherited (Robette et al., 2022). Traits are characteristics that result from certain genes (and environmental factors). There are also traits that are not inherited, but instead acquired by an individual during their lifetime (ex. physical wounds). An example of a highly heritable trait is IQ, with an inheritance probability of 80%. (Robette et al., 2022). Even if we inherit the same genes as our parent, they could be expressed differently and result in different traits (Grebe et al., 2021). Variable penetrance is the concept that individuals with the same genotype may or may not express the phenotype (Figure 4) (Coll et al., 2017). Variable expressivity is the concept that individuals with the genotype all express the phenotypes, but to varying degrees (Figure 4) (Coll et al., 2017). For example, if ten individuals have the genotype for blue hair, variable penetrance would indicate that only some of them have blue hair while the others do not. Variable expressivity would show that they all have blue hair, but different shades. However, heritability is not the only factor that contributes to our genetic material.

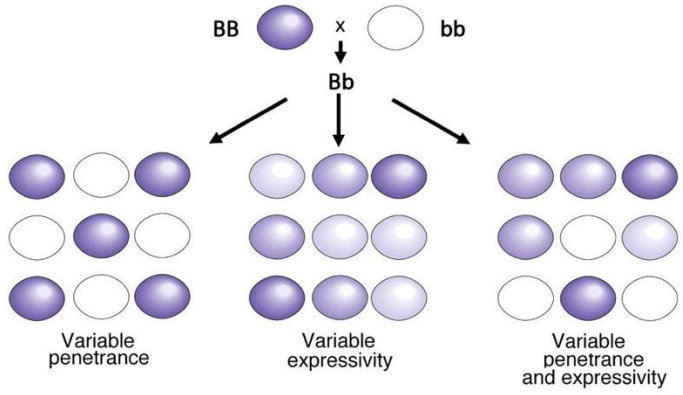

Figure 4: Variable Expressivity vs Penetrance (Penetrance vs Expressivity, n.d.)

Environmental factors are outside influences that may affect gene expression (Robette et al., 2022). Environmental factors are more commonly known as “nurture” in the phrase nature versus nurture. The nature aspect refers to the genes themselves. This is directly related to

criminology's labeling theory that states an individual's behavior is influenced by the label attached to them by society (Besemer et al., 2017). Therefore, an individual labeled as a dangerous criminal is more likely to behave as a dangerous criminal. Additionally, the environment may alter the genetic code that originally came from your parents. Examples of environmental factors include carcinogens, pollution, and sunlight which can put individuals at an increased risk for certain illnesses (Sara et al., 2023). These may increase mutations or turn on/off certain genes that result in different gene expression. Certain behaviors can influence genetics as well. More specifically, the way parents raise their children can alter their genetic expression (Maccoby, 2000). Therefore, the power of parents surpasses simple reward and punishment, but instead may cause changes in a child at the most basic level (Maccoby, 2000). These genetic changes are what may drive behavioral changes (Maccoby, 2000). For example, parental negativity (in terms of disciplinary practices and monitoring) has very strong connections with adolescent depression in their child (Maccoby, 2000). This further adds a layer of complexity, bringing into question the innate nature of genetics. It seems that our genes are sensitive to many factors and therefore have high plasticity. A common misconception is that this set of instructions remains the same for the entirety of our lives. However, we now know that the environment can cause genetic changes.

CHAPTER II: NEUROLOGICAL CHEMICALS AND THEIR INFLUENCE ON BEHAVIOR

Neurotransmitters are chemical compounds that allow neurons to communicate (send signals) throughout the brain (Sheffler et al., 2022). Neurons are the cellular basic units of the brain. An action potential causes neurotransmitters to be released through vesicles on the axon terminal into the synaptic cleft where they bind to receptors located on the dendrite (Figure 5) (Sheffler et al., 2022). After binding to a specific receptor, they will fuse and release their contents into the next neuron and create another action potential (Da & Tian, 2023).

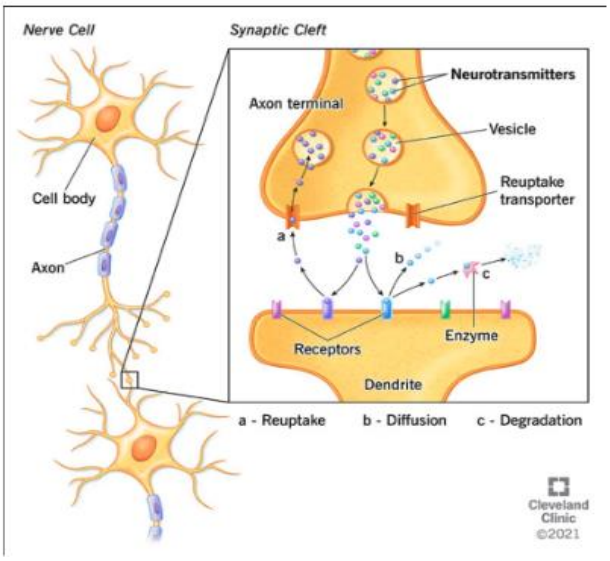

Figure 5: Neuron and Synapse Diagram (Neurotransmitters 2022)

This leads to a complex cascade of neurons which will eventually trigger a biological response (Da & Tian, 2023). Proteins can then reuptake, reabsorb, or break down neurotransmitters (Sheffler et al., 2022). As a result, information is sent from your brain to your body and vice versa (Sheffler et al., 2022) More specifically, neurotransmitters can regulate daily behaviors, learning, memory, sleep, mood, blood pressure, and heart rate (Da & Tian, 2023).

