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Chimeras: Double the DNA - Double the Fun for Crime Scene Investigators, Prosecutors, and Defense Attorneys?

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CHIMERAS: DOUBLE THE DNA-DOUBLE THE FUN FOR CRIME SCENE INVESTIGATORS, PROSECUTORS, AND DEFENSE ATTORNEYS?

*Catherine Arcabascio**

I. INTRODUCTION

The evolution of knowledge about the genetic material that makes us the mono-genetically unique individuals we think we are continues to surprise us with the discovery that there actually are living, breathing human chimeras around us. The only thing that distinguishes the chimeras from the rest of the human beings on the planet lies hidden deep within them in their genetic codes, and only a handful have been identified.¹ While the term “chimera” is often associated with hermaphrodites, who have both male and female sexual organs, it in fact covers a wider range of individuals who have two separate and distinct DNA strands in their bodies.² Unlike hermaphrodites, these other chimeras are quite difficult to discover because they are derived from two same-sex embryos and may have no external differentiating features.³ In addition, there is a condition called microchimerism, or blood chimerism, which results in different types of DNA, albeit in smaller populations, in blood.⁴ Thus, at least from a genetics perspective, there are in fact some of us who are “more unique” than others.

* Catherine Arcabascio is a professor of law at Nova Southeastern University, Shepard Broad Law Center. Thanks to Dr. Martin Tracey and Dr. George Duncan for their invaluable assistance in analyzing and interpreting the complex scientific issues relating to chimerism. A heartfelt thanks also to Matthew Criscuolo, Eloisa Rodriguez-Dod, and Melanie Putnam for their help in researching and editing this article.

1. Charles E. Boklage, *Embryogenesis of Chimeras, Twins and Anterior Midline Asymmetries*, 21 HUM. REPROD. 579, 579 (2006).

2. *Id.* at 581.

3. *Id.*

4. Kristina M. Adams & J. Lee Nelson, *Microchimerism: An Investigative Frontier in Autoimmunity and Transplantation*, 291 J. AM. MED. ASS'N, 1127 (2004).

The only way some types of chimeras can be distinguished from non-chimeras is through extensive DNA testing.⁵ During the past several years, these otherwise indistinguishable chimeras have been surfacing around the world. As a result, recently there has been a flurry of media coverage about these newly discovered chimeras.⁶

This article first explores the mythological origins of the term “chimera.” It then explores the causes and scientific explanations of chimerism and the various conditions covered by the term chimera in the area of genetics. Although this article will discuss the various chimeric conditions that are thought to exist, its primary focus is on chimerism that is the result of the fusing of embryos *in utero*. Next, the article will discuss recent cases of chimerism – and of alleged chimerism – and how the genetic differences between chimeras and the general population came to light. It also will discuss the implications that chimerism may have on the investigation, prosecution, and defense of criminal cases by providing hypothetical criminal scenarios involving a chimeric defendant. Finally, the article will address the possibility that chimerism may have a “Reverse CSI Effect” on criminal cases.

II. THE CHIMERA OF GREEK MYTHOLOGY

Chances are a teenager is more familiar with the Greek beast, Chimera, than you. All young video gamers eventually come into contact with one in the virtual world. Games such as “Warhammer 40,000,” “Dawn of War,” and “Warcraft III” use them as worthy opponents in mythical, virtual worlds.⁷ On any given day, teenagers

5. See Camilla Drexler et al., *Tetragametic Chimerism Detected in Healthy Woman with Mixed-Field Agglutination Reactions in ABO Blood Grouping*, 45 *TRANSFUSION* 698, 701-02 (2005).

6. There are at least thirty-six known cases of chimerism. Bob A. van Dijk, Dorret I. Boomsma, & Achile J.M.de Man, *Blood Group Chimerism in Human Multiple Births is Not Rare*, 61 *AM. J. OF MED. GENETICS* 264 (1996); Neng Yu et al., *Brief Report: Disputed Maternity Leading to Identification of Tetragametic Chimerism*, 346 *NEW ENG. J. MED.* 1545, 1545 (2002); B. Simon-Bouy et al., *Possible Human Chimera Detected Prenatally After In Vitro Fertilization: A Case Report*, 23 *PRENATAL DIAGNOSIS* 935, 935 (2003); *She's Her Own Twin*, ABC NEWS PRIMETIME, Aug. 15, 2006, <http://www.abcnews.go.com/Primetime/story?id=2315693&page=1> [hereinafter PRIMETIME, *She's Her Own Twin*]; Chih-Ping Chen et al., *Prenatal Diagnosis, Sonographic Findings and Molecular Genetic Analysis of a 46,XX/46,XY True Hermaphrodite Chimera*, 25 *PRENATAL DIAGNOSIS* 502, 502 (2005); *I am My Own Twin* (Discovery Channel Health broadcast May 19, 2005); *DNA Sheds Light on "Hybrid Humans"* (National Public Radio broadcast Aug. 11, 2003). There also have been many blogs and websites devoted to Chimeras. See <http://www.google.com/search?hl=en&q=%22chimera%22+%2B+%22blog%22> (searching Google for “chimera” + “blog”).

7. Dawn of War, http://www.dawnofwargame.com/races/index.php#imperial_guard; Warcraft III, <http://www.battle.net/war3/nightelf/units/chimaera.shtml>. For a list of other games

around the world are engaged in a battle to the death with some version of the loathsome, fire-breathing killer.

The Chimera originally was a creature found in Greek mythology.⁸ “She was a most singular portent, a lion in front, a serpent behind, a goat in between. . . .”⁹ She was a “fearful creature, great and swift of foot and strong, whose breath was flame unquenchable.”¹⁰ There are also references to the Chimera in the Fifth Century writings of Pindar, Hesiod’s writing in the Eighth or Ninth Century, and in the Iliad.¹¹

The Chimera of Greek mythology was a force to be reckoned with.¹² She was the creature that everyone feared and no one could conquer.¹³ This was true until Bellerophon came onto the mythological scene. Bellerophon, son of King Glaucus, but rumored to actually be the son of Poseidon, wanted, more than anything, to have Pegasus, the winged horse.¹⁴ Bellerophon went to Athena’s temple, where she provided him with a bridle of gold.¹⁵ With that bridle, Bellerophon was able to finally tame Pegasus and ride him.¹⁶ During these adventures, Anteia, the wife of King Proteus of Argos, fell in love with Bellerophon.¹⁷ He wanted nothing to do with her and, in her anger, spawned by his rejection, she told Proteus that Bellerophon had “wronged her” and that he must die.¹⁸ Proteus did not want to kill Bellerophon himself because Bellerophon had “eaten at his table,” but instead asked Bellerophon to take a letter to the King of Lycia.¹⁹ The letter stated that Proteus wanted Bellerophon killed.²⁰ The King, however, entertained Bellerophon for nine days before reading the letter.²¹ Because the Lycean King also did not want to kill Bellerophon, the King sent him on an adventure to slay the Chimera.²² That way,

that use chimeras, see <http://en.wikipedia.org/wiki/chimera>.

8. EDITH HAMILTON, MYTHOLOGY: TIMELESS TALES OF GOD AND HEROES 139–43 (Warner Books 1999) (1942). There are different spellings used for the mythical creature, and Edith Hamilton refers to the beast as a “Chimaera.”

9. *Id.* at 142.

10. *Id.*

11. *Id.* at 139–40.

12. *See id.* at 142.

13. *See id.*

14. HAMILTON, *supra* note 8, at 139.

15. *Id.* at 140.

16. *Id.*

17. *Id.* at 142.

18. *Id.*

19. *Id.*

20. HAMILTON, *supra* note 8, at 142.

21. *Id.*

22. *Id.*

neither Proteus nor the king would have the blood of Bellerophon on his hands, as the Chimera was known to be unconquerable and Bellerophon would fail in his attempt to slay the Chimera and be killed.²³ However, with the help of Pegasus, Bellerophon was able to slay the Chimera.²⁴

III. THE SCIENTIFIC COMMUNITY BORROWS THE TERM “CHIMERA”

The scientific community has borrowed the jargon of Greek mythology to describe an unusual mixture of species and used it to describe certain types of organisms that also are a mixture of sorts.²⁵ According to *Churchill's Medical Dictionary*, a chimera is “an organism composed of two or more genetically distinct cell types.”²⁶ If cells are genetically distinct, they will have different DNA markers.²⁷ DNA, or deoxyribonucleic acid, is the foundation for all living creatures.²⁸ Under normal circumstances, each of us has one distinct, unique set of DNA markers, also known as our genetic fingerprint or code.²⁹ Those markers will be the same, regardless of what part of the body is subjected to DNA testing.³⁰

A. How a Chimera is Formed

Chimerism can come about in a variety of ways.³¹ One can be a chimera as a result of transfusion, transplantation, or inheritance.³² Transplant and transfusion recipients result in non-spontaneous human chimeras since the mixture of different organs or blood has been intentional.³³ If a person receives a blood transfusion, in very limited situations, some cells from the donor may commingle with the recipient's blood.³⁴ In addition, a person who receives a transplanted

23. *Id.*

24. *Id.*

25. See generally van Dijk et al., *supra* note 6.

26. Boklage, *supra* note 1, at 580 (citing CHURCHILL'S MEDICAL DICTIONARY (1989)).

27. See Kathryn M. Turman, *Understanding DNA Evidence: A Guide for Victim Service Providers*, U.S. DEPT. OF JUST., OVC BULLETIN, Apr. 2001, http://www.ojp.usdoj.gov/ovc/publications/bulletins/dna_4_2001/NCJ185690.pdf.

