"I CONTAIN MULTITUDES": CHIMERAS, CELLS AND THE MATERIALIZATION OF IDENTITIES

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"I CONTAIN MULTITUDES": CHIMERAS, CELLS AND THE MATERIALIZATION OF IDENTITIES

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This dissertation traces the biomedical networks through which human chimeras are clinically constituted. Chimeras are organisms in which two or more genetically distinct cell populations co-exist. Unlike their experimentally produced counterparts (often interspecies mixtures), human chimeras arise spontaneously when fraternal twin embryos fuse in the womb. While undoubtedly a rare occurrence, the true incidence is unknown because many chimeras have no visible signs of their composite being. Hence, chimeras are produced in an inadvertent encounter with the laboratory, during blood donation or tissue typing, for example. A subtype of chimerism, called microchimerism, occurs when the second cell population is tiny. The main context in which microchimerism is discussed in biomedical research is cell exchange between women and their fetuses, now thought to be a normal event during pregnancy. Human chimerism has existed since the 1950's, and microchimerism has become a research theme only in the last decade.

Like multiple personality disorder, conjoined twinning and organ transplantation, human chimerism troubles the connection between the individual and the body. Bodies, in these cases, are not neatly contained, which calls into question the inevitability and naturalness of singular

embodiment. Chimerism, in particular, offers an analytical vantage point for the examination of genetics and identity in contemporary biomedicine. Using historical and ethnographic methods, and analytical tools from science & technology studies, this dissertation explores human chimerism and microchimerism. Interviews with scientists and careful analyses of published and unpublished literature reveals that biomedical researchers speak and write as though cells and people are interchangeable; not only do people contain cells, cells contain people. This tendency is an instantiation of genetic reductionism (we are our genomes), but it also refers to much older Western traditions wherein the material of the body is one and the same as the person. In chimerism, though, ascribing personal identity to cells leads to a confusion of the boundaries by which individuals are normally separated. While the location of personhood in cells is no doubt a reductionist tendency, the result – the fragmentation and interspersion of selves – leads to a provocative anti-reductionist conclusion: we all contain multitudes.

BIOGRAPHICAL SKETCH

Aryn Martin received her B.Sc.H. from Queen's University in Kingston, Ontario in 1996. Her honors thesis, "Diagnosis of Monosomy 18 Mosaicism using Fluorescence In Situ Hybridization of Bladder Exfoliate Cells," won the Queen's Pathology award for the highest standing on an undergraduate thesis. After six months working on women's health policy in Johannesburg South Africa, she began graduate work at York University, Toronto, in women's reproductive health and international development. In 1999, she was awarded a Masters in Environmental Studies. During her Masters work, a change of interests and influences led her to the social studies of science and back to her roots in genetic medicine. In 2000, she moved to the United States, and began a combined M.A./Ph.D. program in Science & Technology Studies at Cornell University, receiving her M.A. in 2003 and her Ph.D. in 2006. She will begin teaching as an Assistant Professor of Sociology at York University in Toronto.

For my parents and my brother,
whom I contain

ACKNOWLEDGMENTS

I am unabashedly the opposite of a rugged individualist, and so the people who have sustained me during this project are many. I am most grateful to my supervisor Michael Lynch, whose rare combination of humility, brilliance and compassion are an inspiring example of how to enrich an academic, or any, community. Since the beginning of my time at Cornell, we have been engaged in an ongoing conversation; whether it is about counting, chromosomes or fly-fishing, I always profit from Mike's unique insights. His cautious embrace of this project, even when it was fledgling and unformulated, allowed me to press on.

Stephen Hilgartner has also been a constant support during my graduate training, and during this project. I am thankful for his encyclopedic knowledge of genetics and of S&TS. It was Steve who first told me about fetal cells in maternal blood; this and other snippets from our conversations would inevitably route and reroute my research. My newest committee member, Rachel Prentice, influenced my work at a formative time. It was invaluable to me to have a confidant who so recently went through the processes of writing and defending a dissertation, and she delivered advice with kindness and with tea. Others who taught and challenged me at Cornell include Anna Marie Smith, Elizabeth Toon, Ron Kline, Trevor Pinch, Christine Leuenberger, Hélène Mialet, Peter Dear and Michael Dennis. The faculty, students and staff in the department contribute to a vibrant intellectual culture. For their collegiality and friendship, I am especially grateful to: Park Doing,

Christina Dunbar-Hester, Lisa Jacobsen, Javier Lezaun, Anna Maerker, Cyrus Mody, Deb Van Galder, Janet Vertesi, Heidi Voskuhl, and Judy Yonkin.

I would not have arrived at this project, let alone this doctorate, had I not encountered three extraordinary mentors along the way. At Queen's University, I was privileged to study with Annette Burfoot and Alessandra Duncan. During my senior year, I simultaneously studied the sociology of reproductive health with Annette and cytogenetics with Alessandra, and it was this temporal coincidence that made me a science and technology studies scholar, though long before I knew it. Joan Steigerwald, my Masters supervisor at York University, introduced me to S&TS and gave me the courage to apply to Ph.D. programs worldwide. Her example of adept interdisciplinarity and rigorous scholarship has given me a model to which to aspire. I am happy to have ongoing relationships with each of these women, and I deeply value their continued interest in my work.

I am grateful to the National Science Foundation for supporting this work with a Dissertation Research Award, which allowed me to travel extensively to connect with interviewees and to attend conferences.[1] During this project, I also received support from the Social Sciences and Humanities Research Council of Canada, and from the journal *Social Studies of Science*, for which I worked as an editorial assistant.

[1] NSF Award #0432120, "I contain multitudes": Genetic chimeras and material negotiations of identity, August 1, 2004-August 1, 2006.

Like any social scientist, I am profoundly indebted to my research subjects. They happily volunteered time and information, and they received my interest in their work with patience and generosity. These include parents and children of the International Mosaic Down Syndrome Association; physicians and scientists in the related fields of chimerism, fetal cell research and microchimerism; and cytogeneticists and technologists at the Montreal Children's Hospital.

While they may not have impacted the content of the research directly, family and friends certainly have impacted the content of the researcher. I thank my parents, Judie and Peter Martin, whose faith in their children is boundless. My mother has taught me much, not the least of which is the importance of telling stories and listening to them, which is the heart of this work. My father's quiet confidence in me is an unwavering source of strength. I thank my brother, my oldest friend, for reminding me that getting a Ph.D. doesn't mean I can get away with being highfalutin'. I am most fortunate to have multitudes in my family – the Morrises and the Martins – who have been there since the beginning, cheering me on. The Bronsons have recently, though no less enthusiastically, taken up the role as my more local mishpocha. I am grateful to my friends Janet Swoger-Ruston, Mary Simms, Alyson Parker and Vicki Toscano with whom I sort through the layers of life, love and work, which are never truly separate. Finally, Eric Bronson fortified my soul in countless daily ways. He is my reader, my rescuer, my song and dance man. Without him, everyone else on this list would have had a much tougher job.

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INTRODUCTION

> Do I contradict myself?
> Very well then I contradict myself,
> (I am large, I contain multitudes)
>
> ---Walt Whitman, *Song of Myself*[1]

The category of the person

The "category of the person" has many guises: self, soul, name, psyche, consciousness, personality, biography, citizen, body.[2] Most of these terms are presumed, in contemporary Western societies, to be unitary, one, to have identity with each other, in the mathematical and sociological meanings of the word. However, under careful historical and cross-cultural scrutiny, all of these concepts prove to be contingent on time and place, rather than essential to human being. Moreover, their alignment may be peculiar to Western modernity. Marcel Mauss showed that among the Kwakiutl Indians of the Northwest US and Canada, names do not attach to persons in the ways in which we are familiar, but rather change according to the season and to the age of the individual. Moreover, a clan has a fixed number of names, and ancestors "live again in the bodies of

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[1] Walt Whitman, *Leaves of Grass*, Bantam classic edition ed. (New York: Bantam Books, 1983 [1892]), 72.

[2] This is in reference to Marcel Mauss, "A Category of the Human Mind: The Notion of Person; the Notion of Self," in *The Category of the Person: Anthropology, Philosophy, History*, eds. Michael Carrithers, Steven Collins and Steven Lukes, trans. W. D. Halls (New York: Cambridge University Press, 1985 [1938]), 1-25.

those who bear their names."[3] Long before the decentered self came into vogue in the academy, William James wrote: "Properly speaking, a man has as many social selves as there are individuals who recognize him and carry an image of him in their mind."[4]

Ian Hacking's history of multiple personality shows how, in the late 1800's, psychologists used cases of *dédoublement* to refute the existence of a transcendental self, soul or ego: "For in those individuals, there was not one single self. Those individuals had two personalities, each connected by a continuous or normal chain of memories, aside from amnesic gaps…. Hence (it seemed) there were two persons, two souls in one body."[5] Studies of multiple personality disorder, including Hacking's, explore the existential confusion encountered by multiples in a world where social and political institutions, such as courts, require individuality to be singular.[6] Similarly, in her work on conjoined twins, Alice Dreger foregrounds the social imperative to contain only one body per person.[7] While almost all twins who have remained conjoined report that they prefer it that way, singleton doctors, judges and parents presume

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[3] Ibid., 8.
[4] William James, *The Principles of Psychology* (New York: H. Holt and company, 1890), 294.
[5] Ian Hacking, *Rewriting the Soul: Multiple Personality and the Sciences of Memory* (Princeton, N.J.: Princeton University Press, 1995), 208.
[6] Hacking, *Rewriting the Soul*; Elyn R. Saks and Stephen H. Behnke, *Jekyll on Trial: Multiple Personality Disorder and Criminal Law* (New York: New York University Press, 1997).
[7] Alice Domurat Dreger, *One of Us: Conjoined Twins and the Future of Normal* (Cambridge, Mass.: Harvard University Press, 2004).

that a life that so radically impinges on normal individuality would be unlivable.

These studies speak not just to a multiplication of selfhood in some rare tribes or disordered people, but also to a dissolution, or at least an historical and cultural fluidity, of the very thing called "the person." Exceptions to the alignment of body and person could be interpreted as proof that this alignment is not, in fact, prescribed by nature. Instead, biomedical discourses most often police the "naturalness" of singular identity by portraying any exceptions as pathological or monstrous and therefore not disruptive to the fundamental norm of discrete individuality. In this dissertation, I introduce another biological phenomenon that appears to trouble the inevitable alignment of the body and the person: human genetic chimerism.

The case: Human chimerism

Human genetic chimeras are individuals who contain more than one genetically distinct population of cells. What biologists know about chimeras is not now, and has never been, stable and well defined. Indeed, the slipperiness of categories and classifications of chimerism is a subject of my research, and so it is difficult to use those categories as a resource. Nonetheless, I appreciate that the reader needs some kind of guide through the forthcoming material. Therefore, I will delineate what "kinds" of chimerism are relevant to my study, and what kinds are not. My inclusions and exclusions have emerged during the course of my research for both methodological and analytical reasons, which I will describe below.

1) Chimeric twins and singletons

The first kind of human chimera I will consider results from a dizygotic (commonly called "fraternal") twinning event, and it has two subtypes, fraternal twins who share blood cells, and singletons who are the result of early embryo fusion.[8] In the first subtype, fraternal twins share blood *in utero*, and blood cells genetically traceable to each twin can be found in the other. The first twin chimera was ascertained in Britain in 1953 when a woman who donated blood was found to contain both A and O blood types; one was labeled "hers," and the other was "borrowed" from her twin during gestation. Early cases were described with fascination, but this is now thought to be fairly common: current estimates suggest that 12% of dizygotic twins contain blood from their twin.[9] In the second subtype of dizygotic chimerism, only one baby is born, and that person is found to contain two populations of genetically distinct cells. At some point in development, dizygotic twins existed, and the second one fused with the first. If the embryos had not fused, they would have developed into fraternal twins, either of the same sex or different sexes. The resulting person has a mixture of two genetically distinct cell types distributed throughout the tissues of his or her body in an unpredictable combination. Any organ may contain one or both of the cell types.

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[8] Twinning specialist Charles Boklage has recently called this distinction into question, by suggesting that both types of twin chimeras arise by the same developmental mechanisms, whether one or two are born. See C. E. Boklage, "Embryogenesis of Chimeras, Twins and Anterior Midline Asymmetries," *Human Reproduction* 21, no. 3 (Mar, 2006), 579-591. Historically, the mechanisms have been understood separately and I will retain this distinction to ameliorate confusion.

[9] Ibid.

The question of just how rarely embryo fusion occurs is fundamentally unanswerable, for a number of reasons. First, the ascertainment of chimerism is most often accidental: human chimeras have been "discovered" when donating blood and when being tissue typed as potential organ donors or recipients. Approximately forty of these cases have been reported, some of which were identified because a patient presented with some degree of intersex development (the fused embryos were XX and XY). However, not all clinicians who discover a case will publish it; I have found reference to several unpublished cases in archives. Furthermore, authors may not have used the word chimera, as they may instead have described patients as mosaics (see below) or hermaphrodites. Many experts believe that there is a large gap between ascertainment and true existence of the phenomenon. Twinning specialist Charles Boklage recently wrote:

> We do not expect to find chimeras because most of us are ignorant of their existence and the informed few just know they are too rare and bizarre to require consideration. We don't look for them because we don't expect to find them and we don't find them until we trip over evidence we cannot ignore.[10]

While we do not know just how rare the phenomenon is, it is certainly true that reports of it are very rare.

[10] Ibid., 581.

2) Fetal microchimerism

The second type of human chimerism considered in this study is much more common. Mothers and their children exchange cells during gestation, and these cells, it seems, can persist in both bodies long after the birth of a child (and, in the mother, long after the termination of a pregnancy). This phenomenon became the subject of biomedical research beginning in the mid-nineties, and it is commonly called "microchimerism." The category microchimerism usually implies a very small (less than 1%) subpopulation of persistently dividing cells (known as a "cell line") within a dominant population of cells.

Not the case

The term chimera and its strict definition (more than one genetically distinct cell population) can apply to several other biological phenomena as well. These are on the periphery of this project, and while meanings move around among cases, the following kinds of chimerism are in the background rather than the foreground of my study. In science and medicine, the term chimera is applied to these cases in some contexts and not in others. In general, it is used when the speaker wishes to emphasize the dissimilar genetic composition of the person, organism or compound.

1) Transplants

Some of human chimerism is artificially produced in the course of medical treatment. Recipients of organs, bone marrow and cell transplants become chimeric by virtue of the introduction of donor cell populations, although they are seldom labeled chimeras. To be considered chimeric, the population needs to establish a long-term

presence, which it does in most of these cases, provided that the transplant is not rejected. Blood transfusion, however, does not usually create chimeras as the introduced cell population is transient.

2) Mosaics

A second human biological situation that is distinct from chimerism, though historically and clinically intertwined, is genetic mosaicism. Mosaics arise when a single fertilized egg undergoes a mutation in early cell division and establishes a second cell line. For example, an embryo that starts out containing three copies of chromosome 21 in all of its cells (the cause of Down Syndrome) might lose the third copy of chromosome 21 in one cell because of an "error" in cell division. The resultant cell, now with two copies of 21, divides and establishes a cell population and the fetus continues to develop with cells of each composition throughout the body. The person may (if enough tissues are sampled to find both cell types) be diagnosed as having "Mosaic Down Syndrome." This can happen to any chromosome in the body, however some cells are more likely to survive than others with extra or missing chromosomes. While mosaics and chimeras are differentiated by their causal mechanism, the clinical situation is easily confused because both are detected by the presence of two distinct cell types.

3) Plants and animals

Plant chimeras and animal chimeras have long been produced artificially, and in many cases materials from different species have been combined. I will give an overview of these experimental organisms in chapter 1, but for the most part, I have excluded them from my analysis. Finally,

xenotransplantation can create animal/human chimerism. Xenotransplantation has generated intense debates about ethics and safety.[11] These cases, too, I set aside.

While my inclusions and exclusions may seem arbitrary at first, I have a very clear sense of the stakes involved in my choices. First, I am focused on *human social and political identity*. Second, I am interested in the clinical domain: where the doctor's office, the hospital and the laboratory meet. I began the project with a desire to include mosaicism and transplantation as human clinical events which exist somewhere on a continuum with chimerism. However, as the project took shape, I excluded mosaics and transplant recipients mostly for reasons of scope. Anthropologists of medicine have already studied transplantation from an ethnographic standpoint, and I make liberal use of these studies, particularly in chapter 4. While mosaicism raises compelling social and classificatory dilemmas about fragmented identity, I observed that the concerns in this community (where does my child fit in?) are very different from those that emerged in communities arranged around chimerism. As I will discuss throughout, the latter phenomenon evokes worries about being or containing "someone else," in ways that are not germane to mosaicism. Finally, I decided to limit my project to those cases that seem to arise spontaneously, however "unnatural" they are

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[11] See, for example, Nik Brown and Mike Michael, "Risky Creatures: Institutional Species Boundary Change in Biotechnology Regulation," *Health, Risk & Society* 6, no. 3 (Sept, 2004), 207-222; Nik Brown and Mike Michael, "Switching between Science and Culture in Transpecies Transplantation," *Science, Technology & Human Values* 26, no. 1 (Winter, 2001), 3-22.

coded by biologists and biomedical researchers. Experimentally or therapeutically created combinations of genetic material do not trouble the naturalness of the alignment of the body, the genome and the person in quite the same way as do chimeras that arise in nature.

Cells and Selves

In this dissertation, I utilize chimerism, and the discourses in which it is characterized, as an analytical window into contemporary "regimes of the self."[12] It is a "test case" of sorts, like phantom limbs were to Maurice Merleau-Ponty, hermaphroditism and transsexuality were to Harold Garfinkel, Michel Foucault and Anne Fausto-Sterling, and multiple personality to Hacking.[13] These rarities and intermediate cases are useful because they can be jarring and disruptive of the categories we take for granted, and which order our social worlds. They can reveal not just how bodies function in the normal order of things (which is how biomedicine has long employed physiological anomalies), but they also expose how scientists and others *think about* and actively delineate how bodies function in the normal order of things. They are useful sites for revealing

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[12] This phrase is borrowed from Nikolas S. Rose, *Inventing our Selves: Psychology, Power, and Personhood* (Cambridge: Cambridge University Press, 1996).

[13] Maurice Merleau-Ponty, *Phenomenology of Perception* (London; New York: Routledge & K. Paul; 1962); Harold Garfinkel, *Studies in Ethnomethodology* (Englewood Cliffs, N.J.: Prentice-Hall, 1967); Michel Foucault, *Herculine Barbin: Being the Recently Discovered Memoirs of a Nineteenth-Century French Hermaphrodite* (New York: Pantheon Books, 1980); Anne Fausto-Sterling, *Sexing the Body: Gender Politics and the Construction of Sexuality*, 1st ed. (New York, NY: Basic Books, 2000); Hacking, *Rewriting the Soul*, 336.

the ways in which normative assumptions in biomedicine shape the materiality (genes, cells, bones and flesh) of bodies.