Serotonin is a neurotransmitter that affects all major organ systems (cardiovascular, pulmonary, gastrointestinal, genitourinary, and circulatory) (Berger et al., 2009). It also heavily affects human behavior such as mood, aggression, anger, reward, as well as other sentiments (Berger et al., 2009). Low serotonin levels are linked to poor memory and depressed mood (Berger et al., 2009). If low serotonin levels persist, this may lead to depression, anxiety, and despair (Jenkins et al., 2016). Individuals with these low levels often experience issues with verbal reasoning, memory, and emotional processes (Jenkins et al., 2016). These individuals also often participate in more high-risk activities and may experience increased impulsivity (Van Erp & Miczek, 2000). However, these symptoms can be treated through tryptophan (serotonin) supplementation (Jenkins et al., 2016).

Dopamine is also a neurotransmitter. Dopamine affects learning, motor control, reward, emotion, and executive functions (Sheffler et al., 2022). In contrast to serotonin, increased levels of dopamine can lead to aggressive behavior (Van Erp & Miczek, 2000). One study suggests that dopamine is elevated during the anticipation or participation of aggressive episodes (ex. fighting) (Miczek et al., 2002). Some researchers believe that this elevation in dopamine may even be the motivation to participate in aggressive behavior (Miczek et al., 2002). Furthermore, disturbances in dopamine levels can lead to psychiatric diseases such as schizophrenia, psychosis, depression, Tourette's syndrome, and ADHD (Miczek et al., 2002).

Norepinephrine is another neurotransmitter, but it is also considered to be a stress hormone (Fitzgerald, 2014). It is synthesized in the central nervous system and affects sleep, stress, focus, attention, inflammation, and autonomic nervous system function (Sheffler et al., 2022). Norepinephrine is often released in individuals in response to an acute stress event (Fitzgerald, 2014). However, norepinephrine dysfunction can lead to a variety of issues such as

anxiety disorders, mood disorders, ADHD, Alzheimer's, and PTSD (Sheffler et al., 2022). More specifically, elevated norepinephrine can lead to bipolar disorder, (paranoid) schizophrenia, and hypertension (Fitzgerald, 2014). Chronic elevation of norepinephrine is most likely due to genetics, but can be exacerbated by stress (Fitzgerald, 2014). Many of these diseases increase stress for individuals, which creates a positive feedback loop of increased norepinephrine (Fitzgerald, 2014).

Adrenaline is both a neurotransmitter and a stress hormone. This means that adrenaline is often released in response to a stress-inducing event or threat (Simister & Cooper, 2005). Although this neurotransmitter is extremely useful in life-threatening events by preparing an individual to fight or flight, it can have some unwanted side effects such as aggression (Simister & Cooper, 2005). More specifically, adrenaline is a vasodilator, which increases heart rate, blood pressure, and respiration (Simister & Cooper, 2005). Overall, since adrenaline is released in response to a certain event, individuals can learn to better control their reaction and decrease adrenaline levels without the use of medication (Simister & Cooper, 2005). Anger manifests in violence, fighting, tantrums, and labeling (Onwubiko, 2022). It's a strong emotion that can be evoked by negative experiences, often accompanied by biological changes (Onwubiko, 2022). It's also associated with increased heart rate, blood pressure, and adrenaline (Onwubiko, 2022). However, our physical reaction to anger can be controlled through a variety of methods. Anger Replacement Training (ART) aims to replace antisocial behavior with desirable prosocial behavior (Onwubiko, 2022). Cognitive behavioral therapy focuses on changing destructive thought patterns that have a negative influence on behavior (Onwubiko, 2022). Although adrenaline may increase the risk of aggression and violence in individuals, there are several methods for controlling our anger.

CHAPTER III: AN INVESTIGATION OF *MAOA* AND *CDH13* GENES

The *CDH13* gene (Cadherin 13) is associated with extremely violent behavior (Tiihonen et al., 2014). Cadherins are transmembrane proteins which mediate cell to cell adhesion and signaling (Maître & Heisenberg, 2013). More specifically, *CDH13* is a neural adhesion protein expressed in the amygdala (Tiihonen et al., 2014). Therefore, it mediates cell to cell (neuron to neuron) adhesion and signaling in the brain (mostly in the amygdala). Although the mechanism is not well known, the disruption in neural connectivity within the brain creates a deficit in impulse control (Tiihonen et al., 2014). Unsurprisingly, this protein is also associated with ADHD, autism, schizophrenia, substance abuse, and bipolar disorder (Tiihonen et al., 2014). Since ADHD is a disorder strongly associated with violent criminality, it's logical to also state that *CDH13* is correlated with violent behavior. This is especially concerning considering that ADHD is the most common neurodevelopmental disorder in youth, affecting approximately 7-10% of children (Saylor & Amann, 2016). Childhood ADHD also seems to affect individuals into adulthood as they continue to exhibit antisocial behavior, among other symptoms (Saylor & Amann, 2016). However, as stated before, a combination of both genetic and environmental factors will ultimately have the greatest influence on the violent tendencies of an individual.

Although there is very little research on *CDH13* in human models, there have been several studies on mice. *CDH13* knockout mice (mice with no *CDH13*) exhibited decreased impulsivity and reduced risk taking (Kiser et al., 2019). This indicates that it's the presence and perhaps an increase in *CDH13* which may lead to violent behavior due to increased impulsivity and risk taking. However, this has only been studied in mice models and it is unclear if this data is applicable to humans. The incidence of *CDH13* in the human population remains unclear.

Alarmingly, *CDH13* is not the only gene associated with violent behavior. The *MAOA* gene is more commonly known as the "warrior gene" due to its relation to violent behavior (Figure 6) (Schlüter et al., 2016). It is located on the X chromosome and encodes the *MAOA* enzyme (Gordon & Greene, 2018).

