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Chimerism And Mosaicism: The Fallibility of DNA Evidence

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I. INTRODUCTION

The collection and testing of DNA evidence has become a vital part of criminal investigations and the backbone of family law proceedings. While the testing of DNA may be an exact science, the interpretation of the results remains open to skepticism and critique. Judges, juries, and prosecutors are comfortable with the idea that a DNA "match" means the defendant did it, and a mismatch means the defendant did not. They are comfortable with the idea that a DNA "match" means that man is the father, while a mismatch can mean a broken family. With the advancement of genetic testing procedures, our understanding of a person's DNA composition is expanding, raising serious questions about the weight DNA evidence should carry in both criminal and civil matters. We are gradually discovering that DNA can raise more questions than answers about who a person is. With the possibility of conditions such as chimerism and mosaicism—where multiple genetic codes can be found in a single person—false understandings about DNA inheritance; and other scientific revelations muddying the waters, DNA evidence may end up being more prejudicial than probative since not even the most experienced DNA technician can tell you what it all means. Therefore, judges must discern what DNA evidence they allow to be admitted, and what expert testimony they will allow juries to hear.

II. DNA EVIDENCE

Generally, DNA evidence is seen as being a conclusive test of what tissues came from what person. The basic understanding is, if the DNA from the donated sample matches the DNA from the forensic sample, then the donor is the person who provided the forensic sample; if not, then the donor is *not* the person who provided the forensic sample. This absolute was clearly described by the Fifth District Court of Appeal of California in *People v. Pizarro*. In *Pizarro* the court notes that "a difference in sequence between two DNA samples demonstrates that the DNA samples come from two different people."[1] It is likewise the general understanding of the courts that matching DNA samples indicates that the sample comes from the same individuals. It is these two complementary doctrines that place DNA evidence in a position of extreme importance in our courts.

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[1] People v. Pizarro, 216 Cal. App. 4th 658, 711 (2013).

A. *Admissibility of DNA Evidence*

1. Frye Standard

In order to test the admissibility of scientific evidence like DNA, many courts, including California, Florida,[2] Illinois, Maryland, Minnesota, New Jersey, New York, Pennsylvania, and Washington, apply the *Frye* standard. This test, derived from *Fyre v. United States*, a 1923 case from the D.C. Circuit, provides that expert opinions based on scientific techniques are admissible only where the techniques are generally accepted as reliable in the relevant scientific community.[3]

In *Frye*, the Court wrestled with the use of systolic blood pressure testing as evidence of deception. Prior to trial, Frye was subjected to such testing and his attorney presented the results to the court and offered the scientist who conducted the test as an expert to testify to the results. The government objected to the expert's testimony arguing:

> The rule is that the opinions of experts or skilled witnesses are admissible in evidence in those cases in which the matter of inquiry is such that inexperienced persons are unlikely to prove capable of forming a correct judgment upon it, for the reason that the subject-matter so far partakes of a science, art, or trade as to require a previous habit or experience or study in it, in order to acquire a knowledge of it. When the question involved does not lie within the range of common experience or common knowledge, but requires special experience or special knowledge, then the opinions of witnesses skilled in that particular science, art, or trade to which the question relates are admissible in evidence.[4]

Ultimately, the Supreme Court in *Frye* ruled in favor of the government stating that, "[w]hile the courts will go a long way in admitting expert testimony deduced from a well-recognized scientific principle or discovery, the thing from which the deduction is made must be sufficiently established to have gained general acceptance in the particular field in which it belongs."[5]

The rule established in *Frye* required that the scientific evidence presented to the court must be interpreted by the court as "generally

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[2] *See* DeLisle v. Crane Co., 258 So.3d 1219 (Fla. 2018) (confirming Florida's adherence to the Frye Standard).

[3] Frye v. United States, 293 F. 1013, 1014 (D.C. Cir. 1923).

[4] *Id*.

[5] *Id*.

accepted" by a meaningful segment of the associated scientific community. This rule not only applied to the testimony given by the expert witness, but also to the procedures, principles, or techniques used in the testing and interpretation of the raw scientific data.

2. Daubert Standard

The standard established in *Daubert*[6] is not substantially different from that of *Frye*. Prior to *Daubert*, relevance in combination with the *Frye* test were the dominant standards for determining the admissibility of scientific evidence in Federal Courts. *Daubert* ruled that the *Frye* test was superseded by Federal Rule of Evidence 702, which, at the time, stated: "[i]f scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education, may testify thereto in the form of an opinion or otherwise."[7] The Court in *Daubert* decided that nothing in the Federal Rules of Evidence governing expert testimony "gives any indication that 'general acceptance' is a necessary precondition to the admissibility of scientific evidence. Moreover, such a rigid standard would be at odds with the Rules' liberal thrust and their general approach of relaxing the traditional barriers to 'opinion' testimony."[8] As new discoveries in molecular biology alter our understanding of DNA, the flexibility of Rule 702 and *Daubert*, in contrast to *Frye's* "generally accepted" standard, allows for revolutionary theories to be admitted into evidence.

Some critics of *Daubert* have claimed that while the elimination of the "generally accepted" standard from the proffer of expert testimony has been beneficial in civil litigation, it fails to address the underlying pathologies of the forensic science system that leads to dubious verdicts in criminal cases.[9] By applying the Federal Rules of Evidence through this method, judges—the gatekeepers of scientific evidence—are allowed broad discretion in admitting testimony that raises the value of relevancy and reduces the importance of peer reviews. Some commentators believe that *Daubert* has led to judges playing the role of "amateur scientists," as Chief Justice William Rehnquist referred to them in his dissent in *Daubert.* Chief Justice Rehnquist's dissent is well-founded as the original intent of Rule 702 was to allow expert witnesses to testify in the hypothetical, therefore presenting opinions not concluded from testable

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[6] Daubert v. Merrell Dow Pharm., Inc., 509 U.S. 579 (1993).