The painting in figure 1 was commissioned from New York artist Cynthia Van Buhler by *U.S.News* to accompany a story about maternal/fetal microchimerism. The magazine added this text to the painting: "like the creature of myth, medical chimeras are a mix of selves." Why does this statement, "chimeras are a mix of selves," seem to make sense? I suggest that this discursive move follows from an extreme genetic essentialism that equates a genome – the full genetic complement contained in the nucleus of a cell – with a self.[14] A mother who contains her son's cells is, we are told, a mixture of her self and his. This slippage from cell to person is not a tendency confined to an oversimplifying media, and in fact

[14] "Geneticization," a worry of science critics in the 1990s seems to be on the wane after the Human Genome Project, where epigenetics has taken on a new relevance. Nonetheless, genetics is insinuating itself into policing, courts, administration of citizenship and rights, not to mention health management. For discussion of genetic reductionism, see Lenny Moss, *What Genes can't do* (Cambridge, Mass.: MIT Press, 2003), 228; Evelyn Fox Keller, *The Century of the Gene* (Cambridge, Mass.: Harvard University Press, 2000), 186; Sahotra Sarkar, *Genetics and Reductionism* (Cambridge, UK ; New York, NY: Cambridge University Press, 1998), 246; Daniel J. Kevles and Leroy E. Hood, *The Code of Codes: Scientific and Social Issues in the Human Genome Project* (Cambridge, Mass.: Harvard University Press, 1992), 397; Richard C. Lewontin, *It Ain't Necessarily so: The Dream of the Human Genome and Other Illusions* (New York: New York Review of Books, 2000), 330. For recent coverage of genetics, governance and identity, see for example, Jenny Reardon, *Race to the Finish: Identity and Governance in an Age of Genomics* (Princeton, N.J.: Princeton University Press, 2005), 237; Carlos Novas and Nikolas Rose, "Genetic Risk and the Birth of the Somatic Individual," *Economy and Society* 29, no. 4 (Nov, 2000), 485-513.

it seems to originate with the biomedical researchers who talk to the media. An article in *Nature* tells us: "Eight years ago a boy was born who, genetically, was two people."[15]

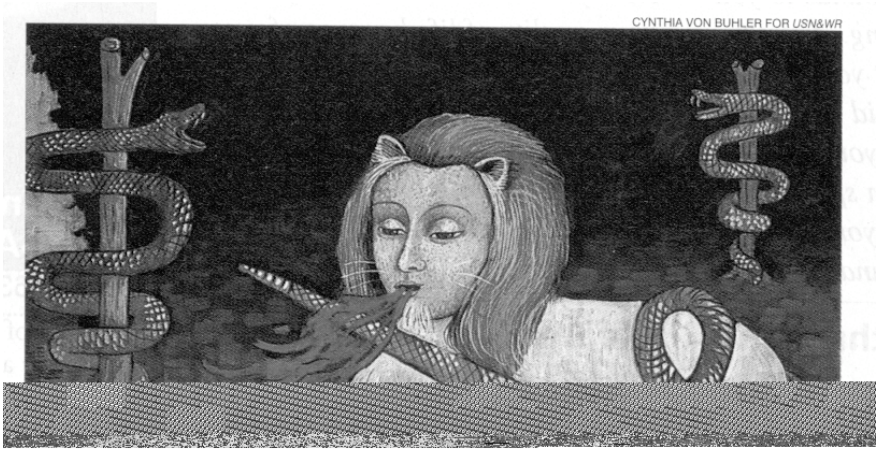

Figure 1: "Myths, mothers and modern medicine" (C. von Buhler)[16]

Surely there is much more to selfhood than cells? Talk of cells as selves, the preoccupation of this entire project, is of course but one vista in a complex landscape of the self. It does not necessarily supersede other

[15] Helen Pearson, "Dual Identities," *Nature* 417, no. 6884 (May 2, 2002), 10.

[16] Reprinted with permission from Cynthia von Buhler. Originally published in Rachel K. Sobel, "Myths, Mothers and Modern Medicine: Do 'Chimeras' Trigger some Women's Illnesses?" *US News and World Report* 130, no. 18 (May 7, 2001), 46.

prominent discourses of the self, like psychology, biography and social roles. Even for those geneticists who spend more time thinking about cells and identity than do most people, it is a way of talking that is elicited in appropriate dialogues, but it is not necessarily the only way they look at people. I do not wish to over-determine the phenomenon of chimerism, but to mark it as emblematic of a prevalent and evocative cultural moment.

The common thread throughout the dissertation is whether and in what contexts it makes sense to ascribe personal identity (and personality) to cellular identity. We will see that in many cases, cells and persons are presumed to exist in a relationship of synecdoche. In linguistics, a synecdoche is a figure of speech in which parts are substituted for wholes and vice versa. It can also apply where one speaks of the material that something is made of instead of the thing itself – the wood, instead of the bat, for example.

Rather than this being simply a linguistic habit, in clinical cytogenetics, synecdoche is the rule that justifies the enterprise. Individual cells from blood or other tissues are isolated on a microscope slide, and a skilled observer examines the genetic material of a few cells in order to make a diagnostic judgment about the whole person. If each cell were found to have an X and a Y chromosome and 3 copies of chromosome 21, for example, the person would be labeled as a male with Down Syndrome. As a rule, one cell could suffice as a stand-in for the entire body. A recent program on the Discovery Channel describes this relationship: "Every cell in our body holds the same completely unique DNA pattern. It is what

defines us, and makes us who we are. It is this individual genetic blueprint that a DNA test reveals."[17] While the relative power and accuracy of genetic discourse is disputed, it is undeniable that genetics is often coupled to human identity in contemporary societies.[18] While not everyone may know the details contained in their "genetic code," there is a widely held belief that our genes could, in theory, divulge many aspects of our biological identity (sex, disease status, kinship, race, etc.). Thus, a cell is not just a "part" of the body, it is widely thought to be – particularly in an era of genetic essentialism – a part that contains the whole.

Chimeric conditions are exceptions to this rule. We will see that this disruption causes people to make some peculiar and seemingly awkward leaps when they ponder what it means for a single person to contain more than one (person's?) cell line. As exceptions to the one-body-one-genome rule, chimeric conditions expose the extent of cultural penetration of the synecdoche between cells and persons. The extension of personhood to cells is a derivative or variant of genetic reductionism, wherein a single cell embodies the complete material necessary for individuality. The cell

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[17] "I am my own twin," Cicada Films, first aired on Discovery Health Channel, May, 2005.

[18] For discussions about the cultural resonances of genetic thinking, and its limitations, see Dorothy Nelkin and M. Susan Lindee, *The DNA Mystique: The Gene as a Cultural Icon* (New York: Freeman, 1995), 276.; Evelyn Fox Keller, *The Century of the Gene*; Lenny Moss, *What Genes can't do*. I am hesitant to suggest that genetics is a universal marker of identity, but I also do not want to exclude countries or parts of the world on the basis of an ethnocentric assumption that this is a "Western" phenomenon. The extent of "genes R us" thinking is an empirical question I simply can't answer.

is the person. This reductionist tendency that I trace throughout the dissertation leads, if taken literally, to a paradoxically anti-reductionist conclusion: The more scientists probe into the cellular material of bodies, the more it seems that we are all chimeras. If the cell is the person, we all contain multitudes.

Conversations

I envision this project as a contribution to several literatures, and I imagine myself in conversation with many authors. Ethnographies of medicine, biology and the body most overtly inform the project, and many of these are feminist in orientation. Authors such as Margaret Lock, Emily Martin, Rayna Rapp and Annemarie Mol have carefully attended to and skillfully presented studies of clinical nodes where patients, physicians, biomedical researchers and instruments come together.[19] Each author has placed a technoscientific object – organ transplantation, the immune system, amniocentesis and atherosclerosis respectively – at the center of a story about the cultural politics of knowledge and the lived body, or rather bodies. Other feminist anthropologists such as Sarah Franklin and Marilyn Strathern, and sociologist Charis Thompson, have interrogated kinship in relation to reproductive and genetic technologies,

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[19] Margaret M. Lock, *Twice Dead: Organ Transplants and the Reinvention of Death* (Berkeley: University of California Press, 2002); Emily Martin, *Flexible Bodies: Tracking Immunity in American Culture from the Days of Polio to the Age of AIDS* (Boston: Beacon Press, 1994); Rayna Rapp, *Testing Women, Testing the Fetus: The Social Impact of Amniocentesis in America* (New York: Routledge, 1999); Annemarie Mol, *The Body Multiple: Ontology in Medical Practice* (Durham: Duke University Press, 2002).

and their work also informs mine.[20] Finally, classic works by Donna Haraway, Evelyn Fox Keller and Anne Fausto-Sterling attend to the content of biological knowledge, and reveal the ways in which this knowledge is often saturated with gendered assumptions.[21]

My study of human chimeras begins with the premise, articulated most clearly by Michel Foucault, that neither the individual nor the body exists as such pre-socially. Instead, they are constituted by power. In his words,

> The individual is not to be conceived as a sort of elementary nucleus, a primitive atom, a multiple and inert material on which power comes to fasten or against which it happens to strike, and in so doing subdues or crushes individuals. In fact, it is already one of the prime effects of power that certain bodies, certain gestures, certain discourses, certain desires, come to be identified and constituted as individuals. The individual, that is, is not the vis-à-vis of power, it is, I believe, one of its prime effects.[22]

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[20] Sarah Franklin and Helene Ragon_, *Reproducing Reproduction: Kinship, Power, and Technological Innovation* (Philadelphia: University of Pennsylvania Press, 1998); Sarah Franklin, *Embodied Progress: A Cultural Account of Assisted Conception* (New York: Routledge, 1997); Marilyn Strathern, *After Nature: English Kinship in the Late Twentieth Century* (Cambridge: Cambridge University Press, 1992); Charis Thompson, *Making Parents: The Ontological Choreography of Reproductive Technologies* (Cambridge, MA: MIT Press, 2005).

[21] Donna Jeanne Haraway, *Simians, Cyborgs, and Women: The Reinvention of Nature* (New York, NY: Routledge, 1991); Evelyn Fox Keller, *Refiguring Life: Metaphors of Twentieth-Century Biology* (New York: Columbia University Press, 1995); Evelyn Fox Keller, *Secrets of Life, Secrets of Death: Essays on Language, Gender, and Science* (New York: Routledge, 1992); Anne Fausto-Sterling, *Sexing the Body*.

[22] Michel Foucault, *Power/knowledge: Selected Interviews and Other Writings, 1972-1977*, 1st American ed. (New York: Pantheon Books, 1980).

My work is in dialogue with the work of scholars such as Ian Hacking, Nikolas Rose and Paul Rabinow who have, in turn, been inspired by Foucault.[23] Rose writes: " 'The body' provides no sure basis for an analytic of subjectification, precisely because corporealities are diverse, nonunified, and operate in relation to particular regimes of knowledge: the configurations of the human body inscribed in the anatomical atlas did not always define a way of delimiting the order of vital processes, or of visualizing and acting on human being."[24] Hacking and Rose have both explored the history of psy disciplines (psychology, psychiatry, psychotherapy) and have shown them to be power-laden discourses which operate to mold certain kinds of selves. Like Foucault, Rose urges that a history of subjectification is not to be found in lofty ideals of philosophers, but in the everyday, mundane enactments of power, such as medical records or IQ tests.

In this endeavor – finding meaning in the minutiae of scientific practice and discourse – the field of science and technology studies is my home and my main methodological resource. Attention to materiality is, I believe, the major strength of this project, in terms of its potential to affect broader discussions about identity and the body. Feminist critical

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[23] Ian Hacking, *Rewriting the Soul*; Ian Hacking, "Making Up People" in *Reconstructing Individualism: Autonomy, Individuality, and the Self in Western Thought*, eds. Thomas C. Heller, Morton Sosna and David E. Wellbery (Stanford: Stanford University Press, 1986), 222-236; Nikolas Rose, *Inventing Our Selves;* Paul Rabinow, *Essays on the Anthropology of Reason* (Princeton, NJ: Princeton University Press, 1996).
[24] Nikolas Rose, *Inventing Our Selves*, 10.

theorists, such as Judith Butler and Elizabeth Grosz, have written influential texts about the fluidity of the body and of biological sex.[25] Grosz, for example, writes: "the body is a pliable entity whose determinate form is provided not simply by biology but through the interaction of modes of psychical and physical inscription and the provision of a set of limiting codes."[26] However, these cultural theorists lack material instantiations of their abstract positions. Butler, for the most part, locates her examples in psychoanalysis and comparative literature. This study of chimerism and microchimerism from the perspective of S&TS is a persuasive case with which to strengthen poststructuralist feminist theory because it follows sex and identity to the places where they are affixed to chromosomes and to bodies, where sex and identity are materially inscribed.

It is a central tenet of S&TS that scientific facts and technical artifacts are made (or constructed or achieved or enacted) in social contexts, and the resultant facts and artifacts are imprinted by those contexts. Methodologically, this means that social scientists need not be held at bay by the authority and objectivity of scientific knowledge, but can instead visit the places where facts are made and observe the processes by which they are assembled. Early and formative studies in S&TS that inform my approach to this project include the laboratory studies of the late 1970's

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[25] Elizabeth A. Grosz, *Volatile Bodies: Toward a Corporeal Feminism* (Bloomington: Indiana University Press, 1994); Judith Butler, *Gender Trouble: Feminism and the Subversion of Identity* (New York: Routledge, 1999); Judith Butler, *Bodies that Matter: On the Discursive Limits of "Sex"* (New York: Routledge, 1993).

[26] Elizabeth Grosz, *Volatile Bodies,* 187.

and early 1980's by Bruno Latour and Steven Woolgar, Michael Lynch, Karin Knorr-Cetina and Sharon Traweek.[27] I also employ analytical strategies formulated by the Sociology of Scientific Knowledge (SSK) and thus my work is in conversation with sociologists Trevor Pinch, Harry Collins, Nigel Gilbert and Michael Mulkay, and David Bloor.[28] These strategies include approaching my material symmetrically (i.e., assuming that beliefs, whether they are later judged to be correct or incorrect, are caused by the same sorts of social factors) and studying controversies in order to reveal the social contingencies that are usually expunged when controversies are resolved.

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[27] Bruno Latour and Steve Woolgar, *Laboratory Life: The Construction of Scientific Facts* (Princeton, N.J.: Princeton University Press, 1986); Michael Lynch, *Art and Artifact in Laboratory Science: A Study of Shop Work and Shop Talk in a Research Laboratory* (Boston: Routledge & Kegan Paul, 1985); Karin D. Knorr, *The Manufacture of Knowledge: An Essay on the Constructivist and Contextual Nature of Science* (Oxford ; New York: Pergamon Press, 1981); Sharon Traweek, *Beamtimes and Lifetimes: The World of High Energy Physicists* (Cambridge: Harvard University Press, 1988).

[28] Trevor Pinch, "Towards an Analysis of Scientific Observation: The Externality and Evidential Significance of Observational Reports in Physics," *Social Studies of Science* 15, no. 1 (Feb, 1985), 3-36; H. M. Collins, *Changing Order: Replication and Induction in Scientific Practice* (London: Sage Publications, 1985); G. Nigel Gilbert and M. J. Mulkay, *Opening Pandora's Box: A Sociological Analysis of Scientists' Discourse* (Cambridge: Cambridge University Press, 1984); David Bloor, *Knowledge and Social Imagery* (London: Routledge & K. Paul, 1976).

This project also connects with some more recent texts in S&TS, most notably Geoffrey Bowker and Susan Leigh Star's *Sorting Things Out*.[29] Their project, like mine, interrogates classification as a profoundly world-making enterprise. Bowker and Star write:

> People often see multiplicity and heterogeneity as accidents or exceptions. The marginal person, who is for example of mixed race, is portrayed as the troubled outsider; just as the thing that does not fit into one bin or another gets put into a "residual" category. This habit of purity has old and complicated origins in western scientific and political culture.[30]

In this dissertation, we will see that fine distinctions between XX cells and XY cells are made in everyday work situations, and these classifications matter to the lived realities of the people they implicate. Finding two genetically different cells in a single person creates a problem of classification.

Finally, this is a story first and foremost about *identity*. Where in the body is identity located and can it be found in genetic code? If so, what if a person contains two codes? My project engages with those S&TS scholars who have grappled with questions of genetics and identity. These include Jenny Reardon and Troy Duster.[31] Those who study patient activism and biosociality also inform my project, although with a few

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[29] Geoffrey C. Bowker and Susan Leigh Star, *Sorting Things Out: Classification and its Consequences* (Cambridge, Mass.: MIT Press, 1999).
[30] Ibid., 300.
[31] Jenny Reardon, *Race to the Finish*; Troy Duster, *Backdoor to Eugenics* (New York: Routledge, 2003).

exceptions, the subjects in my study – chimeras, pregnant and post-pregnant women – are not a politicized patient group, or at least they are not politicized around chimerism. Nonetheless, the works of Paul Rabinow, Michel Callon and Vololona Rabeharisoa, Nikolas Rose and Carlos Novas, and Steven Epstein have shaped my thinking about the politics of patienthood.[32] My project contributes to this literature an example of biosociality that is not necessarily predicated on disease or risk. Finally, Hannah Landecker's historical work on cell culturing, and in particular her piece about the HeLa cell line and its troubled relation to the person Henrietta Lacks was particularly inspirational.[33]

Methodology

My research methodology for this project could itself be described as a mosaic. As is common in S&TS, I combine methodologies from qualitative sociology, such as interviewing and observation; from anthropology and sociology of work, such as ethnography; and from history, such as archival research and discourse analysis.

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[32] Paul Rabinow, "Artificiality and Enlightenment: From Sociobiology to Biosociality" in *Essays on the Anthropology of Reason*, 91-111.; Michel Callon and Vololona Rabeharisoa, "Research 'in the Wild' and the Shaping of New Social Identities," *Technology in Society* 25, no. 2 (Apr, 2003), 193-204; Vololona Rabeharisoa and Michel Callon, "The Involvement of Patients' Associations in Research," *International Social Science Journal* 54, no. 1; 171 (Mar, 2002), 57-65; Carlos Novas and Nikolas Rose, "Genetic Risk and the Birth of the Somatic Individual"; Steven Epstein, *Impure Science: AIDS, Activism, and the Politics of Knowledge* (Berkeley: University of California Press, 1996).

[33] Hannah Landecker, "Immortality, in Vitro: A History of the HeLa Cell Line" in *Biotechnology and Culture: Bodies, Anxieties, Ethics*, ed. P. Brodwin (Bloomington: Indiana University Press, 2000), 53-72.

1) Chimerism

In my first task, constructing a thick description of cases of genetic chimerism, I relied mostly on historical materials. The papers of the MRC Blood Group Unit at the Wellcome Library in London yielded a treasure trove of archival riches, as the Unit identified the first human chimera and became an obligatory passage point in all the early case descriptions. The material from this archive – including correspondence between scientists, doctors and patients, drafts of publications and talks, laboratory notes, notes from phone calls among physicians, and reprints – forms much of the empirical material in chapter 1. I also relied on textbooks, published case reports and review articles to reconstruct biomedical representations of chimeras.

During the course of this project, which I began in 2003, a surge of American public interest in chimerism was spurred by the publicity of one case, a woman called "Karen". When her blood was tested, Karen appeared not to match her sons, which would exclude her as their mother. I discuss this case in chapter 4. I was unable to interview Karen's physician (due to medical leave), and I did not try to gain access to speak to Karen herself. This was partly because I am leery of the potential exploitation of people who are sometimes portrayed as "freaks", and I wanted to study this impulse rather than to contribute to it. However, she has appeared in interviews both on National Public Radio and the Discovery Health channel, and the case has been covered in many media other accounts. I did use these transcripts and articles, and public responses to them posted in internet chat rooms, as research data.

While I did not undertake a lengthy laboratory ethnography, I did spend one week in a hospital cytogenetics lab (in which molecular methods were also used) to familiarize myself with the technical aspects of the work. Because I worked in a cytogenetic research laboratory during my undergraduate training, I did not begin my tutelage in the laboratory from scratch, but this field work served as an intensive reminder of up-to-date technologies, and I was especially attentive to the processes of identity-making in the lab. The clinical laboratory I visited was not engaged in either chimerism research (which comes up rarely and in unpredictable places), or in the detection of fetal cells in women. However the researchers did use most of the technical methods for visualizing genetic material in cells, which is the salient technical aspect of chimerism and microchimerism research.

During my time in the clinical lab, I shadowed technicians at each "station" in the production of a prenatal genetic diagnosis: from delivery and administrative processing of the sample (blood or amniotic fluid); to tissue culture; to the staining and fixing necessary to make cells and chromosomes visible on microscope slides; to the visual work by technicians at the microscope/computer screen; to the diagnostic work by the cytogeneticist, which takes place on a digital printout of the chromosomal material of two cells. During the week, I lodged with the director of cytogenetics who ran the lab (a former professor from my undergraduate work). We had many informal discussions about the organization of labor in the laboratory, the aesthetics of microscopy, the economic, social and political aspects of clinical genetics, etc. In contrast

to my genial but brief interviews with most other respondents, I learned that this deeper engagement with a study participant was a rare and immeasurably valuable pleasure of ethnographic research.

2) Microchimerism

Because fetal microchimerism research is recent and ongoing, and it is not based on the accidental elucidation of rare events, this portion of my research was methodologically more accessible. I began by reading the relevant scientific and biomedical literatures on fetal cell isolation for non-invasive prenatal screening (chapter 2) and on microchimerism, the persistence of those cells in women after the end of the pregnancy (chapter 3). My careful reading of the literature in the field enabled me to become familiar with the technical problems, the debates, the language, and the key investigators who published recurrently and seemed to have a sustained commitment to researching the phenomena. I contacted these researchers, and in most cases, was successful in setting up interviews (see Appendix). Using a "snowball" approach, I would ask my interviewees to recommend others in the field with whom I should speak. Often interviewees would give me a tour of their laboratories or invite me to join them for a meal, and these informal exchanges were important in rounding out my understanding of the field.