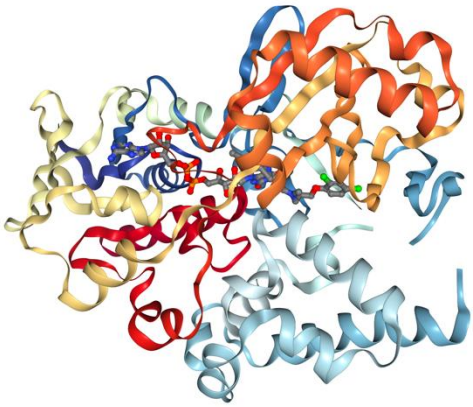

Figure 6: *MAOA* Protein Structure (Monoamine Oxidase a Protein Overview, n.d.)

Males only have one copy (XY) while females have two copies (XX), therefore the low activity *MAOA* variant will disproportionately affect males since it is recessive (Gordon & Greene, 2018). In a clinical setting, low MAOA activity is often diagnosed as Brunner's syndrome (Brunner's Syndrome, n.d.). In males, it is associated with impulsive behavior, aggression, and mild retardation (Brunner's Syndrome, n.d.). However, low-activity *MAOA* seems to have a different effect on females. *MAOA* hypomethylation (low-activity *MAOA*) in females is associated with Panic Disorder (Ziegler et al., 2016). Panic Disorder is characterized by unexpected attacks of intense fear and anticipatory anxiety (Ziegler et al., 2016). Nevertheless, *MAOA* metabolizes (breaks down) serotonin, dopamine, and norepinephrine (Gordon & Greene, 2018). Accordingly, low *MAOA* activity is associated with a buildup of

serotonin, dopamine, and norepinephrine in the presynaptic terminal (nerve ending) (Figure 7) (Da & Tian, 2023).

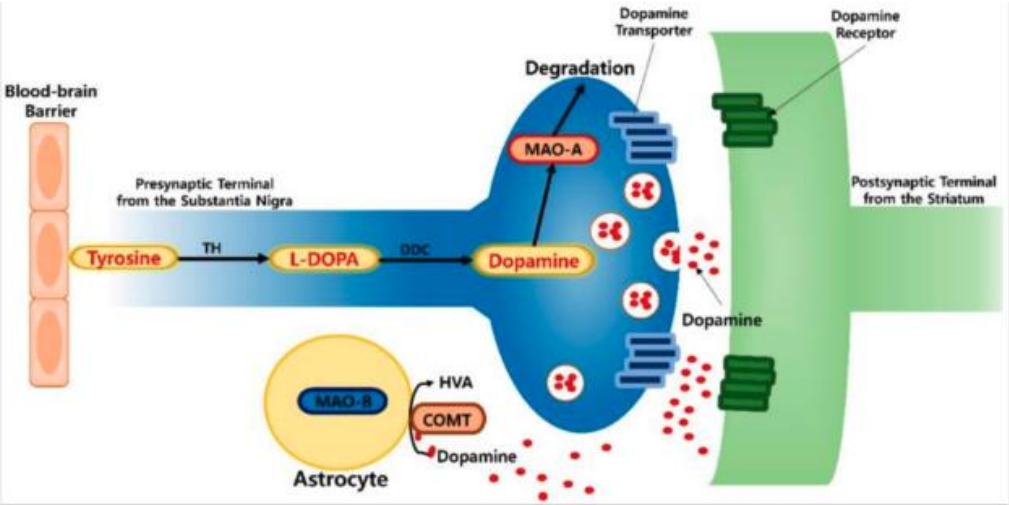

Figure 7: Dopamine Pathway Example with *MAOA* (Moon, 2023)

Therefore, there is a decreased amount of these neurotransmitters in the synapse, so they cannot bind to their associated receptors (Da & Tian, 2023). Low activity *MAOA* is hypothesized to result from a deleterious point mutation on exon 8 (Sohrabi, 2015). This likely causes a frameshift, resulting in a protein which differs from its original function. Low activity *MAOA* has the same effect on neurotransmitters in both females and males. However, it seems that low activity *MAOA* has different impact on the subsequent behavioral outcomes (aggression vs. panic).

Essentially, the low activity *MAOA* causes low serotonin, dopamine, and norepinephrine levels in the affected individual. There is an inverse relationship between serotonin and human aggression (Duke et al., 2013). Therefore, low serotonin levels will result in increased aggression. Interestingly, both low and high dopamine levels are associated with impulsive aggressive behavior (Suzuki & Lucas, 2015**;** Van Erp & Miczek, 2000). Both dopamine and

norepinephrine are substrates of *MAOA* (Schlüter et al., 2016). Therefore, it's logical that low-*MAOA* individuals also have a lower quantity of its substrate.

Individuals with low activity *MAOA* also seem to exhibit some physical indicators. These individuals may have a smaller limbic system and hyperactive amygdala (which regulates fear and emotional responses) (Hunter, 2010). This increase in activity of the amygdala can lead to impulsive aggressive behavior and increased emotionality (Márquez et al., 2013). In 1876, influential Italian psychologist and physician, Cesare Lombroso, argued that criminals were born and not made (Baum, 2013). He believed that criminals could be identified by their primitive physical traits such as nose size, jaw jutting, and tattoos (Baum, 2013). This is interesting considering that tattoos are a personal choice which individuals are not born with. This raises questions regarding Lombroso's credibility. These statements border on the idea of phrenology which states that size/shape of brain influences individual psychology (Parker et al., 2018). Phrenology has been widely disproven and there does not seem to be a correlation between brain size and intrinsic factors. Regardless, low *MAOA* activity is associated with aggressive, antisocial, and impulsive behaviors in males (Kanarik et al., 2021). This leads to the question, could a single nucleotide deletion lead to murder?

