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The Human Chimera: Legal Problems Arising From Individuals with Multiple Types of DNA

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THE HUMAN CHIMERA: LEGAL PROBLEMS ARISING FROM INDIVIDUALS WITH MULTIPLE TYPES OF DNA

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INTRODUCTION

Science continually changes, and with it our understanding of the human body. While some scientific developments are limited in scope, others have widespread effects. Scientists have just recently begun understanding the range of effects chimerism in humans can have. Chimerism, originally associated with hermaphrodites having both male and female sexual organs, is much more common than originally thought. As chimerism becomes more common, so do individuals with separate and distinct deoxyribonucleic acid (DNA) strands in their bodies. Most individuals are unaware of their chimeric genetic code and most will likely never know. Because of the inherent difficulty of testing for chimerism, many problems are presented to legal system.

Part I of this article will begin with the history of human chimeras. The section will then describe the ways in which chimeras are formed. The section will discuss the most common form of chimerism in humans--fetal cell microchimerism (FMC). FMC occurs when cells are transferred from baby to mother or mother to baby via the umbilical cord.[1] Studies have shown that mothers may keep cells from their children for years after giving birth.[2] Moreover, cells can be exchanged between twins while inside the uterus.[3] Secondly, the section will describe the process of embryo fusion, which can cause tetragametic chimerism. Described colloquially as a

[1] *See generally* Gavin S. Dawe et al., *Cell Migration from Baby to Mother*, 1 CELL ADH MIGR. 19, 20 (2007) (discussing the process of cell migration between mother and fetus).
[2] *Id.* at 23.
[3] *Id*. at 19.

"vanishing twin", tetragametic chimerism occurs when one embryo absorbs another.[4] Both FMC and Tetragametic Chimerism are natural forms of chimerism. The section continues with a brief overview of artificial chimerism that occurs through science and medicine. The section will then conclude with a brief discussion on how common human chimeras are and how scientists can test for human chimerism.

Part II of this article will provide an illustration of the concerns with maternity and paternity testing and the criminal justice system when facing chimerism. The section will start with the stories of Lydia Fairchild and Karen Keegan—two mothers that were told by doctors that they bore no genetic similarity with their own children.[5] Regardless of the mothers' distinct memory of giving birth to their children, the scientific community deemed it impossible.[6] Next, the article will study the infamous case of American cyclist Tyler Hamilton, who, after being accused of blood doping, defended himself by claiming he had a "vanishing twin."[7]

Part III will discuss the plethora of problems that natural human chimerism can cause in maternity and paternity testing as well as criminal justice. Maternity and paternity testing is used for many critical considerations, including child support, visitation rights, probate proceedings, and welfare and social security availability. Similarly, the criminal justice system relies heavily on DNA testing in prosecutions and exonerations. Both areas may be greatly impacted by human chimeras and great harm may be caused to both chimeras and non-chimeras alike. Part IV will provide the author's recommendations when facing the chimera problem. Part V concludes.

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[4] *See, e.g.*, Neng Yu et al., *Disputed Maternity Leading to Identification of Tetragametic Chimerism*, 346 N ENG. J. MED. 1545 (2002) (noting tetragametic chimerism in a 52-year-old woman undergoing histocompatibility testing); Ruth Tennen, *Chimeras, Mosaics, and Other Fun Stuff*, GENETICS.THETECH.ORG, (Sept. 27, 2007), www.genetics.thetech.org/ask/ask233.

[5] *See She's Her Own Twin*, ABC NEWS, (Aug. 15, 2006), http://abcnews.go.com/Primetime/story?id=2315693&page=3.

[6] Aaron T. Norton & Ozzie Zehner, *Which Half is Mommy? Tetragametic Chimerism and Trans-Subjectivity*, 36 WOMEN'S STUD. Q. 106, 107 (2008).

[7] *See* Gina Kolata, *A Case of Doping or a 'Vanishing Twin'*, N.Y. TIMES, (May 12 2005), http://www.nytimes.com/2005/05/11/health/11iht-sntwin.html?pagewanted=all.

I. THE HISTORY AND FORMATION OF HUMAN CHIMERAS

This part includes a brief overview of human chimerism, a look into the first discovered human chimera, the ways in which chimerism can occur within humans, the commonality of human chimerism, and the problems scientists face with detecting chimerism.

A. What is a Human Chimera?

The term "chimera" originated from ancient history and literature. Originally a mythical beast, the chimera was a towering monster that devastated humanity.[8] The chimera was made up of three different parts: the body of a lion, the head of a goat, and the tail of a dragon.[9] For years, the chimera laid siege to the ancient world, but Bellerophon, son of King Glaucus, eventually slayed the beast.[10] The science community, however, retained the terminology to describe organisms with two or more types of genetically distinct DNA.[11]

Chimeric humans may be indistinguishable to the unobserving eye. Unless an abnormality occurs during the formation of the chimerism, human chimeras look exactly the same as single genotype individuals.[12] The most common phenotypical abnormalities are hermaphroditism, caused by a fusion of male and female embryos, patch-like skin, and eyes with differing colors and shading.[13]

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[8] Catherine Arcabascio, *Chimeras: Double the DNA-Double the Fun for Crime Scene Investigators, Prosecutors, and Defense Attorneys*, 40 AKRON L. REV. 435, 437 (2007).
[9] *Chimera*, ENCYCLOPEDIA BRITANNICA, http://www.brittanica.com/EBchecked/topic/111597/Chimera (last visited Nov. 12, 2013).
[10] Arcabascio, *supra* note 8, at 437.
[11] Charles E. Boklage, *Embryogenesis of Chimeras, Twins and Anterior Midline Asymmetries*, 21 HUM. REPROD. 579, 580 (2006).
[12] Vivienne Lam, *The Truth About Chimeras*, SCI. CREATIVE Q. (Nov. 20, 2007), http://www.scq.ubc.ca/the-truth-about-chimeras/.
[13] *Id.*