[7] Fed. R. Evid. 702.

[8] *See Daubert*, 509 U.S. 579.

[9] David E. Bernstein, Expert Witnesses, Adversarial Bias, and the (Partial) Failure of the Daubert Revolution, 93 IOWA L. REV. 451, 459-63 (2007).

and empirical facts, but from those facts presented in the hypothetical and considered by the expert "suggesting the inference which should be drawn from applying the specialized knowledge to the facts."[10] The decision to draft Rule 702, as written in 1975, was reached after concluding that "when opinions are excluded, it is because they are unhelpful [to the trier of fact] and therefore superfluous and a waste of time."[11] The intention of the drafters of the Rule was to neither return to *Frye*, nor to have judges rule on scientific matters, but rather to allow judges to make a determination as to whether the testimony of the expert witness will be helpful to the judge or jury in weighing the value of the evidence to be presented. Too often though, judges allow their own preconceptions of DNA evidence to steer their decision making when deciding whether or not to allow a revolutionary new theory to be admitted.

B. General Acceptance of DNA Evidence

1. The "CSI Effect"

The rise in popularity of procedural police dramas, particularly CBS's *CSI: Crime Scene Investigation*, and the many spin-offs thereof, has helped bring DNA testing and DNA evidence into the public consciousness. On the shows, groups of attractive twenty-something police scientists, usually supervised by an older scientist, investigate and solve crimes in under an hour. The technology used in their testing of evidence sits comfortably on the very edge of science fiction. While DNA or bullet ballistics testing takes place every day in real police laboratories, the speed and accuracy shown on the screen in these shows is, quite frankly, impossible with our current technology. The believability of shows like *CSI* leads jurors to believe that DNA testing and results are almost irrefutable in the absence of gross error, such as a contaminated sample or broken chain of custody.

CSI franchise creator, Anthony E. Zuiker, was once quoted as claiming that "all of the science [on the shows] is accurate."[12] Others, including forensic scientist Thomas Mauriello have described up to forty percent of the scientific techniques depicted on *CSI* as "high-tech magic."[13] Not only does the show use unrealistic methods to achieve

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[10] Fed. R. Evid. 702 advisory committee's notes.

[11] *Id.* (quoting 7 Wigmore § 1918).

[12] Ayaz Nanji, *Prosecutors Feel the 'CSI Effect,'* CBS NEWS (Feb. 10, 2005, 4:34 PM), https://www.cbsnews.com/news/prosecutors-feel-the-csi-effect.

[13] N. J. Schweitzer & Michael J. Saks, *The CSI Effect: Popular Fiction About Forensic Science Affects Public Expectations About Real Forensic Science*, 47

unrealistic results, but the show also completely ignores the element of uncertainty inherent in real scientific investigations by presenting the results as the absolute, empirical truth. The result of this popular misrepresentation of the scientific relevance of forensic test results has been dubbed the "CSI Effect." Under this effect, it is believed that victims and their families, jurors, prosecutors, defense attorneys, and even judges, expect instant and conclusive answers from the techniques shown on television, such as DNA analysis and fingerprinting. The reality of the situation is that test results can take weeks and are almost always open to interpretation.

Though the term "CSI Effect" has only been recently termed as such, it has long been recognized that the way the media portrays our legal system can significantly change the way people engage with the *real* legal system. Older television programs such as *Quincy, M.E.,* and *Perry Mason*, which also presented the legal and investigative systems in believably false ways, are also believed to have altered public perception of what DNA evidence is and, possibly just as important, what DNA evidence is not.[14]

Chief Justice Rehnquist's dissent in *Daubert* seems to have been prophetic. Judges are playing arm-chair scientist in determining the value and validity of DNA evidence and the conclusions drawn therefrom, even when the evidence or the methods in gathering and testing that evidence comes under attack. As early as 1996, judges have rejected *Daubert* hearings, taking judicial notice of the reliability of DNA test results. In *United States v. Beasley*, for example, the court found that DNA results could be admitted into evidence even when serious questions as to the testing methodology were raised.[15] It was the determination of the court that the alleged breaches in the testing protocols that occurred in the case "go to the weight of the DNA evidence, not to its admissibility."[16] Most concerning about *Beasley* is that the court went on to say: "we believe that the reliability of the Polymerase Chain Reaction Analysis (PCR) method of DNA analysis is sufficiently well established to permit the court of this circuit to take judicial notice of it in future cases."[17]

JURIMETRICS 357, 358 (2007); See also Simon Cole & Rachel Dioso, Law and the Lab, WALL ST. J. (May 13, 2005).

[14] John Alldredge, *The 'CSI Effect' and Its Potential Impact on Juror Decisions*, 3 THEMIS: RSCH. J. OF JUST. STUD. AND FORENSIC SCI. 114 (2015).

[15] *See* United States v. Beasley, 102 F.3d 1440 (1996).

[16] *Id.*at 1448; *See also* United States v. Johnson, 56 F.3d 947, 953 (1995).

[17] Beasley, 102 F.3d at 1448.

2. Statistical Fallibility

In a survey conducted by Gallup in 2005, eighty-five percent of Americans considered DNA evidence very or completely reliable.[18] Another study conducted by the University of Nevada, Yale, and Claremont McKennen College showed that jurors rate DNA evidence as being ninety-five percent accurate and ninety to ninety-four percent persuasive.[19] What many jurors and the public in general do not consider when weighing the value of DNA evidence, is what is known as the "false positive paradox," where false positive tests are more probable than true positive tests. This occurs when the overall population has a low incidence of a condition and the incidence rate is lower than the false positive rate. This can happen with remarkable frequency when testing DNA.