Most of the fetal cell and microchimerism researchers whom I interviewed worked in Canada, the U.S., Great Britain or Switzerland. This is a function of the demographics of the research community, and also of my financial constraints. The only major laboratory outside these areas, as far as I could tell from the English literature, was in Singapore. I

was able to interview the PI (principal investigator) from this lab at a conference in London. During the project, I attended three international conferences: the first conference of the International Mosaic Down Syndrome Association (IMDSA) in 2004, the American Society of Human Genetics (ASHG) annual meeting (2004), and the Fourth International Conference on Circulating Nucleic Acids and Proteins (CNAPS) in 2005. At these meetings, I attended talks and poster sessions, spoke to researchers between sessions, and participated in informal conversations at meal times and breaks. These were important research moments, as they allowed glimpses of the social interactions among researchers, and of modalities for presenting content that varied from interviews and the published literature. Overall, my combination of research methodologies was opportunistic: I followed up every lead possible in order to gain a rich sense of the creation and negotiation of cellular multiplicity.

Chapter preview

In the following four chapters, I follow cells to the places in which they are given identities, and observe how those cellular identities seem to recast or confuse personal identities. The narrative, and the empirical material, is loosely chronological. In the first chapter, I trace the genealogy of the word "chimera", from its origin as a Greek mythological monster to its use in botany and then in zoology, and finally to its use in clinical medicine. I foreground the persistent linkage between the two meanings: the Greek "she-monster" (composed of a lion, goat and serpent) and the genetically compound being. When researchers talk about genetic chimeras, they almost always invoke the mythical creature,

as they have since the first human chimera, Mrs. McK, was named in 1953. The commonality between the mythical beast and genetic chimeras is that they are mixtures, hybrids and boundary transgressors, and they therefore violate cultural rules about purity. I will show that serologists and geneticists characterized human chimeras in much the same way as embryologists and teratologists characterized anatomical monsters in Enlightenment embryology: they were both objects of fascination and collection; they were tools in debates about embryonic development; and they were described as "Nature's experiment." While anatomical oddities have traditionally been characterized by visible difference and even repugnance, chimeras exemplify a new order of microscopic visibility and social invisibility. They are micromonsters.[34]

Chapters 2 and 3 shift the empirical focus from spontaneous chimeras to fetal cells in pregnant women, and to microchimerism. In chapter 2, I tell the story of a would-be prenatal screening technique that aims to instrumentalize fetal cells in blood samples from pregnant women. In the course of its almost 40-year history, the technique has had numerous iterations, each of which has relied on visualizing the Y chromosome as a "proof of concept," and each of which has been plagued with false positives and false negatives. Instrumental communities have grown and adapted around the rule of binary sex, which relies on an absolute identity between "male" cells and "male" bodies. Implicitly, they rely on an

[34] Georges Canguilhem introduces this term, to refer to an "error" in the genetic code, such as a hereditary biochemical condition. See Georges Canguilhem, *The Normal and the Pathological*, trans. Carolyn R. Fawcett (New York: Zone Books, 1991), 278.

absence of visible markers to exclude female bodies. Exceptions – such as chimeras, cells from previous pregnancies and intersex conditions – are raised as possibilities by investigators only when they explain away "false" results in an isolated experimental instance, but they never prompt scientists to question the rule that undergirds the enterprise. This refusal to acknowledge categorical fluidity, I suggest, may contribute to the failure of the technique to bridge the gap from experimental promise to clinical certainty.

Chapter 3 traces a community of researchers and a phenomenon that were offshoots of the effort to use fetal cells for prenatal screening. During a fetal cell study in the mid-1990s, one laboratory found Y-bearing cells in many of their non-pregnant controls. These women had previously delivered sons; one had given birth as long ago as 27 years before. Thus, it seemed fairly common that fetal cells outlive pregnancy, a phenomenon which researchers called "microchimerism," or "fetal cell trafficking." These cells almost immediately became characterized by a consistent package of metaphors having to do with international migration. They trafficked, migrated and repopulated organs. These vagabond cells were immediately suspected as a cause of autoimmune diseases in women, a theoretical trajectory which I argue was bound up in the geopolitical metaphors permeating the field, and the relations of self and other they presuppose.

Each of these chapters is a story unto itself, but they fit together because of the continuity of techniques and of researchers, and through the attribution of greater and lesser degrees of cellular multiplicity. In each,

at least two kinds of cells were made visible, salient and distinct from each other in the laboratory, and they were inscribed with an identity that normally applies to whole persons (male, immigrant, brother, mother, child). This difference was then read back into and onto whole bodies.

Chapter 4 uses contemporary interview excerpts and media moments to foreground this synecdoche through which part and whole become interchangeable. Both scientists and members of the public speak and write about chimeras and microchimerism as though something of the self is bound up in cells. After exploring the contexts in which references to identity surface in contemporary discussions of chimerism, I turn to literature about organ transplantation and multiple personality disorder. Both of these cases are analogous to chimerism in that patients' identities are multiplied in clinical contexts.

CHAPTER 1:

GODS AND MICROMONSTERS: A GENEALOGY OF CHIMERAS MADE AND FOUND

Introduction

Phyllis Moores, a blood group specialist working in South Africa, delivered a paper at the Blood Transfusion Congress in Port Elizabeth in 1967. By the tone of her introduction, we get the impression that she was more animated about her findings than the average serologist at the conference:

> It is with considerable excitement that I find myself in the privileged position today to bring you a report on the discovery of a new blood group chimera, here in South Africa. She is an Asiatic woman – a Tamil of good caste, and is of the Hindu religion. Her appearance physically, is completely normal; her age is approximately 27 years, and she is in full health having borne three and now four perfectly normal children. The word "Chimera" is borrowed from Greek mythology. It was used to describe a creature with the head of a lion, the body of a goat and the tail of a serpent, which spent its days terrorizing the populace. That such a conglomeration of different species had any chance of living as a single unit, we know nowadays, would be quite impossible, for the components are of vastly different origins, and the anatomical, genetical and immunohaematological difficulties would have been immense. Clearly then, the discovery of a natural chimera, would be an event of the utmost potential interest, and very rare. The first report of a <u>human</u> chimera occurred in 1953. Dunsford and his associates made the remarkable find of a woman with not only one, but two blood groups…. We discovered <u>our</u> chimera during the course of routine antenatal tests at the Natal Blood Transfusion Service towards the end of 1965.[1]

[1] Phyllis Moores, n.d. (approximately 1967), F20/6/3, SA/BGU, The Wellcome Library, London [underlining in original].

Moores' introduction is fairly typical of the genre (although her emphasis on race and religion may express a uniquely South African flair). When medical scientists speak or write about chimeras, they inevitably couple the human subject with the mythological Chimaera.[2] Not only is the reference to the creature purposefully embedded in the nomenclature, it is, as we see above, a blatant feature of professional discourse in the community of researchers. One researcher told me: "We refer to the mythical 'chimera' in almost every talk, especially those where we either are providing an overview of the field or if we are presenting our research to an audience that is not familiar with the field."[3]

In this chapter, I use archival and published materials, as well as interviews with contemporary practitioners, to interrogate this association between, on the one hand, a healthy human with multiple populations of genetically different cells, and, on the other hand, a monster composed of lion, goat and serpent parts. The analysis proceeds in two parts. The first part of the chapter is an etymological chain tracing the word "chimera" from its mythological roots to its first use in a botanical text in 1907 to present-day references. Following Michel Foucault, my method is genealogical.[4] As Foucault writes, "[g]enealogy is gray, meticulous, and

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[2] While they are often used interchangeably, for the sake of consistency, I will use 'chimera' to refer to biological instances, and 'Chimaera' for the mythological monster. Where I am quoting text, I will maintain the spelling that the source uses.

[3] AG email communication, November 7, 2005. The initials of interviewees have been anonymized, however each speaker will be consistently initialed throughout.

[4] For an elaboration of this methodology, see Michel Foucault, "Nietzsche, Genealogy, History," in *Language, Counter-Memory,*

patiently documentary. It operates on a field of entangled and confused parchments, on documents that have been scratched over and recopied many times."[5] The purpose of such a careful reconstruction, he claims, is to eschew the search for origins, or for teleology, and to recover "the vicissitudes of history."[6] Genealogical projects inherently question the inevitability of things as we know them, and in so doing, they uncover the political moves made to secure things (such as "liberty" or "the body"). Behind things, the genealogist finds "not a timeless and essential secret, but the secret that they have no essence or that their essence was fabricated in a piecemeal fashion from alien forms."[7]

My purpose in carefully reconstructing the chain by which human genetic chimeras have acquired their name is to reveal the intentions, accidents, missteps and controversies inherent in the historical practices of this naming. There is nothing inevitable about the outcome. While it may appear that human genetic chimeras are *in essence* like the mythological Chimaera, this appearance is an historical achievement. Using archival evidence, I will establish that each time the term was appropriated by biologists or medical scientists, they intentionally evoked the connection between the monster and the organism (be it animal, plant or human). This reiteration, I suggest, has epistemological significance: what we know about chimeras and the way we know about them has always been colored by their aura of monstrosity.

Practice: Selected Essays and Interviews, edited by D. F. Bouchard (Ithaca: Cornell University Press, 1977).
[5] Ibid., 139.
[6] Ibid., 144.
[7] Ibid., 142.

However "monster" is a daunting and unwieldy category, which requires some specification. While any strict taxonomy would be an oversimplification, we could imagine subcategories of monsters such as fictitious (e.g., Frankenstein, Cookie Monster), apocryphal (e.g., Loch Ness), violent (e.g., serial murderers) and anatomical (e.g., two-headed calf). Overlaps and slippages abound, of course, particularly between morphological and moral transgressors. For example, the Greek Chimaera could conceivably fit in all of the above categories, as could Frankenstein. Because my concern is primarily about the interplay of biomedical knowledge and monstrosity, the history of anatomical monsters, specifically, will inform my analysis of human biological chimeras and the anxieties they inspire.

Later in the chapter, I will show how the mythological Chimaera is invoked in contemporary clinical medicine. Judging from where it is invoked – and where it is not – *I suggest that the analogy between the Chimaera and the chimera works precisely because medical scientists consistently locate human genetic chimeras within the realm of the anatomically monstrous*. Anatomical monsters have a specific history in Enlightenment embryology and anatomy, where they were classified, displayed and dissected as foils for nature's regularity. While the contours of the objectifying display have changed in the twentieth century, many of the basic features persist in the medical handling of these morphological rarities. I will conclude the chapter with the proposal that human chimeras are an example of twentieth century anatomical monsters, which both share and diverge from some characteristics of their predecessors.

Why study monsters?

Scholarly analyses of the monstrous seem inevitably to agree that monsters aren't epistemologically neutral. In a footnote to her article, *The Promises of Monsters*, Donna Haraway urges us to "remember that *monsters* have the same root as *to demonstrate*; monsters signify."[8] In science and technology studies in the early 1990's, monsters were adopted as signifiers of optimistic heterogeneity, hybridity and resistance to classificatory or purifying domination. Complementing Haraway's "Promises of Monsters"[9] were Bruno Latour's "proliferation of hybrids,"[10] and John Law's edited volume, "A Sociology of Monsters."[11] In Law's account everybody is a monster, and we should embrace our monstrosity:

> We will come to appreciate that we are all monsters, outrageous and heterogeneous collages … and how it is that we might work towards a form of modest, multivocal organization where all could be reborn as hopeful monsters – as places where the necessary incompatibilities, inconsistencies and overlaps come gently and creatively together.[12]

These hopeful pronouncements identified and attempted to rescue a prevalent (and heretofore negative) characterization of monsters: the mixing together of unlike elements.

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[8] Donna Haraway, "The Promises of Monsters: A Regenerative Politics for Inappropriate/d Others" in *Cultural Studies*, eds. Lawrence Grossberg, Cary Nelson and Paula A. Treichler (New York: Routledge, 1992), 333.

[9] Ibid.

[10] Bruno Latour, *We have Never been Modern* (Cambridge, Mass.: Harvard University Press, 1993), 157.

[11] John Law, *A Sociology of Monsters: Essays on Power, Technology, and Domination* (London; New York: Routledge, 1991).

[12] Ibid, 18-19.

In medical discourse about human chimeras, the main characteristic that renders them fascinating is not any kind of visible repugnance or physical threat, but their tendency to violate clear boundaries. It is their embodiment of self and other, of male and female, that puts them in the same class as the lion/goat/serpent hybrid, and which seems to inspire some degree of cultural anxiety about the violation of natural and social order.

In *Purity and Danger*, Mary Douglas draws our attention to common cultural taboos that proscribe mixing. For example, "hybrids and other confusions are abominated. … Holiness requires that different classes of things shall not be confused."[13] During this discussion, Douglas cites the following passage from Leviticus: "You shall not let your cattle breed with a different kind; you shall not sow your field with two kinds of seed; nor shall there come upon you a garment of cloth made of two kinds of stuff."[14] Using slightly different language than Leviticus, mixtures or hybrids are often accused of being "unnatural", whereas wholeness or purity is considered more natural. For example, Curt Stern, a geneticist, wrote that chimeras are "seemingly created 'against Nature.'"[15] Geoffrey Bowker and Susan Leigh Star observe that "a monster occurs when an object refuses to be naturalized."[16] Bowker and Star would argue, and I

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[13] Mary Douglas, *Purity and Danger: An Analysis of Concept of Pollution and Taboo* (New York: Routledge, 2002), 66-67.
[14] Leviticus XVIII, from Ibid., 66.
[15] Curt Stern, *Genetic Mosaics and Other Essays* (Cambridge, Mass: Harvard University Press, 1968), 28.
[16] Geoffrey C. Bowker and Susan Leigh Star, *Sorting Things Out*, 304.

concur, that monstrosity is not inherent or essential in the monster (or the chimera) but in its inability to fit into cultural categories. "Monsters and freaks are also ways of speaking about the constraints of the classifying and (often) dichotomizing imagination."[17] Hence, monsters are made – in the sociological sense - by community assent, by collective imagination, by culture-bound regulation of the norms and margins of being.

PART 1: A Genealogy of Chimeras

In this part of the chapter, we will see an intriguing inversion of the usual order of things, wherein art represents nature. This reversal can be nicely summed up by Oscar Wilde's aphorism "Nature imitates Art."[18] Chimaeras first existed in fantastical tales and artistic depictions. The word was then given material existence when Hans Winkler chose it to name the mixed-species plant he created; he selected it precisely because such a thing did not exist in nature.[19] Andrezej Tarkowski, who created the first mouse-mouse chimeras, later wrote that the very creation of artificial chimeras was a "bow and a tribute" to mythology:

> Creating embryos and occasionally even animals composed of cells derived from two different species is in a way a bow and a tribute paid by experimental embryology to ancient mythology which created monsters of dual, triple or even multiple origin, without paying much attention to the taxonomic relationship between the "contributing" species.[20]

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[17] Ibid., 304.

[18] Oscar Wilde, *The Decay of Lying* (New York: Syrens, 1995), 64.

[19] Hans Winkler, "_ber Pfropfbastarde Und Pflanzliche Chim_ren," *Ber. Dtsch. Bot. Ges.* 25 (1907), 568-576.

[20] A. K. Tarkowski, "Mouse Chimaeras Revisited: Recollections and Reflections," *The International Journal of Developmental Biology* 42, no. 7 (1998), 904-905.

Eventually the term was appropriated in the 1950's for genetically mixed organisms "found in nature," however unnatural their constitution was thought to be. First fraternal twin cows, and then humans, were found to contain blood cells from their fraternal twins. In the 1960's, the term was used to describe humans found to contain two genetically different cell populations in every tissue, not just blood. Several researchers have called chimeric animals and humans "Nature's experiments," suggesting a purposeful creation by Nature that mimics the artifice of the human experimenter.[21] In the latter part of the twentieth century, the term chimera has been applied to sub-organismic entities, such as proteins and DNA strands, where molecules from different origins are spliced together, either experimentally or accidentally.

In the early twenty-first century, a biological chimera can refer to many things; when the name was appropriated to name a newly created or discovered entity, the entities from which it was borrowed continued to exist. These overlapping meanings are confusing, but it is their very relationship that I wish to trace in this chapter, so I cannot begin with a simple definition. In an attempt to ease the reader's potential confusion, therefore, I have created a loose typology of what the word has been *used for* in biology (table 1).

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[21] I. Dunsford and others, "A Human Blood-Group Chimera," *British Medical Journal* 2, no. 4827 (Jul 11, 1953), 80-81; Patricia Tippett, "Blood Group Chimeras. A Review," *Vox Sanguinis* 44, no. 6 (1983), 333-359.

Table 1: A Chimera Typology

Kind	Interspecies/ same species	Found/ Made	Combinations	Sample Citations
Chimaera of Myth	Interspecies	"Found"	Lion/Goat/Serpent	Homer 720 B.C.
Plant	Interspecies	Made	Tomato/Nightshade	Winkler 1907
Animal	Interspecies	Made	Newt/Fish Mouse/Rat Goat/Sheep "geep"	Spemann 1921 Stern 1973 Fehilly et al., 1984
Animal	Same species	Found	Cow twins	Owen 1945 Anderson et al., 1951
Human	Same species	Found	I "Blood Group Chimeras" Mrs. McK W twins (later considered "microchimerism")	Dunsford et al., 1953 Booth et al., 1957
			II Human singleton (also called "dispermy," "tetragametic chimera")	Gartler et al., 1962 Yu et al., 2002
			III Human microchimerism Transplant Maternal/fetal	Starzl 1992 Bianchi 1996
Animal	Same species	Made	Mouse/mouse	Tarkowski 1961 Mintz 1962
Molecular Compound Animal Human Plant	Interspecies Or Same Species	Made	Virus /Mouse DNA Jellyfish/Rabbit protein "GFP bunny" YAC artifacts (accidental biproducts) Human chimeric proteins (spliced gene products)	Chu 1981 Kac 2001 Green 1991 Hansen et al., 1998
Human	Same species	Made	Human/human	Gleicher 2004

The most salient division, in my view, is that between organisms that have been "made" by experimental scientists, and those that have been "found" by medical personnel, including clinicians and investigators in clinical labs. Another relevant distinction is that between interspecies combinations of genetic material, and combinations from the same species. Giving each kind of organism the same name purposefully blurs the distinctions between made and found, and between interspecies and same species mixes.

The Chimaera in Myth, Literature and Art

Homer's *Iliad*, the earliest known literary mention of the Chimaera, described her as "a creature none could conquer, born of gods, not of men: she was a lion in front, a snake behind, and a goat in the middle, and her fearful breath was a blast of blazing fire."[22] Hesiod, from around the same era (9th or 8th Century B.C.), tells the same story, elaborating only that the creature had three heads. [23] In Homer, as in many subsequent references, the Chimaera is a singular beast rather than a race (such as the satyrs). The monster has a remarkably stable personage over the almost

[22] Homer, *The Iliad*, trans. Martin Hammond (New York: Penguin Books, 1987), 95.

[23] In most cases, I was directed to the Chimaera references in this section by two unlikely sources, an Italian chemist and a Greek dentist. Ugo Bardi, a chemistry professor in Florence, maintains an excellent website about the Chimaera in mythology and art, at: Ugo Bardi, "The Page of the Ancient Chimera - Or Chimaera - Myth," http://www.unifi.it/unifi/surfchem/solid/bardi/chimera/ (accessed 11/20, 2005). The other source is a review by Greek dentist: E. Bazopoulou-Kyrkanidou, "Chimeric Creatures in Greek Mythology and Reflections in Science," *American Journal of Medical Genetics* 100, no. 1 (Apr 15, 2001), 66-80.

thirty centuries passed in retelling the story: she is inevitably figured as fire-breathing, most often female (originally owing to the ancient Greek literal translation of χιμαιρα as "young she-goat"), and she is always a combination of lion, goat and serpent. In Homeric legend, she was the offspring of the gods Typhon (a giant) and Echidna (half-serpent, half-woman), and was a sibling of Cerberus (the hound of Hell), Hydra (the nine-headed water snake) and Orthrus (another multi-headed dog). The Chimaera terrorized Lycia, and she was much feared.

Paraphrased from *The Iliad* (6, §151-191), the highlights of the story are as follows: Bellerophon, whom the gods granted "beauty and all that is lovely in manhood,"[24] made Anteia, the wife of the king of Ephyre, angry by refusing to lie with her. She told her husband, Proitos, quite the opposite, and he, unwilling to kill the lovely Bellerophon himself, sent him off to Lycia with a message to the king there to see that Bellerophon meets his demise. (Apparently Bellerophon couldn't read, or he was too polite to open someone else's mail). In response to the request, the Lycian king told Bellerophon to kill the Chimaera, a task that would doom him to sure death. In what is allegedly one of the oldest hero-kills-dragon stories, Bellerophon, riding the famed steed Pegasus, did in fact kill the Chimaera, with some help from the gods. After Bellerophon avoided a few more "cunning snares" meant to kill the hero, the king of Lycia threw up his hands and offered Bellerophon his daughter in marriage.