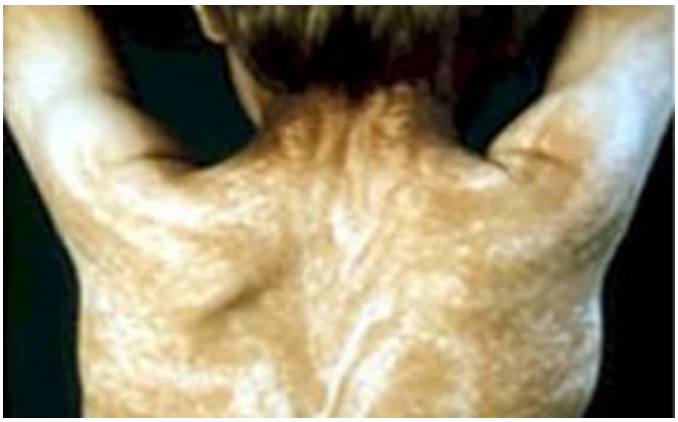

Figure 1[14]*: An example of a human chimera with an abnormal phenotype.*

B. The First Documented Human Chimera

The first natural human chimera was reported in the British Medical Journal in 1953.[15] The case involved Mrs. Mck, a British woman with reportedly varying blood types.[16] Prior to the realization of human chimeras, scientists believed that a human could only have one type of blood, either A, B, O or AB.[17] Mrs. Mck's results determined that she had both O and A type blood.[18] Believing this to be impossible, the clinic in northern England tested her again to rule out possible mistakes with the original sample.[19] The results remained the same.[20] It was not until Robert Race, the director of the MRC Blood Group Unit, remembered a study he had read illustrating twin cattle that had mixed blood from gestation.[21] Hoping that this theory could be applicable to Mrs. Mck, Race inquired as to whether Mrs. Mck ever had a twin.[22] Race was

[14] Natalie Reed, *Bilaterally Gynandromorphic Chickens and Why I'm Not 'Scientifically' Male*, (Mar. 28 2012), http://freethoughtblogs.com/naliereed/2012/03/28/bilaterally-gynandromorphic-chickens-and-why-im-not-scientifically-male/.
[15] C.C. Bowley et al., *A Human Blood-Group Chimera*, 2 BRIT. MED. J. 81, 81 (1953).
[16] *Id.*
[17] Aryn Martin, *'Incrongruous Juxtapositions': The Chimaera and Mrs McK*, 31, ENDEAVOUR 99, 99 (2007).
[18] Bowley, *supra* note 15, at 81.
[19] *Id.* (noting that the Sheffield Blood Transfusion Centre originally believed the differing blood types were a result of sample contamination).
[20] *Id.*
[21] Martin, *supra* note 17, at 99.
[22] *Id.*

relieved to hear that she had in fact been a twin, but the twin had died months after birth.[23] The Blood Group Unit subsequently took a saliva culture from Mrs. Mck because saliva is also an indicator of blood type.[24] The saliva indicated that Mrs. Mck had Type O blood.[25] Race, therefore, believed Mrs. Mck to have had originally type O blood but received type A from her twin.[26] Rice then deemed Mrs. Mck a chimera and science had discovered a new anomaly.[27]

C. How Natural Chimerism is Formed

This article draws a distinction between natural and artificial formations of human chimerism. Natural chimerism occurs unbeknownst to the chimera, and can remain unnoticed for the chimera's life.[28] Natural chimerism occurs prior to birth and the degree of varying DNA may differ from one chimera to another. [29]

i. Fetomaternal Microchimerism

The most common form of natural chimerism is fetomaternal microchimerism (FMC). FMC is the minor presence of cells in a human that did not originate from that human.[30] FMC occurs most commonly during pregnancy after cells exchange between a fetus and the mother.[31] Scientists have noted that cell transfer between dizygotic twins in utero is common.[32] Scientists

[23] *Id*.
[24] *Id*. at 100.
[25] Bowley, *supra* note 15, at 81.
[26] Martin, *supra* note 17, at 100.
[27] *Id*. (noting that it remains unclear why Race coined the term 'chimera' for Mrs. Mck. It seems likely that Race relied on a 1951 article in which Peter Medawar described skin graft exchanges between twin cattle that used the term 'chimaera.').
[28] Boklage, *supra* note 11, at 579 (explaining that that "Without such cause for notice (as would usually be the case), [chimeras] are impossible to differentiate from single-genotype people by ordinary observation and seriously difficult to identify even with the best of the newest biomedical technologies.").
[29] *See generally* Dawe, *supra* note 1, at 24.
[30] Kian Hwa Tan et al., *Fetomaternal Microchimerism: Some Answers and Many New Questions*, 2 CHIMERISM 16, 16 (2011).
[31] Boklage, *supra* note 11, at 582 (noting that science has long used fetal cells in maternal blood for prenatal diagnoses).
[32] *Id*. ("At upwards of one in 12, chimerism cannot be considered rare among liveborn dizygotic twins.").

have documented cases in which fetal cells have been present in the mother for decades after the pregnancy. [33] While the actual percentage of FMC pregnancies is unknown, scientists have speculated that FMC could occur in nearly every pregnancy. [34]

The process of FMC remains unclear; however, the anatomy of the placenta has led to various scientific hypotheses. Figure 2 is a diagram of the human placenta. The fetal blood travels through the umbilical cord and enters the mother's placenta.[35] Theoretically, the fetal blood should remain separated from the maternal blood at all times by a thin wall of placenta.[36] However, the possibility exists that a micro-rupture could occur in the placenta, thus allowing the comingling of fetal and maternal blood.[37] Scientists have also accepted the possibility that certain maternal or fetal cells are capable of migration through the placental barrier.[38]

It has become clear that no matter the scientific reasoning behind cell migration, the process occurs early in pregnancy. [39] The effect of FMC in mothers is also controversial. Evidence suggests that fetal cells within the mother can have both positive and negative consequences with regards to autoimmune diseases and cancer.[40]

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[33] *Id*.
[34] Dawe, *supra* note 1, at 23.
[35] *Id.* at 20.
[36] *Id*. at 21.
[37] *Id*.
[38] *Id*.
[39] Dawe, *supra* note 1. at 22 (noting that fetal cells have appeared in maternal blood consistently within seven weeks).
[40] Nancy Shute, *Beyond Birth: A Child's Cells May Help or Harm the Mother Long After Delivery*, SCI. AM., (Apr. 30, 2010), http://www.scientificamerican.com/article.cfm?id=fetal-cells-microchimerism (noting that fetal cells have been found in the skin of women with autoimmune diseases but also may aide the body in triggering a response after a detection of cancer cells).