In 2013, the First District Court of Appeals in Michigan heard a case wherein the defendant, Frank Adkins, was convicted of criminal misconduct in the third-degree.[20] The defendant was sentenced to prison for eighteen to one hundred-eighty months and appealed his conviction, questioning the inclusion of DNA evidence used against him in the trial.[21] The expert witness called to testify regarding the DNA evidence against him stated that, while she could not say definitively that Adkins was the donor of the forensic sample based on a DNA analysis of ten out of thirteen loci, "the probability of a random person matching the DNA mixture in this case was 'one in 60,000 in the Caucasian population and one in 44,000 in the African American, and one in 24 of the Hispanic.'"[22] In weighing the sufficiency of the evidence against Adkins, who is African-American, the court stated that, "the jury was free to determine that the DNA evidence was persuasive and what inferences could be drawn from it including whether defendant was the donor or not."[23] But statements such as "one in 60,000" are misleading to the layperson and should not be presented by a geneticist as the statistical relevance of the DNA sample; rather, it should be presented and interpreted by an expert in statistics.

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[18] *Crime*, GALLUP (Oct. 2005), https://news.gallup.com/poll/1603/crime.aspx.

[19] Joel D. Lieberman et al., *Gold Versus Platinum: Do Jurors Recognize the Superiority and Limitations of DNA Evidence Compared to Other Types of Forensic Evidence?*, 14(1) PSYCH., PUB. POL'Y, & L 27, 27-62 (2008).

[20] People v. Adkins, No. 309898, 2013 Mich. App. LEXIS 76 (Mich. Ct. App. Jan. 17, 2013).

[21] *Id*.

[22] *Id.* at 3.

[23] *Id.* at 8.

As of 2013, there were approximately 9.9 million people living in Michigan.[24] Of those ten million people, approximately eighty percent were Caucasian, fourteen percent were African-American, and five percent were Hispanic or Latino.[25] This means that when considering the overall statistics presented by the expert witness in *Adkins*, there are the 21,334 people who could match the DNA profile presented in that case. This works out to a false positive rate of about 0.21%. While this may sound statistically insignificant against the "one in 60,000" statistic, it means that the reliability of the match, in the face of such a high overall false positive rate, is less than 0.005%. This evidence of reliability was never communicated to the jury in *Adkins*. Perhaps the defense should have raised the point that, based on the expert's statistics, the DNA profile was *most likely* Hispanic or Latino since there would be 21,270 similar matches within the Hispanic community of Michigan; or *more likely* to be Caucasian than African-American with one hundred thirty-two matches amongst Caucasian community in Michigan compared to thirty-two matches amongst the African-American community in Michigan.

Paternity DNA tests use a higher standard for determining a match compared to DNA tests used in criminal cases. With paternity DNA testing, between thirteen and twenty-one alleles are tested. Alleles are variant forms of a given gene.[26] Should the putative father fail to match on any single allele, he is excluded as the father. For AABB accredited laboratories, testing must be accurate to a one percent false positive rate.[27] The industry standard seems to be a 0.01% false positive rate. Even so, this standard for testing, when applied to the population of Michigan, would only be 0.1% reliable. This is because if we tested all 9.9 million Michiganders, we would have 997 people determined to be "fathers" of the child in question—only one of whom could actually be the father of the child. This means that the test yields a 1/997 reliability since the false positive rate must be taken into account with the true positive rate. Allowing an expert to testify anything conclusive on the statistical probability of a match when using an incomplete DNA profile serves only to mislead the jury as to the value of the evidence. DNA evidence is given far too much weight in practice when one views all of the statistics available. Therefore, we should temper our view of

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[24] *Michigan Population 2013,* WORLD POPULATION STATISTICS (Aug. 21, 2013). http://www.worldpopulationstatistics.com/michigan-population-2013/.

[25] *Id*.

[26] E.J. Wood, *The Encyclopedia of Molecular Biology*, 23(2) BIOCHEMICAL EDUC. 105 (1995).

[27] *Id*.

DNA evidence by removing its status as the definitive piece of evidence, and simply including it with all the other evidence available to tell a complete story.

C. Federal Rules

Under Federal Rule of Evidence 403, the court may exclude relevant evidence when it determines that the probative value is outweighed by the danger of prejudice that the evidence presents.[28] If the evidence that is to be introduced confuses the issues or misleads the jury, then the court may also exclude the evidence.[29] DNA evidence presents just this kind of problem. While evidence and testimony, such as that presented in *Adkins,* are certainly relevant, the presentation of impressive sounding statistical data that could mislead the jury as to the actual likelihood of a false positive, or lead the jury to believe that a ten out of thirteen match is good enough, presents a greater probability of admitting evidence that is more prejudicial than probative.

Under Rule 702, when a DNA technician makes statistical evaluations, their qualifications as a statistician should be called into question. Per Rule 702, expert testimony must "*help* the trier of fact to *understand* the evidence."[30] Where the evidence and the expert's testimony with respect to that evidence are misleading, it cannot be said that the trier of fact is being helped to understand the evidence. It is very likely that the trier of fact is being helped to *mis*understand. Therefore, this kind of testimony, based on incomplete genetic profiling, must be excluded under Rule 702.

D. Testing DNA Evidence

The various tests used to decode a person's genetic profile are not easy to make sense of. The science behind the tests is still relatively young but is developing rapidly in both precision and scope. The two most common tests are the Restriction Fragment Length Polymorphism Analysis ("RFLP") and the Polymerase Chain Reaction Analysis ("PCR"). These tests look for patterns present in a DNA sample in order to build a profile, much like is done the individual whorls and lines in a fingerprint. This profile is then compared to other samples in order to find a match.