The answer is quite complex. However, it seems that many scholars agree that genetics alone does not fully dictate violent behavior. Instead, it's a combination of both genetic influences and life experiences (Bernet, 2007). Children who grew up with aggressive siblings (often falsely classified as a sibling rivalry) can themselves become aggressive later in adulthood and experience trauma symptoms (Mangold & King, 2021). This is especially alarming when considering that 40% of individuals with siblings have reported experiencing sibling aggression (Mangold & King, 2021). In general, children who are victimized are more likely to victimize

others in adulthood and participate in violent behavior in relationships (Maxwell et al., 2016). Males with low activity *MAOA* who experienced childhood maltreatment were significantly more likely to be convicted of a violent crime compared to other males who experienced childhood maltreatment (Gordon & Greene, 2018). Ultimately, aggressive/violent behavior is not only caused by low *MAOA* activity, but also particular environmental factors.

However, 40% of individuals have low *MAOA* activity, but 40% of our population aren't murderers (Hunter, 2010). This could be due to the influence of environmental factors such as child physical abuse, which occurs in 18% of children (Brown & Rabbitt, 2019). These two factors combined estimate that 7.2% of the general population are murderers. In 2019, there were 16,425 murders in the United States within a population of 328,239,523 (Federal Bureau of Investigation, 2019; US Census Bureau, 2019). Assuming that there was a one-murderer-per-kill ratio (maximizing the potential number of murderers), the proportion of murderers in the U.S. is roughly 0.005%. This is significantly less than the predicted 7.2%, which indicates that there must be other variables that prompt individuals to commit violent acts. This also serves as evidence that murderous behavior may be dictated by more than just genetics and the environment. Additionally, there is no evidence that all murderers have either low activity *MAOA* and/or *CDH13*.

CHAPTER IV: MEDIA ANALYSIS OF GENETICS AND MURDER

Although TV shows are not necessarily intended to be accurate or educational, they can still spread misinformation. A popular TV show, *Riverdale* (originally aired in 2017), entertains the idea that certain genes do cause murderous tendencies. Harold Cooper (also known as the Black Hood), father of the main character Betty Cooper, is a serial killer and brutal murderer. It is greatly implied that his violent behavior is due to certain genes he possesses, *MAOA* and *CDH13*. After discovering the heritability of these genes, Betty Cooper is immediately frightened that she too might also become a killer. After testing positive for the two murder genes, Betty begins reflecting on her life history and remembers moments of cruelty and violence. Despite her best efforts, she cannot seem to stop her violent behavior.

As a result of this popular series, an increasing number of individuals have become fascinated with the idea of murderous genes. As stated before, *MAOA* is located on the X chromosome, so it is unlikely that Betty would have this gene simply due to her father having it. Women are significantly less likely to be affected by genes that are X-linked recessive as they would need two copies of the gene for it to be expressed. Additionally, it is unclear what the probability of heritability for low-activity *MAOA* and *CDH13* genes are. Regardless, it is widely accepted in the scientific community that genetics alone does not dictate human behavior. We also do not know what occurred in Betty's childhood and, therefore, do not know of any environmental factors that may work alongside her genes in promoting violent behavior. Ultimately, we do not know enough about Betty to claim with certainty that she is a future murderer. It's improbable that we will ever be able to make such a claim about anybody. It is dangerous and ignorant to use a TV show meant for entertainment as educational. Although it

may seem unnecessary to analyze a fictional TV show in-depth, it is essential to be aware of the misunderstandings it promotes.

Although genetics may influence our brain chemistry, this only affects the risk of violent behavior. It is not the cause of violent behavior. Therefore, Betty Cooper should not be worried about having low-activity *MAOA* or *CDH13* genes. Viewers of this popular TV show should also be proactive about further researching information introduced before accepting claims made by fictional characters. The relationship between genetics and behavior is quite complex. Individuals should refrain from making broad claims in an effort to stop the propagation of misinformation.

The film *Minority Report* (released in 2002) depicts a futuristic society where crime can be stopped before it occurs. The precrime department receives a notification with both the victim and murderer's name and they are tasked with stopping it. There are three precogs (psychic humans) who experience futuristic dreams which predict murder. However, these predictions may vary since there can be multiple outcomes for certain situations. This casts doubt on the whole operation, raising questions about how just/ethical precrime prevention is. The main character, John Anderton, experiences an intense inner conflict as the system he has always believed in turns out to be incorrect. He is personally responsible for the potentially wrongful imprisonment of many individuals and suffers under the guilt.

This film depicts the conflict between determinism and free will. Although it does not necessarily use genetics to predict crime, it relies on a similar principle. Attempting to predict behavior using any information can be both controversial and inaccurate. This film emphasizes the importance of free will that humans possess. We're not robots who strictly obey their code. Humans are conscious and capable of complex thoughts which have the largest influence on our

behavior. *MAOA* and *CDH13* are risk factors for certain behaviors, but they are not determinants. It is important that we refrain from predicting the potential violent nature of individuals with low *MAOA* and *CDH13*. They do have free will and autonomy over their actions. As this film alludes to, it would be both incorrect and unjust to label individuals as future murderers due to genetics.

The film *Gattaca* (released in 1997) takes place in a futuristic city where DNA is used to categorize humans and create a biological power structure. Natural conception is no longer the most popular manner to create a child. Parents now choose their child in a more artificial and selective manner. Embryos are artificially inseminated, those with a high chance of developing unfavorable traits or diseases (ex. heart disease, alcoholism, etc.) are discarded. Only the "genetically superior" embryo is reimplanted in the mother and carried to term. These genetically superior individuals are known as Valids, while naturally conceived individuals are known as Invalids. Valids are believed to be both intellectually and physically superior to Invalids. Therefore, prestigious careers are reserved for Valids while Invalids are forced to work less skilled jobs (ex. janitorial services). However, there are laws in place to protect individuals against bias due to genetics. Individuals do not have to reveal their genetic makeup to employers. Nevertheless, potential employees are always asked to submit to genetic testing. Although they can refuse this request employers can easily obtain their DNA illegally though a used cup or other means.