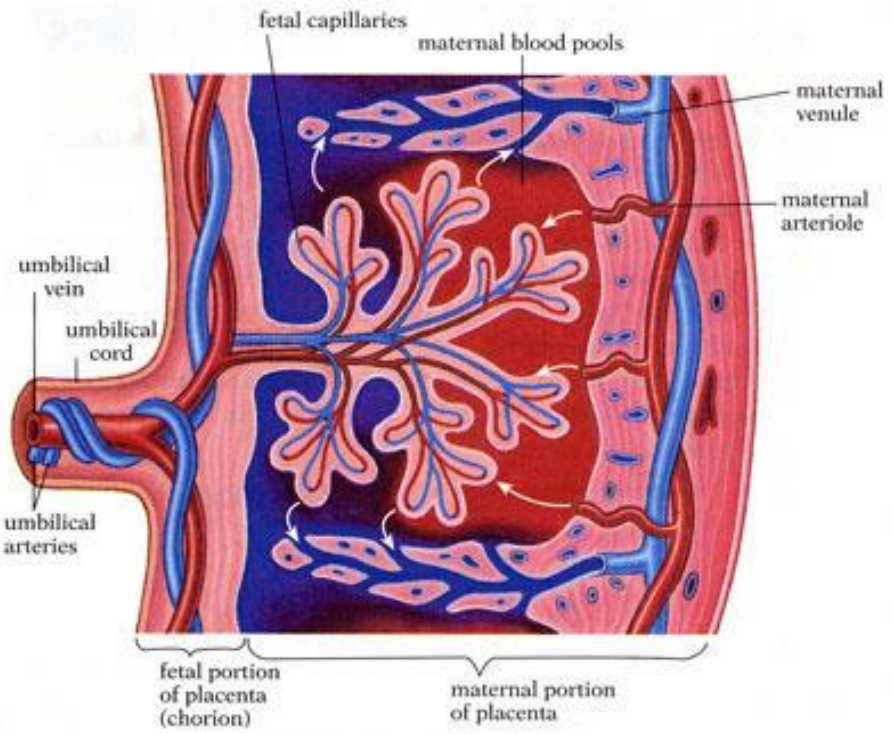

Figure 2 [41]

ii. Tetragametic Chimerism

Chimerism can be the product of dizygotic (fraternal) twinning.[42] In such an instance, the process begins when two separate eggs are fertilized by two sperm and create two separate embryos.[43] However, early on in gestation the two embryos may naturally fuse into one single embryo.[44] After the fusion occurs, the resulting single embryo will contain traces of DNA from both embryos.[45]

[41] PREGNANCYPRO, comment to *How Can Mother and Baby Have Different Blood Types? The Placental Barrier*, (Oct. 26, 2011), http://www.prenatalanswers.com/category/general/life-in-the-womb/.
[42] *See* H.J. Landy & L.G. Keith, *The Vanishing Twin: a Review*, 4 HUM. REPROD. UPDATE 177, 177 (1998).
[43] Ruth Tennen, *Chimeras, Mosaics, and Other Fun Stuff*, TECH. MUSEUM OF INNOVATION, (Sep. 27, 2007), http://genetics.thetech.org/ask/ask233.
[44] Landy, *supra* note 42, at 177 ("The loss of one member of a twin pair can be understood quite simply as part of the highly imperfect biology of human reproduction." Charles E. Boklage et al., MULTIPLE PREGNANCY: EPIDEMIOLOGY, GESTATION AND PERINATAL OUTCOME, 41-50, L.G. Keith et al. eds., 1995).
[45] Arabascio, *supra* note 8, at 440.

Embryo fusion involves a scientific process that starts very early on in the embryonic life.[46] Figure 2 shows the early stages of embryonic development. A sperm will fertilize an egg, creating a zygote.[47] The zygote will begin dividing until it eventually becomes a blastocyst.[48] After an embryo becomes a blastocyst, it contains a group of cells called the inner cell mass.[49] The cells within the inner cell mass are stem cells, meaning they are able to develop into any cell in the body.[50] In a pregnancy containing dizygotic twins, the embryos may fuse at this stage.[51] Because the cells are stem cells and are able to develop into any cell in the body, the embryos can successfully fuse and eventually become a phenotypically normal human.[52] The immune system will not attack the foreign cells because, as the immune system is formed in the embryo, cells from both embryos will be present.[53] Therefore, once the immune system is developed in the embryo, it will already have learned to recognize the foreign cells and not destroy them.[54]

[46] Tennen, *supra* note 43.
[47] *Id*.
[48] *Id*.
[49] *Id*.
[50] *Id*.
[51] Tennen, *supra* note 43.
[52] *Id*.
[53] *Id*. (explaining that "The immune system memorizes the proteins on the body's own cells and calls these proteins 'self'. It learns not to destroy 'self' proteins.").
[54] *Id*.

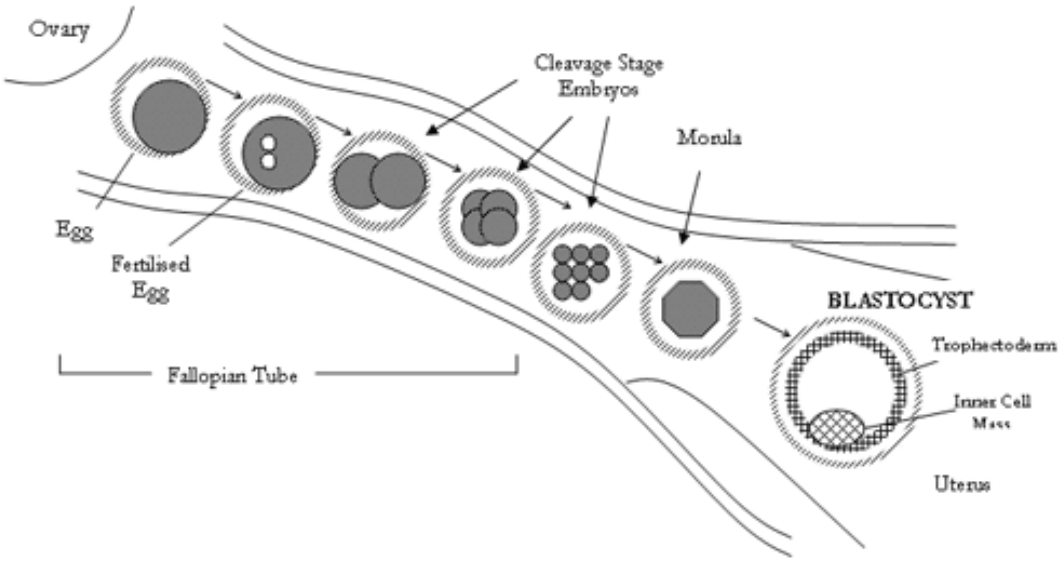

Figure 3 [55]

D. The Creation of Artificial Chimerism

Artificial chimerism occurs through scientific and medical intervention. Scientific progress has successfully been able to grapple the power of chimerism and turn it into medically necessary procedures.[56] The degree of chimerism is a critical determination after hematopoietic stem cell transplantation (HSCT).[57] However, science is currently seeking to expand chimerism's usefulness.[58] While artificial human chimerism is not the type of chimerism this paper seeks to address, it is nevertheless important to note its distinctions.