[24] Homer, *The Iliad,* 95.

In the ancient world, the Chimaera was sustained in artistic representations. The monster is depicted on many plates, cups and other pottery from antiquity. The most popular visual representation, at least among geneticists, is the Chimaera of Arezzo (figure 2), a bronze statue of about 80 cm, unearthed near the city gates of Arezzo, Italy in 1553.[25] The statue was of Etruscan origin, created by an anonymous sculptor around the 5th century B.C. Once rediscovered, the statue was taken from Arezzo by the Grand Duke of Tuscany, Cosimo I, to his palace in Florence. It is now a prized piece at the National Archaeological Museum in Florence, where it sits near the entrance in a room of its own. It has become an icon for researchers who explore genetic chimerism and microchimerism.

Figure 2: Replica of the Chimaera of Arezzo[26]

[25] These details are from Bardi, *The Page of the Ancient Chimera.*
[26] This photograph is of a replica, courtesy of Galleria Frilli, Firenze. The original Chimaera of Arezzo is at Museo Archeologico Nazionale di Firenze, Etruscan, ca 5th-4th Century B.C.

The Chimaera is mentioned in a number of ancient and classical texts by, for example, Euripedes, Aristotle, Plutarch and Galen,[27] Plato, Lucretius and Virgil.[28] In the middle ages, the Chimaera was adopted as a portent of the evils of women. In the *Malleus Maleficarum*, the enormously popular "guidebook" for inquisition of witches, Heinrich Kramer and James Sprenger wrote:

> Hear what Valerius said to Rufinus: You do not know that woman is the Chimaera, but it is good that you should know it; for that monster was of three forms; its face was that of a radiant and noble lion, it had the filthy belly of a goat, and it was armed with the virulent tail of a viper. And he means that a woman is beautiful to look upon, contaminating to the touch, and deadly to keep.[29]

Feminization of the monster implied and adopted a misogynist tone in its early literary history. I am reluctant to make strong claims about the association between women, the Chimaera, and the medical phenomena because explicit connections in the historical record are rare. Nonetheless we will see that anxieties about sexuality and fertility become an important part of the medical context of chimeras and microchimerism, and this association may subtly reach back to the *Malleus* which, in addition to being relentlessly misogynist, fixated on sexuality and reproduction.

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[27] According to Bazopoulou-Kyrkanidou, "Chimeric Creatures".
[28] According to Bardi, *The Page of the Ancient Chimera*.
[29] Heinrich Kramer and Jakob Sprenger, "Part I, Question VI" in *Malleus Maleficarum*, ed. Montague Summers, unabridged online republication, Windhaven Network, 1928 [1486]), http://www.malleusmaleficarum.org/.

Modern literary references to the Chimaera include popular texts such as *Bullfinch's Mythology*[30] and Nathanial Hawthorne's *A Wonder-Book for Girls and Boys*.[31] Both were published in the 1850's, and both recounted the tale told by Homer of the hero Bellerophon and the fire-breathing monster. Hawthorne's story makes the creature sound ghastly indeed:

> According to the best accounts which I have been able to obtain, this Chimæra was nearly, if not quite, the ugliest and most poisonous creature, and the strangest and unaccountablest, and the hardest to fight with, and the most difficult to run away from, that ever came out of the earth's inside. It had a tail like a boa-constrictor; its body was like I do not care what; and it had three separate heads, one of which was a lion's, the second a goat's, and the third an abominably great snake's. And a hot blast of fire came flaming out of each of its three mouths! Being an earthly monster, I doubt whether it had any wings; but, wings or no, it ran like a goat and a lion, and wriggled along like a serpent, and thus contrived to make about as much speed as all the three together.[32]

Hawthorne takes great license in elaborating Homer's brief tale of Bellerophon and the Chimaera and describes the grueling battle in detail. The Chimaera story was picked up from Hawthorne and reprinted in another popular children's book, *Myths Every Child Should Know: A Selection Of The Classic Myths Of All Times For Young People,* around the turn of the 20th Century.[33] W.H. Auden makes an allusive reference to

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[30] Thomas Bulfinch, *The Age of Fable, Or, Beauties of Mythology* (Boston: S.W. Tilton, 1855), 488.
[31] Nathaniel Hawthorne, *A Wonder-Book for Girls and Boys* (Boston: DeWolfe Fiske, 1852).
[32] Ibid.
[33] Hamilton Wright Mabie and Mary Hamilton Frye, *Myths Every Child should Know* (Garden City, N.Y.: Doubleday, Page & company, 1911), 6.

the monster in his poem "The Chimeras." Absence of heart, mind and worth, he writes, "Are telltale signs that a chimera has just dined/ On someone else; of him, poor foolish fellow/ Not a scrap is left, not even his name."[34]

Given its persistence in popular literature and iconography, the mythological Chimaera – along with its interspecies kin the Centaurs, Cerberus, the Griffin and others – have maintained a life in the popular imagination up to and including the 20th Century. In the next section, I turn to a genealogy of the word and meaning of "chimera" as a technical term in botany, zoology and clinical medicine.

Chimeras in Biology and Medicine

For the most part, the following account is ordered chronologically. However in order to highlight some important genealogical departures, I will divide the story into chimeras that are "made" in the laboratory and those that are "found" in nature. The term was first used for plants, and then taken up by animal embryologists, to mean experimentally created organisms of more than one species (e.g. mouse/rat; chick/quail). The experimental tradition of making chimeras, mostly as tools for developmental biologists, continues to the present. However, the genealogy will branch off in the early 1950's, where we see a new kind of usage of the term. First cows, and then humans, were "found" that contained more than one genetically distinct cell population, the second population being derived from a twin. It is this departure in which I am

[34] W. H. Auden, *Collected Shorter Poems, 1927-1957* (London: Faber, 1966), 311.

most interested, as I will argue that it fits within a pre-established tradition of medical fascination with anatomical monsters.

Chimeras: Made

Hans Winkler, a German botanist in the early 20th century, was the first scientist to appropriate the term "chimaera" to emphasize dissimilar genetic constitution, the meaning in which I am most interested.[35] Winkler experimentally produced a plant that was, on one side, a tomato plant and on the other side, a nightshade. The name he chose explicitly recalled the Greek monster:

> To my knowledge *there is nothing in nature* that is analogous to our plant, i.e. there is no organism which consists to one half of one species and to the other half of another species ... such that the only remaining analogies were mythical creatures such as the Centaurs, which were half man, half horse, or the Chimaera, which was [in the forepart a lion, the hindpart a dragon, and in the middle a she-

[35] The first use of chimaera in biology seems to have been its appropriation to describe a fish species, *Chimaera monstrosa*, the origin of which the Oxford English Dictionary dates to 1804. See "Chimera, Chim_ra" in *Oxford English Dictionary*, Online Edition ed. (Oxford: Oxford University Press, 2006), http://dictionary.oed.com (accessed March 11, 2006)]. This shark-like class of fish has maintained the name, although its common names include "ratfish", "rabbitfish" and "catfish". Importantly, for my linguistic genealogy, this use seems to refer to the strange appearance of the fish, rather than to an implication of any fundamental dissimilarity beneath the scales of the fish. In other words, the name was descriptive of the exterior morphology, rather than the interior anatomy of the fish. In this sense, the term represents a linguistic cul-de-sac, and is not a link in the etymological chain of human genetic chimeras.

> goat].[36] In order to have a short unambiguous name for the category of completely new kinds of organisms which have appeared with our plant, I have therefore taken the liberty to call them plant chimaeras...[37]

Note that Winkler experimentally created his plant mixture, and he argues that a new name is needed specifically because such an amalgamation does not exist in nature. Also, the analogy to mythical creatures is meant to capture species difference. Finally, one could suppose that what brought the analogy to Winkler's mind was the jarring difference in appearance between the two halves of his plant. We will see that by the time the term is in use to refer to humans – found "in nature," whose parts are of the same species, and whose difference is invisible from the outside – it has taken on quite a different meaning than Winkler intended. Ironically, Winkler also chose the word for its lack of ambiguity.

At least one botanist, W. Neilson-Jones lamented the generalization of the term's usage, and complained:

> Zoologists still use *Chimaera* in its original technical sense of the name of a group of fishes; chimera, on the other hand, is no longer confined by all biologists to plants having the kind of unlike, allied tissues to which Winkler originally bestowed the name. The term is now often applied, unfortunately and wrongly in my opinion, to

[36] In the original German text, this portion was in ancient Greek symbols; translated at http://www.translatum.gr/.
[37] Hans Winkler, "_ber Pfropfbastarde Und Pflanzliche Chim_ren." [italics mine]. Thanks to Anna Maerker for the translation from German.

> any kind of tissue, plant or animal, that is not genetically homogenous.[38]

While Neilson-Jones seems to wish for a narrowly restricted technical use of the word, he also takes some liberties with its metaphorical connotations, as he describes such plants as "having what might be called a multiple personality,"[39] and he suggests that "a grafting operation was responsible for the introduction of the word chimera into botanical terminology."[40] Neilson-Jones begins and ends his book-length treatment of these grafted plants by airing his pet peeve about nomenclature. In the end, he grudgingly concedes that "it would be unrealistic to expect that the use of a term should be restricted to its legitimate application once its inappropriate use has gained wide publicity. Yet I feel some expression of regret that this is so."[41]

For better or worse, the name did escape botany, however initially it retained the connotations of an interspecies mixture created experimentally in the laboratory. The first reference to an animal chimera I have been able to locate is in a German article by Hans Spemann, published in 1921, whose title translates as: "The production of animal chimaera by heteroplastic embryonal transplantation between triton

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[38] W. Neilson-Jones, *Plant Chimeras*, 2nd ed. (London: Methuen & Co. Ltd., 1969), 1.
[39] Ibid., 2.
[40] Ibid.
[41] Ibid., 112.

cristatus and taeniatus."[42] Spemann was a renowned experimental embryologist, and in this paper he describes the amalgamation of newt and fish embryos. Spemann cites Winkler, whose creation and naming of plant chimeras is, Spemann suggests, "well-known." Moreover, Spemann elaborates on the comparison between Winkler's plants and his own animal embryos. This comparison is taken up as well by C.H. Waddington in his textbook, *An Introduction to Modern Genetics* (1939), in which he refers to "studies on 'germ-layer chimaera,' which are obtained by adding presumptive mesoderm cells of one species to the blastula of another."[43] Making the jump from animals to plants explicit, Waddington writes that "these correspond among animals to periclinal chimaeras among plants."[44] Their similitude was, as I have pointed out, a result of being both interspecies and man-made.

In the 1950's, the word took on a new use, and this branch of its genealogy will take us to the human chimeras of clinical medicine. However, in the meantime the experimental production of chimeric organisms has persisted. Particularly in the 1970's and the 1980's, a subgroup of developmental biologists working with mice, rats, chicks and quail, among other creatures, created chimeric animals in order to visualize developmental processes. Anne McLaren, a central researcher in this field who still heads a lab in Cambridge and still produces mouse

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[42] Hans Spemann, "Die Erzeugung Tierischer Chimaren Durch Heteroplastiche Embryonale Transplantation Zwischen Triton Cristatus Und Taeniatus," *Archiv Fur Entwicklungsmechanik* 48 (1921), 533-570.
[43] C. H. Waddington, *An Introduction to Modern Genetics* (London: George Allen & Unwin Ltd., 1939), 147.
[44] Ibid.

chimeras, describes the remarkably simple process of making chimeras: "You take two embryos at the eight cell stages, which in mice is two days after fertilization … you remove, with an enzyme the outer [membrane] called zona pellucida - and you push the two egg cells together." In 1984, researchers made a "geep" by amalgamating goat and sheep embryos.[45] The result – not to be confused with a goat/sheep hybrid which would result from mating – had patches of goat tissue, and patches of sheep tissue (figure 3). The analogy to the mythical Chimaera appears frequently in discourse about such interspecies mixes.

Figure 3: A geep (photo: Gary Anderson, UC Davis)

[45] C. B. Fehilly, S. M. Willadsen and E. M. Tucker, "Interspecific Chimaerism between Sheep and Goat," *Nature* 307, no. 5952 (Feb 16-22, 1984), 634-636.

Continuing in the vein of man-made chimeras, the word has been adopted in recombinant genetics to mean two strands of DNA or amino acids that have been artificially spliced together (they can either be from different species or the same species). This usage, which I will not trace in detail, began in the mid-1970's and has become by far the most common usage in contemporary biology. In these cases, the word chimera will usually be preceded by a molecular descriptor such as protein or plasmid. Interestingly, neither imagery of the mythical Chimaera, nor an explicit reference to the etymology of the scientific term is a prominent feature in discourse about molecular chimeras, a point to which I will return later.

Chimeras: Found

In what was to become a classic paper in immunology, and a touchstone in the establishment of chimerism found in nature, D. Anderson, R. E. Billingham, G.H. Lampkin and Peter Medawar slightly altered the meaning of chimera and did some definitional work to fix its meaning.[46] Their experiments with cattle twins touched on a trajectory of research initiated by Frank Lillie's work, in 1916, which elaborated the "freemartin" effect.[47] Often, when twin cows are born, one twin, the freemartin, will have female external genitalia and some degree of masculinization of internal gonads. That this cow was infertile was long known to cattle breeders. Lillie undertook substantial explorations of

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[46] D. Anderson and others, "Use of Skin Grafting to Distinguish between Monozygotic and Dizygotic Twins in Cattle," *Heredity* 5 (1951), 379-397.
[47] F. R. Lillie, "The Theory of the Free-Martin," *Science* 43 (1916), 611-613; see also B. Capel and D. Coveney, "Frank Lillie's Freemartin: Illuminating the Pathway to 21st Century Reproductive Endocrinology," *J Exp Zoolog A Comp Exp Biol* 301, no. 11 (Nov 1, 2004), 853-856.

cattle embryology and hypothesized, first, that the freemartin was genetically female and second, that the female twin is exposed to male hormones because the twins' blood supplies have become linked during gestation. In 1945, Ray Owen, at the University of Wisconsin, used blood typing to confirm that fraternal twin cows exchange cells *in utero* by way of anastomoses, or interconnected blood vessels. Without naming them anything other than twin cows, Owen concludes:

> These cells are apparently capable of becoming established in the hematopoietic tissues of their co-twin hosts and continuing to provide a source of blood cells distinct from those of the host, presumably throughout his life.[48]

Owen foreshadows a common theme in subsequent reports of animal and human chimeras by describing the phenomenon as "nature's experiment," differentiating it from scientists' experiments while reinforcing the analogy. Indeed this theme recurs in the literature about "spontaneous" chimeras: they are found in nature, though they are "unnatural."

Owen's work would become important when, five years later, Sir Peter Medawar and colleagues made another peculiar discovery about cow twins. In his autobiography, Medawar explains the circumstances leading to the experiment reported in Anderson et al's classic article "Use of skin grafting to distinguish between monozygotic and dizygotic twins in cattle." At a meeting of the International Congress of Genetics in Stockholm, Medawar met Hugh Donald, who was comparing identical

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[48] Ray D. Owen, "Immunogenetic Consequences of Vascular Anastomoses between Bovine Twins," *Science* 102, no. 2651 (1945), 400.

(monozygotic) and fraternal (dizygotic) twin cattle to shed light on the question of inborn versus acquired character differences. But his entire enterprise depended on the correct classification of cow twins into identical or fraternal, which is apparently tricky. Medawar reports his response to Donald's problem:

> 'My dear fellow,' I said in the rather spacious and expansive way that one is tempted to adopt at international congresses, 'in principle the solution is easy: just exchange skin grafts between the twins and see how long they last. If they last indefinitely you can be sure these are identical twins, but if they are thrown off after a week or two you can classify them with equal certainty as fraternal twins.'[49]

Medawar "somewhat injudiciously" offered to demonstrate the technique of skin grafting. A few months later, when his offer was called in by Donald, Medawar traveled north to Birmingham to undertake the intensive task of removing patches of skin from cows and sewing them on to other cows. Much to the team's surprise, all the skin grafts lasted, even in fraternal twins, in which the grafts "should" be rejected by the host cow's immune system because they are no more genetically related than siblings. Medawar and company were stumped that fraternal twins in cattle respond differently than any other animal in which they had exchanged skin grafts, including humans.[50]

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[49] P. B. Medawar, *Memoir of a Thinking Radish: An Autobiography* (Oxford ; New York: Oxford University Press, 1986), 111.

[50] Incidentally, Medawar tells another story about using the (rather invasive!) skin-grafting method to prove that two little French boys had been switched at birth. P. B. Medawar, *The Uniqueness of the Individual* (London: Methuen, 1957), 146-148.

At this point, they encountered Owen's work, which provided an explanation for the anomalous finding. Dizygotic cattle twins were able to tolerate skin grafts from their twin precisely because they had been exposed to, and indeed contain, cells from their twin. They were immunologically desensitized to their twin during embryonic development. In their publication, Anderson et al. (Medawar's team) explained that "the dizygotic twin calf at birth is already, in fact, a genetical chimæra."[51] At the end of this sentence, they placed an asterix which leads to the following passage at the bottom of the page:

> In the current embryological (which is also the classical) sense, a "chimaera" is an organism whose cells derive from two or more distinct zygote lineages, and this is the sense in which the term "genetical chimaera" is here intended to convey. "Genetical mosaic" is less suitable, because a mosaic is formed of the cells of a single zygote lineage. In a sense, the dizygotic cattle twin is what the botanist would call a "graft hybrid."[52]

This passage is often quoted verbatim in subsequent publications, and thus it is a crucial moment in the definitional life of the word. Of note here is that we are meant to assume that the classical (i.e. Greek) sense of the term refers to the "cells" and "zygote lineages" of the lion, goat and serpent despite the impossibility of thinking in these terms before the 20th century. Second, we are to accept the premise that it was the different embryological origins of animal parts that mattered in principle, not that they were of different species and featured visibly incongruous parts. By

[51] Anderson and others, *Use of Skin Grafting*, 395.
[52] Ibid.

virtue of this passage, Anderson et al.'s twin cows, which came from the same species and indeed the same uterus were the *same kind of creature* as the lion-goat-serpent, the tomato-nightshade and the fish-newt because in each case the parts derived from different zygotes had amalgamated into one organism. Where experimental agency of the scientist was very much a part of the early trajectory, the agency of the creator is irrelevant or implicit in the new meaning of the word. While theistic notions of a Creator are not found in the secular story of human chimeras (with one exception, described later), "Nature" is often credited for its experiment in the making of chimeras. The naming of human chimeras picks up where the cow story left off, and it continues the linguistic slippage from made to found.

The story of naming human chimeras has not, to my knowledge, been told in one place before, so I will elaborate in some detail on the subtleties here. My main archival source is the MRC Blood Group archive, held by the Wellcome Library for the History and Understanding of Medicine in London. The MRC Blood Group Unit was founded in 1946, with Robert Race as its director. Race was a blood group serologist who had, before and during the war, done important work on the ABO blood groups in humans, and he had been instrumental in the discovery of the Rh factor, an antigen in some people's blood and not others. Ruth Sanger was hired as Race's assistant when the new Unit opened, and she later became his collaborator, his wife and his successor as director of the Unit when he retired in 1973. According Race's biographer, "Rob and Ruth effected such a symbiosis that like a chimera each had something of the other and

in the fullness of time another biographer will have the same problem – to try and find out who did what."[53]

It seems that the main function of the Unit was as a research facility to work up cases that routine blood donor and transfusion clinics, for example, did not have the time, equipment or expertise to pursue. Moreover, following Race's early work on ABO and Rh systems, the MRC Unit continued to describe new antigens and groups that differ among individuals. The sources of samples coming to them were not limited to clinics throughout England. They "acted like a magnet, attracting problems from people all over the world."[54] And so it happened that in March of 1953, Dr. Ivor Dunsford sent a vial of Mrs. McK's blood to this puzzle-solving laboratory. He could not work out why one donor's

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[53] Cyril Clarke, "Robert Russell Race, 28 November1907-15 April 1984," *Biographical Memoirs of Fellows of the Royal Society* 31 (November, 1985), 482. As Clarke predicted, I found that it is difficult to tell which of the two, Race or Sanger, made which notes, did which lab work, and wrote which correspondence. The Blood Group files are intertwined, and often where I attribute authorship, it is based on my best guess due to handwriting or some other indicator. Several boxes of the archive are devoted to chimeras, and they contain files loosely organized into correspondence; laboratory records and miscellaneous notes made during lab meetings or telephone conversations; and draft articles and reprints. Earlier files (1950's and 1960's) tend to be organized by specific patients or cases – "Mrs. McK", "Colchester Chimera", "Wa twins" etc. Later files, from the 1970's, 80's and 90's, are more likely to be labeled "twin chimeras" or "dispermic chimeras" and they contain a variety of correspondence and notes about cases not necessarily worked up by the MRC lab. These cases were actively solicited by the MRC group for inclusion in Race & Sanger's serial editions of "Blood Groups in Man", the so-called "bible" for blood-groupers.