28. *Id.*

29. *Id.*

30. See *id.*

31. Myra J. Hird, *Chimerism, Mosaicism and the Cultural Construction of Kinship*, 7 *SEXUALITIES* 217, 219 (2004). See also J. Lee Nelson, *Microchimerism: Incidental Byproduct of Pregnancy or Active Participant in Human Health*, 8 *TRENDS IN MOLECULAR MEDICINE* 109, 109 (2002).

32. Hird, *supra* note 31, at 219.

33. See generally Boklage, *supra* note 1, at 580.

34. van Dijk et al., *supra* note 6. This type of “artificial chimerism” can occur, for example,

organ can have the donor's DNA passed along with that organ.³⁵ In the case of a bone marrow transplant, a successful transplant patient will have a mixture of his own blood and that of the donor.³⁶

Alternatively, a person also could naturally be a chimera, through inheritance, either by the free passage of blood between mother and child, or between child and child *in utero*.³⁷ This free passage of blood may result in a condition known as microchimerism.³⁸ "The term 'microchimerism' refers to a small population of cells or DNA in one individual that derives from another genetically distinct individual."³⁹

Cell traffic between mother and fetus during pregnancy recently has been found to result in long-term persistence of fetal cells in the mother ("fetal microchimerism") and maternal cells in her children ("maternal microchimerism").⁴⁰ Microchimerism may also result from twin-twin transfer of blood *in utero*.⁴¹ This also is known as "blood chimerism" or "twin chimerism."⁴² Although not formally proven, fetal microchimerism can exist even after miscarriage and abortion.⁴³ Theoretically, microchimerism also could occur from the transfer of an older sibling's DNA, through the mother's blood circulation, to the fetus in a later pregnancy.⁴⁴ Amazingly, it is possible for a child to have his mother's maternal cells for forty to fifty years.⁴⁵ Conversely, it also is possible for a mother to have her child's DNA for decades after the

when there are transfused blood stem cells, which occurs through intrauterine transfusion or bone marrow transplants. *See id.* Interestingly, when laboratories are collecting blood samples, they want to know whether the donor has had a blood transfusion within the past 90 days. *See, e.g., Physical Evidence Bulletin, CALIFORNIA DEPARTMENT OF JUSTICE, <http://www.cci.ca.gov/Reference/peb/PEB4.doc>. According to the Canadian National DNA Databank, a red blood cell transfusion will not transfer the donor's DNA. National Canadian Data Bank, http://www.nddb-bndg.org/train/docs/faq_e.pdf. If the transfusion contains white blood cells or platelets, however, it could transfer some of the donor's DNA to the recipient. *Id.* The Canadian Database suggests waiting one month after a transfusion before providing a DNA sample. *Id.* Except for this passing reference, blood transfusions are outside the scope of this article.*

35. *See* Boklage, *supra* note 1, at 580. Except for this passing reference, chimera transplantation issues are outside the scope of this article.

36. National Canadian Data Bank, *supra* note 34, at Q.10.

37. *See generally* Boklage, *supra* note 1, at 580.

38. *Id.* *See also* Nelson, *supra* note 31, at 109.

39. Nelson, *supra* note 31.

40. *Id.*

41. Drexler et al., *supra* note 5, at 698; Adams & Nelson, *supra* note 4, at 1127.

42. Drexler et al., *supra* note 5; Adam & Nelson, *supra* note 4, at 1127.

43. Adams & Nelson, *supra* note 4, at 1127.

44. *Id.*

45. C. Spencer et al., *Report From the Ross Petty Pediatric Rheumatology Symposium: Old Challenges & New Directions in Pediatric Rheumatology*, Apr. 2, 2005, 195, 199. <http://www.pedrheumonlinejournal.org/may-june05/pdf/Petty%20symposium.pdf>.

birth.⁴⁶ Low concentrations of male DNA can be found in a woman for decades after carrying a son.⁴⁷ In one experiment using a control group of twenty-eight women who previously had given birth to a son, doctors discovered that thirty-six percent of the women had male cells in their livers.⁴⁸ The investigators in this trial surmised that this was a result of fetal microchimerism.⁴⁹ Thus, microchimerism could result in small clusters of a secondary DNA source in a person's blood or organs.⁵⁰

A person also could naturally be a chimera through the merging of embryos *in utero*, which is known as tetragametic chimerism.⁵¹ These are considered spontaneous human chimeras and are the focus of this article.⁵² Unlike microchimerism, small populations of different cells are not necessarily found, for example, in an organ of a tetragametic chimera.⁵³ Instead, when two embryos merge, the result is a person who could have two genetic profiles in their blood or separate and distinct DNA markers in different parts of the body.⁵⁴ This may result from either a merging of two different embryos that fused or the existence of one cell mass from a split, singular embryo.⁵⁵ In his writings on chimeras and twins, Dr. Charles E. Boklage suggests that spontaneous human chimeras are primarily formed by some sort of embryonic fusion or splitting.⁵⁶

Most people who are familiar with the genetic anomaly that causes

46. J. Lee Nelson et al., *Microchimerism and HLA-Compatible Relationships of Pregnancy in Scleroderma*, 351 THE LANCET, 559, 559 (1998) ("fetal cells have been shown to persist in the material circulation for up to 27 years after pregnancy").

47. *Id.*

48. Anne Stevens et al., *Liver Biopsies from Human Females Contain Male Hepatocytes in the Absence of Transplantation*, 84 LABORATORY INVEST. 1603, 1603 (2004).

49. *Id.*

50. *See id.*

51. Boklage, *supra* note 1, at 582. Tetragametic chimeras also are called dispermic, whole body, or generalized chimeras. *Id.* Tetragametic means four gametes, two from each embryo. *See* George Q. Daley, Assoc. Professor of Pediatrics, *Stem Cell Research: Science, Ethics and Policy*, (Nov. 2004) in LAHEY CLINIC MED. ETHICS, Winter 2005, at 2.

52. *See generally* Boklage, *supra* note 1, at 580.

53. *Id.* at 582.

54. *See* Drexler et al., *supra* note 5, at 698.

55. Boklage, *supra* note 1, at 579.

56. *Id.* Boklage's latter theory regarding the splitting mechanism that triggers chimerism is more novel. The traditional notion has been that two embryos fused to form a chimera. *Id.* For purposes of this article, the author will track the more traditional view of spontaneous chimerism. Spontaneous tetragametic chimerism can also occur in other ways. For a detailed explanation, refer to Lisa Strain et al., *A True Hermaphrodite Chimera Resulting from Embryo Amalgamation After In Vitro Fertilization*, 338 NEW ENG. J. MED. 166, 166 (1998). *See also* Yunis et al., *Identification of a Phenotypically Normal Tetragametic Chimeric Fertile Woman By HLA and STR Typing*, available at <http://www.promega.com/geneticidproc/ussymp12proc/contents/yunis.pdf>.

chimerism first think of hermaphrodites.⁵⁷ A hermaphrodite can be a type of chimera that occurs when one person is derived from two or more zygotes or embryos of different sexes.⁵⁸ In other words, a tetragametic chimera is the result of “amalgamation of two embryos, each derived from an independent, separately fertilized, ovum.”⁵⁹ A hermaphrodite chimera, however, may derive from a male embryo and a female embryo, and thus can have both male and female genitalia.⁶⁰ This is what experts call “sex discordance in the cell line.”⁶¹ Accordingly, the fusion of a male and female zygote may result in a visibly identifiable chimera.⁶²

Other visible “developmental anomal[ies] in one of the cell lines” exist.⁶³ Some chimeras have a patchwork-type skin anomaly in which patches of skin are of different colors.⁶⁴ Others may have two different colored eyes.⁶⁵ As one scientist describes,

[c]himeras are not visibly different from the rest of us unless a developmental anomaly in one of the cell lines, or sex discordance between the cell lines, sometimes causes a visibly abnormal phenotype. Without such cause for notice (as would usually be the case), they 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. Cases are discovered in the population with low frequency and high technical difficulty, *creating the pervasive false impression that they are rare.*⁶⁶

Other chimeras, however, are not visually distinguishable at all.⁶⁷ Without extensive DNA testing, there is no way to know that their bodies contain different strands of DNA.⁶⁸ That is what makes them the most fascinating and elusive of the natural chimeras. They are not visually distinguishable, like hermaphrodites, because there is no “sex

57. Boklage, *supra* note 1, at 581.

58. See Strain et al., *supra* note 56, at 167.

59. *Id.* According to Strain, this is not the only way a hermaphrodite can result. *Id.* It also can result with the fertilization of a mature ovum and its first polar body or the fertilization of a mature ovum and a second polar body. *Id.*

60. *Id.* at 166. Note that not all hermaphrodites are chimeras.