Chimerism currently plays an extremely important role in HSCT.[59] HSCT remains one of the primary treatments for many hematological disorders.[60] After bone marrow transplantation,

[55] *What is a Blastocyst?*, SIMS IVF, http://www.sims.ie/treatments/blastocyst.1046.html (last visited Dec. 3, 2013).
[56] *See generally* F Khan, A Agarwal & S Agrawal, *Significance of Chimerism in Hematopoietic Stem Cell*, 34 BONE MARROW TRANSPLANTATION 1, 1 (2004).
[57] *Id*; Ajay Perumbeti & Ronald A Sacher, *Hematopoietic Stem Cell Transplantation*, MEDSCAPE, (Nov. 11, 2013), http://emedicine.medscape.com/article/208954-overview (noting that HSCT involves "[T]he intravenous infusion of autologous or allogenic stem cells to reestablish hematopoietic function in patients whose bone marrow or immune system is damaged or ineffective.").
[58] *See generally* Laura Smith-Spark, *UK Takes Step Toward 'Three-Parent' Babies*, CNN, (June 28, 2013), http://www.cnn.com/2013/06/28/health/uk-health-dna-ivf/.
[59] Khan, *supra* note 56, at 1.

the degree of chimerism in the recipient is an important indicator as to the level of success of the transplant.[61] If the recipient has 'complete chimerism', meaning the recipient lacks any evidence of recipient cells, the success rate becomes relatively high, whereas if the recipient has 'mixed chimerism', the success rate can depend on the percentage of recipient cells that remain.[62]

Recently, an elaborate form of chimeric In Vitro Fertilization (IVF) has garnered both positive and negative views. The United Kingdom, in an effort to battle mitochondrial disorder, has said that three-person IVF procedure may be available in 2015.[63] With current IVF techniques leaving babies susceptible to life-threatening mitochondrial diseases, three-person IVF seeks to eliminate the dangers.[64] The IVF technique involves removing nuclear DNA from a donor embryo and replacing the nuclear DNA with the nuclear DNA of a mother's egg or embryo.[65] Thus, the new embryo would contain differing DNA: one set from the mother and father and another set from the donor embryo.[66]

E. How Common is Human Chimerism?

Most humans will live their entire life without ever realizing their chimeric status and, as a result, most chimeras will remain unidentified to science.[67] Nevertheless, scientists have speculated that chimeras are more common than originally thought. In fact, some argue that

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[60] *Id.*
[61] *Id.*
[62] Marco Andreani et al., *Relationship Between Mixed Chimerism and Rejection After Bone Marrow Transplantation in Thalassaemia*, 6 BLOOD TRANSFUSION 143, 143-149 (2008) (noting a recent study involving 93 patients suffering from Thalassemia illustrated this effect. Post transplant, 50 patients had 'complete chimerism' and only one of those patients rejected their graph. However, 43 patients had 'mixed chimerism' and ultimately seven of those patients rejected their graph).
[63] Christian Nordqvist, *UK Backs Three-Person IVF*, MEDICAL NEWS TODAY, (June 2013) http://www.medicalnewstoday.com/articles/262673.php.
[64] *Id.*
[65] Smith-Spark, *supra* note 58.
[66] *Id.*
[67] Boklage, *supra* note 11, at 581 ("We don't look for [chimeras] because we don't expect to find them and we don't find them until we trip over evidence we cannot ignore. The human spontaneous chimeras identified as such to date comprise only the small fraction of all chimeras in the human population which we have been unable to ignore.").

almost every human, at one point in their life, was chimeric.[68] Most commentators attribute high rates of human chimerism to FMC.[69] However, others believe that rates of tetragametic chimerism are also much higher than suspected. Dr. Boklage estimates that "at upwards of one in 12, chimerism cannot be considered rare among live-born dizygotic twins, and its occurrence in more than 20% of dizygotic triplet sets has to be called common."[70]

Science has agreed that one thing is certain: Assisted reproductive technology may cause a rise in the number of human tetragametic chimeras.[71] Generally, natural born fraternal twins occur in 1 out of 30 pregnancies.[72] Both fertility drugs, which increase the odds of multiple eggs being released at the same time, and IVF can increase the odds of having twins by 20-40 percent.[73] With dizygotic twins allowing for the possibility of tetragametic chimerism, scientists speculate that the rate of chimerism has also risen.[74]

F. The Difficulty in Testing for Chimerism

Certain forms of chimerism, namely tetragametic chimerism, can be incredibly difficult to detect in humans.[75] After the embryos fuse, the stem cells from the two embryos combine and will develop into all different parts of the human body.[76] Sometimes, the DNA from the vanished

[68] Esther Inglis-Arkell, *There's a Good Chance You're a Human Chimera*, (May 18, 2012, 1:40 PM), http://io9.com/5911357/theres-a-good-chance-youre-a-human-chimera.
[69] *Id.* ("It turns out a lot of mothers are chimeras…..and if you're a child, it's likely that part of you is your mother.").
[70] Boklage, *supra* note 11, at 582.
[71] Roger Highfield, *IVF Babies 'More Likely' to Have Mixed-Up* Genes, TELEGRAPH, (Nov. 13, 2003, 12:01 AM), http://www.telegraph.co.uk/science/science-news/3315330/IVF-babies-more-likely-to-have-mixed-up-genes.html.
[72] *Your Likelihood of Having Twins or More*, BABYCENTER, (Mar. 2012), http://www.babycenter.com/0_your-likelihood-of-having-twins-or-more_3575.bc (noting that the rate of twins has risen by about 76 percent over the past 30 years. The reasons behind such an increase include hormonal changes in women that are waiting longer to have babies and assisted reproductive technologies).
[73] *Id.*
[74] Highfield, *supra* note 71.
[75] *Chimeras, Mosaics, and Other Fun Stuff*, TECH. MUSEUM OF INNOVATION, (Nov. 17, 2011), http://genetics.thetech.org/ask/ask443
[76] *Id.*

twin will be found within the chimera's blood, therefore making detection relatively easy.[77] Other times, however, the vanishing twin's DNA will be found in random organs.[78] If this is the case, unless a DNA test is taken from that specific organ the chimeric status of the individual will remain unknown.[79]

Because of these difficulties in testing for chimerism, chimeras are usually discovered in one of two ways.[80] Dr. Boklage explains that, "There is a blind chance, among people with unremarkable phenotypes, who are discovered in some genotyping situation to carry three or four, instead of one or two, alleles at multiple loci." [81] However, these discoveries are rare because most blood tests will not discover small admixtures.[82] The second way that chimeras are generally found in society is irregular sexual anatomy or function.[83] The main shortcoming with this is that chimeras with normal phenotypes may never be discovered because their sexual anatomy can be normal.[84]

II. MODERN DAY HUMAN CHIMERAS

With the growing realization that natural chimeric humans are more common than originally thought, the consequences have only begun taking shape. Every aspect of law that relies on the validity of DNA may be affected. The first case study involving modern day human chimeras includes two mothers that had their lives changed forever when a DNA test proffered the impossible: their own children were not genetically related to her. The second case study

[77] *Id.*
[78] *Id.*
[79] *Id.*
[80] Boklage, *supra* note 11, at 581.
[81] *Id.*
[82] *Id.*
[83] *Id.* (noting that "Most of the other chimeras we know about have been found because of a sex difference between the cell lines in a chimeric individual, manifested by anomalies of sexual anatomy or maturation or function, causing a search for an explanation for the odd sexual phenotype, leading to the discovery of mixed cell lines.").
[84] Lam, *supra* note 12.

looks at Tyler Hamilton, an American cyclist who used tetragametic chimerism as a unique defense against positive blood doping results.