[54] Clarke, "Robert Russell Race," 482.

blood had both A and O types of blood, even though she claimed never to have received a transfusion, and accidental mixing was ruled out by repeating the blood draw.

Race, Sanger and colleagues were also able to separate the blood into O and A, and Race recalled having heard about the mixed-blood situation in cattle. At Race's suggestion, Dunsford asked his patient whether or not she was a twin. And, much to everyone's surprise, she said she had been a twin, though her brother died when they were three years old. Race's next question, following the cow model, was about Mrs. McK's fertility: "I suppose Mrs. McK is not obviously a freemartin – has she been pregnant I wonder?"[55] Dunsford replies: "I am told by Dr. Bowley that Mrs. McK is a 'femine [sic] female' with a sufficient quota of curves and bumps to attract and wed a spouse and bear him one child."[56] As I mentioned previously, sex, gender and fertility are common themes in correspondence between the (mostly male) doctors and investigators. Another colleague, Alan Drury, wrote in a note to Race: "I was interested to have the letter about your extraordinary case … I did not think that you would get on to a line that suggests that when a woman has twins she behaves so extraordinarily like a cow!"[57] This comment exemplifies the ways in which human chimerism was, from the start, embedded in discourses of gender, a point to which I will return.

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[55] Robert R. Race to Ivor Dunsford, March 27, 1953, F20/1 Part 1 of 2, SA/BGU, Wellcome Library, London.
[56] Ivor Dunsford to Robert R. Race, March 31, 1953, F20/1 Part 1 of 2, SA/BGU, The Wellcome Library, London.
[57] Alan Drury to Robert R. Race, April 8, 1953, F20/1 Part 1 of 2, SA/BGU, The Wellcome Library, London.

In order to verify his twin hypothesis, Race sent inquiries to colleagues, including Peter Medawar, and solicited more of Mrs. McK's blood, and some saliva, as well as both from her family members. "I will be disappointed," he wrote to Dunsford, "if other members of the family [have the abnormality]. The twin idea seems much more attractive."[58] Race also considered "dispermia," a condition which had been found in birds, in which two fertilized eggs result in only one, genetically mixed, individual. To rule this out, he suggested that Dunsford check if Mrs. McK is "more or less bilaterally symmetrical," by checking if her eye color, hair color, ear shape and fingerprints are the same on both sides[59] – which apparently they were. After a "triumphant day with… the wonderful samples,"[60] the Blood Group Unit had re-confirmed that there were two different types of blood. They also determined that the second type could not come from Mrs. McK's mother, a possibility which Race didn't seem to take seriously, but he wished to rule out because critics might. Finally, they used Mrs. McK's saliva to "fix her as genetically O," and therefore her brother's "truly begotten blood" as type A.[61]

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[58] Robert R. Race to Ivor Dunsford, April 19, 1953, F20/1 Part 1 of 2, SA/BGU, The Wellcome Library, London.
[59] Ibid.
[60] Robert R. Race to Ivor Dunsford, April 28, 1953, F20/1 Part 1 of 2, SA/BGU, The Wellcome Library, London.
[61] Robert R. Race to Alan Drury, May 3, 1953, F20/1 Part 1 of 2, SA/BGU, The Wellcome Library, London.

In a second letter to Medawar, Race wrote "Isn't it extraordinary to be able to group fully a person who has been dead for 30 years!"[62] Medawar makes this re-vivification of Mrs. McK's brother more explicit in an essay on "the Uniqueness of the Individual" which he wrote shortly after the investigation of Mrs. McK:

> There is no telling how long Mrs McK will remain a chimera, but she has now been so for twenty-eight years; probably, in the long run, her twin brother's red blood cells will slowly disappear, and so pay back the still outstanding balance of his mortality.[63]

This notion – that someone lives on in the cells that are "genetically theirs," though contained in another person – is a recurrent theme in accounts of chimerism and microchimerism, but it is rarely stated so poetically. This theme, that cells embody persons (rather than the other way around), is addressed more fully in chapter 4.

With regard to naming Mrs. McK a chimera, the record isn't entirely clear, or without controversy. The first time Race mentions the word in the files pertaining to Mrs. McK is on a handwritten page of laboratory notes dated April 27, 1953, which simply says "Chimaera? Transfused," and the word transfused seems to have been crossed out.[64] Race would, in 1957, recall: "I thought I (Dunsford Bowley et al.) had pinched the word chimera from the botanists, but quite recently, I saw that Medawar et al.

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[62] Robert R. Race to P. B. Medawar, April 29, 1953, F20/1 Part 1 of 2, SA/BGU, The Wellcome Library, London.
[63] Medawar, *The Uniqueness of the Individual*, 151-152.
[64] Robert R. Race, April 27, 1953, F20/1 Part 2 of 2, SA/BGU, The Wellcome Library, London.

had used it two years before, in the same context."[65] However, Medawar himself had, in a letter to Race dated April 23, 1953 (just days before Race's first written notation of the term), made reference to having reproduced the cattle situation in laboratory mice, which were thus "cattle-like genetical chimaeras."[66] Whether Race got the idea from Medawar's letter, or directly from the botanical references in the textbooks he mentions, is not necessarily important. I am more interested in the degree to which Race, when he named the first human chimera, was reflective or deliberate about the link to its mythological or monstrous meaning.

The publication reporting on Mrs. McK came out on July 11, 1953, and it was titled "A Human Blood Group Chimera" (hereafter, "Dunsford et al.").[67] No mention is made to the Greek Chimaera in the text, but Race did mention in a letter to Bowley during the drafting of the article that "the biggest reference to chimaera in the Ency. Britt. is to the sort of meaning we are wanting."[68] In the edition of the *Encyclopedia Britannica* closest in date to this letter, the "biggest" reference describes plant chimaeras, the first paragraph of which ends: "A chimaera was a

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[65] Robert R. Race to J. W. Nicholas, February 16, 1957, F20/1 Part 2 of 2, SA/BGU, The Wellcome Library, London.
[66] P. B. Medawar to Robert R. Race, April 4, 1953, F20/1 Part 1 of 2, SA/BGU, The Wellcome Library, London.
[67] I. Dunsford and others, "A Human Blood-Group Chimera," 81. It is at this point that the change in spelling from chimaera (in drafts) to chimera (in print) seems to have come about. Race mentions in one letter that the British Medical Journal insisted on spelling it without the "a", though I have no evidence to explain why this was the case.
[68] Robert R. Race to C. C. Bowley, May 11, 1953, F20/1 Part 1 of 2, SA/BGU, The Wellcome Library, London.

mythological monster of composite nature, having the head of a lion, the body of a goat and the tail of a dragon. The plant chimaeras are truly of composite nature and origin."[69] As further evidence that Race was reflective about the mythological, or at least ancient, meaning of the word, there is a curious note on a scrap of paper in the Mrs. McK files which says: "If one of twins survives he is named Vopiscus." While there is no date or further explanation on this note, the word Vopiscus seems to come from Plutarch's *Coriolanus* (75 A.D.):

> There are some, too, who even at this day take names from certain casual incidents at their nativity: a child that is born when his father is away from home is called Proculus; or Postumus, if after his decease; and when twins come into the world, and one dies at the birth, the survivor has the name of Vopiscus.[70]

Vopiscus was never taken up in biological nomenclature, but it was apparently on the minds of Race and/or the other blood groupers.

In the same issue of *BMJ* as the Dunsford et al. report, an anonymous editorial reflects on the case. The opening paragraph states that:

> The *chimaera* of classical tradition was a creature consisting of parts of several different vertebrate species. In the natural world, individuals composed of two genetically distinct parts are rare. They are found in the plant kingdom and more rarely among insects. In their more obvious manifestations chimeras are

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[69] "Chimaera" in *Encyclopedia Britannica*, Vol. 14th Edition, 1929, 502-503.

[70] Plutarch, *Coriolanus*, trans. John Dryden, 75 AD, http://classics.mit.edu/Plutarch/coriolan.html (accessed November 20, 2005).

> unknown among mammals, but serology, more subtle than the unaided eye, has shown that they do exist in cattle. And now Mr. I. Dunsford and his colleagues … have demonstrated the existence of a composite human being.[71]

From its first use in human biology, therefore, the "classical" Greek monster was recalled and pointed out to readers, as it was when used by Winkler with regard to plants, and by Anderson et al. with regard to animals.

Around the time of the *BMJ* publication, Race was involved in a peculiar exchange regarding terminology with two scientists in the United States. While the potential dispute was easily resolved, it is a telling episode with respect to the politics (both personal and national) and the contingencies involved in scientific naming. Clyde Stormont, a veterinary serologist at the University of California, Davis, wrote to Ray Owen, the aforementioned investigator who had identified mixed blood groups in cattle twins. In the letter which Stormont copied to Race (though they had not before met), he takes issue with the latter's use of the word "chimera" to describe "their remarkable discovery of erythrocyte mosaicism (a la Owen et al. J. Hered. 37:291-297, 1946) in man"[72]:

> In a separate letter to you, I am discussing the inevitable problem which often seems to follow when English researchers write on subjects developed first by American investigators – namely, the problem of nomenclature. Shall admixed or compound blood types

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[71] "Human Chimera," *British Medical Journal* 2, no. 4827 (Jul 11, 1953), 89.

[72] Clyde Stormont to R. D. Owen, June 29, 1953, F20/1 Part 1 of 2, SA/BGU, The Wellcome Library, London.

> associated with the birth of twins or higher order multiples be referred to as erythrocyte mosaicism (a la Owen et al. loc. cit) or by such terms as "genetical chimera", "blood group chimera", etc. now being substituted by Anderson et al Hered. 5:379-397, 1951 and Dunsford et al in their ms?[73]

Excerpts from Owen's lengthy and jocular response, also copied to Race, follow:

> Fact is, Clyde, though I deeply appreciate your willingness to take up the cudgel for EM, I don't feel that the nomenclatorial issue here is a profound one; I regard it as something of a chimaera (var. of chimera, a monster vomiting flames; a horrible illusion; a vain or visionary conception). If you are right in accusing our English colleagues of toying with our terminology, I suspect that part of the explanation might lie in their generally more sensitive discrimination in the use of English; for myself, I have long envied the writing of Englishmen. I rather wish I'd thought of chimera first myself; it is a somewhat more specific term than mosaic and, as far as I can see, almost entirely appropriate to the situation…. I have an impression of *incongruous juxtapositions* when I see the term chimera – perhaps, as Anderson et al would say, in the "classical sense" – quite different from the neatly matched elements of a mosaic.[74]

From this letter we learn that a contemporary of Race's (even a linguistically stunted American!) was aware of the monstrous connotation of chimera. Owen goes on to note, tongue-in-cheek, that ambiguity of terms can only benefit him:

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[73] Ibid.

[74] R. D. Owen to Clyde Stormont, July 3, 1953, F20/1 Part 1 of 2, SA/BGU, The Wellcome Library, London.

> One pleasant aspect of a diffuse terminology for the phenomenon is that as long as no single consistent term provides an unambiguous shorthand designation for it, authors continue to specify in effect that what they are talking about is the phenomenon described by Owen in 1945 in his brilliant studies on bovine twins, etc. etc. This of course is sweet to me, and if I had a press agent I am sure that we would advise me to foster a confusion of terms.[75]

In a handwritten note to Robert Race at the bottom of the copy sent to him, Owen wrote: "I hope you will find some fun in parts of the above, as I did in writing it… I do find some of my old friend's phraseology unfortunate, but when you meet him I'm sure you'll agree that he's a fine chap all the same."[76]

Race's response to the exchange was to note, in a letter to Owen, the lack of thought he had actually given to using the term:

> I am sorry [Stormont] is getting a bit excited about the word chimera (as the BMJ insists on spelling it). My only thought in using it was to get a good title for the paper. Thank you for your flattering remarks about our English but, to tell you the truth, I cribbed the word from Waddington's book and from Darlington and Mathers.[77]

The proto-controversy seems to have ended here. Owen's failure to insist on "erythrocyte mosaicism" seems to have taken the wind out of Stormont's sails. The exchange demonstrates that, at the time of naming

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[75] Ibid, 2.
[76] Ibid.
[77] Robert R. Race to R. D. Owen, July 13, 1953, F20/1 Part 1 of 2, SA/BGU, The Wellcome Library, London.

human chimeras, participants were fully aware of the multivalence of the term, of its historical roots, and of the desirability of signifying "incongruous juxtapositions," which is at the heart of the word.

After Mrs. McK, the MRC Blood Group Unit was involved in several other investigations of twin chimeras, and the London laboratory became somewhat of a repository to which chimera cases were inevitably reported and discussed. Another early case was the W twins, fraternal twins also from England, whose status as chimeras was discovered when the 21 year old woman, "Miss W," donated blood.[78] She was found to have 1% of type A blood, from her brother, while he had 14% of her blood type O. They became the subjects of decades of research involving repeated blood typing of the sister and brother, their parents, and eventually their spouses and children. In a reiteration of Anderson et al.'s skin graft swap between cow twins, the W twins were subjected to (or volunteered for) a reciprocal skin graft, which was not rejected.

In the same issue of the *British Medical Journal* in which Booth et al. reported on the W twins, another team, Nicholas et al., described another set of blood chimera twins.[79] Nicholas thought a clarification in nomenclature was necessary, he writes to Race, because "most

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[78] P. B. Booth and others, "Blood Chimerism in a Pair of Twins," *British Medical Journal* , Vol. 5033 (Jun 22, 1957), 1456-1458.

[79] J. W. Nicholas and others, "Human Blood Chimeras a Study of Surviving Twins," *British Medical Journal* Vol. 5033 (Jun 22, 1957), 1458-1460.

pathologists appear to be unfamiliar with the word."[80] In a repetition of the formula, the first paragraph states:

> The term "chimera" (originally a fabulous fire-spouting monster, part lion, part goat and part serpent) has been used in botany for many years to denote an individual plant in which there are two or more tissues differing in their genetic constitution, such as a graft hybrid.[81]

Here, too, species difference is conflated with individual genetic difference within a species, as Nicholas emphasizes "tissues differing in their genetic constitution," without mentioning species difference. This is significant because it renders the difference between individuals (brother/sister in this case) as the same kind of thing as the difference between species (lion/goat/serpent).

Another find: Genetic chimeras

By the early 1960's, techniques in cytogenetics (meaning "cell genetics") were much improved and allowed visual scrutiny of nucleus-containing cells in blood (white blood cells have nuclei, while red blood cells generally don't). In 1962, Doctors at the University of Washington in Seattle saw a two-year-old patient for "surgical correction of an enlarged clitoris."[82] She also, they noted, had two different colored eyes. When

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[80] J. W. Nicholas to Robert R. Race, February 14, 1957, F20/1 Part 2 of 2, SA/BGU, The Wellcome Library, London.

[81] J. W. Nicholas and others, "Human Blood Chimeras" 1458.

[82] S. M. Gartler and others, "An XX/XY Human Hermaphrodite Resulting from Double Fertilization," *Proceedings of the National Academy of Sciences of the United States of America* 48 (Mar 15, 1962), 332-335. Several authors, notably Alice Dreger and Anne Fausto-Sterling

they karyotyped[83] 13 of her white blood cells, they found that "seven had an XX chromosome pattern and six were XY."[84] They also found mixed XX and XY cells in her gonadal tissue (an "ovotestis"), and in skin from her abdomen. They concluded that they were studying the first human instance of "generalized tissue mosaicism." In keeping with the nomenclature for intersex individuals at the time, Gartler et al. called their patient a hermaphrodite (again drawing on the residues of ancient myth). Shortly after the paper describing the case, the same team published a second paper which used blood grouping – done by Race and Sanger – to confirm the "mosaicism."[85]

From a nomenclature point of view, it is interesting to note that Gartler et al. do not call their case a chimera, although they mention "twin blood group chimeras," as a similar phenomenon, in their introduction. In 1963, a second case was discerned in the U.S., though this time in an "apparently healthy 18 year old male of Negro-Amerindian-Caucasian

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have written about widely practiced, but unnecessary, normative surgery performed on intersex babies. See Alice Domurat Dreger, *Hermaphrodites and the Medical Invention of Sex* (Cambridge, Mass.: Harvard University Press, 1998), 268; Anne Fausto-Sterling, *Sexing the Body,* 473.

[83] A karyotype is a visual representation of all the chromosomes in a single cell, at a magnification achieved under a microscope. X and Y chromosomes differ in appearance significantly.

[84] S. M. Gartler and others, "An XX/XY Human Hermaphrodite," 332.

[85] E. R. Giblett, S. M. Gartler and S. H. Waxman, "Blood Group Studies on the Family of an XX/XY Hermaphrodite with Generalized Tissue Mosaicism," *American Journal of Human Genetics* 15 (Mar, 1963), 62-68. Race and Sanger are mentioned in the acknowledgements, but unfortunately the archive doesn't seem to contain correspondence about this case.

ancestry" who started as a blood donor and became a "case" because of abnormal blood typing.[86] Again, the subject of the article is not called a chimera, but "a new example of generalized tissue mosaicism." It is possible that, because these early cases were found and published in the U.S., the choice of nomenclature may be colored by the exchange between Owen, Stormont and Race described above, in that the Americans used Owen's original term "mosaic" instead of chimera.[87]

In 1965, Race and Sanger determined the blood groups in the third case of mixed XX/XY cells, originating in Milwaukee, in which they used the phrase "dispermy," but not chimera. In their 1968 chapter reviewing chimeras, they state that "dispermy thereby falls into the chimera class but

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[86] W. W. Zuelzer, K. M. Beattie and L. E. Reisman, "Generalized Unbalanced Mosaicism Attributable to Dispermy and Probably Fertilization of a Polar Body," *American Journal of Human Genetics* 16 (Mar, 1964), 38.

[87] In a parallel story, beginning in 1961, biologists were beginning to create animal chimaeras for experimental studies. See for example, A. K. Tarkowski, "Mouse Chimaeras Developed from Fused Eggs," *Nature* 190 (Jun 3, 1961), 857-860; Beatrice Mintz, "Formation of Genotypically Mosaic Mouse Embryos," *American Zoologist* 2, no. 432 (1962), Abstr. 310. Tarkowski, a Polish biologist working in a laboratory in North Wales, was the first to make a mouse chimera from aggregated embryos. Unbeknownst to both of them, Beatrice Minsk was working in Philadephia on the same thing, which she published shortly thereafter. Disputes about nomenclature apparently fell along the same national lines as the disagreements about naming in human chimerism. One British researcher told me, "Minsk insisted that they should be called allophonic mice, not chimeras. We had a big battle for years about what to call them. But I'm one for priorities, and the term chimera had priority and I argued nationally and internationally that they should be called chimeras, and in the end, I think now, everybody calls them chimeras."

we prefer to place it in a class of its own."[88] In a contemporaneous review, Curt Stern, working in the U.S., demonstrated that the question of naming these cases was not yet closed. As is customary, he parenthetically describes that chimeras are "named after the mythical monster that was compounded of a lion's head, a goat's body, and a serpent's tail."[89] He goes on to say that – because of the difficulty of discerning the difference between mosaics and chimeras with total confidence, "it seems appropriate … to use the term 'mosaic' for any kind of genetic multiplicity in an individual."[90]

The next year, Charles Ford published an essay in the *British Medical Bulletin* which begins by quoting the famous passage by Anderson et al., and states quite clearly that "the component cell lines of mosaics will have an underlying genetic identity, whereas in chimaeras they will be genetically distinct."[91] A handwritten note in the MRC Blood Group file, dated 1971, was possibly in preparation for a talk or a publication, or perhaps just Race's way of working out the issue. On it is stapled a typed copy of Anderson et al.'s passage. Below it, Race writes:

> Twin chimeras are derived from 2 distinct zygote lineages but their second lineage is rather superficial, scarcely more that a tissue graft. The cases of dispermy are indeed wholly derived from 2 distinct zygote lineages and really deserve the name of chimeras more than the twin type. We do need two names to distinguish

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[88] R. R. Race and Ruth Sanger, *Blood Groups in Man*, 5th ed. (Oxford: Blackwell, 1968), 599.
[89] Curt Stern, *Genetic Mosaics and Other Essays*, 86.
[90] Ibid.
[91] C. E. Ford, "Mosaics and Chimaeras," *British Medical Bulletin* 25, no. 1 (Jan, 1969), 104.