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[28] Fed. R. Evid. 403.
[29] *Id.*
[30] Fed. R. Evid. 702(a) (emphasis added).

1. Restriction Fragment Length Polymorphism Analysis ("RFLP")

RFLP was one of the first methods of DNA analysis. It involves cutting the DNA into small pieces using a "restriction enzyme," which is an enzyme capable of cutting DNA at, or near, specific recognition sites within the DNA molecule.[31] This generates DNA fragments of different sizes as a consequence of variations in the DNA sequences between different individuals. This form of DNA analysis would result in a sort of photo-negative, known as a "Southern Blot."[32] Radiolabeled probe molecules would be added next, which complement sequences in the genome that contain repeat sequences. These sequences vary in length from person to person and are called variable number tandem repeat sequences or "VNTRs."[33] The radiolabeled DNA would then be exposed to an x-ray plate and developed showing bands of radiolabeled VTNRs as fluorescent bands on the film.

This method does come with its downfalls. Unfortunately, this method requires a large amount of DNA which needs to be largely non-degraded. It also struggles to differentiate between different alleles making its use for paternity testing impossible.

2. Polymerase Chain Reaction Analysis/Short Tandem Repeat Analysis ("PCR")

In 1983, a process was developed wherein specific portions of the sample DNA could be amplified almost indefinitely. This process, called polymerase chain reaction ("PCR") mimics the way that the body naturally replicates DNA but confines it to specific DNA sequences of interest.[34] This method allows DNA sampling from very small or degraded samples since large amounts of identical DNA for testing could be replicated, thus turning a small sample into a much larger one which was easier to work with. This method was readily adaptable for analyzing VNTRs, particularly, tracts of repetitive DNA in which certain DNA motifs are repeated. The tracts are referred to as "short tandem

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[31] Richard J. Roberts & Kenneth Murray, *Restriction Endonucleases,* 4(2) CRC CRITICAL REV. IN BIOCHEMISTRY 123 (1976); Craig Kessler & V Manta, Specificity of Restriction Endonucleases and DNA Modification Methyltransferases a Review, 92 GENE (1990); A. Pinguod et al., (1993) Restriction Enzymes, 16 METHODS OF MOLECULAR BIOLOGY 107-200 (1993).

[32] Edwin Mellor Southern, Detection of Specific Sequences Among DNA Fragments Separated by Gel Electrophoresis, 98 J. OF MOLECULAR BIOLOGY 503 (1975).

[33] *Id*.

[34] John M. S. Bartlett & David Stirling, *A Short History of the Polymerase Chain Reaction*, 226 METHODS IN MOLECULAR BIOLOGY 3 (2003).

repeats" or "STRs".[35] Though the alleles actually tested in STR are very common (shared by around five to twenty percent of individuals), it is the length and pattern of these alleles that is believed to be unique to each individual person. Because unrelated people almost certainly have different numbers of repeat units, STRs can be used to differentiate between unrelated individuals.

The greatest improvement made with STR analysis lies in the fact that it has a greater degree of statistical discrimination than the earlier RFLP analysis. Though the presence of the twenty alleles commonly tested with the CODIS standard[36] may be common, the locations and lengths of those STR alleles creates a pattern to which the product rule of probabilities applies. This means that the mathematical probability of a false match is 1 in 1×10^{18} or more.[37] This number, however, has been shown to be unrealistic after an Arizona state crime lab analyst, while running tests on Arizona's DNA database, discovered two felons whose DNA was strikingly similar.[38] These two unrelated men matched nine out of thirteen loci, the odds of this supposedly being about one in 113 billion.[39] These men were not alone. In the years following, the same analyst discovered dozens of similar matches throughout the Arizona system.[40]

PCR technology is widely applied to determine genetic family relationships such as paternity, maternity, siblingship, and other kinships. There are predictable inheritance patterns at certain locations ("loci") within the human genome which are useful in determining a blood relationship. These STRs can be inherited from either parent, but the child will always inherit from both. As an example, if the mother of a child has STRs of lengths twenty-eight and thirty at loci D21S11, and the child has twenty-eight and thirty-one, then an inspection of the putative father's DNA must show a thirty-one in order to be included as the father of that child. This holds true with all sixteen of the loci used in a test for paternity. While these tests themselves are fairly accurate, the

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[35] Guy-Franck Richard et. al., COMPARATIVE GENOMICS AND MOLECULAR DYNAMICS OF DNA REPEATS IN EUKARYOTES, 72 Microbiology Molecular Biology Rev 686 (2008).

[36] "Combined DNA Index System (CODIS)". Federal Bureau of Investigation. Retrieved 12 November 2018.

[37] Jason Felch & Maura Dolan, *FBI Resists Scrutiny of 'Matches,'* LA TIMES (July 20, 2018), https://www.latimes.com/archives/la-xpm-2008-jul-20-me-dna20-story.html .

[38] *Id*.

[39] *Id*.

[40] *Id*.

conclusions we draw from them may very well be skewed by any number of genetic abnormalities.

III. CHIMERISM AND MOSAICISM

The general idea is that a DNA match means that a person provided the tested sample, and absent that match, there is no way that a person could have provided that sample. Yet, conditions exist where a single person can have more than one DNA profile in their bodies. Chimerism and mosaicism are such conditions. Though both conditions have historically been considered rare occurrences, new research, assisted by new technologies in DNA sequencing, are showing us that the rarity of these conditions is far from certain.