A. The Effect of Chimerism on Maternity and Paternity Testing

The scientific finding of chimerism in humans has solved seemingly unsolvable mysteries presented to courts and government agencies. In 1998, one such mystery puzzled the Beth Israel Deaconess Medical Center for two years.[85] Karen Keegan, a mother of three, was suffering from renal failure and desperately needed a kidney transplant.[86] Karen underwent histocompatibility testing in order to prepare for her kidney transplant.[87] Karen was stunned when, after her test results came back, she was told that two of her three sons were not hers.[88] Doctors repeated the tests but the results remained the same: Karen could not genetically be the mother of two of her sons because her sons had a haplotype from an origin other than their mother.[89]

Karen finally received an answer after tests showed that Karen's brother carried the same haplotype as Karen's two sons.[90] Showing a probability that Karen was indeed the mother of her children, the doctors then took other tissue samples from Karen's thyroid gland, mouth and hair.[91] The team of doctors found that Karen had one type of DNA in one tissue and another type

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[85] Claire Ainsworth, *The Stranger Within*, 180 NEW SCI. 34, 34 (2003) (Ainsworth refers to the chimera in her story as "Jane". However, comparing the circumstances, facts, and details with the story of Karen Keegan, the author has concluded that Ainsworth's story is about Karen Keegan).
[86] Yu, *supra* note 4, at 1545.
[87] Ainsworth, *supra* 85, at 34 (describing histocompatibility testing as "[T]ests based on a set of genes called the HLA complex, which encode many different immune proteins, including cell surface proteins that immune cells use to distinguish the body's own tissues for foreign material….transplant doctors know that the closer the match between two people's HLA haplotypes, the lower the risk of a transplant…"); Yu, *supra* note 4, at 1545.
[88] Ainsworth, *supra* note 85, at 34.
[89] *Id.*; *Haplotype*, MERRIAM-WEBSTER, http://www.merriam-webster.com/dictionary/haplotype (last visited Dec. 3, 2013) (defining a haplotype as "A group of alleles of different genes on a single chromosome that are closely enough linked to be inherited usually as a unit.").
[90] Ainsworth, *supra* note 85, at 34.
[91] *She's Her Own Twin*, *supra* note 5.

of DNA in another tissue, including the mysterious haplotype that was found in her two sons.[92] The doctors concluded that Karen's differing DNA was the result of tetragametic chimerism, meaning Karen had fused with an unknown embryo during gestation and had retained the differing DNA of that embryo.[93]

In 2003, a similar situation occurred in Washington State. Lydia Fairchild, a mother of two applied to receive government assistance through the welfare program.[94] In order to receive welfare aid, the State of Washington first required blood tests to verify parentage.[95] The results of Lydia's blood test claimed it was impossible for Lydia to be the mother of her children.[96] Lydia was denied government assistance and suspected of committing welfare fraud.[97] Lydia's social worker informed her that the State could "come get (her) kids at any time." [98]At the time, DNA tests were considered infallible.[99] Lydia attempted to rebut the DNA findings through possession of her children's birth certificates and assurance from her obstetrician who was present for all three births.[100] Nevertheless, the Judge eventually told Lydia to seek legal counsel.[101]

In an attempt to reconcile the mystery, the Court ordered an officer to accompany Lydia for the birth of her third child and witness immediate DNA tests.[102] However, DNA tests from the baby and Lydia, taken immediately after birth, showed it was impossible for Lydia to be the

[92] Ainsworth, *supra* note 85, at 34.
[93] *She's Her Own Twin*, *supra* note 5.
[94] Norton, *supra* note 6, at 107.
[95] Arcabascio, *supra* note 8, at 450.
[96] *She's Her Own Twin*, *supra* note 5.
[97] *Id.*
[98] *Id.*
[99] *Id.*
[100] *Id.*
[101] *She's Her Own Twin*, *supra* note 5.
[102] Arcabascio, *supra* note 8, at 451.

actual mother of the child.[103] Officials started believing that Lydia was being paid to act as a surrogate.[104] The mystery surrounding Lydia's children thankfully ended when Lydia's lawyer heard about Karen Keegan's story.[105] Lydia's case was postponed, and blood results indicated that Lydia was indeed a chimera.[106]

These two stories illustrate the dangers chimerism presents to the legal system. Karen and Lydia both presented as much evidence as possible proving their maternity, including birth certificates and testimony from an obstetrician, but the courts persistently relied on the DNA evidence and found their stories unbelievable. With such a devotion to DNA tests, the legal system essentially perpetuates the negative effects chimerism creates. While these stories showed the effect chimerism has had on government assistance programs and pre-operation medical testing, similar affects may also occur in other aspects of maternity and paternity testing that rely on the validity of DNA testing.

B. Human Chimerism Used as a Defense

In 2004, Tyler Hamilton, an American cyclist, won the gold medal in the Athens Olympics. However, in 2005, the United States Anti-Doping Agency found Hamilton guilty of homologous blood doping.[107] If the accusations remained true, Hamilton would lose his gold

[103] *She's Her Own Twin*, *supra* note 5.
[104] *Id*.
[105] *Id*.
[106] *Id*.
[107] Kolata, *supra* note 7; Dan Kois, *What is Blood Doping? And How Does it Work?*, SLATE, (Sept. 23, 2004, 1:47 PM) http://www.slate.com/articles/news_and_politics/explainer/2004/09/what_is_blood_doping.html (noting that blood doping refers to "Any illicit method of boosting an athlete's red blood-cell supply in advance of competition." Red blood cells are the blood stream's source of oxygen and therefore increasing their number gives the athlete's blood more oxygen to combat fatigue); *What Are the Different Types of Blood Transfusions for Doping?*, WORLD ANTI-DOPING AGENCY, http://www.wada-ama.org/en/resources/q-and-a/blood-doping/ (last visited Dec. 3, 2013) (stating that there are two different types of blood doping: autologous and homologous. Autologous blood doping is the transfusion of one's own blood, which has been stored until needed, whereas Homologous blood doping is the transfusion of blood that has been taken from another person with the same blood type).