> these essentially different organisms, which at present most writers describe as chimeras, both of them. If the very attractive word chimera, which by the way, in the non-mythological sense – means a she-goat, is to persist, perhaps it should be confined to the dispermic condition & some other name be found for the twin type.[92]

Attached to this page by a paper clip is a smaller note which reads:

> Chimera, χιμαιρα, means a female goat and also, as a proper noun the mythical monster slain by Bellerophon. One of the modern meanings given by the O.E.D. is 'an unfounded conception' which refers to ideas but is oddly close to a description of our genetical puzzle.[93]

By the time Race and Sanger published the 6th Edition of *Blood Groups in Man*, in 1975, the nomenclature seems to have stabilized.[94] While they continued to compile cases of both types of chimeras, it seems that at some point it became redundant for blood bankers or geneticists who stumbled on new cases to publish them in journal articles. The MRC archive contains much correspondence in which Race, Sanger, and later their successor Patricia Tippett followed up on or received notice of chimera cases. In one such letter, M. Ferguson Smith writes "I am truly ashamed to say that I never got round to publishing the case of F.B. It is somehow never quite so exciting to write up something that has been

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[92] Robert R. Race, February 2, 1971, F20/6/1, SA/BGU, The Wellcome Library, London.
[93] Ibid.
[94] Robert Russell Race and Ruth Sanger, *Blood Groups in Man*, 6th ed. (Oxford; Philadelphia: Blackwell Scientific Publications; distributed by Lippincott, 1975), 659.

described before."[95] Of the 22 cases of dispermic chimeras they describe in 1975, 9 were unpublished. Of 20 sets of twin chimaeras, 4 were unpublished. Race and Sanger end their 1975 chapter with the following plea:

> Those in the position to find these cases are all very busy people who need not be called on to write a formal paper: all that is needed is a brief report, perhaps in telegrammatic form, giving such facts as time has allowed the gathering.[96]

This is significant, I think, because estimates of the prevalence of chimerism often take the paucity of published cases as evidence of their rarity.

The use of the term chimera for found cases of genetic multiplicity continues to the present, and sporadic cases of tetragametic chimeras are still published and publicized. Notable recent cases included a woman in Massachusetts who is a same-sex chimera (XX/XX),[97] and a boy in England who is has both populations of cells, XX and XY, and he was born after In Vitro Fertilization (IVF).[98] Contemporary definitions of "chimera" tend to refer to dissimilar genetic elements derived from two or

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[95] Malcolm Ferguson-Smith to Robert R. Race, February 19, 1973, F20/7, SA/BGU, The Wellcome Library, London.
[96] R. R. Race and Ruth Sanger, *Blood Groups in Man*, 6th edition, 541.
[97] N. Yu and others, "Disputed Maternity Leading to Identification of Tetragametic Chimerism," *The New England Journal of Medicine* 346, no. 20 (May 16, 2002), 1545-1552.
[98] L. Strain and others, "A True Hermaphrodite Chimera Resulting from Embryo Amalgamation After in Vitro Fertilization," *The New England Journal of Medicine* 338, no. 3 (Jan 15, 1998), 166-169.

more fertilized zygotes. This definition does, indeed, encompass all of the cases I have described above, although it retrospectively collapses many of the specificities implied by the word at particular historical moments.

Linguistic labyrinths

Ludwig Wittgenstein writes that:

> Our language can be seen as an ancient city: a maze of little streets and squares, of old and new houses, and of houses with additions from various periods; and this surrounded by a multitude of new boroughs with straight regular streets and uniform houses.[99]

The history of the word "chimera" fits nicely into this allegory. Some of its users (Winkler, Anderson et al., Race) modified, expanded or regulated the meaning while others (Neilson-Jones, Stormont, Stern) tried to without success. We have seen that two meanings of the word, the monster and the biological organism, have remained coupled together for a century. It did not have to be so; at any point, one or the other could have fallen into disuse. The type of organism could have been named something else (we have seen "mosaic," "dispermy," and "allophonic" in the running). The monster part of the analogy could have become a dead metaphor, the word left to mean only a genetically composite organism, no one the wiser. In fact, the metaphor seems to be in limbo. It is neither alive – or people wouldn't have to explain it all the time, nor dead – because people are able to explain it all the time.

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[99] Ludwig Wittgenstein, *Philosophical Investigations,* 2nd ed. (New York: Macmillan, 1958) § 18, 8.

As a counter-example, the use of "chimera" in molecular biology is an instance of a dead metaphor. Molecular biologists and genetic engineers do worry about the spontaneous creation of chimeric material – the unpredictable melding of bits of DNA or RNA - as obstacles to their experiments. A vague sense of the combination of unlike elements remains, but the monster itself has fallen away from discourse about the chimeric protein, or the chimeric plasmid. The creature is neither depicted nor described in articles and talks about molecular recombination, and the monster is not constitutive of the concept in the same way that it seems to be in clinical medicine.[100] I suspect that this is because a string of molecules is not a whole organism, and hence is not amenable to "monstering" in quite the same way. In the case of human genetic chimeras, researchers have implied notions of composite being, of a melding together of patches of fundamental difference (be it between species or within a single species). Despite this difference, the creature/organism holds together as an unlikely single functioning whole, and this similarity is made salient each time the connection between monster and human is reiterated.

Because both the biological chimera and the mythical Chimaera belong to relatively esoteric fields, the maintenance of the analogy has required work by the scientists who used it, and it still does. In early 20th Century America, those who use the word, or its derivatives "chimerism" and "microchimerism," to refer to medical phenomenon often explain its link

[100] Thanks to Stephen Hilgartner for pointing this out.

to the mythological monster. Why do these researchers bring figurative mythology into the technical discourse of cytogenetics and medicine? Like Robert Race and others in some of the passages I quoted above, the scientists I speak to find the metaphor and the images very compelling. One laboratory director told me that it implies mystery: "I feel this visual link puts the research into a perspective that is personal, fantastic, mystical and silly."[101] Another uses it in a different kind of pedagogical sense than introducing lay people or students to the field. He uses a visual image of the creature to cue colleagues into the fact that his work is related to what has come before:

> I use the analogy of the chimera because the people who have previously worked on intact cells have generally used such an analogy. The extension of this analogy to the cell-free DNA world would make the concept more easily comprehensible to these groups of scientists.[102]

From my observations, it seems like this community-building use is common. The Chimaera has become an icon in the field, and, as another researcher told me, images are easy to come by with Google. "Always use pictures in talks!"[103] One researcher told me that she specifically traveled to Arezzo in Italy while on vacation in order to see the statue, and she uses her own photograph of the monster in presentations.[104]

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[101] AG, email communication, November 7, 2005.
[102] RV, email communication, October 29, 2005.
[103] TH, email communication, October 29, 2005.
[104] BB, email communication, November 1, 2005. While researchers in the 50's, 60's and 70's were quick to describe the Greek myth, they were far less likely to use the image, because images were presumably harder to come by and to reproduce.

The point at which the monster is most likely to make its appearance is in the introduction to a talk, an article, or a book. Hence it is used as a tool for clarification, or a descriptive "hook", before the speaker or writer goes on to say whatever else they want to say – that the "foreign" cells may be causing an immune reaction, for example. Let us presume that the reader or listener does not know the word at all.[105] If they do, they most likely know it to mean something fanciful, or made-up, which is exactly NOT what our hypothetical scientist wants them to believe about this important research. In order to make the explanation quick and memorable, the speaker describes, or shows an image of, a creature that has three quite different parts. And then they imply that like the monster, the human has different parts (usually only two). Hence the crux of the metaphor, which is obvious by now, is the composite nature, the amalgamation, the mixing involved in both cases.

I am often told by chimerism researchers that they don't think the word has any bad connotations, or that they deliberately avoid the word "monster." When I noted, in discussion with one pediatrician, that the Greek myth is often invoked in scientists' communications, she went on at some length about the playfulness of it:

> Oh, just to be cute. We all like to be based in being philosophical. Yeah, so people who give a talk on chimeras show a picture of chimeras. That's somehow to give it legitimacy… [whispers] but it's sort of dumb…. Nobody would tell a patient that they've got a

[105] Chimerism researchers have mixed opinions, or no idea, about who, if anybody, does know either meaning of the word.

> monster child. We all want to find some legitimacy in history. Of course people do that. I'm giving a talk on twins, I use Romulus and Remus for heaven's sakes, to talk about it. Because there's a fascination with that. [BL]

The common element in all these reasons for using the analogy is to build associations in the minds, imaginations, memories, etc. of the listener or reader. Although scientists and doctors tell me that they don't believe that this analogy has negative implications, I will argue in the next section that the analogy works because people *do* think of genetic chimeras as anatomical monsters. While I don't think this does a particularly grievous disservice to the people so-described, it does make them objects of fascination and subjects them to intrusion – literally and figuratively – from inquiring medical people (who stand to gain a publication) and the media (who stand to gain a freak story).[106] Certainly knowing about their cellular "quirk" does them no medical good, as they aren't, and needn't be, "treated" for it.

PART II: Anatomical Monsters

In this portion of the paper, I will draw upon historical literatures about anatomical monsters to demonstrate that chimeras are a kind of modern-day morphological monster. Historians are generally in agreement about the broad characteristics of monster discourse in the European Middle Ages and the Enlightenment. Beginning around 1500, Lorraine Daston and Katharine Park argue, treatment of monsters and attitudes about them

[106] Genetic chimeras have featured in a number of recent newspaper stories and in a television documentary, "I am my own twin," which first aired on the Discovery Health channel in 2005.

began to change remarkably. In popular literature, monsters (which were not limited to human oddities, but included all manner of peculiar or perilous natural phenomena) were originally invested with divine and portentous meaning. "As the period progressed, they appeared more and more as natural wonders – signs of nature's fertility rather than God's wrath."[107] Fear and superstition about monsters persisted among the Early Modern Christian populace, but the seventeenth century saw the educated laymen and Baconian scientists distancing themselves from the less educated classes. [108] Attitudes about monsters – now seen by elites as "curiosities and sports of nature"[109] rather than ominous otherworldly signs – mark this growing gap.[110]

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[107] Katharine Park and Lorraine J. Daston, "Unnatural Conceptions: The Study of Monsters in Sixteenth- and Seventeenth-Century France and England," *Past and Present* 92 (August, 1981), 23.

[108] Ibid.

[109] Michael Hagner, "Enlightened Monsters" in *The Sciences in Enlightened Europe*, eds. William Clark, Jan Golinski and Simon Schaffer (Chicago: The University of Chicago Press, 1999), 175-217.

[110] I have encountered only one reference to God's hand in twentieth century chimera formation. In their 1958 review, Race and Sanger write about the fourth case of chimeric twins, found in Mexico:

> To Dr. Velez-Orozco's enquiry whether she were a twin she answered no; but Dr. Velez-Orozco was then taken aside by her mother who said that there had indeed been twins but the boy was stillborn because of God's anger at the drunkenness of her husband.

Sanger refers to this case in correspondence contained in the MRC files: "I, Ruth, secretly suspect that Mrs. PM's mother is like the mother of Velez Orozco's propositus and is keeping quiet about God striking a blow in anger." (Ruth Sanger to George W. G. Bird, November 30, 1973, F20/2/1 Part 2 of 3, SA/BGU, The Wellcome Library, London.) Like in the seventeenth century, these comments convey disdain (or more likely amusement) at religious superstition. In this case, the distance it charts is that between British secular academics and Mexican lay people.

In the seventeenth century, monsters became ubiquitous. They were discussed in popular and educated circles and they appeared "as spectacles in court culture, at marketplaces, and at fairs. Numerous case studies filled erudite journals… and natural oddities were desired objects for collectors' cabinets."[111] Hagner describes in some detail Czar Peter I's court in St. Petersburg Russia, in which anatomically unusual humans, such as dwarfs and hermaphrodites, were kept as curiosities and courtly entertainments. In her book *The Platypus and the Mermaid and Other Figments of the Classifying Imagination*, Harriet Ritvo devotes a chapter to animals and humans considered monstrous and their role as public spectacles. "The house of the monstrous," she writes, "contained many mansions. And from the seventeenth century onward, those mansions were ever more densely tenanted."[112]

At the turn of the eighteenth century, a new scientific impulse to systematize and classify monsters prevailed, particularly among anatomists and medical men.[113] While monsters' status as spectacle and curiosity did not disappear, connoisseurs of the monstrous during this century were more likely to view anomalies as rare foils for Nature's remarkable orderliness than as products of "her" artfulness and trickery. Monsters presented a challenge to Enlightenment visions of natural and

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[111] Hagner, "Enlightened Monsters," 176.
[112] Harriet Ritvo, *The Platypus and the Mermaid, and Other Figments of the Classifying Imagination* (Cambridge, Mass.: Harvard University Press, 1997), 134.
[113] This transition has been emphasized by most of the historians of monstrosity, including Hagner, Canguilhem and Ritvo.

social order and so, Hagner argues, they needed to be "domesticated" or brought into order through methodical display and classification.

During this century, monstrous births and miscarriages garnered a new epistemic status, particularly in teratology (literally "the study of monsters"), the forerunner of embryology. They became instruments in scholarly debates between, for example, advocates of preformationism (all traits present at embryo creation) and advocates of epigenesis (form emerges gradually over time).[114] No longer just objects of value and prurience in themselves, monstrous conceptions and births became objects of dissection and experimentation, for learning about nature through its aberrations. Etienne Saint Hilaire and his son Isidore Geoffrey Saint Hilaire were the most famous proponents of teratology. The latter "domesticated" monsters:

> By placing them among anomalies, by classifying them according to the rules of the natural method, by applying a methodical nomenclature to them that is still in use, and above all by naturalizing the compound monster, the monster in whom one finds united the elements, complete or incomplete, of two or more organisms.[115]

Where monstrosities had previously been preserved and displayed whole, they now were more likely to be opened up, in parts, or in pictorial representations. While they did not lose their status as curiosities and

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[114] Georges Canguilhem, "Monstrosity and the Monstrous"; Evelleen Richards, "A Political Anatomy of Monsters, Hopeful and Otherwise: Teratogeny, Transcendentalism, and Evolutionary Theorizing," *Isis* 85 (1994), 377-411.

[115] Georges Canguilhem, "Monstrosity and the Monstrous," 35.

"good finds," anatomical monsters had by now lost the ability to inspire fear. By the end of the nineteenth century, monstrosities offered "forbidden sight of the secret work-room of nature."[116]

Chimeras as anatomical monsters

Little scholarly work has been written about twentieth century anatomical monsters, especially in comparison to previous centuries. That which does deal with monstrous themes tends to emphasize vague but ubiquitous concerns about experimental biology, genetic engineering and reproductive technology. Jon Turney's *Frankenstein's Footsteps*, for example, argues that Shelley's story is "the governing myth of modern biology."[117] Turney's book explores the trope of monstrosity, and in particular Frankenstein, as it is deployed by scientists, and more often by worried publics. An article by Melinda Cooper directly connects eighteenth century teratology to modern stem cell science, and argues that: "What is exceptional about recent developments in stem cell research is the fact that such monstrous possibilities are being exploited as a source of regenerative tissue. "[118] In other words, what used to be coded as dangerous excess is now seen as a life-giving panacea.

While these authors explore the rhetorical use of monstrosity in recent and contemporary science, their cases do not follow in the tradition of

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[116] George M. Gould and Walter L. Pyle, quoted in Harriet Ritvo, *The Platypus and the Mermaid*, 138.
[117] Jon Turney, *Frankenstein's Footsteps : Science, Genetics and Popular Culture* (New Haven: Yale University Press, 1998), 3.
[118] Melinda Cooper, "Regenerative medicine: stem cells and the science of monstrosity" *Medical Humanities* 30 (2004):21.

anatomical teratology, which contemplated individual instances of monstrosity and sought to learn general rules of development from them. Chimeras, however, seem to have direct continuity with the anatomical monsters described above. While the actual term "monster" has fallen out of favor in medical contexts, many features of eighteenth and nineteenth century monster discourse endure in contemporary biomedical discourse about human chimeras. The 1974 article titled "Another Human Chimaera"[119] is reminiscent of the 1864 Lancet article about a malformed fetus entitled "Another Monster."[120]

Like the teratologists before them, the discoverers of early human chimeras persistently expressed a kind of prurient pleasure in their subjects. The most striking aspect of the correspondence contained in the MRC Blood Group Archives is the persistent fascination inspired by chimeras, exemplified in the excited speech by Moores with which I began this chapter. Letter-writers frequently congratulated each other when someone discovered a chimera. They were described as "fascinating," "exciting" and "remarkable finds." In exchanges about Mrs. McK, Medawar tells Race that "we are all agog."[121] In Race's reply, he writes "we have enjoyed this blood,"[122] and signs off the letter with an enthusiastic "Fe Fi Fo Fum." (In this case, like in *Frankenstein*, there is

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[119] D.A. Battey and others. "Another human chimaera," *Journal of Medical Genetics* (September 1974): 283-7.
[120] J. D. Hulme, "Another Monster," *Lancet* (June 14, 1862), 481.
[121] P. B. Medawar to Robert R. Race, April 4, 1953, F20/1 Part 1 of 2, SA/BGU, The Wellcome Library, London.
[122] Robert R. Race to P. B. Medawar, April 29, 1953, F20/1 Part 1 of 2, SA/BGU, The Wellcome Library, London.

some confusion about whether the scientist or the "patient" is the monster.) In another letter from around the same time, Race thanks Dunsford, the doctor who sent the samples to the MRC, for "letting us share in this superb blood."[123] These sentiments express the pleasure associated with rare and challenging work, but they also imply that Mrs. McK was thought of as a wonder of nature. Even long after the thrill of the first cases wore off, Race, Sanger et al. remained enthralled with chimeras. In 1973, Sanger writes "I've just realized that it's 20 years since the first twin chimera was spotted and they are still an excitement."[124] These comments suggest that, as in the eighteenth century, researchers took "an erudite pleasure in and fascination with monsters, regarded as highlights in a collection."[125]

The MRC group collected cases like former monster connoisseurs collected objects for their curiosity cabinets. They also used their rare finds to impress visitors:

> We have frozen two of the samples and kept one in the fridge to use as a demonstration. We are being visited by some of the Medical Research Council soon and to have a visible example of dispermy to show should impress them.[126]

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[123] Robert R. Race to Ivor Dunsford, April 28, 1953, F20/1 Part 1 of 2, SA/BGU, The Wellcome Library, London.
[124] Ruth Sanger to B. C. R. Lowes and J. P. Sullivan, November 26, 1973, F20/2/1 Part 2 of 3, SA/BGU, The Wellcome Library, London.
[125] Hagner, *Enlightened Monsters*, 176.
[126] Robert R. Race to J. M. Opitz, January 19, 1965, F20/2/7, SA/BGU, The Wellcome Library, London.

Instead of the whole person, they collected vials of blood and punch cards with their blood groups. Catherine Williams, a serologist in Miami, sent a sample to the Lister Unit with a note saying "we thought you might like to have the enclosed specimen for your curiosa file. It is a blood group chimera."[127] In her reply, Sanger writes "thank you very much for letting us look at this fine fellow."[128] This exchange demonstrates the scientists' habit of conflating the blood and the person, as in "whole bottle of sister sent to Jan,"[129] and "herewith some of the W family."[130]

Sometimes these samples were hard to come by and members of the team would literally have to coordinate field trips to "collect" blood at the people's homes. Unlike desperate patients eager to have researchers look at their bodies and tissues, chimeras – being healthy – had little reason to want to be researched, and they were not in regular attendance at clinics or hospitals where blood could be easily procured.[131] Maintenance of relationships with these singular "cases," then, required some careful

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[127] Catherine Williams to Ruth Sanger, March 7, 1965, F20/2/7, SA/BGU, The Wellcome Library, London.
[128] Ruth Sanger to Catherine Williams, March 21, 1965, F20/2/7, SA/BGU, The Wellcome Library, London.
[129] Robert R. Race, December 28, 1956, F20/2/1, SA/BGU, The Wellcome Library, London.
[130] T.E. Cleghorn, October 16, 1967, F20/3, SA/BGU, The Wellcome Library, London.
[131] This kind of selective disclosure, and wooing of patients foreshadows the more recent court case, *John Moore v. the Regents of the University of California,* 793 P.2d 479 (Cal. 1990), about which I will have more to say in Chapter 4. Moore was encouraged to return to the hospital for so-called "treatments," during which doctors were extracting his economically valuable tissues without full disclosure to Moore.

management, which seems to have included Christmas cards, and selective information-sharing:

> If these could be obtained without unduly worrying the patient (and I would have thought this possible if the presence of a second cell type was explained to her without telling her that one was male) it would be very good to get to the cause of the chimerism as such people are, as you know, extremely rare.[132]

Investigators also discussed strategies for enrolling patients and their families in the projects so continuous sources of blood would be available. The W twins, who were particularly heroic "volunteers" for blood draws and exchange of skin grafts, were given "the Oliver Memorial Award" by the British Blood Transfusion Service for their selfless contributions (including blood).