61. Boklage, *supra* note 1, at 579.

62. *Id.*

63. *Id.*

64. Yu et al., *supra* note 6. See also van Dijk, et al, *supra* note 6.

65. *Id.* See Drexler et al., *supra* note 5, at 701.

66. Boklage, *supra* note 1, at 579. (emphasis added). See also Drexler et al., *supra* note 5, at 701.

67. Boklage, *supra* note 1, at 579. See also Drexler et al., *supra* note 5.

68. *Id.*

discordance” in the cell line and there are no other cues, such as patchwork skin or different colored eyes.⁶⁹ These chimeras, like those that have patchwork skin or different colored eyes, derive from same-sex embryos.⁷⁰ This condition occurs when one embryo fuses with another *in utero*, leaving the other embryo unaccounted for; hence, the term “vanishing twin.”⁷¹ These tetragametic chimeras require the fertilization of two eggs by two spermatazoa, after which the two zygotes, or early embryos, fuse together during the early stages of the pregnancy.⁷² They must be dizygotic embryos, arising from two separate, fertilized eggs, as opposed to monozygotic embryos, which occur when a single egg splits into two.⁷³ Dizygotic embryos would result in what is commonly known as fraternal twins, if they had both made it to term.⁷⁴ Conceivably, there could be a fusion of three embryos, but to date, there is no reported medical evidence of such a case.⁷⁵ Dizygotic twins do not have the same DNA.⁷⁶ On the other hand, monozygotic embryos, which result in identical twins, have the same DNA.⁷⁷ Thus, if monozygotic embryos merge *in utero*, only one genome of identical DNA would be present.⁷⁸

With chimeras, what started out as multiple embryos could end up as a “singleton” at birth, and, virtually, no one would be the wiser.⁷⁹ When this occurs, the DNA from the vanished twin can become

69. *Id.* Another possible explanation for persons who have different colored eyes is a condition called mosaicism. *Id.* at 580. Unlike chimerism, mosaicism occurs during cell division of a single zygote and some cells will be comprised of one chromosome constitution and others will be comprised of another. BLACK’S MEDICAL DICTIONARY 113 (40th ed. 2004) (defining chimera); *c.f.* BLACK’S MEDICAL DICTIONARY 412 (40th ed. 2004) (defining mosaicism).

70. Drexler, et al, *supra* note 5, at 701.

71. Helain J. Landy et al., *The “Vanishing Twin”: Ultrasonographic Assessment of Fetal Disappearance in the First Trimester*, 155 AM. J. OBSTETRICS & GYNECOLOGY 14, 14 (1986). *See also* Helain J. Landy & L.G. Keith, *The Vanishing Twin: A Review*, 4 HUM. REPROD. UPDATE 177, 177 (1998).

72. Yu et al., *supra* note 6, at 1545. Tetragametic chimerism can also occur through the double fertilization of a binovular egg. Yunis et al., *supra* note 56, at 1. However, a review of the medical literature regarding the known chimeras suggests that the fusion of two embryos in utero is the more likely explanation. *See* Yunis et al., *supra* note 56, at 1.

73. Yu et al., *supra* note 6, at 1545.

74. Eszter Vladar, *Ask a Geneticist*, <http://www.thetech.org/genetics/ask.php?id=23netics>.

75. In one reported case, where three embryos were implanted and only one fetus survived for several weeks in utero, DNA testing was not done and, accordingly, it is impossible to determine whether the fetus had two or three strands of DNA in its body. Doctors were only able to determine that the fetus would have had both male and female DNA had the pregnancy not been terminated. *See* Simon-Bouy et al., *supra* note 6.

76. Glossary Twin Studies, <http://www.ngfn.de/englisch/glossar865.htm>.

77. *Id.*

78. *Id.*

79. *See* Boklage, *supra* note 1, at 579.

enmeshed with the DNA of the surviving twin.⁸⁰ However, a completely new single DNA genome is not introduced.⁸¹ Instead, the two genetically distinct DNA lines from both embryos survive intact in one body.⁸² Thus, a chimera is born that has no visible signs of the genetic condition.⁸³

B. Just How Many Chimeras are There?

Unless extensive genetic testing is done on every single baby that is born with no visual chimeric clues, no one will ever know exactly how many chimeras actually exist.⁸⁴ There are, however, ways to calculate the odds of chimeric births, which provide an idea of the possible numbers. According to experts, approximately twenty-five percent of what begins as a twin pregnancy ends up as a “singleton” birth.⁸⁵ Dr. Boklage also surmises that only one in fifty, or two percent, of twin fertilizations end in twin births.⁸⁶ For the seventy-three percent of remaining twin fertilizations, there are no survivors at all.⁸⁷ Thus, for every eight babies born, one started out as a twin.⁸⁸ Most chimeras, then, are born as single babies.⁸⁹ Boklage has calculated that, in addition to the singleton births that started out as multiple births, more than one in twelve live born dizygotic twins could be chimeras and more than twenty percent of dizygotic triplets could be chimeras.⁹⁰ Boklage suggests that ten percent of the population could be chimeras through this means.⁹¹

Other experts have come to different conclusions about how many chimeras exist. In a 2005 *New York Times* article discussing chimerism, Dr. Ann Reed of the Mayo Clinic suggested that fifty to seventy percent

80. Yu et al., *supra* note 6, at 1545.

81. *Id.*

82. *Id.*

83. *Id.*

84. Doctors would have to take cell samples from numerous parts of each person's body before determining whether someone is a chimera.

85. Boklage, *supra* note 1, at 583; *See also* Landy & Keith, *supra* note 71, at 181 (approximating singleton births at thirty percent).

86. Boklage, *supra* note 1, at 583; *c.f.* Landy & Keith, *supra* note 71.

87. Boklage, *supra* note 1.

88. *Id.* at 583.

89. *Id.*

90. *Id.* at 582. (citing van Dijk et al., *supra* note 6). In this study, only blood was tested. van Dijk et al., *supra* note 6. No other organs were tested to determine whether they also could have been tetragametic chimera. *Id.*

91. *Id.* at 588.

of the entire population could be chimeric.⁹² In yet another article, which appeared in the *Denver Post*, Paul Robinson, president of the International Society of Analytical Cytology and a professor at Purdue University, stated that the odds of a chimera are about one in every 2,400 persons.⁹³ Of course, these are only estimates, and the frequency of naturally occurring chimerism remains an open question.

The number of chimeras may be increasing because of the assistance mother nature has been getting in providing a more conducive environment for fertilizing embryos.⁹⁴ Some doctors and geneticists point to *in vitro* fertilization (“IVF”) as a potential contributing factor.⁹⁵ IVF actually is one of the more common types of assisted reproductive technologies (“ARTs”).⁹⁶ IVF has been a viable, if not expensive, alternative for thousands of people who have fertility problems.⁹⁷ The

92. See Gina Kolata, *Cheating, Or an Early Mingling Of the Blood?*, N.Y. TIMES, May 10, 2005, at F1. While Dr. Ann Reed does not go into detail about how she arrived at the percentage, the author is assuming that Dr. Reed is taking into account all types of spontaneous chimeras, as well as non-spontaneous chimeras. This would include live-born multiple birth siblings, mothers and children who have commingled blood, transplant patients, and transfusion patients. Thus, it likely includes not only these cases of tetragametic or “whole body” chimerism, but also cases of microchimerism, which may be more common.

In *The New Scientist* article entitled “The Stranger Within,” Claire Ainsworth offers a viable and consistent explanation with her hypothesis:

[S]ome researchers now think that most of us, if not all, are chimeras of one kind or another. Far from being pure-bred individuals, composed of a single genetic cell line, our bodies are cellular mongrels, teeming with cells from our mothers, maybe even our grandparents and siblings. . . . During pregnancy, the blood of the mother and fetus are kept separate, but some cells manage to slip through, meaning that you will have picked up some cells from your mother, and she some from you. In fact, some 80 to 90 per cent of women carry their children’s cells or DNA in their blood during pregnancy and up to 50 per cent carry them for decades after giving birth, a condition called microchimerism. If your mother then had more children, some of your cells could in principle slip back through into your younger sibling’s body. And twins can end up swapping cells in the womb, especially if they share a placenta. So a single person can be a veritable menagerie of different cell types from different generations.

Claire Ainsworth, *The Stranger Within*, NEW SCI., Nov. 15, 2003, at 34 (citations omitted).

93. John Henderson, *Hamilton Won’t Go Down Without a Fight. Cyclist is Optimistic the Court of Arbitration for Sport Will Rule in His Favor as He Tries to Get His 2-Year Suspension Lifted*, DENV. POST, May 22, 2005, at B1. Both Henderson and Kolata referenced allegations against Tyler Hamilton, the cyclist accused of doping. *Id.*; Kolata, *supra* note 92. For a more detailed discussion of the Tyler Hamilton case, see Section III, C, 2, *infra*.

94. See Strain et al., *supra* note 56.

95. See *id.*

96. DEP’T OF HEALTH & HUMAN SERV., CENTERS FOR DISEASE CONTROL & PREVENTION, ASSISTED REPRODUCTIVE TECHNOLOGY REPORT at 34 (2003), <http://www.cdc.gov/art/art2003/PDF/ART2003.pdf> [hereinafter CDC, *ART Report*]. Am. Soc’y for Reprod. Med., Frequently Asked Questions About Infertility, <http://www.asrm.org/Patients/faqs.html#Q7> (last visited June 7, 2006).