A. Mosaicism

In genetics, a mosaic, or mosaicism, involves the presence of two or more populations of cells with different genotypes in one individual who has developed from a single fertilized egg.[41] Though the causes of mosaicism are many and varied, it can generally be described as the result of random mutation which is non-fatal to the resulting mutated cell. This genetic alteration is usually minor and is passed on as the cell divides. This usually results in a very small population of cells carrying the mutation, and the mutation typically represents only a minor difference in the two genotypes.

B. Chimerism

The more significant anomaly is genetic chimerism. Like mosaicism, chimerism generally involves the presence of two or more populations of cells with different genotypes in one individual, but, unlike mosaicism, the two genotypes come from different fertilized eggs. In chimerism, the presence of cells with differing genotypes can be felt in a larger, more significant way. Differences in phenotype, or the composite of an organism's observable characteristics or traits, can be observed in some individuals with chimerism.[42] Famous examples of individuals with chimeric phenotype differentiation include actress/model/singer/songwriter Taylor Muhl, whose abdomen, among other body parts, contains two genotypes, and presents with the skin on

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[41] *See* Tom Strachan, & Andrew P. Read, Human Molecular Genetics (Fran Kingston ed., 2nd ed.1999).

[42] Aaron T. Norton & Ozzie Zehner, *Which Half is Mommy?: Tetragametic Chimerism and Trans-Subjectivity*, 36 WOMEN'S STUD. Q. 106, 109 (2008).

her midriff having two distinct colorations divided on the midline.[43] More often than not, there are no visible indications of chimerism. The genotypes can exist in a single organ system, multiple organ systems, or the same organ system (such as Ms. Muhl's skin containing both genotypes).

Chimerism can also present as an intersex condition, either in the form of "true" hermaphrodism (the presence of both sex organs to some degree) or pseudo-hermaphrodism, (where the intersex condition is less apparent) but the individual has both female (46, XX) and male (46, XY) cells.[44] While it is simple to identify chimerism in an individual with phenotypic "abnormalities," such as ambiguous genitalia, other intersex conditions, which have no such visual indicators, may require genetic testing to diagnose.

Donor chimerism is a condition caused by the intentional inclusion of cells with a different genotype into an organism. It occurs as the result of organ transplants, bone marrow transplants, and blood transfusions. This particular form of chimerism is easily diagnosed since it is the natural side-effect of an intentional act. Microchimerism is the presence of a small number of cells that are genetically distinct from those of the host individual. Most people fall into this category, as maternal cells often pass through the placenta and are passed on to the child. Likewise, most mothers contain cells from their child(ren) which passed through the placenta as fetal stem cells and propagated within them.[45]

Tetragametic chimerism is by far the more complex condition. This condition is created *in utero* when four reproductive cells, two sperm and two eggs, fuse after fertilization.[46] In this condition, the cells propagate as normal though the genotypes can be spread throughout the body in larger numbers.[47] Taylor Muhl is an example of such a chimera. The most likely explanation for her particular condition is that when she and her "twin"[48] were only blastocysts vying for space within their mother's womb, they fused and developed into a single individual. The cells from each blastocyst continued to develop and formed organ systems as necessary according to their genetic "plan." This would explain why she

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[43] Rachel Rettner, *This Woman Is Her Own Twin: What is Chimerism?*, LIVESCIENCE (Feb. 28, 2018), https://www.livescience.com/61890-what-is-chimerism-fused-twin.html.

[44] Norton, *supra* note 42, at 116-17.

[45] Charles Q. Choi, *Son's DNA Shows Up in Mom's Brain*, LIVESCIENCE (Sept. 26, 2012), https://www.livescience.com/23490-fetal-dna-mom-brain.html.

[46] Norton, *supra* note 42 at 106.

[47] *Id*.

[48] This twin would be her heterozygotic twin with whom she shared a womb at this stage in their development.

has skin cells in one part of her body that are one shade, and cells in another part that are another shade as each are producing melanin according to how that particular gene is coded in that particular genotype.

While novel, chimerism is not unheard of in jurisprudence, but is believed to be too rare to consider. In *People v. Pizzaro*, for example, the court explicitly acknowledged the existence of the condition, while rejecting its possibility as being extremely remote.[49] Another such incident involved the case of then twenty-six-year-old Lydia Fairchild of Washington state.[50] As a pregnant single mother of two children, Ms. Fairchild applied for public assistance.[51] As a routine measure, the state ordered DNA testing of both Fairchild and the children's putative father, Jamie Townsend, to establish parentage.[52] To Fairchild's surprise, the test also revealed that she was not their mother.[53] Fairchild was put on trial for welfare fraud, identity theft, and child abduction. There were also allegations that Fairchild was acting as a surrogate, bearing children for money.[54] Fairchild's mother, who was present at the birth of both children, as well as Dr. Leonard Dreisbach, Fairchild's obstetrician, testified that the children were, indeed, hers.[55] Regardless of this testimony, the court ordered that a court officer be present at the birth of her third child and personally witness the taking of DNA samples from both Fairchild and her third child for testing.[56] Fairchild again, failed the test. It was only after a protracted legal battle and numerous DNA tests that the courts in Washington were convinced that Fairchild was a human chimera.

On the other side of the country, fifty-four-year-old Karen Keegan, who was suffering from kidney failure and preparing to receive a transplant, also discovered that two of the three children that she had given birth to were not biologically hers.[57] It was only after the testing of multiple tissues from Keegan, that her condition became apparent: she

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[49] People v. Pizarro, 216 Cal. App. 4th 658, 711 (2013) ("We recognize that there are instances in which mutation occurs in the DNA in one part of the body (e.g. sperm or cancerous tissue) but not in the DNA in another part of the same body (e.g. blood), and instances of other genetic phenomena, such as chimerism (e.g. due to the fusion of two fraternal twin zygotes into a single zygote); however, we imagine these to be fairly rare scenarios.").