The skin grafting experiment performed on the W twins is a good example of researchers using rarities as instruments for resolving theoretical debates. Indeed much of the early excitement about blood group chimeras related to early work on immunology and transplantation. Medawar and others were very interested in why some transplants are rejected and others tolerated. In his essay "The Uniqueness of the Individual," Medawar uses chimeras as an exception which proves the rule of genetic individuality:

> The non-identical twins between which it is possible to exchange skin homografts are among the most remarkable animals in nature

[132] Patricia A. Jacobs to Dr Herborn, January 31, 1990, F20/5, SA/BGU, The Wellcome Library, London.

> for they are graft-hybrids or chimeras…[they react] in complete defiance of the principles formulated in this article.[133]

The tendency to use anomalies found in nature to illustrate the normal is, many historians suggest, a characteristic of eighteenth century scientific treatment of monsters. Daston and Park explain: "Interest in exotic creatures was tolerated only in so far as it illuminated the anatomy of more common ones."[134] In an eerily similar passage, an Anonymous reviewer of chimeric twins writes:

> Although the cases discussed are rare, it is interesting how many basic deductions can be made from such a small amount of material – in sharp contrast to the results sometimes obtained from large-scale population surveys. The rare abnormality can lead to our understanding a normal mechanism.[135]

When, in 1983, the MRC group was still collecting and publishing cases, but less able to justify theoretical interest in them, Tippett concludes her review by saying that although more than 70 chimeric cases are known, "investigation of these rare people, who are natural experiments, is still entertaining and worthwhile."[136]

People with both male and female sexual organs are an enduring kind of morphological rarity which clearly ties together medical discourses of the past with those of the current century. Alice Dreger, in her thorough

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[133] Medawar, *The Uniqueness of the Individual*, 150-151.
[134] Park and Daston, *Unnatural Conceptions*, 52.
[135] "Unusual Twins," *British Medical Journal* 2, no. 517 (Oct 1, 1966), 783-784.
[136] Patricia Tippett, "Blood Group Chimeras. A Review," 346.

history of hermaphroditism, writes that "stories of hermaphrodites are sprinkled throughout virtually every era of recorded history."[137] The history of Western attitudes about hermaphrodites is in keeping with that of monstrosity more generally, as described above. From a mediaeval fear and mistreatment of hermaphrodites as supernatural portents of evil, to an early modern fascination which recast them as "marvels," to a modern scientific "domestication" of them as pathological specimens, hermaphrodites seem to be exemplars of anatomical monsters.

Chimeras overlap with hermaphrodites and intersex conditions, both as biological phenomena, and because they both inspire anxieties about sexual classification. Blood group chimeras contain blood cells from their fraternal twins; in some cases, the twin is of the opposite sex. In cows, the first known instance of this phenomenon, female cows would be sterile. Dr. Dunsford's report that his patient had "a sufficient quota of curves and bumps to attract and wed a spouse"[138] translated, in the published account of the case, to the statement that she "is feminine in appearance and has had one child: she is clearly not a freemartin."[139] Worries about potential infertility in men were handled in an even more delicate manner, probably in order to avoid emasculating implications. With regard to a 1957 case in which 25% of a young man's blood cells were genetically traceable to his sister, Race writes the following in a letter to a co-author about the draft publication:

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[137] Dreger, *Hermaphrodites and the Medical Invention of Sex*, 32.
[138] Ivor Dunsford to Robert R. Race, March 31, 1953, F20/1 Part 1 of 2, SA/BGU, The Wellcome Library, London.
[139] Dunsford and others, *A Human Blood-Group Chimera*, 80-81.

> I did not, in the Discussion, mention the possibility that, in Man, it may be the male who gets it in the neck (to put it with all delicacy). There seems to be no evidence yet for this and it would surely cause worry to Mr. W or to his parents.[140]

Race's speculation that "it may be the male who gets it in the neck" means that while Mrs. McK had proven that female blood chimeras could definitely be fertile, there had been no similar demonstration from a human male. Consequently, Race implies, human males may be infertile like female twin cows. (This turns out not to be the case.) Concealment from patients has been characteristic of the medical sciences that deal with intersex, and paternalistic attempts to protect patients from self-knowledge featured in scientists' handling of chimeras as well. Race and Sanger were not, however, so delicate in their reference to Mrs. McK's long deceased brother: "This rather puts to shame the human male embryo whose feeble hormones appear to have absolutely no effect on his sister."[141] The reference to "feeble hormones" is obviously a denigration of the "manhood" of the human male embryo.[142]

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[140] Robert R. Race to Gertrude Plaut, January 25, 1957, F.20/2/1 Part 1 of 3, SA/BGU, The Wellcome Library, London.

[141] R. R. Race and Ruth Sanger, *Blood Groups in Man*, 3d ed. (Oxford: Blackwell Scientific Publications, 1958), 308.

[142] See Martin's analysis of scientific descriptions of the egg and the sperm for a classic discussion of the blatant ways in which assumptions about gender overlay expectations and observations of biological processes: Emily Martin, "The Egg and the Sperm: How Science Has Constructed a Romance Based on Stereotypical Male-Female Roles," *Signs: Journal of Women in Culture and Society* 16 vol. 3 (1991): 485-501.

The other kind of human chimerism – dispermy or tetragametic – is one of several potential "causes" of intersex development. Some (though not all) XX/XY chimeras have some degree of dual-sex tissue development. This was, in many cases, why these people came under medical scrutiny in the first place. Their "condition" was diagnosed with the demonstration of karyotypes of both collections of chromosomes from different cells. In one noteworthy case, a woman was found to have almost entirely XY cells in her blood. Her doctor wrote a letter to Race and Sanger, which he titled: "the Strange Case of the Pregnant Male."[143] In it, he writes, "PD looks female both to me and the obstetrician. It seems she has enough XX to look female and obviously to make eggs – if you see what I mean. Otherwise it seems one can make out a good case for her being a male."[144] Whether or not clinicians' anxieties about sex in chimerism intertwine with the gendering of the Chimaera is difficult to say. One could speculate that the ferocious and violent tendencies of the Chimaera, a female creature, suggests some sort of gender ambiguity or multiplicity, which is also present in discussions about mixed-sex human chimeras, although I have no direct evidence that this was a purposeful analogy.

Certainly the more germane norm that the Chimaera is violating is the rule that an animal should only be one species. Indeed, this norm has been the recent subject of debate in bioethical, legal and theological circles. While plant and animal combinations that transgress species divides have long been created without much uproar, the possibility that part-human

[143] G. Bird to Robert R. Race and Ruth Sanger, April 30, 1973, F20/2/1 part 2 of 3, SA/BGU, The Wellcome Library, London.
[144] Ibid.

organisms could be engineered has incited public controversy. Francoise Baylis and Jason Robert opened a heated philosophical debate about animal-human chimeras in *the American Journal of Bioethics* with their article "Crossing Species Boundaries."[145] In it, they write:

> As against what was once commonly presumed, there would appear to be no such thing as fixed species identities. This fact of biology, however, in no way undermines the reality that fixed species exist independently as moral constructs. That is, notwithstanding the claim that biologically species are fluid, people believe that species identities and boundaries are indeed fixed and in fact make everyday moral decisions on the basis of this belief.[146]

Interspecies chimeras, particularly those that involve human components, are considered monstrous because they violate a social or moral norm. I will conclude by speculating about what social norms human clinical or "found" chimeras violate.

Conclusion

To return to a point I made in the introduction of this chapter, monsters do not exist *a priori*, but are manifestations of culturally specific rules and anxieties. In some cases, "monstering" has been used to police classifications in the service of overt political aims. During colonial campaigns, for example, the portrayal and public display of indigenous peoples as morphological freaks of nature were used to denigrate the

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[145] See Jason S. Robert and Francoise Baylis, "Crossing Species Boundaries," *American Journal of Bioethics* 3 no. 3 (Summer 2003), 1-13. Also included in this issue are numerous responses to Baylis and Robert's provocative paper.
[146] Ibid., 6.

"savages," and thus justify colonization.[147] Hence, biological norms are simultaneously social norms. When something out of the ordinary appears in nature, it is not violating nature's law, but the laws that human beings (often scientists) have attributed to nature. Monsters are valuable, Canguilhem writes, because they reinscribe the ordinary, the ordered:

> By demonstrating how precarious is the stability to which life has accustomed us - yes, only accustomed, but we made a law out of its custom - the monster gives an all the more eminent value to specific repetition, to morphological regularity, to successful structure; it makes us realize that these are not necessary.[148]

Making a similar point, Harriet Ritvo underscores the propensity of biological hybrids and crosses to "emphasize the existence of boundaries between groups and simultaneously obliterate them."[149]

Human chimeras have been persistently fascinating to medical researchers in the latter half of the 20th Century because they violate the rule that organisms derive from a single fertilized egg and contain the self-same genome in every cell. Beyond simply implying that genetic chimeras are rare or unusual, biomedical representations of them as anatomically monstrous imply that humans, or biological organisms *should* only

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[147] For historical accounts of the display of indigenous peoples as part of colonial entertainment and science, see Anne Fausto-Sterling, "Gender, Race and Nation: The Comparative Anatomy of 'Hottentot' Women in Europe, 1815-1817" in *Deviant Bodies: Critical Perspectives on Difference in Science and Popular Culture*, eds. Jennifer Terry and Jacqueline Urla (Bloomington: Indiana U Press, 1995), 19-48 and Londa L. Schiebinger, *Nature's Body: Gender in the Making of Modern Science* (Boston: Beacon Press, 1993), 289.
[148] Georges Canguilhem, "Monstrosity and the Monstrous," 29.
[149] Ritvo, *The Platypus and the Mermaid*, 130.

contain one genome. This rule has gained a heightened salience in the age of forensic DNA testing. The imperative to have a singular genetic identity is now an instrumental part of governance in most nations. That chimeras threaten this rule has not escaped public notice, though experts dismiss this worry on grounds of the rarity of the phenomenon.

Dreger writes that sexual ambiguity is so captivating and so unsettling because "the discovery of a 'hermaphroditic' body raises doubts not just about the particular body in question, but about all bodies."[150] That "Nature" can transgress fundamentally held social categories (like sex) troubles the perceived naturalness of those categories. Chimeras, too, raise doubts about all bodies. Particularly because of the invisibility of outward signs, we could all be chimeras. This differentiates chimeras from their eighteenth century counterparts such as Siamese twins, dwarfs and two-headed babies. Monstering, in the past, has largely relied on visible anomalies, gross features which distance the object from the viewer, and often inspire repugnance. Domestication of monsters often meant that scientists and medical men would provide a rational explanation for why a human was the way he or she was, which perhaps alleviated some of the stigma.

Chimeras, however, harbor invisible difference. "Passing" as normal is not a social issue; without the laboratory, they have no difference. In order to become chimeras, people or their tissues have to enter the clinic and then the laboratory, which they often do by accident (as blood donors,

[150] Dreger, *Hermaphrodites and the Medical Invention of Sex*, 6.

for example). The first surprise is that such doubly-endowed people *exist*, and the second surprise is that they are *not* visibly monstrous, despite such a fundamental "pre-zygotic mishap."[151] In a small number of cases, chimeras have photo-worthy patchy skin or unusual genitalia, but in most instances the case reports are devoid of photographs of the person described. [152] However, pictures of chromosomes, and of fluorescently-tagged Y chromosomes, make the anatomical oddity visible to the audience, and to the person themselves.

This, then, is a twentieth-century innovation in anatomical monstrosity. Monstering, a social process of delineating norms and violations of them, still relies on visualizing anomalies. Where two heads and parasitic twins once inspired public awe and scientific scrutiny, there has been a change in the order of magnitude of morphological abnormalities. Our body parts have gotten much smaller. Chimeras are, to borrow Canguilhem's term, micromonsters.[153] In chapters 2 and 3 I will explore a recent area of research that suggests that chimerism may in fact be a biological norm. Certainly with the therapeutic employment of transfusions, transplants and stem cell therapies, the occurrence of genetic multiplicity is increasing. Hence, chimeras may be a transient kind of micromonster,

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[151] W. W. Zuelzer and others, "Generalized Unbalanced Mosaicism," 38.
[152] While researchers often call these people "patients" because they are encountered in medical contexts, I purposefully avoid this label because I wish to critique this characterization.
[153] Georges Canguilhem, *On the Normal and the Pathological*, 278. Canguilhem applies the term to "hereditary biochemical errors" which are monstrous because they are "errors of nature." Because of their continuity with centuries of anatomical monstrosity, I suggest that chimeras are even better examples of micromonsters.

marking a contemporary, though not eternal, preoccupation with individual genetic integrity. This contingency would come as no surprise to a genealogist.

CHAPTER 2:

THE WRONG TOOL FOR THE JOB: FETAL CELLS AND THE Y CHROMOSOME

> Bodies cannot be said to have a signifiable existence prior to the mark of their gender; the question then emerges: To what extent does the body come into being in and through the marks of gender?
>
> ---Judith Butler, *Gender Trouble*[1]

Introduction

Attention to the materiality of scientific practice is a persistent concern of science and technology studies (S&TS). Rather than leaving the science settled and attending to the social interests that swirl around it, S&TS is adept at looking for sociotechnical hybrids within the minutiae of the work done by scientists. In this chapter, I will describe the techniques by which identities are affixed to cells, which allows scientists to differentiate them from one another. Human genetic chimeras are made when biomedical researchers find cells in people that, by some genetic or immunological measure, do not belong there. While immunological markers and blood groups have played a part in the discernment of chimerism, by and large the most important tool for researchers has been chromosomal sex. Many of the cases of chimerism described in chapter 1 were discerned by the visualization of cell populations that contained both XX and XY cells, when only one of these cell types was expected. For example, cells "out of place" are located, in women, by their tell-tale Y-chromosomes, marks that "should not" be found in women.

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[1] Judith Butler, *Gender Trouble*, 8.

Because chimeras are found so rarely, it was methodologically impossible for me to capture the mundane laboratory practices by which they are constituted. Fortunately, spontaneous genetic chimerism is not the only situation in which biomedical investigators go searching for cells out of place. In this chapter, I will trace the clinical history of a technique which actually *aims* to find Y-chromosomes in women. In this case, finding a Y is a routine, even desired, outcome that does not call the woman's identity or femininity into question. Unlike the subjects we encountered in the previous chapter, these women are pregnant. Because pregnant women contain beings with their own (albeit contested) identity and their own genetic profile, notions of pregnancy were not radically altered when researchers discovered that some cells escape through the so-called placental barrier, and can be found in pregnant women's blood. In a sense, according to modern Western ideas about pregnancy, pregnant women's bodies are already multiple, they have already compromised whatever cellular purity is expected of non-pregnant people. When investigators started finding Ys in pregnant women, their thoughts turned to utility rather than pathology: How could these cells be put to good use to find out more about the growing fetus inside the woman?

In his superb history of the experimental culture of fruit flies and their scientists, Robert Kohler claims that the Drosophilists made the fruit fly into a "living instrument."[2] The flies, he writes, became both biological and technological at the same time. In this chapter, I aim to tell a similar

[2] Robert Kohler, *Lords of the Fly: Drosophila Genetics and the Experimental Life* (Chicago: University of Chicago Press, 1994), 321.

kind of story about one bit of material culture, around which small teams of clinical and laboratory scientists grouped, dispersed and regrouped. My living instrument is not a whole organism, or even a whole cell, but a single human chromosome: the Y. It is living in the sense that it is organic material, rather than metal or plastic. It is derived from a living body, a woman's body. Kohler shows us that successive generations of fruit flies became physically adapted to the interests of the humans working with them, and vice versa. In my story, generations of investigators organized research programs and laboratories around their trick of finding Y-chromosomes in pregnant women and (sometimes) showing that they coincide with male babies. However the materiality of the Y chromosome – what counts as a Y – has changed over time. In the sense of continual transformation, the Y, like Kohler's fruit fly, is a living instrument.

Incidentally, fetal cell researchers never aspired to find the Y chromosome specifically for performing prenatal sex identification. It was a means rather than an end. Their endgame was a "noninvasive" prenatal genetic test, using fetal cells isolated from a mother's blood. The goal, fetal cell researchers have always maintained, was to isolate a few fetal cells from a sea of maternal cells, and to examine their genetic material under the microscope, in much the same way that cytogeneticists currently examine fetal cells extracted from amniotic fluid. As with amniocentesis, they would be looking for extra chromosomes (e.g., Down Syndrome) and for deletions and rearrangements of chromosomal material (e.g., Prader-Willi Syndrome). The advantage of using maternal blood is that it would circumvent amniocentesis, an invasive procedure that always

presents some risk of inducing a miscarriage. Because of this hazard, amniocentesis is generally only offered to women who have some kind of increased risk for an abnormal pregnancy, such as "advanced age" (over 35). The investigators who aim to bring a fetal cell technology to hospitals and markets have a vision that every woman would have access to prenatal genetic testing.[3] Such an innovation would reduce the economic costs of invasive procedures as well.

This goal was first articulated in 1969, around the time when amniocentesis began to be used clinically. While amniocentesis has become routinized, fetal cell isolation has foundered. Generations of researchers have tried to reliably find the Y chromosome in the blood of pregnant women carrying male babies. Their successes have always been hampered by false positives. For example, the outcome of a recent ten-year, multi-million dollar study was a 41% specificity for correctly matching Y cells to male babies.[4] The assumption guiding this effort was that the Y chromosome is a fool-proof marker of a fetal cell, because mothers (being women) don't have Y chromosomes. True, this marker can only be used in half of all pregnancies, but scientists argue that 50% is better than any other fetal marker. The investigators call the Y a "tool," a "surrogate," a way to "calibrate" the technique. As one medical geneticist

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[3] Most women in the United States (insurance permitting) do have access to prenatal screens such as AFP or ultrasound, but these generate risk assessments rather than actual diagnoses from looking directly at the chromosomes.

[4] D. W. Bianchi and others, "Fetal Gender and Aneuploidy Detection using Fetal Cells in Maternal Blood: Analysis of NIFTY I Data. National Institute of Child Health and Development Fetal Cell Isolation Study," *Prenatal Diagnosis* 22, no. 7 (July 2002), 609-615.

told me, “the Y chromosome was a means of validating the system. It was no more than that”[MR]. And so the Y chromosome is an instrument, even according to the actors in my study.

Because the experimental cultures in this research field have been organized around the instrumentality of the Y chromosome, a stringent binary logic of sex (as XX=female and XY=male) is embedded in the experimental system. There is, however, a disjuncture between this crude and mutually exclusive rule that makes the Y seem like a good tool, and the ambiguities that open up when this rule is applied to actual bodies. The simple calculus – that female bodies contain only XX cells and male bodies contain only XY cells, unless a woman is pregnant with a son – is undermined by biological and technical glitches or exceptions. The number of these seems to keep growing in light of new theories (about the prevalence of chimerism, and about fetal loss in early pregnancy, for example); in light of new therapies (like transplants and transfusions); and in light of new techniques for looking at bodily material with greater resolution.

In what follows, I will use theoretical tools from science and technology studies, and from feminist theory, to argue that the Y chromosome, as a proxy for sexed bodies, has been mistaken as a stable instrument around which assemblages of technical and social variables have been adjusted during the life of this would-be technique. This misplaced confidence in the intransigence of the Y, and of “maleness,” has contributed to the inability of researchers to mobilize the technique across the divide from experimental laboratory to hospital clinic.

In a corroborating postscript to this story, we will see that a small private lab, called Acu-gen, has recently been able to cash in on the investment made by the generations of fetal cell researchers. Acu-gen, unconnected to the publicly-funded, above-board and self-consciously ethical fetal cell researchers, offers the "Baby Gender Mentor" kit direct-to-consumers over the internet. They claim 99.9% accuracy at identifying fetal gender from a pin-prick of women's blood as early as five weeks into the pregnancy. Not surprisingly, given the troubled history of the Y, more and more women are asking for their money back when their ultrasounds and births contradict the kit results. In the course of the controversy, scientists and consumers have criticized the company and the technique, but not the infallibility of the XX/XY divide, the devotion to which is what makes the kit marketable in the first place.