97. See Am. Soc’y for Reprod. Med., Frequently Asked Questions About Infertility,

first IVF baby, also known as the test tube baby, Louise Brown, was born in 1978.⁹⁸ IVF is a procedure that extracts eggs from a woman's ovaries and fertilizes them outside of the body in a petri dish.⁹⁹ After approximately forty hours, the eggs are examined to determine whether the eggs are fertilized and dividing.¹⁰⁰ If they are, these embryos are placed in the woman's uterus.¹⁰¹ It is standard operating procedure to place more than one embryo in a woman's uterus after IVF.¹⁰²

There are several other ART methods of treatment for infertility that are similar to IVF. One is gamete intrafallopian tubal transfer ("GIFT").¹⁰³ In a GIFT procedure, the egg is fertilized in the fallopian tube.¹⁰⁴ Another treatment is called tubal embryo transfer ("TET"), or zygote intrafallopian transfer ("ZIFT").¹⁰⁵ The egg is fertilized outside of the body and then transferred into the fallopian tube.¹⁰⁶ Approximately fifty percent of ART embryo transfers result in live births.¹⁰⁷ In all of these cases, the average number of embryos transferred was 2.6.¹⁰⁸ In situations where two embryos are transferred, 67.1 percent result in a singleton birth.¹⁰⁹ When three embryos are transferred, 62.9 percent result in a singleton birth and thirty-two percent result in a twin birth.¹¹⁰ When four embryos are transferred, 62.9 percent result in a singleton birth, 32.2 percent result in a twin birth, and 4.9 percent result in a triplet birth.¹¹¹

According to the American Society of Reproductive Medicine, almost 300,000 babies have been born in the United States through the use of IVF.¹¹² In 2002, approximately one of every 100 babies born in the United States was conceived using some sort of assisted reproductive

<http://www.asrm.org/Patients/faqs.html#Q6> (last visited June 7, 2006).

98. Joshua Kleinfeld, Comment, *Tort Law and in Vitro Fertilization: The Need for Legal Recognition of "Procreative Injury"*, 115 YALE L.J. 237, 238 at n.10 (2005).

99. CDC, *ART Report*, *supra* note 96, at 486.

100. *Id.*

101. *Id.*

102. *Id.* at 15, 39.

103. *Id.* at 486.

104. CDC, *ART Report*, *supra* note 96, at 486.

105. *Id.* at 487.

106. *Id.*

107. *Id.* at 75. These numbers reflect the transfer of fresh embryos. *Id.* The frozen embryo success rate is 30.1 percent. *Id.*

108. CDC, *ART Report*, *supra* note 96, at 75. The average number of frozen embryos is 2.8. *Id.*

109. *Id.* at 40.

110. *Id.*

111. *Id.*

112. Am. Soc'y for Reprod. Med., *supra* note 96.

technology, ninety-nine percent of which were IVF procedures.¹¹³ Since standard operating procedure is to implant more than one embryo in each IVF procedure, if Boklage's theory is correct, ten percent, or 30,000 of these IVF babies, could be chimeras.¹¹⁴

In one reported case, doctors transferred three embryos into a thirty-six-year-old woman during an IVF procedure.¹¹⁵ Four weeks and five days later, an ultrasound detected one fetus.¹¹⁶ At seventeen weeks, the doctors discovered severe growth retardation in the fetus and the woman and her partner asked that the pregnancy be terminated.¹¹⁷ Tests on the fetus revealed that the embryo had two distinct cell lines, one was female and one was male.¹¹⁸ Doctors concluded that two of the three implanted embryos had fused either before, during, or after embryo implantation.¹¹⁹ In response to the medical journal article in which this case was reported, Dr. David T. Bonthron of the University of Leeds, Molecular Medicine Unit writes, *inter alia*, "[t]he report of Simon-Buoy et al. (2003) underlines that chimaerism is a real complication of current IVF procedures. Its true frequencies remain unknown, since in the majority of cases, amalgamation chimaerism, even if XX/XY, must go undiagnosed."¹²⁰

There is no certainty that all of these embryos are fused into the surviving embryos to form chimeric individuals. But, in reviewing the statistics regarding multiple embryo implantations that result in singleton births, as well as those that, perhaps, end up with fewer babies born than embryos implanted, the question remains, "What happened to the cells that comprised the other embryos?" As is evident from the reported IVF case in which the surviving fetus clearly had fused with at least one of the other implanted fetuses, it is happening.¹²¹ Odds are, however, that, as difficult as it is to diagnose hermaphroditic chimeras, it is even harder to diagnose those cases in which there has been a same-sex fusion of embryos.

113. *Id.*

114. See Boklage, *supra* note 1, at 588. By a conservative estimate, sole survivors of multiple conceptions are at least as frequent as one live birth in eight; and Boklage estimates that ten percent of the population may be chimeras through embryos merging. *Id.* These chimeras could be of the visually or non-visually distinguishable variety.

115. Simon-Bouy et al., *supra* note 6, at 935.

116. *Id.*

117. *Id.*

118. *Id.*

119. *Id.*

120. David T. Bonthron, *Letter to the Editor: XX/XY Chimerism After IVF*, 24 *PRENATAL DIAGNOSIS* 573, 578 (2004).

121. Simon-Bouy. et al., *supra* note 6, at 935.

It is fair to say that no one really knows, for sure, how many people are chimeras.¹²² How could they? There have, however, been human chimeras discovered in Belgium, Japan, Kuwait, Scotland, Switzerland, the Netherlands, and the United States.¹²³ And many in the medical community that are familiar with chimerism, twins, and *in vitro* fertilization suspect that chimeras are more common than once believed and that, more significantly, their numbers are growing.¹²⁴

C. Chimeras Come to Light

Lately, it seems as though scientists are stumbling randomly onto chimeras.¹²⁵ This should come as no surprise, given that more and more genetic counseling and testing is being done by the scientific community, for example, to predict the path of diseases such as cancer, prepare for an organ transplant, or establish paternity.¹²⁶ There is little doubt that, if chimeras really exist in greater numbers than the medical community first thought, it will eventually come to light because of the increase in genetic testing for other maladies.¹²⁷ For example, fetal microchimerism is being studied as a potential source of all sorts of diseases, especially autoimmune ones.¹²⁸ The reason for this is that some genetics experts believe that, when cells misbehave, the response may be linked to the body rejecting other cells in the body.¹²⁹ As organ transplants become more common, more DNA testing will be done on individuals in an attempt to find donors.

Genetic testing is now being conducted, even in the private sector, to determine whether someone is a descendant of Genghis Khan,¹³⁰ Thomas Jefferson,¹³¹ or Jesse James.¹³² The proliferation and

122. *DNA Sheds Light on "Hybrid Humans"* (National Public Radio broadcast Aug. 11, 2003).

123. *Id.*

124. *Id.* Boklage, *supra* note 1.

125. *Id.* See Drexler et al., *supra* note 5.

126. See generally *Genes & Diseases*, <http://www.ncbi.nlm.nih.gov/books/bookres.fcgi/gnd/gnd.pdf>, for a review of gene related diseases.

127. See Yu et al., *supra* note 6, at 1551.

128. See generally Nathalie C. Lambert et al., *Cutting Edge: Persistent Fetal Microchimerism in T Lymphocytes Is Associated With HLA-DQA1*501: Implications in Autoimmunity*, 164 *J. IMMUN.* 5545 (2000) (noting that, of thirty-one women who gave birth to at least one son, forty-five percent had male DNA).

129. See *id.*

130. Jill Lawless, *Genghis Khan DNA Test Attracts Hordes of Takers*, ASSOC'D. PRESS, July 6, 2006, <http://www.msnbc.msn.com/id/5379014/genghiskahndna>.

131. Daniel P. Jordan, STATEMENT ON THE TJMF RESEARCH COMMITTEE REPORT ON THOMAS JEFFERSON AND SALLY HEMINGS, Jan. 20, 2000, http://www.monticello.org/plantation/hemingscontro/jefferson-hemings_report.pdf.

availability of genetic testing will, no doubt, lead to the discovery of more curiosities than we have ever imagined. When it comes to genetics, we are at the tip of the proverbial iceberg. The first two of the following cases illustrate how doctors recently have discovered the chimeras among us. The third case illustrates how chimerism has been posited as a potential defense to the charge of blood doping.