[50] *She's Her Own Twin*, ABC NEWS (Aug.15, 2006 at 1:21 PM), https://abcnews.go.com/Primetime/shes-twin/story?id=231569.

[51] *Id*.

[52] *Id*.

[53] *Id*.

[54] *Id*.

[55] *Id*.

[56] She's Her Own Twin, *supra* note 50.

[57] Howard Wolinsky, *A Mythical Beast: Increased Attention Highlights the Hidden Wonders of Chimeras*, 8 EMBO REPORTS, 212, 213 (2007).

was a chimera whose ovaries each contained their own separate genotypes.[58] Fairchild's attorney heard about Keegan's situation and had Fairchild submit herself to multiple DNA samplings, including blood draws and hair follicle tests, which eventually revealed that she too was a chimera, incapable of having her maternity established by the standard, court-ordered DNA test.

Chimerism could be disturbingly common with some studies revealing that certain forms such as "blood group" chimerism, which typically occurs when the blood of twins intermixes in the womb, could be as common as one in twelve live births.[59] With these kinds of numbers, the standard DNA testing procedures comes into serious question as to its ability to accurately exclude a whole person as being the source of a microscopic sample of the genetic material. The inability to identify a person based on a single DNA sample makes using that sample to determine whether or not that person is the parent of any particular child especially difficult since we cannot be sure as to the DNA of the putative parent or the child in question.

IV. PARENTAGE THROUGH DNA

A. Significance of Parentage

Many times, mothers are the ones that choose to establish the paternity of their child. The reasons can be as sentimental as a simple desire to have the knowledge of the father's identity. More often though, the reasons for determining the paternity of the child are more practical, such as determining the likelihood of developing certain diseases or other inherited health issues or to establish what person should have the legal rights and responsibilities of raising and providing for the child. Establishing legal paternity grants fathers the right to be involved in parenting decisions and to become a part of the child's life. When the legal father is established, the courts know what man should be held accountable for the financial responsibilities of the child in question. Ruling out certain individuals can also be a motivation for determining the biological lineage of a child.

Sometimes, women may simply want to ensure that a particularly unfit individual will not be bound to their child for his or her entire life. Knowing whether or not a particular man is the father of a child is likewise important to putative fathers. Besides knowing who will be "on

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[58] *Id*.

[59] Bob A. van Dijk. et. at., *Blood Group Chimerism in Human Multiple Births Is Not Rare*, 61 AM. J. MED. GENETICS 264, 267 (1996).

the hook" for child support, the putative father gets the satisfaction of knowing the child is his.

The legal significance of parenthood is more varied. Once paternity has been established, the child is entitled to such benefits as ordained by law. For example, a father may add their legitimate child to their insurance or other benefits. Though a person can usually add any person as a beneficiary of an insurance policy, inheritance laws will allow a legitimated child to inherit automatically in the event that the father dies intestate. In most jurisdictions, the child can still inherit without a determination of genetic fatherhood through the legal process of legitimation.

1. Voluntary Paternity

In the absence of strange and unusual situations like those of Keegan and Fairchild, it is the general belief of courts that the mother of a child is the woman who gave birth to the child. This is reflected in many jurisdictions either in a statute, such as the Civil Code of Germany § 1591, which says exactly that,[60] or by doctrines such as the Roman law principle of *mater semper certa est* ("the mother is always certain"). This principle survived until the late 1970's, when the first child was conceived by *in-vitro* fertilization. The counter-principle is that of *pater semper incertus est* ("the father is always uncertain") and is supplemented by the idea that *pater est, quem nuptiae demonstrant* ("the father is he to whom marriage points").

When a child is born to any couple, the couple is generally free to assume parentage voluntarily. Likewise, the courts may in certain circumstances and certain jurisdictions assume the parentage of a child. Some jurisdictions, such as North Carolina, provide that the legal father of a child, in the absence of DNA evidence to the contrary, is the husband of the woman to whom the child was born.[61] When a child is born out of wedlock, but the parents then subsequently marry, the legal parentage is likewise assumed. Even without marriage, a child born out of wedlock can be legitimated by completing certain affidavits or forms available in those jurisdictions. In the world of trans-gendered parents and same-sex couples, these marriage-related parentage statutes, which reference only a single *father* and single *mother*, fail to account for the *intended* parentage of the child. More complicated measures are required to establish who is and is not a legal parent as they continue to look

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[60] Bürgerliches Gesetzbuch [BGB] [Civil Code], § 1591, https://www.gesetze-im-internet.de/bgb/__1591.html (Ger.) ("Mutter eines Kindes ist die Frau, dies as geboren hat," meaning the mother of a child is the woman who gave birth to this).

[61] *See* N.C.G.S § 130A-101(e).

toward a relationship between the *woman* who carries the child and the *man* who provided the sperm for conception.

2. Involuntary Paternity

Involuntary paternity is established almost as a matter of course in many jurisdictions. This is when, prompted by litigation, the court orders, or the parties submit, DNA evidence as to the likelihood of paternity of the child in question. These findings are considered to be over 99% accurate and the courts can and will order a DNA test even when the paternity of a child is not in question.[62] When genetic anomalies affect common notions as to parentage, the excessive weight given to DNA evidence becomes an unbearable burden on parents and putative parents.