medal and be the subject of worldwide criticism.[108] Instead, Hamilton attempted to use chimerism as a defense in his appeal, creating a huge controversy in the process.[109]

Hamilton argued that the positive test result was due to his "vanishing twin"; stating, therefore, that he was a tetragametic chimera.[110] Hamilton received the help of Dr. David Housman, a professor of molecular biology at the Massachusetts Institute of Technology.[111] Housman offered to testify during Hamilton's US Arbitration panel hearing and claimed that the testimony against Hamilton was "riddled with factual errors and inconsistencies."[112] Housman strongly believed that blood doping was not the only possible reason behind Hamilton's test results, and that tetragametic chimerism could actually be the cause.[113] The Anti-Doping Agency's expert, Dr. Ross Brown, attempted to refute Dr. Housman's theories.[114] He testified that human chimeras were exceedingly rare and added that another cyclist on Hamilton's team also tested positive for blood doping.[115] Dr. Brown claimed that "it is inconceivable to me that there would be two people who were rare chimeras on the same cycling team."[116] Unfortunately for Hamilton, his defense failed to convince the arbitration panel and the agency's finding was upheld.[117]

With other members of Hamilton's team being accused of blood doping, Hamilton's appeal was unlikely to be successful. However, using tetragametic chimerism as a defense to such an accusation raised many questions. If chimerism could be used as a defense for blood

[108] Kolata, *supra* note 7.
[109] William Fotheringham, *Banned Cyclist Blames "Twin" After Dope Test*, OBSERVER, (June 4, 2005) http://www.theguardian.com/world/2005/jun/05/usa.cycling.
[110] *Id*.
[111] *Id*.
[112] *Id*.
[113] *Id*.
[114] Kolata, *supra* note 7.
[115] *Id*.
[116] *Id*.
[117] *Tyler Hamilton Loses Appeal*, ACTIVE, http://www.active.com/articles/tyler-hamilton-loses-appeal (last visited Dec. 3, 2013).

doping, it could theoretically be used for a plethora of other charges that rely on DNA. Thus, while the Hamilton defense's reliance on chimerism was very narrow, the door was opened for other aspects of the criminal justice system being affected by human chimeras.

III. THE PROBLEMS FACING THE LEGAL SYSTEM WHEN FACING NATURAL CHIMERISM

Natural chimerism can cause incredible difficulties for all aspects of society relying on the validity of DNA testing. Whether it is DNA testing determining maternity or paternity for welfare benefits, or DNA testing to determine the identity of a murderer, natural chimerism causes large obstacles for courts to overcome. The first part of this section will look at possible difficulties natural chimerism causes in the context of maternity and paternity testing, primarily in child support, visitation rights, probate proceedings, and government assistance programs. The next section will look at difficulties presented to the criminal justice system when facing chimerism.

A. Natural Chimerism and its Effects on Maternity and Paternity Testing

The validity of maternity and paternity tests are paramount to many aspects of life. Identifying the correct mother or father of a child allows the child to create a maternal or paternal bond with whom they are related.[118] A valid DNA test can also create financial support for a single parent, develop a history of disease and other health concerns for the child as they grow up, and qualify the parents and/or the child for government assistance programs.[119] This section will focus on a few such concerns.

i. Child Support

[118] *The Importance of Knowing the Truth*, http://www.dnatesting.com/blog/dnatesting/2011/12/the-importance-of-knowing-the-truth/ (last visited Dec. 3, 2013).
[119] *Id*.

Consider contested paternity actions where DNA is relied upon to secure child support payments and allocation of visitation rights with the child. If the father is a tetragametic chimera, it is possible that the DNA received from a buccal swab of his cheek will not match the DNA of his child, thus showing a negative paternity test.[120] Because maternity and paternity DNA tests are considered nearly infallible, the mother, in this situation, would almost have no choice but to believe the DNA test and rule out the possibility of the chimera being the father.[121] These types of false negative DNA results can arise in other similar contexts, such as non-contested paternity actions where the biological father is attempting to prove paternity in order to maintain a legal relationship with his child. In such a situation, if the biological father is a natural chimera, and thus clueless to the fact he is a chimera, he could receive negative paternity results even though he is the actual father and lose the opportunity to visitation and parenting rights.

ii. Probate Issues

Natural forms of chimerism can also cause issues in paternity and maternity testing for unintentionally omitted children of a will. Consider *In Re Estate of Dicksion*, an Oklahoma Supreme Court case that dealt with this exact issue.[122] In *Dicksion*, Thomas Powell, an alleged son of the decedent born out of wedlock, argued that he was a pretermitted son of the deceased.[123] To support this contention, Powell presented a posthumous paternity test of the

[120] *Frequently Asked Questions Regarding Paternity/Parentage* Testing, www.geneticprofiles.com/main_files/faq.htm (last visited Dec. 3, 2013) (noting that a buccal swab is the most common method of DNA testing. It is conducted through a specialized applicator with a sponge, cotton, or Dacron tip. The applicator is brushed against the inside of the cheek and collects cells).
[121] *Id*. (noting that DNA testing is considered an extremely accurate science. An alleged father who receives a positive paternity test has a probability of 99% or higher that he is the actual father).
[122] *See* In the Matter of the Estate of Valatus Merral Dicksion, 286 P. 3d 283, 287 (2012).
[123] *Id*.; Pretermitted *Heir*, http://legal-dictionary.thefreedictionary.com/Pretermitted+heirs (last visited Dec. 3, 2013) (A pretermitted heir is defined as "The child of a person who has written a will in which the child is not left anything and is not mentioned at all.").

decedent showing parentage.[124] The trial court admitted the DNA test but another heir of the decedent challenged whether a posthumous DNA test could be used in probate proceedings.[125] The Supreme Court determined that posthumous paternity tests were admissible in probate proceedings, holding "it is illogical to allow posthumous genetic DNA testing under the Uniform Parentage Act, but not to allow it in intestate and probate proceedings…" [126]

It certainly seemed logical for states to extend paternity testing to probate matters; however, how does natural chimerism affect such matters? Because Thomas Powell was determined by the court to be a pretermitted heir, the decedent's will would be altered or nullified and Powell would be given the same share of the estate that he would have taken if his father had died intestate. If the decedent, Mr. Dicksion, was a natural chimera the validity of the DNA test would be skewed unbeknownst to the court. If that was the case, and the buccal swab from Mr. Dicksion showed that Powell was not his son, Powell would not receive any share of the estate.

iii. Welfare and Social Security

Circumstances arise where government benefits will only be issued after a positive DNA test showing parentage.[127] In such circumstances, the stakes are incredibly high because welfare and social security may be the primary or only source of income for an individual or family. That being the case, natural chimerism could create tragic consequences if false negative results occur.