1. Two High-Profile Cases of Chimerism in the United States

In 1998, a fifty-two year-old woman named Karen Keegan was in renal failure and needed a kidney transplant.¹³³ She sought help from Dr. Margot Kruskall at Beth Israel Deaconess Hospital in Boston.¹³⁴ Dr. Kruskall suggested that Mrs. Keegan and her immediate family undergo compatibility testing in order to find a kidney donor.¹³⁵ In doing so, Dr. Kruskall would have to conduct histocompatibility testing, which compares the potential donor's human leukocyte antigens, or "HLAs," to those of the recipient.¹³⁶ This is known as "tissue typing."¹³⁷ HLAs are a group of genes on human chromosome six.¹³⁸ HLAs have a sequence of DNA markers, called haplotypes, which encode a set of antigens that make the cells of each of us almost unique.¹³⁹

When the doctors performed DNA testing on the samples from Mrs. Keegan, they used commercially available testing kits.¹⁴⁰ The test performed is based on the polymerase chain reaction ("PCR") procedure, which involves the replication or amplification of a DNA sample.¹⁴¹

132. Press Release, The Jesse James Family DNA Project, <http://www.civilwarstlouis.com/History2/jamespressrelease.htm>.

133. Yu et al., *supra* note 6, at 1545. In the article written by Yu, the patient is not identified by name. Subsequent newspaper articles and television programs have identified the facts and circumstances of Karen Keegan's case and they are identical to those presented in the article by Yu. Thus, the author has concluded that the case presented by Yu is that of Mrs. Keegan.

134. Ainsworth, *supra* note 92, at 34. Insights and additional research by Dr. Kruskall, who also was a professor at Harvard University School of Medicine, would have proved invaluable to the writing of this article and to the greater understanding of chimerism. Unfortunately, Dr. Kruskall passed away on August 27, 2005 at the age of fifty-six.

135. *Id.*

136. *Id.*

137. Chronic Lymphocytic Leukemia, Frequently Asked Questions, <http://cllfaq.acor.org/answers/32.html>.

138. Ainsworth, *supra*, note 92, at 34. For a simple explanation of HLA genes, view a short video available at <http://www.dnai.org/text/mediashowcase/index2.html?id=473>.

139. Ainsworth, *supra*, note 92, at 34. See generally Yu et al., *supra* note 6.

140. Yu et al., *supra* note 6, at 1545.

141. Human Genome Project Information, www.ornl.gov/sci/techresources/Human_Genome/elsi/forensics.shtml.

This method can be “likened to a molecular Xeroxing machine.”¹⁴² With this method, scientists can make millions of identical copies of the specimen DNA.¹⁴³ Scientists looked at STRs, or short tandem repeats, which refer to a technology that is used to distinguish individuals from one another by looking at specific areas of nuclear DNA, called loci.¹⁴⁴ Not only is PCR-STR testing the most widely used testing in the field of molecular biology, it is the most commonly used DNA testing in the criminal justice system.¹⁴⁵ The criminal profiling done through the use of CODIS, the Combined DNA Index System, is done with PCR-STR testing.¹⁴⁶ The following thirteen loci are used in the CODIS system: CSF1PO, FGA, TH01, TPOX, vWA, D3S1358, D5S818, D7S820, D8S1179, D13S317, D16S539, D18S51 and D21S11.¹⁴⁷ In Mrs. Keegan’s case, with the exception of CSF1PO, all the same loci were used for the test.¹⁴⁸ Several other loci were used as well.¹⁴⁹

The tests revealed that Mrs. Keegan could not be the biological mother of two of her three sons.¹⁵⁰ The two sons did not have any of their mother’s HLA haplotypes, but they did have those that matched the HLA haplotypes of their father.¹⁵¹ They also had another unique set of HLA markers.¹⁵² After that discovery, Dr. Kruskall took mucosa buccal swabs, hair follicles, and skin samples from Mrs. Keegan.¹⁵³ She also

142. Catherine Arcabascio, *Freeing the Innocent: Obtaining Post-Conviction DNA Testing in Florida*, 28 NOVA L. REV. 61, 77 (2003) (citing ANDRES A. MOENSSE NS ET AL., SCIENTIFIC EVIDENCE IN CIVIL AND CRIMINAL CASES 877 (4th ed. 1995)).

143. Human Genome Project Information, *supra* note 141.

144. *Id.*

145. UNITED STATES DEP’T JUSTICE, OFFICE OF JUSTICE PROGRAMS, NATIONAL INSTITUTE OF JUSTICE, POST-CONVICTION DNA TESTING: RECOMMENDATIONS FOR HANDLING REQUESTS at 27 (1999) <http://www.ncjrs.gov/pdffiles1/nij/177626.pdf> [hereinafter NIJ].

146. *Id.* at 27-28. There are other types of DNA tests that can be done for forensic purposes. For example, in order to distinguish mixtures of male and female DNA in sexual assault cases, or for distinguishing between different males, Y-PCR testing can be used. *Id.* In contrast to PCR testing, Y-PCR testing will focus on the Y-chromosome markers in a sample. *Id.* In addition, mitochondrial DNA analysis can be conducted. *Id.* Instead of using nuclear DNA as in PCR-STR testing, mitochondrial DNA testing uses only the mitochondria, which is inherited maternally. *Id.* If these testing methods are used, however, they cannot be compared with DNA that is stored in CODIS. *Id.*

147. John M. Butler, Ph.d., *Genetics and Genomics of Core Short Tandem Repeat Loci Used in Human Identity Testing*, 51 J Forensic Sci. 253, 253 (2006).

148. Yu et al., *supra* note 6, at 1545.

149. *Id.*

150. *Id.*

151. *Id.*

152. *Id.*

153. *Id.* A buccal swab is a cotton tipped stick which is placed into the mouth and rubbed against the inside of the cheek to remove epithelial cells. Canadian National Databank, Glossary, http://www.nddb-bndg.org/glossaire_e.htm#b.

tested thyroid and bladder tissue.¹⁵⁴

When she blood-typed the family, Dr. Kruskall discovered that Mrs. Keegan had Type A, RH positive blood and her husband had Type O blood.¹⁵⁵ One son was Type A and the other was Type O.¹⁵⁶ Mrs. Keegan's blood had only one set of DNA haplotypes: 1, 3.¹⁵⁷ However, there were two different DNA types found in her buccal swab, hair follicle, skin sample, and thyroid and bladder tissues; although, in each sample, one set of haplotypes or the other was always seventy-five percent dominant.¹⁵⁸ Apparently, Mrs. Keegan had one HLA haplotype 1, 3 and one HLA haplotype 2, 4.¹⁵⁹ Doctors surmised that, at her conception, there were two female embryos that later fused.¹⁶⁰ One embryo must have had HLA haplotype 1, 3 and the other must have had HLA haplotype 2, 4.¹⁶¹ The DNA testing of Mrs. Keegan's blood produced a DNA profile that contained haplotypes 1, 3, as did the DNA testing of her buccal swab.¹⁶² The other organs tested contained haplotype 2, 4.¹⁶³ Thus, Mrs. Keegan had two distinct DNA profiles in her body.¹⁶⁴ Through this extensive testing, Dr. Kruskall was able to determine that Mrs. Keegan is a chimera.¹⁶⁵

In 2003, another case came to light. Lydia Fairchild, a mother of three who was pregnant with her fourth child, was applying for public assistance in the state of Washington.¹⁶⁶ As a requirement for processing the application, she submitted DNA samples to establish the paternity of her estranged partner, Mr. Townsend, and maternity of her three children.¹⁶⁷ The DNA results established that Mr. Townsend was indeed the father, but that Ms. Fairchild was not the biological mother of the children.¹⁶⁸ As a consequence, she was denied public assistance and accused of attempting to defraud the government.¹⁶⁹ Even worse,

154. Yu et al., *supra* note 6, at 1546.

155. *Id.*

156. *Id.*

157. *Id.* 1546-48. In addition, to the print, see Figure 1b.

158. *Id.* at 1548, (See Figure 1b). See Illustration 1, *infra* at 39.

159. *Id.* at 1548.

160. Yu et al., *supra* note 6, at 1550.

161. *Id.*

162. *Id.* at 1548.

163. *Id.*

164. *Id.*

165. *Id.*

166. PRIMETIME, *She's Her Own Twin*, *supra* note 6.

167. *Id.* Information on Lydia Fairchild also available at http://en.wikipedia.org/wiki/Lydia_Fairchild.

168. PRIMETIME, *She's Her Own Twin*, *supra* note 6.

169. *Id.*

prosecutors asked that the children be taken from her and placed into foster care.¹⁷⁰ Ms. Fairchild found the children's birth certificates and tried to prove that she was the mother of her children.¹⁷¹ She even called the obstetrician who delivered her children and who was willing to vouch for the fact that they were hers.¹⁷² Still, the court proceedings and investigation continued.¹⁷³ At one point, the judge in the case told her that she needed a lawyer.¹⁷⁴ Luckily, Ms. Fairchild was set to deliver her fourth child during the time she was under investigation.¹⁷⁵ The judge ordered that a witness be present at the birth and that the witness observe blood samples being taken from both the mother and child.¹⁷⁶ The judge ordered that these samples be submitted for DNA testing.¹⁷⁷ After two weeks, the DNA tests established that Ms. Fairchild also was not the mother of the fourth child, which she had obviously carried and delivered in front of a court-appointed witness.¹⁷⁸ Even though a witness observed the birth of her fourth child, officials still thought that she might have been acting as a surrogate and they were still not convinced that the children were hers.¹⁷⁹

After reading about Karen Keegan's case, Ms. Fairchild's lawyer suspected that she, too, could be a chimera.¹⁸⁰ Her lawyer then requested further DNA testing of Ms. Fairchild and of her extended family.¹⁸¹ Interestingly, while the children's DNA did not match their mother's, the children's DNA was consistent with the DNA of their maternal grandmother.¹⁸² The DNA found in Ms. Fairchild's skin, hair, and saliva did not match her children's, but a sample taken from her cervical smear did match theirs.¹⁸³ Ms. Fairchild was yet another chimera.