The movie follows an Invalid (naturally conceived) individual named Vincent Freeman. Vincent was genotyped upon birth, which led to the discoveries that he has a propensity for violence, life expectancy of 30 years, and a 99% probability of developing a heart defect. Vincent dreams of going into space and is very knowledgeable about astronomy. He is a physically healthy boy aside from his heart defect, which does not seem to significantly affect his

physical abilities. However, he never had the chance to prove his abilities due to his inferior genetics. He would go on to adopt another man's identity who is genetically superior (valid) and begins working at Gattaca (a space company). Ultimately, Vincent (now known as Jerome) earns a spot on the next space mission which is destined for Mars. Contrary to popular belief, he was both physically and mentally strong enough to pursue such a prestigious career regardless of his Invalid status.

This film depicts the dangers of using genetics to categorize individuals. Viewers are in a unique position where they would be considered outsiders in this society. As potential Invalids ourselves, we are rooting for Vincent to prove everyone wrong and achieve his dreams. As stated previously, genetics alone does not dictate human behavior and cannot be used to predict it either. That being said, it would be both unjust and inaccurate to categorize humans based on their genes. Since the low-activity *MAOA* and *CDH13* genes cannot predict murderous behavior, their presence cannot be used to classify humans as future murderers. This would be subjecting them to unfair treatment and stripping them of their free will. We should also be hesitant to treat these individuals differently, as they are no different from others. Although it is a fictional film, Vincent's travel to Mars proves that genetics can hardly define an individual's potential.

CHAPTER V: GENETIC DETERMINISM AND AUTONOMY

Genetic determinism, also known as biological determinism, is a theory which states that genetic contributions to phenotype (ex. behavior) are much more important than other factors, such as the environment or epigenetics (Carver et al., 2017). This is a rival theory to environmental determinism which claims the opposite. Environmental determinism emphasizes the strength of the environment in dictating human behavior. An example of this would be the refrigerator mother theory, which was popularized in the 1950s and claimed that cold/unloving mothers caused their children to develop autism and schizophrenia (Harden, 2023). Both genetic determinism and environmental determinism are very appealing theories due to their potential predictive power (Carver et al., 2017; Harden, 2023). Genetic determinism states that one gene is associated with one trait (Carver et al., 2017). For example, if you have the brown eyes gene, you will have brown eyes. However, the probabilistic perspective has a multifactorial ratio (Carver et al., 2017). This means that for one trait there are multiple genes involved which interact with environmental and epigenetic factors (Carver et al., 2017). For example, intelligence would be affected by genes, but also the environment and family history. Despite limited scientific support for genetic determinism, it continues to be a popular belief within the public (Carver et al., 2017). Supporters of genetic determinism are probably the portion of the public with limited scientific knowledge. Genetic determinism can be dangerous as it diminishes responsibilities for one's actions, as well as the need for government safety nets (Alper, 1998). This raises concerns about the processing of criminals. Would this allow individuals to simply blame their genes and take no ownership of their actions? It also raises questions regarding free will and autonomy, however that is outside the scope of this thesis.

XYY is a rare sex chromosome aneuploidy commonly referred to as super-male disease (Jacob's syndrome) which affects approximately 1 in every 1,000 newborn males (NORD, 2015). These individuals received an extra Y chromosome from their father, resulting in two Y's instead of one (NORD, 2015). This usually occurs as the result of a sperm division error prior to conception. It's a rare chromosomal disorder that only affects males (NORD, 2015). XYY males are very tall and often experience severe acne (NORD, 2015). Physicians, researchers, and the general public believed that males who had this disease were overly aggressive and lacked empathy (NORD, 2015). Robert Peter Tait, Daniel Hugon, and John Farley all had an extra Y chromosome (XYY) (Human Aggression and the Extra Y Chromosome, n.d.). All three of these individuals murdered someone (Human Aggression and the Extra Y Chromosome, n.d.). This seemed to further support the idea that XYY males were predisposed to violence, which both researchers and physicians accepted.

However, this was a major misconception. Most XYY males lived unremarkable, quiet lives (Human Aggression and the Extra Y Chromosome, n.d.). XYY males constitute an insignificant proportion of perpetrators of violent crimes (Human Aggression and the Extra Y Chromosome, n.d.). Therefore, the murderous XYY individuals seem to be outliers or anomalies. XYY males are at increased risk for learning disabilities and behavioral problems, but they are not overly aggressive (NORD, 2015). Some affected individuals experience hyperactivities, explosive tempers, and antisocial behavior (NORD, 2015). However, it would be incorrect to claim that all XYY males experience these symptoms. This serves as a cautionary tale. It is very risky and may be inaccurate to make assumptions on behavior based on genes. Therefore, this highlights fallacies in the genetic determinism theory.

Eugenics is a theory which sought to improve human beings through planned breeding and selecting for favorable traits (National Human Genome Institue, 2021). Some scientists and other individuals sought to create perfect humans through genetics and understanding heritability (National Human Genome Institue, 2021). Positive eugenics refers to increasing (breeding) the population of genetically strong individuals (Grodin et al., 2018). Negative eugenics refers to decreasing the population of genetically weak individuals (Grodin et al., 2018). Francis Galton, cousin of Charles Darwin, developed this theory in 1883 (National Human Genome Institue, 2021). He believed that health, social, and intellectual characteristics are inherited (National Human Genome Institue, 2021). This sparked widespread discrimination and scientific racism. Scientists believed that "feebleminded" (mentally retarded) individuals were responsible for a wide range of social problems (Kevles, 1999). Hereditarian biology attributed poverty and criminality to bad genes (Kevles, 1999). In an effort to stop the spread of these bad genes, forced sterilizations became increasingly common (Kevles, 1999). The ultimate goal was to create superior humans through the exclusion of biologically inferior individuals (Kevles, 1999). Unsurprisingly, this led to the creation and development of multiple hate groups. Eugenic segregation led to the growth of the Ku Klux Klan, Jim Crow segregation, and Nazi Germany in hopes of creating a homogenous homeland (Stern, 2022). White supremacy gained more power through the weaponization of genetics.