V. CHIMERISM'S EFFECTS NN PARENTHOOD UNDER THE CURRENT MODEL

As used today, the DNA that identifies a person in paternity disputes and most maternity issues is DNA sourced from the cheek cells of the putative parent. A parent whose cheek cells do not show a parentage relationship to the child in question is excluded as a possible parent to the child. But when the person took part in the creation of the child, we as a society impart rights and responsibilities on that person for the care and support for the child. How then, is justice served by excluding a person who took part in the creation of the child based on the findings of incomplete science? The heavy-weight of evidence placed on DNA sampling excludes that extrinsic evidence of a same-sex partner's involvement in the decision to have a child. In the interest of true justice, it is not the people who provided some DNA, but the people who made choices and took actions to bring a child into the world that ought to be held responsible for that child's existence.

As discussed above, there is a statistical paradox that takes place in situations that involve testing which has a significant false-positive or false-negative rate. If we use the estimations given for the prevalence of chimerism in the population at large, we get a false negative rate for exclusion in paternity cases of 8.3%.[63] This is more than statistically significant and renders the "exclusion" of a person as a biological father to be a little more than a guess. This would mean that one in eight of all exclusions are incorrectly excluding a biological father who may have undiagnosed chimerism or another genetic anomaly that can "fool" a

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[62] *See* County of Durham North Carolina v. Ellis, 12-CVD-3071 (NCFC 2012).
[63] Dijk, *supra* note 59.

standard DNA screening. Simply because we have failed to achieve a genetic match does not mean that there is no parentage. Where DNA exclusions fail is where they purport to show positive evidence of exclusion based on a *lack* of positive evidence of inclusion.

Is a showing that a person cannot support their claim with affirmative evidence enough to deprive them of their existing rights? This may be happening at an amazing rate within family courts around the country every day. Fathers, primarily, may be stripped of their rights in regards to their children based solely on a single test with an extremely high rate of false negatives.

In the alternative, the standard DNA test is where the inquiry should begin, not end. Circumstances of chimerism require that a one-for-one DNA sampling be done in order to ensure the highest reliability in the match or exclusion. It is a simple matter to request a sperm sample from a father whose parentage has been called into question because he failed the "cheek-swab" test. Where the DNA present in his sperm fails to match the child, we can say with greater certainty that the man was not the provider of the original genetic material and has no legal claim or responsibilities to the child. In the cases of Karen Keegan and Lydia Fairchild, it required digging deeper into their *entire* genetic make-up in order to find the truth. Had their inquiries begun at the standard DNA analysis, with those results simply being seen as raising questions and not being treated as conclusive, Ms. Fairchild could have been saved the cost and embarrassment of being charged for a crime.

A. Chimerism in Criminal Cases

The fallibility of DNA evidence has an even greater impact on criminal cases. Where incomplete DNA that could match thousands of people in the area is used to convict a suspect, or an exclusion based on incomplete genetic profiling of a person who is quite possibly chimeric is used to exonerate a suspect, injustice is done.

i. "John Donor"

In 2015, a thirty-four-year-old man, who we will simply call "John Donor," donated sperm to a couple for *in vitro* fertilization but failed a paternity test after doctors revealed that he was a human chimera and his absorbed twin was the one who had fathered the child.[64] His

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[64] Shehab Khan, *'Human Chimera': Man Fails Paternity Test Because Genes in His Saliva are Different to Those in Sperm,* INDEPENDENT (Oct. 24, 2015), https://www.independent.co.uk/news/science/human-chimera-man-fails-paternity-test-because-genes-in-his-saliva-are-different-to-those-in-sperm-a6707466.html.

particular example provides for a very frightening scenario: a man whose sperm is not his own could very easily be exonerated by the failed DNA match for a rape that he had actually committed.

In this scenario, John Donor rapes a woman leaving sperm in and on his victim. Donor is then tested using the standard cheek-swab method. When the DNA from the cheek-swab is compared to that of the sperm collected from the victim, the samples do not match. Most juries would assume that the rape was then committed by someone who looked like him, or Donor was in the wrong place at the wrong time and had been accused of a rape he did not commit. The victim is then forced to watch her rapist be found not guilty of assaulting her.

The liability is not one of faulty testing, but rather faulty conclusions. We assume that, since a DNA code can only be found in one person, only one DNA code can be found per person. We believe this so strongly that, we, and the courts on which we rely, reject the idea that chimerism could be as common as some experts believe it to be. According to Dr. Barry Starr, the Stanford geneticist who reviewed Donor's case, who had the technicians running the DNA test, actually found a second genetic code within the sample taken from John Donor, something that would generally be assumed to be a contamination resulting in a mix up.[65] Starr's team had to test Donor's blood, hair, and ejaculate in order to tell the entire story of what happened in the conception of Donor's child. Running a single test in many situations does not tell the whole story.

ii. The Innocence Project

Cardozo Law is famous for, among other things, creating the Innocence Project which "exonerates the wrongly convicted through DNA testing and reforms the criminal justice system to prevent future injustice."[66] While their goal is justice and reform, they too must operate within a system that is blind, perhaps willfully, to the idea that DNA mismatches do not define innocence nor do matches define guilt.

According to their website, The Innocence Project has affected three hundred sixty-two exonerations using DNA and found the *real* perpetrators in one hundred fifty-eight cases.[67] Of those, the case of James O'Donnell may be one similar to that of John Donor, above. In

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[65] Jessica Richardson, *Man Fails Paternity Test Due to Passing on Unborn Twin's DNA*, BIONEWS (Nov. 2, 2015), https://www.bionews.org.uk/page_95259.

[66] *About,* INNOCENCE PROJECT (Mar. 13, 2013), https://www.innocenceproject.org/about/.

[67] *Exonerate the Innocent,* INNOCENCE PROJECT (Feb. 12, 2007), https://www.innocenceproject.org/exonerate/.