[124] Dicksion, 286 P. 3d at 288.
[125] *Id*. at 290.
[126] *Id*.
[127] *Ensure Your Social Security Benefits With a Paternity Test*, http://usamdt.com/local/westchester-new-york/ensure-your-social-security-benefits-with-a-paternity-test/ (last visited Dec. 4, 2013).

After the death of a parent, children are sometimes able to collect the deceased parent's social security income.[128] However, in order to receive social security the individual must be a biological child, adopted child or dependent stepchild.[129] Now, imagine the situation in which a mother is pregnant out of wedlock and the father passes away during pregnancy.[130] In order for the unborn child to receive the social security payments of his deceased father, a DNA test will be ordered and parentage must be shown. However, if, in this example, the father was a natural chimera, the posthumous buccal swab could produce a false negative. Similarly, as seen in the Lydia Fairchild case, states may require proof of parentage in order to receive welfare benefits.[131] A mother having different DNA in her cheek and her cervix could be deemed an impostor and denied welfare benefits.

Admittedly, these hypotheticals largely remain just that—hypotheticals. The mother or father would have to have been a natural chimera. The chimerism in the individual must cause differing DNA between skin cells and other parts of the body, namely blood and certain reproductive organs. If that is the case, there is then a chance that the child of the chimera would receive the DNA from the reproductive organs and blood, while any cheek swab from the chimera would provide skin cells with differing DNA. While this is a string of consequences, the fact that it has happened twice through the stories of Lydia Fairchild and Karen Keegan support such concerns.

B. Concerns with the Criminal Justice System

[128] *Benefits for* Children, SOCIAL SECURITY ADMIN., http://www.ssa.gov/pubs/EN-05-10085.pdf (last visited Dec. 3, 2013) (According to the U.S. Government, "About 4.4 million children receive approximately $2.5 billion each month because one or both of their parents are disabled, retired or deceased.").
[129] *Id*.
[130] *Establishing Paternity for a Child Born Out of* Wedlock, OFF. CHILD. SUPPORT ENFORCEMENT, http://www.acf.hhs.gov/programs/css/resource/establishing-paternity-child-born-out-of-wedlock (last visited Dec. 3, 2013) (noting that a child born to parents unmarried has no legal bond with his father until paternity is established. Establishing paternity for a child out of wedlock is critical in providing the child with access to financial support).
[131] Arcabascio, *supra* note 8, at 450.

Chimerism can also have many effects on the criminal justice system. Although not the first attack on the credibility of DNA testing in criminal proceedings, human chimerism presents another problem.[132] This section will discuss three possible realities that challenge the validity and integrity of DNA testing in the criminal justice system.

i. The Uncatchable Chimeric Criminal

Imagine a murder in which the perpetrator was a chimera. Assuming there was a violent struggle between the perpetrator and the victim, the perpetrator could very easily have left DNA at the scene of the crime.[133] If such DNA is found at the crime scene, the prosecution will rely on it heavily.[134] Because the perpetrator is a chimera, the DNA left at the scene could be different from a buccal swab test. After a forensic investigator conducted a test comparing the DNA of the chimera to the DNA left at the scene and discovered a mismatch, the investigation could be hindered or charges could be dropped. Even if the investigation eventually led to a trial, the prosecutor would have a hard time convicting the perpetrator when the DNAs are mismatched. Prosecutors generally have high conviction rates with matching DNA between the defendant and

[132] Phil Reilly, *Legal and Public Policy Issues in DNA Forensics*, 2 NATURE REV. 313, 313 (2001) (noting that "During the late 1980's and early 1990's, several scientists teamed up with defense attorneys to challenge [DNA] reliability. Expert witnesses questioned the laboratory techniques that were used to type the DNA markers, the algorithms that were used to declare that two samples matched, and the relatively sparse population data that were used to calculate the probability that DNA from a randomly selected person would match the profile of a sample obtained from a crime scene.").

[133] *Understanding DNA Evidence: A Guide for Victim Service Providers*, NAT'L INSTIT. JUST., https://www.ncjrs.gov/pdffiles1/nij/bc000657.pdf (last visited Dec. 3, 2013) (Common DNA evidence collected at crime scenes may include hair, skin cells, blood, or other bodily fluids). https://www.ncjrs.gov/pdffiles1/nij/bc000657.pdf).

[134] *See* Andrea Roth, *Safety in Numbers- Deciding When DNA Alone is Enough to Convict*, 85 N.Y.U. L. REV. 1130, 1135 (2010) (discussing that there are two distinct types of DNA criminal prosecutions. A "confirmatory" case occurs when the police have found a suspect and subsequent DNA sampling indicates a match. The other kind, entitled "cold hit cases", involve a finding of DNA at a crime scene and a matching of that DNA to a database. Cold hit DNA cases have increased within the last decade, showing an increased reliance on DNA by prosecutors).

the crime scene sample; however, if the chimeras DNA did not match the sample in the above hypothetical there is a much higher chance the perpetrator would be acquitted.[135]

Further, if the perpetrator's chimeric status directs the investigation to other individuals, it is possible that certain individuals may become wrongfully accused. For instance, a boyfriend, neighbor, or best friend could be accused due to other forms of circumstantial evidence linking them to the murder; all the while the chimeric perpetrator is obviated as a suspect.

ii. The "Reverse CSI Effect"

Other commentators on chimeric criminals have hypothesized about the possibility of a "reverse CSI effect."[136] The theory rests on the assumption that chimerism is becoming more mainstream in the public.[137] With various plots of television shows and talking points in newspapers revolving around chimerism, it is possible that the public, namely the jury in the criminal context, could begin minimizing the weight of mismatching DNA evidence.[138] If chimerism becomes a household term, the theory argues that juries could begin believing that every criminal defendant could theoretically be a chimera and thus a DNA mismatch could be ignored.[139]

iii. Chimerism and its Effect on the Exoneration Movement

The exoneration movement is an umbrella term consisting of various public policy organizations and advocacy groups that work to expose and release wrongfully convicted

[135] Jeffrey M. Prottas & Alice A. Noble, *Use of Forensic DNA Evidence in Prosecutors' Offices*, 2007 Journal of Law, Medicine & Ethics 310, 312 (discussing a study examining the effectiveness of DNA evidence in Denver, in which the Colorado prosecutor offices revealed that when matching DNA evidence was used in a criminal proceeding, the conviction rate was 90%).
[136] *See generally* Arabascio, *supra* note 8, at 457-462.
[137] *Id*.
[138] *Id*. (noting that the television show CSI aired an episode "Bloodlines" in which a woman is raped by a chimeric criminal. The rape kit evidence is subjected to DNA testing which ultimately does not match the suspect and results in the suspect being ultimately released).
[139] *Id*.

individuals through DNA testing.[140] Many of the prisoners that are exonerated were incarcerated prior to the usage of DNA testing in criminal proceedings and therefore never were able to use a DNA mismatch toward their defense.[141] The majority of DNA exonerations are the result of inadequate scientific practices.[142]

The increasing rate of human chimerism could greatly affect the exoneration movement, both for the better and for the worse. If science and the criminal justice system begin appreciating chimerism, more of the wrongfully accused could be released. For example, an investigation into a chimera that was previously dropped because of mismatching DNAs might be reopened and, as a result, an innocent individual would be released.