Nazi Germany used eugenics to justify the mass genocide of Jewish individuals. Jewish people, among others, were labeled as physically, mentally, or racially unfit (Grodin et al., 2018). Therefore, German physicians claimed to be cleansing/purifying Germany by murdering these individuals and preventing the propagation of their genes (Grodin et al., 2018). These physicians considered themselves biological soldiers, not healers or caretakers (Grodin et al.,

2018). Hitler passed the Law for the Prevention of Genetically Diseased Offspring in 1933 (Grodin et al., 2018). This led to the forced sterilization of individuals who had diseases such as feeble-mindedness, schizophrenia, bipolar disease, epilepsy, Huntington's, chorea, blindness, deafness, malformation, or severe alcoholism (Grodin et al., 2018). Three hundred thousand individuals were murdered, and 375,000 individuals were sterilized during the purification of Nazi Germany (Grodin et al., 2018). Therefore, the idea that some genes are superior to others will inevitably lead to the belief that certain individuals, races, or cultures are superior to others. Superiority creates a hierarchy of power which oftentimes relies on illegitimate reasoning. Nevertheless, it breeds a society where inequality is sustained. Sometimes, it can even lead to individuals being labeled as sub-human and treated unethically. It's important that we exercise caution when labeling the *MAOA* and *CDH13* genes as murderous and unfavorable. It would not only be inaccurate, but unjust as well.

Although *MAOA* and *CDH13* genes do increase the risk of violent behavior in combination with environmental factors, we should not use it to discriminate against certain individuals. These genes also do not serve as concrete indicators/predictors of violent behavior. Their heritability probability is also unclear, so even if parents have it, that does not mean the child will inherit it. This is in contrast to some monogenetic diseases such as Huntington's disease. Individuals with the Huntington's gene mutation will 100% develop Huntington's disease (Huntington's Disease, n.d.). Children who have a parent with Huntington's disease have a 50% chance of inheriting the gene (Huntington's Disease, n.d.). In this situation, genetic testing could be beneficial to predict future events. However, the same cannot be said for individuals with low-activity *MAOA* and *CDH13* genes.

PKU, also known as Phenylketonuria, is characterized by an ability to metabolize phenylalanine present in protein-rich food (Baum, 2011). Phenylalanine can build up and cause irreversible brain damage in individuals with PKU (Baum, 2011). Individuals can inherit PKU from parents in a simple recessive pattern (Baum, 2011). However, there is a simple treatment option. A low phenylalanine diet (substrate reduction) has been effective in keeping phenylalanine levels to an acceptable amount (Baum, 2011). This proves that we are not determined exclusively by our genes as we can modify our environment (ex. diet) (Baum, 2011). Although at times genetics can be useful indicators of the onset of physical traits (ex. Huntington's disease), this is not the case for many genes (ex. *MAOA, CDH13* and *PKU)*.

CHAPTER VI: THE ETHICS OF *MAOA* AND *CDH13* GENE EDITING

Gene editing can correct, introduce, or delete almost any DNA sequence in humans (NIH, 2019). This is especially beneficial when treating both genetic and acquired diseases (NIH, 2019). Although gene editing is a relatively new technology, researchers predict that gene editing can cure Alzheimer's, Type I Diabetes, Cystic Fibrosis, and Duchenne Muscular Dystrophy, Huntington's Disease, Human Immunodeficiency Virus Infection, among many others (Overview Genetic Diseases CRISPR Could Cure, n.d.). We do not fully understand what causes Alzheimer's, however there are certain genetic mutations associated with it (Overview Genetic Diseases CRISPR Could Cure, n.d.). In theory, gene editing could correct these mutations and cure the individual. The same logic can be applied to the other diseases listed.

There are a variety of gene editing technologies which have recently emerged such as CRISPR, Prime Editors, Base Editors, ZFNs, TALENs, CAS-CLOVER, MegaTAL, and MegaNucleases (Overview Genetic Diseases CRISPR Could Cure, n.d.). CRISPR/Cas-9 stands for clustered regularly interspaced palindromic repeats (Redman et al., 2019). Palindromes refer to segments of DNA which can be read the same both backwards and forwards (ex. RACE CAR or TACAT). CRISPR/Cas-9 has two essential components: a guide RNA which locates the corresponding palindrome and Cas-9 which breaks the DNA (Redman et al., 2019). A new DNA sequence can then be inserted (Redman et al., 2019). Ultimately, CRISPR Cas-9 can correct errors in the genome or turn certain genes on or off (Redman et al., 2019). However, there are still several challenges which prevent this technology from clinical applications in humans. It's a new genetic technology which has yet to be perfected and can cause toxicity or be off target (Redman et al., 2019).

Aside from the practical limitations, it would not be ethical to edit/fix the genome of individuals with low-activity *MAOA* and/or *CDH13*. It would not only put an unnecessary financial burden on these individuals but may also have unknown psychological impacts on their mental health. Additionally, we already know that it's a combination of both genetic and environmental factors which may ultimately lead an individual to commit murder. Therefore, it would not be enough to simply "fix" their genes. Also, we know that there are plenty of individuals with low-activity *MAOA* and *CDH13* who live normal lives, therefore it would be subjecting them to unnecessary medical procedures.