170. *Id.*

171. *Id.*

172. *Id.*

173. PRIMETIME, *She's Her Own Twin*, *supra* note 6.

174. *Id.*

175. *Id.*

176. PRIMETIME, *She's Her Own Twin*, *supra* note 6.

177. *Id.*

178. *Id.*

179. *Id.*

180. *Id.*

181. PRIMETIME, *She's Her Own Twin*, *supra* note 6.

182. *Id.*

183. *Id.*

2. A Chimera Wannabe?

Another highly publicized case is not one of actual chimerism, but of a legal defense alleging chimerism, brought in a blood doping case. This recent case, which involved allegations of both transfused blood and inherited chimerism, involves world famous cyclist and olympian Tyler Hamilton.¹⁸⁴ In September 2004, Mr. Hamilton was accused of injecting someone else's blood ("blood doping") in order to raise his red blood cell count, and thereby increase his endurance during the Summer Olympics and the 2004 Tour de Spain.¹⁸⁵ Blood tests showed that he had two different types of red blood cells in his system.¹⁸⁶ Mr. Hamilton's defense was a fascinating, and to some, an outlandish one. He claimed that he was a twin, but that his twin died *in utero* and that he had received his twin's stem cells, which produced different red blood cells.¹⁸⁷ In other words, Mr. Hamilton was claiming he was a chimera.

The United States Anti-Doping Agency rejected all of Mr. Hamilton's defenses and suspended him for two years, and an arbitration panel voted two-to-one against his appeal.¹⁸⁸ Mr. Hamilton also lost his appeal in The Court of Arbitration for Sport in Lausanne, Switzerland.¹⁸⁹ Dr. David Housman, a molecular biology professor at the Massachusetts Institute of Technology, in reference to the Hamilton case, commented in *The New York Times* that some form of chimerism and a vanishing twin were real possibilities in the case because ". . . he knew that stem cells turn off and on throughout life so that a stem cell from a twin, for example, might be producing red blood cells and then stop, making a tiny amount of foreign blood come and go at random."¹⁹⁰

Mr. Hamilton's attempt to invoke chimerism of the tetragametic, or vanishing twin variety, brought an whirlwind of publicity to the case, but in the end, the defense failed.¹⁹¹ According to the literature, however, blood chimerism is far more common than tetragametic chimerism and could, in fact, account for many more cases than tetragametic

184. William Fotheringham, *Banned Cyclist Blames 'Twin' After Dope Test: Olympic Champion Claims Ignorance of His Rare Blood Condition Has Cost Him \$1m*, THE OBSERVER, Jun. 5, 2005, at 23.

185. Henderson, *supra* note 93; Kolata, *supra* note 92.

186. *Id.*

187. *Id.*

188. *Id.*

189. *Tyler Hamilton's Appeal of Doping Suspension Rejected*, ASSOC'D. PRESS, Feb. 11, 2006, http://www.usatoday.com/sports/cycling/2006-02-11-hamilton-appeal_x.htm.

190. Kolata, *supra* note 92, at 3.

191. Henderson, *supra* note 93; Kolata, *supra* note 92.

chimerism.¹⁹² Thus, if Mr. Hamilton truly is a chimera, of any variety, further genetic testing would easily settle the debate about whether and what kind of chimera he could be.

D. Unanswered Questions

There are still many unanswered questions with respect to chimeras, apart from just how many of them exist. For example, there is no literature in the field that explains the division of different cell lines in different organs, and so the question of whether or not there are patterns to the division remains unanswered. In Karen Keegan's case, her blood sample actually had the same DNA as the majority of her buccal swab and her hair sample, even though her buccal swab and hair sample had a seventy-five percent – twenty-five percent mixture of the two strands of DNA.¹⁹³ In Lydia Fairchild's case, her cervical smear had different DNA than her hair, skin, and buccal swab.¹⁹⁴ There is no scientific evidence that explains whether or not there is a consistent apportionment of cells among chimeras. For example, it is unknown whether chimeras consistently have the same DNA in blood, skin, saliva, and semen. For criminal justice purposes, that sort of data would be helpful because so many of the DNA cases that exist have that type of evidence. Another question would be whether there generally exists a majority of organs that carry the same type of DNA.

In addition, the two most publicized cases in the United States of tetragametic chimeras happen to involve females, Mrs. Keegan and Ms. Fairchild, even though there does not seem to be any scientific reason why chimerism would not exist in the same numbers in males. A review of the medical literature did not reveal the genetic details of any male tetragametic chimeras that are not hermaphrodites. Thus, another question is whether a male's semen sample could conceivably be different from a saliva or blood sample in a chimeric individual. In Ms. Fairchild's case, her cervical smear contained a type of DNA different from that in her hair, skin, and saliva, which lends itself to the theory that the DNA in chimeric males' semen samples could differ from the DNA in their blood or saliva samples.

192. *Id.* See also Ainsworth, *supra* note 92.

193. See *infra* Illustration 1, at 36.

194. There is no indication of which DNA was contained in her blood. See PRIMETIME, *She's Her Own Twin*, *supra* note 6.

IV. WHAT DOES IT ALL MEAN TO CRIMINAL CASES?

It is important to first state that one should not take the “Chicken Little” approach when dealing with this issue. The DNA sky is not falling upon the criminal justice system simply because chimerism exists. However, the fact that it does exist should, first and foremost, serve as a reminder of how much there is still to learn in the world of forensics.

That being said, chimerism could, in theory, impact criminal cases in a variety of ways. It is likely that the greatest impact would be on the criminal investigation of a case itself, rather than on the trial of a defendant already in custody. In other words, the lack of information at the beginning of the criminal investigatory process is most problematic because it can confuse the rest of the process.

A. *Criminal Case Scenarios*

Take, for example, the hypothetical case of a chimeric criminal who leaves DNA at the scene of the crime. The suspect may leave a sample of hair, semen, saliva, perspiration, urine, earwax, mucus, bone, fingernail scrapings, blood, or skin.¹⁹⁵ He may even leave a combination of those forensic clues at the scene. If he is a chimera, however, the DNA from his saliva could, in theory, differ from the DNA in his semen, skin, blood, or some other sample left at the scene.

An analyst viewing these samples taken from the scene would have no way of knowing that these samples came from the same person.¹⁹⁶ In fact, that analyst might logically assume that there were two suspects at the scene of the crime. If there are no witnesses, all of the interested parties would be working on the false assumption that there was more than one person who perpetrated the crime. If there was a witness or victim in the case, the forensic evidence may be inconsistent with the statements of the witness, thereby weakening or confusing the investigation.

Another way in which an investigation can be impeded by the existence of a chimeric criminal is in the apprehension of the actual suspect. Suppose, for example, that the suspect leaves only semen or blood at the scene of the crime. Police may seek to obtain DNA samples from potential suspects in an attempt to solve the crime. One of the

195. See Turman, *supra* note 27, at 2.

196. If the analyst had a suspect's DNA, it would match the DNA in less than one-half of the loci because it would be the equivalent of a sibling's DNA. See Aaron Shafer, *Ask a Geneticist*, <http://www.thetech.org/genetics/ask.php?id=166>.

most common samples is from a buccal swab.¹⁹⁷ If the suspect is a chimera, a DNA sample extracted from a buccal swab may not exactly match the blood or semen sample taken at the scene.¹⁹⁸ An investigation may lose momentum or a crime may go unsolved as a result of the chimerism.

In a related scenario, if the police do not have a suspect, they may nonetheless try to solve the crime by taking the DNA sample that they retrieved from the scene, conducting PCR-STR testing on it, and entering it into the DNA database, CODIS, to see if there is a match with someone whose DNA sample already is in the system. With a chimeric individual, the buccal swab could differ from the sample retrieved from the scene, and again, the investigation is impacted, and the crime could remain unsolved.

Another way the existence of a chimeric individual could impact a criminal case would be in the post-conviction setting. There, a defendant could request that a court re-open his case in order to conduct DNA testing on evidence recovered at the scene of the crime, but which was never tested. While each state has different requirements that outline when and on what type of evidence testing is permitted, generally speaking, this type of request comes when DNA testing was not previously done on the collected evidence.¹⁹⁹ These cases often arise when evidence has been stored for many years and the crime occurred at a time when no DNA testing was available. Again, if the preserved evidence happens to be different from the evidence collected from the incarcerated defendant, usually from a buccal swab, there is the possibility that the two would not match.

B. Is the Sky Falling Yet?

The difference between the non-custodial and the custodial hypotheticals is that, in the latter, the suspect is already in custody and, therefore, other DNA samples can be obtained from the defendant. Thus, at least in the post-conviction setting, there always is a fail-safe solution that will preclude a guilty person from going free. Blood can be tested against blood, saliva can be tested against saliva, and semen can be tested against semen. That way, the outcomes will never be different.