1998, O'Donnell was convicted of attempted sodomy and second-degree assault.[68] His conviction came by the presentation of evidence that his dental impressions matched bite marks on the victim, as well as an eyewitness identification of O'Donnell as the perpetrator.[69] Two years later, DNA was sampled from the rape kit and O'Donnell was excluded as the source of the saliva from the bite and skin found under the victim's nails.[70] Considered the new understanding that John Donor, Keegan and Fairchild's situation has given us, what is the weight of the DNA evidence when compared to the eyewitness testimony provided? What is the weight of the dental impressions that matched the bite mark found on the victim?[71] We have already seen that the skin tissue of an individual can drastically differ from other DNA sources provided by the same individual. Comparing the skin cells found on the victim with O'Donnell's blood, for example, may turn up the same mismatch of DNA even if O'Donnell had committed the assault.

VI. CONCLUSION

Under the Federal Rules of Evidence 702, and similarly constructed state rules of evidence, DNA analysts should be disqualified from testifying as to whether or not a specific DNA sample "matched" a specific individual or not. To say that nine of sixteen loci matched is a simple matter, but when drawing conclusions as to what that match means, most DNA analysts do not have the necessary statistical expertise to form an opinion. Allowing for a DNA analyst to testify, that a DNA sample, which is less than a one hundred percent match, came from the individual in question violates the requirement of Rule 702(b), that the testimony be based on sufficient facts and data.[72] This because their testimony lacks the necessary statistical analysis of the general population to rule out possible false positives, like those discovered in Arizona,[73] or the requisite inclusion of genetic abnormalities and difficult to diagnose conditions that could be resulting in a false negative.

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[68] *James O'Donnell,* INNOCENCE PROJECT (Aug. 1, 2004), https://www.innocenceproject.org/cases/james-odonnell/.

[69] *Id*.

[70] *Id*.

[71] *See* Fernanda Santos, *Evidence from Bite Marks, It Turns Out, is Not So Elementary,* N.Y. TIMES (Jan. 28, 2007), https://www.nytimes.com/2007/01/28/weekinreview/28santos.html, (bite mark analysis is notoriously dubious science and, by itself, subject to mass criticism. Studies have found that Odontology, as it's called, can have a false positive rate of up to 63%.).

[72] Fed. R. Evid. 702(b).

[73] *See* Felch, *supra* note 37.

In evaluating the weight given to DNA evidence in any proceeding, it is vital to determine its appropriate probative value. As the world begins to understand the DNA composition of people, our understanding of the value of DNA evidence must change with it.[74] If chimerism is as common as some experts believe, then failure to match DNA in either criminal or family court proceedings may also fail to survive an evidentiary challenge under Rule 403 as "its probative value [would be] substantially outweighed by a danger of . . . misleading the jury."[75] Much of the expert testimony as to the relative probabilities of any particular sample, which fails to match one hundred percent of the individual in question, coming from any particular individual, is based upon incomplete statistical data at best. The experts doing the testifying are not statisticians, and any testimony as to the likelihood of the sample coming from any particular individual, based upon a DNA technician's probability analysis, is of little probative value and risks misleading the jury, or other finders of fact, as to the meaning of data provided. Should a statistician be called separately to proffer an opinion based on the probabilities involved, and also drew statistical conclusions based on the likelihoods, then both parties could insist that their experts take into account the "rare" condition and localized population data into their probability analysis that would be open to a more fair cross-examination and rebuttal testimony.

Most attorneys today, like those of Lydia Fairchild, are not willing to fight DNA evidence.[76] While a complete match is still a match, we cannot rule an individual out simply because we did not look hard enough at the DNA we were trying to find. Instead of the standard STR, which can only determine whether the person tested is the *parent* of the child in question, a more detailed, microarray-based test should be used. This test looks at the expression of genes and not just their presence and is capable of determining the *degree* of relationship between the two.[77] While this test is more expensive and requires more time to acquire a result, it gives a more complete picture of the genes involved. It would

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[74] *See* Cathleen O'Grady, *Plot Twist: Mitochondrial DNA Can Come From Both Parents*, ARS TECHNICA (Nov. 28, 2018), https://arstechnica.com/science/2018/11/plot-twist-mitochondrial-dna-can-come-from-both-parents (DNA, which has long been determined to be passed on from the mother of a child exclusively, has been discovered to be able to be inherited from the father of a child as well, upsetting a standard testing procedure in DNA based maternity determinations.).

[75] Fed. R. Evid. 403.

[76] She's Her Own Twin, supra note 50.

[77] Li Li et al., SNP Genotyping by Multiplex Amplification and Microarrays Assay For Forensic Application, 162 FORENSIC SCI INT. 74 (2006).

have detected quite quickly that Fairchild and Keegan were their children's aunts and that Donor was his son's uncle.

DNA testing which determines that a man is the father of a specific child or that a woman is that child's mother is still good science. DNA evidence showing that a DNA sample taken from a crime scene is identical to one taken from a criminal defendant is likewise reliable. To justify the heavyweight given to DNA evidence by jurors and judges, and especially where "innocent until proven guilty" meets "beyond a reasonable doubt," we cannot allow the "CSI Effect" to determine what is and isn't a reasonable doubt. Under Rule 403, incomplete DNA profiles that are likely to sway the jury heavily must not be admitted for their ability to mislead the jury. Further, the testimony of DNA technicians who are not qualified experts in statistical analysis or who testify as to the meaning of the DNA results (e.g., "In my professional opinion, Mr. X provided the sample found at the scene") should be likewise inadmissible, as these genetic peculiarities mean that, unless the condition has been definitively diagnosed as absent or present in the person tested, the expert's opinion is based on incomplete data in violation of Rule 702(b).