This is akin to individuals within the deaf community. They do not believe they are disabled and push back against any arguments which imply that there's something wrong with them. These individuals often live normal functioning lives and simply experience the world differently than hearing individuals. Many deaf individuals enjoy their distinct culture and do not want to hear (Cooper, 2019). Therefore, they do not want to be "cured" and may even be insulted by scientists attempting to do so (Cooper, 2019). Researchers recently discovered that a point mutation in *Tmc1* (a protein channel associated with cochlear hair cells) has been associated with hearing loss (Cooper, 2019). In mice, CRISPR/Cas-9 was used to target the mutant *Tmc1* allele and knockdown its expression (Chien, 2018). Mice treated with CRISPR/Cas-9 had greater hair-cell survival and hearing than their *Tmc1* mutated counterparts (deaf mice) (Chien, 2018). This has created conflict in both the scientific and deaf community since in theory CRISPR/Cas-9 can be used to "cure" humans of deafness. Although the dominant culture in the U.S. may see this as great news, deaf individuals believe it is unnecessary. Although the application of CRISPR in deaf individuals is certainly more controversial than its use in low-activity *MAOA* and *CDH13* individuals, both situations raise major ethical concerns regarding the use of gene editing.

CHAPTER VII: AN ANALYSIS OF THE U.S. JUSTICE SYSTEM

Individuals convicted of crimes will more than likely use any argument possible to decrease their sentence or severity of punishment. This often means pleading insanity even if the defendant is not mentally ill. As previously established, the *MAOA* and *CDH13* genes do not directly cause murderous activity and therefore should not be used to justify murder. Allowing individuals to do so would set a dangerous precedent of not taking responsibility for one's actions.

In Italy in 2009, a woman named Stefania Albertani pleaded guilty to both murdering her sister and burning her body (School, 2011). Additionally, she also attempted to murder her parents but was unsuccessful (School, 2011). A structural MRI revealed that Albertani had abnormalities in her amygdala and had the low activity version of *MAOA* (School, 2011). The trial court reduced her sentence from life in prison to 20 years (School, 2011). The court made this decision due to the apparent partial mental illness of Albertani (School, 2011). It remains unclear whether she was required to live out the rest of her life in a mental institution or be released into society. Regardless, the question remains whether justice was served. Albertani's sister was both murdered and burned in a brutal manner; it's unfair that those actions would go unpunished.

This is not an isolated event. In 2009, an Italian appeals court reduced the sentence of a defendant by one year due to the individual's genetic predisposition to violence (Baum, 2013). More specifically, the sentence was changed from 9 to 8 years due to the presence of low activity *MAOA* in their genome (Baum, 2013). Although this may seem insignificant, it shortened the individuals' prison time by approximately 11%. Abdelmalek Bayou (the defendant) was insulted and physically beaten by a group of youth who disapproved of the eyeliner he was wearing

(Baum, 2013). Bayou decided to change out of his bloody clothes and grab a knife in an effort to seek revenge (Baum, 2013). He went on to murder an innocent individual who he falsely believed was one of the youths (Baum, 2013). The convicted man, Bayou, struggled with schizophrenia but had no history of child abuse or maltreatment (Baum, 2013). Regardless, the judge believed that this made him prone to aggression under stressful circumstances (Baum, 2013). Once again, it remains unknown if Bayou was released into the public afterwards or required to seek mental treatment. The judge reducing his sentence due to the presence of low activity *MAOA* insinuates that he did not have full control over his actions. This may be true, but it would be incorrect to state that his lack of control is due to low activity *MAOA*.

Courts reducing sentences due to certain genetic markers appears to be restricted to Italy; however, this is not the case. An American judge recently ruled similarly in a Tennessee trial. The defendant, Waldroup, killed his wife's friend who he believed was having an affair with his wife (Baum, 2013). As his wife tried to run away, he shot her in the back (Baum, 2013). After Waldroup's wife kicked the gun out of his hand, he proceeded to slash her with a pocketknife (Baum, 2013). This process was repeated with a shovel and machete until Waldroup was able to drag her back inside the home (Baum, 2013). Despite the damage the wife endured, first responders were able to save her (Baum, 2013). Waldroup has the low-activity *MAOA* gene and was abused as a child. This resulted in his sentence being reduced from murder to voluntary manslaughter. He also received two counts of aggravated kidnapping and second-degree attempted murder resulting in a 32-year sentence. All three of these cases depict criminals who had reduced sentence due (in part) to low-activity *MAOA*. However, it is important to reiterate that low-activity *MAOA* only increases the risk for participating in aggressive behavior and does not cause it.

These cases depict sympathetic judges and jurors who made decisions on the premise that individuals with low activity *MAOA* may be less responsible for the crime and therefore less deserving of the punishment (Scurich & Appelbaum, 2017). If these individuals have less responsibility over their actions, then who is at fault? Doctors who failed to conduct genetic testing or perhaps caretakers who did not supervise these individuals sufficiently? Interestingly, even if it is true (which it is not) that individuals with low activity *MAOA* and *CDH13* cannot fully control their actions, how would a lighter prison sentence protect society? Wouldn't they be more likely to murder someone else if they were released early since they have limited control over their actions? Inevitably with the highly publicized cases above this defense strategy will become more popular among criminals attempting to get a lighter sentence. It's a good legal strategy considering that 40% of individuals have low-activity *MAOA* (Hunter, 2010). This raises the question, why is the justice system basing sentencing on genetic rationale which has already been disproven to cause murderous tendencies?

This is especially confusing considering that behavioral genetics fail consistently to affect judgment and capability decisions in experimental settings (Scurich & Appelbaum, 2017). One research project investigated a large representative sample of the U.S. to determine if the general public considers genetic evidence to affect or drive criminal behavior (Scurich & Appelbaum, 2017). They varied the heinousness of the crime, the presence/absence of behavioral genetic evidence, and other characteristics of the criminal (Scurich & Appelbaum, 2017). Researchers then asked the individuals to render a guilty or not guilty verdict by reason of insanity and what the length of incarceration should be (Scurich & Appelbaum, 2017). Ultimately, the presence of behavioral genetic evidence had no effect on the perceptions of responsibility nor punishment (Scurich & Appelbaum, 2017). These findings complement what behavioral geneticists have

been stating in their subsequent research. Behavioral genetic research has continued to find consistent impact on culpability judgments based on neuroscientific explanations (and certain genes) (Scurich & Appelbaum, 2017). So, if the general public does not believe that presence of certain genes should affect culpability or punishment, why do judges and jurors rule in favor of them?