197. See NIJ, *supra* note 145, at 22.

198. See Yu et al., *supra* note 6, at 1541, 1545.

199. For a list of post-conviction laws by State, see The Innocence Project: Other Projects by State, http://www.innocenceproject.org/about/other_projects.php. See also Arcabascio, *supra* note 142.

Even in the non-custodial hypothetical where the police have a suspect, they can always attempt to obtain like samples to test against the ones found at the crime scene.

Nonetheless, while the presence of someone's DNA at the scene of the crime or on the victim is strong evidence that could very well lead to a person being charged with a crime, a lack of a match between the suspect's DNA with the DNA found at a crime scene does not, necessarily, preclude a prosecution because, at least from the prosecution's perspective, the DNA from the scene may have come from other sources. In these types of situations, the prosecution may have other evidence that will support its probable cause determination, giving it a good faith reason for going forward with the prosecution.

Suppose, for argument's sake, that a person has been charged in a murder case. If the DNA sample recovered from the scene does not match the defendant's, the prosecution will certainly have a much harder time obtaining a conviction. Nonetheless, there have been cases where DNA from the scene has not matched the defendant's and, yet, the defendant has been convicted with other evidence.

In 2006, Father Gerald Robinson was tried in Ohio for the 1980 murder of Sister Margaret Ann Pahl.²⁰⁰ Her body was wrapped in a bloody altar cloth.²⁰¹ DNA samples taken from her underwear and from underneath her fingernails did not match that of Father Robinson.²⁰² There was other evidence that linked him to the crime scene, but a jury convicted Father Robinson, even without a DNA match.²⁰³

There is no doubt that a defense attorney will make the lack of a DNA match between the defendant and the evidence collected at the crime scene the centerpiece of a case. While there is no crystal ball when it comes to jury verdicts, it is reasonable to conclude that certain juries will feel uncomfortable convicting someone where the DNA does not match the defendant's, and others, like the one in the Father Robinson case, will not rest the entire decision solely on the lack of DNA evidence. Thus, even if the defendant is a chimera, it does not mean that his condition will necessarily allow him to walk free. This is especially true where there is more than just DNA linking him to a

200. *The Priest Has Been Found Guilty*, ASSOC'D. PRESS, May 11, 2006, <http://www.abclocal.go.com/wtv/story?section=local&id=4089701>. See also John Seewer, *Expert Can't Link Priest's DNA to Nun*, ASSOC'D. PRESS, Apr. 26, 2006, http://www.boston.com/news/nation/articles/2006/04/26/coroner_priests_letter_opener_fits_wound.

201. Seewer, *supra* note 200, at 1.

202. *The Priest Has Been Found Guilty*, ASSOC'D. PRESS, May 10, 2006, <http://www.abclocal.go.com/wtv/story?section=local&id=4089701>.

203. *The Priest Has Been Found Guilty*, *supra* note 202.

crime. In contrast, if there is no evidence at all and the DNA does not match, a defendant's chimerism could work in his favor.

In all of the above hypotheticals, one would first have to assume that the defendant is a chimera. Getting to that assumption, as evidenced by the above discussion, is difficult because of the lack of scientific data that exists regarding how many chimeras actually exist. In addition, having a direct impact on criminal justice requires a few more analytical steps. First, the most obvious and basic requirement is that there exists a chimera who happens to have committed a crime. Even if we assume that Boklage is correct in determining that ten percent of the population is chimeric, not every one of them is going to live a life of crime. Second, not every criminal case actually has DNA evidence. Thus, in order to have any impact at all, DNA evidence would have to be collected in the case. Third, if there was a chimeric criminal who left DNA at the scene, it would have to be DNA that is inconsistent with whatever other DNA evidence the police collected from him at a later time.²⁰⁴ Or, the chimera would have to leave two distinct samples of his own at the scene in order to confuse an investigation. In order for chimerism to have an impact on criminal cases, all of these other factors must exist.

C. *The Possibility of a Reverse "CSI Effect"*

The greater concern for criminal lawyers may not be that they actually have a criminal chimera, but that jurors could believe that it is a possibility in a given case, even when there is no evidence of chimerism. Recently, the issue of chimerism has been the subject of various radio and television programs. National Public Radio aired a program called *DNA Sheds Light on Hybrid Humans*.²⁰⁵ On May 19, 2005, the Discovery Channel also aired a program called *I Am My Own Twin*.²⁰⁶ Both of these programs discussed the cases of Lydia Fairchild and Karen Keegan.²⁰⁷ Recently, ABC *PrimeTime Live* also featured chimerism on

204. Recall that in Karen Keegan's case, while all the DNA samples, with the exception of the blood sample, contained a mixture of four haplotypes, there were two predominant haplotypes in all of the samples. For example, if they had compared a buccal swab with a blood sample, Haplotypes 1, 3 would have been predominant in the saliva (buccal swab) and would have been exclusively found in the blood sample. In a hypothetical case using a defendant with a similar chimeric profile, had the police obtained a buccal swab from the defendant, the DNA found in the buccal swab would have been very similar to a blood or hair sample, even though the blood and hair samples would have shown a secondary set of DNA markers.

205. *DNA Sheds Light on "Hybrid Humans," supra* 122.

206. Discovery Health Channel, *I am My Own Twin, supra* note 6.

207. *Id.*

its *Medical Mysteries* series.²⁰⁸

It is no mystery that jurors throughout the years have been influenced by the media.²⁰⁹ In the past few years, the media has coined the use of the term “CSI Effect” for the perceived effect *CSI: Crime Scene Investigation* (“*CSIP*”), and other television programs like it, have on potential jurors.²¹⁰ Currently, the *CSI* franchise alone includes *CSI*, *CSI Miami*, and *CSI New York*.²¹¹

The CSI Effect has more than one definition. The most utilized definition is that the “CSI [Effect] creates unreasonable expectations on the part of the jurors, making it more difficult for prosecutors to obtain convictions.”²¹² Another definition suggests that scientific evidence is infallible, and therefore unquestionable, from an evidentiary standpoint.²¹³ The third definition relates to the public’s heightened interest in forensic sciences.²¹⁴ The last two definitions are related to the first, more commonly used, definition.²¹⁵ The second definition, that science is infallible, is linked to the erroneous presumption that prosecutors should have some sort of forensic evidence to support their case.

Most, if not all, of the discussion of the CSI Effect revolves around the notion that juries have unrealistic expectations about what testing can and ought to be done in a given case when DNA is lacking.²¹⁶ However, the CSI Effect could have an impact on the defense case in a criminal trial if, without any evidence, a juror thinks, for example, that a chimeric criminal could explain the lack of DNA in a case. Thus, the greater problem with chimerism may not be that it actually could exist and actually could affect an investigation and trial, but that jurors could take the lack of a DNA match to mean that there may be a chimera involved. In that sense, the defense could be greatly impacted.

On May 20, 2004, the television show *CSI* aired its season finale,

208. PRIMETIME, *She’s Her Own Twin*, *supra* note 6.

209. Tom R. Tyler, Review, *Viewing CSI and the Threshold of Guilt: Managing Truth And Justice in Reality and Fiction*, 115 YALE L.J. 1050, 1056-1060 (2006). See also Kimberlianne Podlas, “*The CSI Effect*”: *Exposing the Media Myth*, 16 FORDHAM INTELL. PROP. MEDIA & ENT. L.J. 429, 443 (2006).

210. Tyler, *supra* note 209, at 1052-53; Podlas, *supra* note 209, at 430-33.

211. *CSI: Crime Scene Investigators*, <http://www.cbs.com/primetime/csi/>; *CSI: Miami*, http://www.cbs.com/primetime/csi_miami/; *CSI: NY*, http://www.cbs.com/primetime/csi_ny/.

212. Podlas, *supra* note 209, at 433.

213. *Id.* at 437.

214. *Id.* at 442.

215. *Id.* at 447.

216. *Id.* at 433.

called *Bloodlines*.²¹⁷ Almost twenty-six million viewers tuned in for the episode, in which the suspect was a chimera.²¹⁸ In the episode, a woman is raped by someone she later identifies in a lineup.²¹⁹ When the rape kit evidence is subjected to DNA testing, the sample does not match the suspect that she identified.²²⁰ The suspect is ultimately released, despite the victim's objections that she identified the correct man.²²¹ The fictional forensic team discovers that the suspect is really a chimera, but not in time to prevent him from hunting down the victim and killing her.²²² During the last interview with the suspect, Grissom, the leader of the forensic team, has the following discussion with the killer:

GRISSOM: You know that bone marrow donation you gave your brother? (GRISSOM draws the blood.) I checked your medical records. His body rejected it and he died. My guess is that's when you first found out about your unique condition.

(Busted, TODD COOMBS gives it up. He turns and glares, almost smirks at GRISSOM.)

TODD COOMBS: The doctors explained it. I'm a creature of myth.

GRISSOM: A chimera. Head of a lion, body of a goat, tail of a dragon. You're a genetic anomaly. One person, two completely different sets of DNA.²²³

Later, as another police investigator interviews Coombs, Grissom watches while explaining to his colleague, Catherine, how chimerism occurs:

GRISSOM: Sometimes fraternal twins, two separately fertilized eggs, develop into only one person.