However, the opposite effect may also result from an increase in attention to human chimerism. Similar to the "reverse CSI effect" theory, the exoneration movement could be hindered if society begins believing that any DNA mismatch is the result of human chimerism. Typically, the exoneration movement succeeds with prisoners who did not benefit from a DNA test when convicted, but the subsequent DNA test showed a mismatch. If the media over utilizes chimerism in the criminal justice system, the support behind the exoneration movement would dwindle and hinder the effectiveness of DNA in exoneration efforts.

IV. RECOMMENDATIONS

[140] *See e.g., Unreliable or Improper Forensic Science*, INNOCENCE PROJECT, http://www.innocenceproject.org/understand/Unreliable-Limited-Science.php (last visited Dec. 3, 2013) *(*the Innocence Project is a public policy organization dedicated to exonerating the wrongfully convicted and reforming the criminal justice system to prevent future injustice); *The Exoneration Initiative*, http://www.exonerationinitiative.org/our_mission.php (last visited Dec. 3, 2013) (the Exoneration Initiative is a free legal assistance program in New York that provides "[F]ree legal services to indigent prisoners and works to inform and educate the public about the fallibility of the criminal justice system.").

[141] *Resurrection After Exoneration*, http://www.r-a-e.org/about/facts-exoneration (last visited Dec. 3, 2013).

[142] *Unreliable or Improper Forensic Science*, *supra* note 125 (the Innocence Project estimates that "in more than 50% of DNA exonerations, improper forensic science contributed to the wrongful conviction.").

There are not any perfect solutions to the various problems human chimerism presents to the legal system. As of right now, scientists are limited in how they can test for chimerism. A DNA sample of the blood might miss the presence of chimerism in organs, while a DNA sample of tissues and organs might miss the presence of chimerism in epithelial cells or the blood.[143] The obvious solution is for the development of a scientific test to determine whether differing strands of DNA are present within a human body. Short of that, however, there are other means that could potentially alleviate aspects of the chimera problem.

Firstly, contrary to the "reverse CSI" effect theory, chimerism must be brought to the attention to the public. While there have been certain television shows and novels that have used chimerism in their respective plots, chimerism remains relatively unknown to the public.[144] The public could be enlightened through media stories on chimerism as a medical condition or the condition could even be taught in schools. Because society is largely unaware of this problem, a DNA test that provides a false negative, as seen in the Lydia Fairchild case study, is still deemed to be accurate. Widespread recognition of chimerism as a medical condition could allow judges to consider chimerism as a plausible explanation to an issue, rather than to assume the DNA test is infallible. Moreover, an increase in recognition might put pressure on scientists to begin developing a test to determine chimerism. While this suggestion seems at odds with the "reverse CSI" effect referenced earlier, that is not the case. The "reverse CSI" effect assumes the widespread recognition of chimerism will lead to society believing every negative DNA test could be the result of a human chimera. However, if the public is properly educated on chimerism and it's effects, it will recognize that chimerism, while becoming more common, is still a rare condition and therefore should not be applied to every situation. This type of

[143] *Chimeras, Mosaics, and Other Fun Stuff*, *supra* note 75.
[144] Boklage, *supra* note 11, at 581 (noting that "We do not expect to find chimeras because most of us are ignorant of their existence and the informed few just know they are too rare and bizarre to require consideration.").

education would result from accurate documentaries, the school system, and the media and, in doing so, the dangers discussed in the "reverse CSI" effect" that television shows and other forms of entertain create would be eliminated.

Secondly, the legal system should provide an avenue in which mothers and fathers can prove their parentage if their DNA test shows a false negative. This article has shown the power that maternity and paternity tests have. They can deny a child social security, a share in their parent's estate, or deny a parent the right to visit their child. Therefore, the court system should allow alleged chimeras an opportunity to prove their parentage without being threatened to have their children taken away or accused of fraud. Due to the difficulty in testing for chimeras, many parents might not be able to affirmatively prove their chimeric status like Lydia Fairchild and Karen Keegan were able to do. Thus, the courts should allow a parent to prove their parental status through a "totality of the circumstances" test, in which parents are able to provide birth certificates, testimony from their OB-GYN, DNA tests, and any other means necessary to prove parentage. The power of DNA tests is absolute; however, the accuracy of DNA tests is not.

CONCLUSION

When scientists discovered that Mrs. Mck had two different blood types in 1951, it is doubtful they knew the range of effects that could theoretically happen. It was not until about 50 years later, when Lydia Fairchild and Karen Keegan were told they were not the mothers of their children that the legal implications of chimerism began to surface. Between the presence of fetal cells in a mother after birth, and the process of embryo fusion during the earliest stages of pregnancy, and even the presence of foreign DNA in a transplant recipient, chimeras are more common than originally thought. Moreover, with the increase of artificial reproductive technologies, chimerism is thought to become even more common.

As chimerism becomes more common, the likelihood of legal issues arising becomes greater. Wide ranges of legal implications depend on the accuracy of DNA testing. Whether a child is attempting to inherit from their chimeric parent or whether a chimeric mother is attempting to receive government aid to raise her children, a DNA test that provides a false negative could be devastating. Similarly, the power that DNA tests wield in the criminal justice system is seemingly unlimited. However, the presence of chimeras in our population, no matter how minor that presence is, questions the validity of DNA tests and the integrity of the justice system as a whole. Until chimerism is easily determined through a medical test, the possibility exists that an innocent man could be convicted, or fail to be exonerated because the actual perpetrator is a chimera. Sir William Blackstone argued, "It is better that ten guilty persons escape than that one innocent suffer."[145] That theory, embodied eternally in the core of United States jurisprudence, is threatened with the scientific discovery of human chimerism.[146]

[145] *Sir William Blackstone*, Encyclopedia Britannica, http://www.britannica.com/topic/68589/supplemental-information (last visited Dec. 4, 2013).
[146] Henry v. United States, 361 U.S. 98, 104 (1959) (noting that "It is better, so the Fourth Amendment teaches, that the guilty sometimes go free than that citizens be subject to easy arrest.").