One explanation suggests that the public simply does not fully comprehend behavioral genetic evidence (Scurich & Appelbaum, 2017). Therefore, they ignore it when rendering decisions regarding culpability and length of punishment (Scurich & Appelbaum, 2017). Another theory suggests that individuals do understand behavioral genetics but do not believe it to be the primary or even the major driver of criminal behavior (Scurich & Appelbaum, 2017). This may explain the inconsistencies between sentencing and public perception. Therefore, it seems that the majority of individuals agree with scholars (Scurich & Appelbaum, 2017). So, where does the disconnect arise between general public consensus and the justice system? The law requires the presence of decreased rationality or impaired ability to control behavior as an indicator of diminished responsibility (Scurich & Appelbaum, 2017). Therefore, lawyers must prove that the presence of low activity *MAOA* must lead to decreased rationality or impaired behavioral control. However, this has not been backed by scientific evidence. As previously stated, merely the presence of low activity *MAOA* is insufficient to account for an increased risk in violent behavior (Scurich & Appelbaum, 2017). Ultimately, defendants facing the death penalty have little to lose by pursuing every argument that could possibly reduce their prison sentence (Scurich & Appelbaum, 2017). It is an advantageous strategy for defendants, but brings into question the morality, ethics, and accuracy of the argument. The defendants must show that genes created an external force which overcame their freewill, which is both highly controversial and (should be)

very difficult to claim (Alper 1998). The United States justice system continues to view this as a valid argument, but in doing so is reducing the justice received by their victims and may even be further promoting violence.

CHAPTER VIII: CONCLUSION

Violent crime is present all over the United States. We are all affected either directly or indirectly by the violent acts committed by some individuals. It is very difficult to understand why humans commit such treacherous acts such as murder. We've looked to both philosophy and science in an effort to understand and perhaps prevent it. It's sensible that we would seek a solution to prevent violent acts before they are committed, especially when there is the potential to save innocent lives and better communities. Perhaps the theory that murderers could be identified through their genetics gained traction due to the convenience of genetic testing. It would be easy to simply add *CDH13* and *MAOA* to the newborn screening which tests for genetic abnormalities. The ability to stop crime before the future criminal could even walk would be a breakthrough in both scientific and judicial discovery. However, genetics do not predict nor create murderers. It would not make sense to screen newborns and potentially sentence them to infant incarcerations. Furthermore, gene editing to correct low activity *MAOA* and *CDH13* would be unethical.

Therefore, genetics is not the solution we should be seeking when trying to decrease violent crime. Genetics are the foundation of who we are, but our genes do not dictate our actions. They are powerful in the sense that they are responsible for every protein created within our bodies. Our sex chromosomes serve as a reminder of the information passed down from both our parents, but also our ancestors. It's important to emphasize that genes play an integral role in the function of our body. However, we must also understand their limitations. We are not computers which are programmed with specific code that they follow precisely. Our bodies are made up of A, T, G, and U's (nucleotides) instead of ones and zeroes (binary code). Neurotransmitters may affect our mood, but they do not dictate our actions. There are many

analogies which relate DNA to computer code or instruction manuals, but as humans we have free will. Epigenetics and environmental factors may alter our genetic expression and increase our risk for certain behaviors (Carver et al., 2017). However, they do not dictate our actions. Hopefully in the future the U.S. justice system will make changes to reflect a more accurate understanding of low activity *MAOA* and *CDH13* genes. Nevertheless, ideals surrounding genetic superiority should not be entertained. They are both dangerous and inaccurate. It would inevitably lead to discrimination. Ultimately, we are all equal humans.

Matthew Baum created an analogy that compares the *MAOA* gene to a car's anti-lock brake system (ABS). The majority of cars have an ABS which overestimates the amount of time it would take to brake, while some underestimate it (Baum, 2011). This is then used to calculate how many times per second to engage the brake in order to stop (Baum, 2011). Therefore, if you were driving a car with an ABS which underestimates the time to brake and slammed on your brakes, it would take longer to stop (Baum, 2011). However, if you're driving in good weather with good driving technique, it's not likely that the ABS system would be engaged as you most likely wouldn't be slamming on your brakes (Baum, 2011). In the winter you are more likely to slam on your breaks, therefore individuals with a slower ABS system are more likely to crash (Baum, 2011). Regardless, the ABS system is not solely responsible for the crash as speed, alertness, distance between cars, and actions of other drivers also play a role (Baum, 2011). The slower ABS system is analogous to individuals with low-activity *MAOA*. They may be more likely to commit violent acts (crash), but it is not solely due to their genetics (ABS system). It also depends on environmental factors. Therefore, there are certain environmental factors (ex. child abuse) that increase the probability of committing murder in certain individuals. However, it is not a 100% guarantee. It would be false to assume that individuals with low-activity MAOA

or CDH13 will become murderers or commit violent acts due to their genetics. Although we can enjoy TV shows and movies which entertain the idea of murder genes, it would be a mistake to accept and support those beliefs.

The controversy surrounding *MAOA* and *CDH13* genes alludes to a larger issue regarding science communication. There is a boundary that separates the general population from information circulating in academia. This divide even exists between scientists with different specialties. Published scientific articles are filled with complex terminology. This prevents readers who are unfamiliar with the topic or lack the necessary knowledge from understanding the findings of the article. Additionally, it could lead to misinterpretation of the results and the propagation of misinformation. This could be prevented by third parties translating these articles using simpler terminology, which is more understandable and does not require a college degree to comprehend. Researchers could also define complex terms in the introduction section of the articles. Regardless, it is important that we prioritize the sharing of information to everyone despite their educational background in order to prevent the spread of false information. This starts with correcting the rumor that individuals with *MAOA* and/or *CDH13* will commit violent acts.

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