(Quick Scope View of one embryo incorporates into the other.)

GRISSOM: (v.o.) In effect, one twin dies in embryo [sic] but its DNA survives in the other.

217. *CSI: Crime Scene Investigators: Bloodlines* (CBS broadcast May 20, 2004), <http://crimelab.nl/transcripts.php?series=1&season=4&episode=23>.

218. *Id.*

219. *CSI Files* – 'Bloodlines' Episode Guide, <http://www.csifiles.com/reviews/miami/bloodlines.shtml>.

220. *Id.*

221. *Id.*

222. *Id.*

223. *CSI: Crime Scene Investigators: Bloodlines*, *supra* note 219.

(End of Scope view. Resume to present.)

GRISSOM: That's why the DNA from his buccal swab matched his hair but not his semen.

CATHERINE: So he had two strains of DNA in his body.

GRISSOM: Yeah, and the DNA in his semen, was evidently from his dead twin brother.²²⁴

This CSI episode spawned thousands of web discussions from all over the world about chimeras.²²⁵ Little, if any, empirical data suggests that there is such a thing as the CSI Effect, or that it creates more acquittals.²²⁶ That does not mean, however, that jurors are not affected in some way by these types of television programs.²²⁷ Indeed, “[t]here are large research literatures in the field supporting the argument that the mass media presentation of crime could produce a CSI Effect of some kind.”²²⁸ “These literatures suggest that media presentations of background material shape juror verdicts in specific cases.”²²⁹ The fact is that prosecutors feel so strongly that the CSI Effect exists that some organizations are providing training to combat the CSI Effect. For example, the New York Prosecutors Training Institute held training session in 2005 called “Homicide Forensics in a Post-CSI World.”²³⁰ Moreover, in June 2005, the Maricopa County Attorney’s Office reported that, because of a perceived CSI Effect, seventy percent of its prosecutors ask jurors, in *voir dire*, about their viewing of forensic TV shows and consider it when determining whether to strike a juror.²³¹ Regardless of whether empirical data exists, prosecutors are taking the CSI Effect seriously.

They are not alone. It also is reasonable to conclude that it is as likely that the defense is as affected as the prosecution by the CSI

224. *Id.*

225. For a sampling of websites, the author “Googled” the terms “CSI” and “chimera” or “chimeras.”

226. Tyler, *supra* note 209, at 1083.

227. *Id.* at 1084.

228. *Id.* at 1083-84.

229. *Id.* at 1084.

230. Kathianne Boniello, “CSI Effect” Challenges Prosecutors: Crime Dramas Influence Juries, POUGHKEEPSIE J., July 18, 2005 <http://www.poughkeepsiejournal.com/projects/crimebeat/po071805s1.shtml>.

231. CSI: Maricopa County: The CSI Effect and its Real-Life Impact on Justice, June 20, 2005, (Page 5) <http://www.maricopacountyattorney.org/Press/PDF/CSIReport.pdf>.

Effect.²³² One theory propounded by Tom Tyler, in his article entitled *Viewing CSI And The Threshold Of Guilt: Managing Truth and Justice in Reality and Fiction*, is that the defense can be affected because, when jurors desire justice for the victim and that desire is greater than the desire for justice for the defendant, they may engage in the justifications that would lead to a reverse CSI Effect.²³³ The *Bloodlines* episode that featured a killer chimera is a perfect example of how jurors could be impacted by television with the worst possible scenario – a chimera who almost gets away with murder because of his condition. If justice for a victim prevails over justice for a defendant, and the CSI Effect does exist, it is just as likely that jurors will erroneously discount a lack of DNA in a case in order to convict a defendant and avoid what they perceive as a potential miscarriage of justice for the victim.

Given that twenty-six million viewers tuned in to the first airing of the final episode, that in general about the same number tune in weekly,²³⁴ that several other television and radio shows about the subject have recently aired, and that a large number of websites have discussions about chimeras, it is a safe bet that chimeras now are in the public's vocabulary. These days, potential jurors are bombarded with television shows such as *CSI* that depict criminal investigations solved through the use of DNA and other forensic testing.

If it seems improbable that jurors may be impacted by a *CSI* episode like *Bloodlines*, simply look at a series of recent message board postings on the website for "Court TV."²³⁵ On August 24, 2006, a thread appeared entitled, "Arrest in Jon Benet Ramsey Murder."²³⁶ The thread discussed John Mark Karr, the man arrested in Thailand and ultimately brought to Colorado, presumably to be charged with sexually assaulting and killing the six-year-old girl.²³⁷ In discussing the possibility of a lack of a DNA match between the DNA found on the victim and Karr, a discussion of chimeras, as well as the *CSI Bloodlines* episode dealing with a chimeric defendant, ensued.²³⁸

232. Tyler, *supra* note 209, at 1084.

233. *Id.*

234. Bill Keveney, *Why not 'CSI: Kink'?*, U.S.A. TODAY, Feb. 8, 2006, at D1, available at http://www.usatoday.com/life/television/news/2006-02-07-csi-kink_x.htm.

235. Court TV News, <http://boards.courtstv.com/showthread.php?s=dac956da93b2a6500ffa6ad3a8b10e4d&postid=8436096&highlight=chimera>.

236. *Id.*

237. *Id.*

238. *Id.* This threaded discussion took place four days before it was announced to the press that no charges would be brought against Karr because the DNA found on Jon Benet Ramsey did not match his. *No DNA Match, No JonBenet Charges*, CNN, Aug. 28, 2006, <http://www.cnn.com/2006/LAW/08/28/ramsey.arrest/index.html>.

As attorneys and scholars, we correctly give little weight to the truth of the content in posts and blogs, and discard most of it as an unreliable source of information. However, what we see in posts like the ones in the Jon Benet Ramsey thread cannot simply be ignored because we do not agree with the posters' conclusions. To the contrary, in these posts and blogs we see tomorrow's potential jurors making causal connections between a lack of a DNA match and a chimera. What matters is that the thought that a defendant may be a chimera crossed the minds of tomorrow's potential jurors when they were faced with the possibility of a lack of a DNA match. No one knows for sure whether jurors will carry those thoughts into the jury room or whether they would actually act upon them in determining a verdict. But it would be unwise to turn a blind eye to the impact that the CSI Effect could have on the defense. With the mass media's discovery of chimeras, it seems just as likely that the CSI Effect could impact the defense as much as the prosecution.

V. CONCLUSION

The revelation that chimeras exist is exciting, controversial, fascinating, and, most importantly, enlightening. It reminds us that in science there always are mysteries waiting to be solved. In 1953, when Crick and Watson discovered DNA's double helix, Crick told Watson that they had "found the secret of life."²³⁹ In 2003, fifty years later, scientists completed the "Human Genome Project" and were able to identify all the genes in the human body and determine the sequences for the three billion base pairs of human DNA.²⁴⁰ In 1953, few would have thought that scientists would be able to identify genes that would assist in determining if someone was at high risk for certain diseases such as cancer.²⁴¹ In 1988, when DNA was used for the very first time in a criminal case in the United States, no one would have imagined that DNA testing could be done on physical evidence that is not visible to the naked eye, or that DNA could be replicated in a machine and tested by

239. Robert Wright, *Molecular Biologists: Watson & Crick*, TIME, Mar. 29, 1999, at 172. Credit for finding the double helix also goes to Rosalind Franklin, a scientist who took the first x-ray photographs of the double helix. Franklin died in 1958 at the age of thirty-seven, the year before Crick and Watson won the Nobel Peace Prize for the discovery of the double helix. *Id.* Additional information regarding Franklin and other DNA pioneers can be found at http://www.ornl.gov/sci/techresources/Human_Genome/project/about.shtml.

240. Human Genome Project, *supra* note 141 http://www.ornl.gov/sci/techresources/Human_Genome/project/about.shtml.

241. *See generally*, Genes & Diseases, *supra* note 126.

using the PCR-STR method that is so common today.²⁴²

As attorneys and scholars who rely upon scientific evidence and study its trends, the most important lesson to remember is simply that, in science, there always seem to be more questions than answers. More and more, lawyers are involved in cases that require some knowledge of the natural sciences. Experts almost always are required to present this type of evidence, and it is always best to rely upon their advice. If you do not know the questions to ask, however, you will not receive the answers you may need.

After a careful review of the medical literature, it is fair to say that no one knows for certain how many chimeras exist in the world. It is also fair to say that experts in the field believe that there are more chimeras than we think and that the numbers may be rising due to *in vitro* fertilization techniques. The fact that they do exist should serve as a constant reminder of just how much we do not know about an area that will continue to evolve.

Finally, we cannot discount the fact that future jurors are being bombarded with information about the forensic sciences. If the polls are correct, there is no end in sight to the fascination the public has with shows such as *CSI*. If that is the case, then lawyers engaged in a practice of law that involves these types of forensic sciences must, at the very least, be able to distinguish for themselves fact from fiction. The only way we can do that is by keeping abreast of what is being sold in the media as science, while educating ourselves about the accurate scientific data that is available.

242. *Andrews v. State*, 533 So. 2d 841 (Fla. App. Ct. 1988).

Illustration 1

Karen Keegan's Genetic Profile