Externality

In his article "Towards an Analysis of Scientific Observation," Trevor Pinch sets out to explore why some observational reports in science are accepted, while some are not.[5] He develops the notion of the varying "externality" of those reports, which I will make use of to explore the acceptance or rejection of particular observations of "fetal cells." Rather than fetal cells, Pinch's physicists were looking for solar neutrinos, byproducts of nuclear fusion in the core of the sun. Solar neutrinos cannot, however, be directly observed, and these physicists rely on a

[5] Trevor Pinch, "Towards an Analysis of Scientific Observation."

series of translations that are "highly mediated by experimental manipulations, practices and processes of interpretation."[6] Specifically, the following three reports come at different stages in the experiment, and can be made equivalent, depending on the context of the report:

a) Splodges on a graph were observed.
b) Ar^{37} atoms were observed.
c) Solar neutrinos were observed.[7]

Pinch calls these steps in observational translation "degrees of externality." Splodges are closest, or "proximal" to the observer and solar neutrinos are farthest, or "distal" to the observer. Proximal reports are more modest, while distal reports are more profound, though risky, and entail assumptions about the observational situation.[8] "By this process of externalization," he writes, "observation becomes a question of studying a chain of surrogate phenomena via a series of manipulations and interpretations, and this highlights the fundamental ambiguity over *just what has been observed*."[9]

Similar to the solar neutrino scientists, the researchers in my case cannot directly observe fetal cells. Even through a microscope (a mediator), these cells are indistinguishable from surrounding maternal cells and must be processed in order to be visibly distinguishable. Since the beginning of

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[6] Ibid., 7.
[7] Ibid., 9.
[8] Pinch uses externality in a similar way as Latour and Woolgar use the concept of "modalities" in *Laboratory Life,* 75-88. The fewer modalities, or qualifiers, a statement has, the more fact-like it becomes.
[9] Ibid., 8, emphasis in original.

the efforts to isolate fetal cells, the first, or most proximal, step of observation has fluctuated in response to the available technologies and commercial reagents. This step has always entailed some manner of staining or fluorescence, but the stain and the target (the whole Y chromosome, or just a segment of it) have varied. I will describe these variations in more detail below. The next degree of externality – what the stain is meant to indicate – is always the same: the Y chromosome. Finally, the most distal observational report is a fetal cell from the current pregnancy, which must therefore be male. So, in keeping with the analogy to Pinch's solar neutrinos, we see the following possibilities:

a) A green dot was observed.
b) A Y chromosome was observed.
c) A fetal cell was observed.

Using externality as a framework to discuss his case studies, Pinch goes on to make several important analytical points. First, in disputes about what was observed in a particular experiment, competing parties attack their opponents' claims by pushing back the degree of externality. For example, one party may claim to have seen solar neutrinos, while an opponent in the debate may successfully make the case that splodges on a graph were indeed seen, but the evidence cannot sustain the report of either Ar^{37} atoms or solar neutrinos. Then, Pinch writes, "the chain of inference will have been broken."[10] A second contention Pinch makes is that experimenters are faced with a dilemma about the level of externality

[10] Ibid., 16.

they should adopt in framing their claims in publications or elsewhere. The more distal the claim, the more open it is to criticism.

We will see that fetal cell researchers did not usually have a dilemma about what observation to report; there was no gap between a) and c), in their view, because the assumptions embedded in the chain of inferences were deemed utterly self-evident, and were, for the most part, endorsed by their community. These assumptions were that 1) the staining technique at hand could reliably adhere to and reveal Y-chromosomes; and 2) the Y-chromosome could only be from a fetal cell. Beneath this assumption is the rule of binary chromosomal sex. Because the steps in the chain of inference were seemingly obvious, every publication made the most distal report: that fetal cells were observed (at least in cases where the birth outcome matched the observation).

The degree of externality was not usually pushed back by opponents or competitors,[11] but it often was by investigators themselves, in post-hoc attempts to explain away false-positives and false-negatives. This "repair work"[12] is a common feature of published accounts of fetal cell research.

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[11] Jacobs and Smith are the one notable exception to this, and their contestation will feature in the first example, under the heading "karyotype".

[12] I am using "repair" in a similar, although much more generalized, way as did Schegloff, Jefferson and Sacks. (Emanuel A. Schegloff, Gail Jefferson and Harvey Sacks, "The Preference for Self-Correction in the Organization of Repair in Conversation," *Language* 53, no. 2 (June, 1977), 361-382.) Repair is an aspect of conversation in which the speaker (in self-repair) or someone else (in other-repair) makes corrections in clarifications to ongoing speech in order to enhance intelligibility. Schegloff et. al. identify an empirical preference for self-repair over or

Explaining "false" (i.e. unexpected) results by scaling back on the externality of the observational report works to preserve the fidelity of the technique and the assumptions behind it. The primary assumption repaired throughout this case study is that XY cells only come from male bodies. This will become clearer as I describe the reports by consecutive generations of fetal cell researchers, below. I organize them chronologically and by the particular staining method that constitutes the first degree of observation: karyotype, quinacrine, FISH, and PCR.

Fishing for the Y

1) Karyotype: a small dark object

In 1969, Walknowska, Conte and Grumbach published an article in *The Lancet* that initiated a line of research aiming specifically to retrieve fetal cells for prenatal diagnosis.[13] Their method for analyzing cells was to prepare karyotypes from dividing cells in culture, and to examine them under a microscope for the presence or absence of a Y chromosome. A karyotype is a visual convention in which chromosomes are arrayed in matching pairs. To produce a karyotype, cells must be cultured so that chromosomes will divide, and then cell division is stopped at metaphase, when chromosomes are condensed and at their most visible. The chromosome images are then literally cut out, one by one, from a photograph of the microscope slide on which they were randomly arrayed. Staining of chromosomes in the late 1960's was such that they appeared

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other-repair. I suggest that this tendency operates in this realm of scientific publication as well.

[13] J. Walknowska, F. A. Conte and M. M. Grumbach, "Practical and Theoretical Implications of Fetal-Maternal Lymphocyte Transfer," *Lancet* 1, no. 7606 (Jun 7, 1969), 1119-1122.

uniformly dark, unlike the banded or striped chromosomes one would see now. Consequently, the only way to match pairs and to differentiate them from each other was by size, and by the location of the centromere, a constriction in the middle or on one end of the chromosome.

Walknowska et al. studied blood samples from thirty pregnant women, and in twenty-one of them "metaphase figures with 5 small acrocentric chromosomes interpreted as 46/XY were found."[14] One would normally expect to find four small acrocentric chromosomes (two of chromosome 21 and two of chromosome 22) in women. Nineteen of these twenty-one women subsequently delivered male infants, which suggests, the authors contend, that the fifth small chromosome was a Y, and the cells were fetal in origin. They suggest that the "false positives" (i.e., female babies were born) were the result of an "artefact or chimaerism for fetal 46/XY cells persisting from an earlier pregnancy."[15] The category "artefact" can include many things, such as stained material that is not chromosomal, dirt on the slide, etc. From this first report we also see that the authors considered the possibility that cells from prior pregnancies persist. Hence, where a fifth small darkly stained body was seen, and a male baby was born, the authors reported that they had seen a fetal cell. Where what they thought was a fetal cell was seen, and a girl baby was born, they moved back the degree of externality to say that either a Y chromosome was seen, and it was from a prior pregnancy, or only a darkly stained body was seen, and it was an artifact.

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[14] Ibid., 1119. "Acrocentric" refers to the placement of the centromere closer to one end than the other, but not at the very end.
[15] Ibid.

Four months later, cytogeneticists Patricia Jacobs and Peter Smith published a short letter, also in *The Lancet*, that offers other possible explanations for Walknowska's findings. They authors contested whether or not fetal cells were truly observed by introducing ambiguity about what should count as a Y chromosome:

> Firstly, the fifth small acrocentric chromosome might not be a Y but might be a group-G autosome, the "46/XY" resulting from a loss of a medium-sized chromosome and the gain of a small acrocentric autosome, presumably due to double non-disjunction. Secondly, the fifth small acrocentric chromosome might have arisen as the result of a deletion of much of the chromosome material from a medium-sized chromosome, giving it the appearance of a small acrocentric chromosome.[16]

While it is not necessary to understand the technicalities of this excerpt, the basic premise is that what looks like a Y might not be a Y, but a small chromosome (21 or 22) that was picked up from another cell. Alternatively, they suggest, it might be a longer chromosome that has lost a chunk.

Moreover, Jacobs and Smith revisited their own extensive cytological evidence and found 17 cells from "normal, non-pregnant women" that could have been interpreted as having a Y chromosome had they used the same criterion as had Walknowska et al. While Jacobs and Smith were explicit in saying that their results "do not refute the explanation given by

[16] P.A. Jacobs and P.G. Smith, "Practical and Theoretical Implications of Fetal-Maternal Lymphocyte Transfer," *Lancet* 2, no. 7623 (Oct. 4, 1969), 745.

Walknowska and her colleagues,"[17] and should instead be read as a cautionary tale, subsequent investigators cited this article as a refutation, and somewhat of a controversial setback. Like the combatants in Pinch's solar neutrino debates, Jacobs and Smith questioned whether Walknowska et al. were warranted in their claim to have seen fetal cells, or even Y chromosomes, and accepted only that they had seen a small, darkly staining object. Jacobs and Smith's article is idiosyncratic in a field that largely lacks contestation and debate about observational reports. In other words, different groups of researchers in this field are far more likely to comment on each other's laboratory technique than on what they say they saw.

2) Y-body: a bright yellow spot

In the early 1970's, Jim Schroder and his colleagues published a number of positive results identifying Y-bearing cells in the blood of pregnant women who later delivered male infants. What counted as a Y chromosome, in his work, was called a "Y-body." Schroder and his colleagues stained cell preparations with quinacrine hydrochloride, a chemical which causes Y chromatin (constituent material of Y chromosomes) to glow brightly under a special fluorescence microscope. Chromatin glows because it is rich in A-T base pairs, which are particularly amenable to fluorescent dyes. Y-bodies are found in interphase nuclei, the point in the cell cycle when the chromosomes are all clumped up in a ball, rather than individually distinguishable. An interphase nucleus, stained with quinacrine, would look like an intact

[17] Ibid.

circle, faintly glowing yellow. The Y body is a bright yellow spot near the margin of the circle. A contemporaneous paper establishing the method describes that Y chromatin "showed much stronger fluorescence than other fluorescent material often present in the same nucleus."[18]

This method, as one might imagine, invites interpretive flexibility. The potential ambiguity required stringent rules for counting: "To avoid erroneous identification at interphase, only obvious or probable double structures with strong fluorescence were scored as Y-bodies."[19] Even so, Schroder, and others who used this method, always encountered false-positives (Y-bodies where girls were born) and false negatives (no Y-bodies, boys born). Investigators would follow up incorrect results by staining the parents' cells. Often they would discover that the chromosomes of the parents had idiosyncrasies that were inconsistent with their sex. For example, in one woman, "the fluorescence of the centromere region in chromosome 3 was stronger that usual,"[20] and hence was probably mistaken for a Y-body and resulted in a false-positive. One false negative was apparently explained by the male child's father's Y chromosome, which would have passed on to the son: it "was relatively small."[21] In another study, Schroder controlled for this variability: "Mothers were excluded if their own autosomes had regions of brilliant

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[18]A. B. Mukherjee, G. C. Moser and H. M. Nitowsky, "Fluorescence of X and Y Chromatin in Human Interphase Cells," *Cytogenetics* 11, no. 3 (1972), 219.
[19] J. Schr_der and A. De la Chapelle, "Fetal Lymphocytes in the Maternal Blood," *Blood* 39, no. 2 (1972), 155.
[20] Ibid., 159.
[21] Ibid., 158.

fluorescence that simulated Y-bodies" and "All 18 boys had a Y chromosome of large or medium size."[22]

This labor-intensive retrospective repair work would follow false-positives and false-negatives, but was not done where the Y-body assessment was deemed correct. While this may seem sensible, it does not, for example, account for a situation in which a mother has a glowing chromosome 3, and the son has inherited a small Y. A cell with a "Y-body" in this case would be incorrectly labeled a fetal cell.

Most who used the quinacrine-staining method concluded that it had limitations, particularly that "the definition of a Y-body varies considerably from one laboratory to another."[23] Because of the possibility of aborting a healthy female fetus, Schroder declares the false positive rate too high to use for prenatal sex identification[24] and concludes that "the method can hardly be recommended for routine use."[25] Siebers et al. come to a similar conclusion, citing as possible causes of false results

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[22] J. Schroder, A. Tilikainen and A. De la Chapelle, "Fetal Leukocytes in the Maternal Circulation After Delivery. I. Cytological Aspects," *Transplantation* 17, no. 4 (1974), 348.
[23] Ibid., 353.
[24] Schroder, and others, had proposed that this method could be used in families who are carriers of X-linked recessive genetic disorders, such as hemophilia. In these cases, where daughters would be healthy but sons might be affected, one could abort if they knew they were carrying a male.
[25] Schroder and A. De la Chapelle, *Fetal Lymphocytes in the Maternal Blood*.

"autosomal fluorescence," "variability in the size of the Y-chromosome" and "impatience of the investigator."[26]

While Siebers and Schroder judged the clinical utility of the technique pessimistically, the evidence that male cells were indeed present in maternal blood, at least in some pregnancies, was enough to invite further attempts to extract and examine them. In the late 1970's, Leonard Herzenberg's laboratory at Stanford University was enrolled in the pursuit of a "universal non-invasive screening technique for prenatal diagnosis of genetic abnormalities."[27] Herzenberg's major innovation was to enrich the number of fetal cells, which so far seemed to be present in the tiny proportion of about one cell per 1000-5000 maternal cells. (This estimate was later judged to be too generous, and it is now believed that fetal cells number about one in a million maternal cells.) His lab introduced a technology called the fluorescence-activated cell sorter (FACS) that aimed to increase the likelihood of finding fetal cells.

For detection of the Y, Herzenberg's team used the same quinacrine staining method used by Schroder and Siebers. They found between one

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[26] J. W. Siebers, I. Knauf and H. G. Hillemanns, "Antenatal Sex Determination in Blood from Pregnant Women," *Humangenetik* 28, no. 4 (1975), 161.

[27] L.A. Herzenberg and others, "Fetal cells in the blood of pregnant women: detection and enrichment by fluorescence-activated cell sorting," *Proceedings of the National Academy of Sciences of the United States of America* 76, no. 3 (1979), 1455. Diana Bianchi, then a medical student in Herzenberg's lab, has remained at the center of the field ever since, while Herzenberg, like most who tried the problem during the 1970's and 1980's, moved on to other research questions.

and six Y-positive cells (from around 500-1000 screened for each woman) in each case in which a male infant was born. In short, they did find "fetal" cells in every case where they expected to and in only one where they did not. The "false positive," they conclude, could be from a previous pregnancy, or from "an extreme deviation from the usual frequency of Y chromatin-bearing cells in maternal blood."[28] The authors, in a recitation of Schroder's and Seiber's previous conclusions, suggest that fetal cells really are present, but that the "proportion is still low for diagnostic purposes."[29] They cite "very serious maternal contamination in the sorted population"[30] as an obstacle, but end the article with a promise of increased efficiency to facilitate "universal screening." Throughout the 1980's, several labs sought better methods for making use of the putative fetal cells,[31] but it was not until molecular methods for targeting the Y chromosome became available that the field began to generate interest among numerous research groups, the NIH and corporations.

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[28] G. M. Iverson and others, "Detection and Isolation of Fetal Cells from Maternal Blood using the Flourescence-Activated Cell Sorter (FACS)," *Prenatal Diagnosis* 1, no. 1 (1981), 72.
[29] Ibid.
[30] Ibid.
[31] A. E. Covone and others, "Analysis of Peripheral Maternal Blood Samples for the Presence of Placenta-Derived Cells using Y-Specific Probes and McAb H315," *Prenatal Diagnosis* 8, no. 8 (Oct, 1988), 591-607; A. E. Covone and others, "Trophoblast Cells in Peripheral Blood from Pregnant Women," *Lancet* 2, no. 8407 (Oct 13, 1984), 841-843; A. Selypes and R. Lorencz, "A Noninvasive Method for Determination of the Sex and Karyotype of the Fetus from the Maternal Blood," *Human Genetics* 79, no. 4 (Aug, 1988), 357-359.

3) PCR: an autoradiograph band

Reviews from within the field cite the adoption of molecular techniques, such as Polymerase Chain Reaction (PCR) and Fluorescence in situ Hybridization (FISH), as the basis for a turning point that would establish consensus about the existence of fetal cells in maternal blood. Both of these techniques entailed radical changes in the treatment of cells and the inscription that was to count as a Y chromosome. They did not, however, eradicate ambiguities, false-positives and false-negatives. In 1989, Dennis Lo and colleagues at Oxford used PCR to amplify a 149 base-pair segment of the Y chromosome.[32] Commercially-made primers, Y1.1 and Y1.2, were added to the DNA extracted from maternal blood. The primers attach to particular stretches of the Y and instigate replication (called "amplification") and re-replication (in "nested PCR") of that segment during repeated rounds of heating and cooling. When the resultant segments of DNA are run through an agarose gel, the many copies of the amplified segment (if it was there in the sample) will appear as a distinct band. Lo et al. report having correctly identified the sex of nineteen fetuses by presence or absence of a Y band on a PCR gel.

In 1990, Diana Bianchi's laboratory in Boston was the first to combine FACS with PCR to amplify a segment of the Y chromosome.[33] While

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[32] Y.M. Lo and others, "Prenatal Sex Determination by DNA Amplification from Maternal Peripheral Blood," *The Lancet* (December 9, 1989), 1363-1365.

[33] D. W. Bianchi and others, "Isolation of Fetal DNA from Nucleated Erythrocytes in Maternal Blood," *Proceedings of the National Academy of Sciences of the United States of America* 87, no. 9 (May, 1990), 3279-3283.

previous attempts to isolate fetal cells had targeted lymphocytes (a type of white blood cell), Bianchi's lab sorted maternal blood for nucleated red blood cells (NRBCs). Bianchi et al. drew blood from nineteen women, who would subsequently undergo amniocentesis because of their "advanced maternal age or anxiety," and sorted it for NRBCs using the FACS. They then used PCR to amplify a particular 222 base-pair segment from the short arm of the Y chromosome. Finally, they ran amplified samples on an agarose gel under ultraviolet light, and they found Y-bands in 6 of 8 male pregnancies and 1 of 11 female pregnancies.

The authors suggest that in the infant girl who had registered as a false positive, "there may have been a low level of sex chromosome mosaicism, XX/XY chimerism, or the presence of the Y411 sequence on another chromosome."[34] Once again, we see an investigator raise the possibility that some people have chromosomal arrangements that do not conform to the XX/XY dichotomy. Bianchi herself had previously co-authored a paper on a clinical case of "sex chromosome mosaicism," where a patient had both XX and XXY cells.[35] The possibility of non-binary chromosome arrangements comes up only as a post-hoc explanation to repair the results. While I will return to this theme later in the chapter, I want to highlight an inconsistency in the use of chimerism as an explanatory resource. Researchers in this field will immediately dismiss any suggestion that non-standard chromosome profiles are a

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[34] Ibid., 3281.

[35] U. Tantravahi and others, "Use of Y Chromosome Specific Probes to Detect Low Level Sex Chromosome Mosaicism," *Clinical Genetics* 29, no. 5 (May, 1986), 445-448.

threat to the Y chromosome calibration method. Sex chromosome abnormalities, they tell me, are far too rare to worry about. The only time anomalies come up in investigators' discourse (other than when I press them) is when they can be used to rationalize troublesome results. However, if chimerism was even close to as common as investigators propose after the fact (in this case 1/19), it would certainly threaten the validity of the instrument.

A more likely explanation for false positives with PCR, researchers report, is contamination. Lo and his colleagues were careful to outline the precise window of amplification cycles for which a Y band will show up: less than 15 cycles will not show the Y, and more than 20 will show the Y band in women carrying female fetuses, presumably because of "background contamination." The major drawback to PCR is its susceptibility to contamination, because even one cell, amplified many times, can throw off the result. As part of a rigorous protocol to reduce contamination, the researchers "extracted no DNA samples from men whilst these experiments were in progress, and all blood samples were taken and subsequently handled by women."[36] In the case of PCR, we see that the instrument – the Y chromosome – ordered the social organization of labor around it. This practice continues where PCR is used to detect Y-specific DNA. As one researcher told me: "everything is wiped off before we use it. So we have pipettes that males are not allowed to handle, just to ensure that … because you're gripping them, you've got skin cells" [PT].

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[36] Y. M. Lo and others, "Prenatal Sex Determination by DNA Amplification from Maternal Peripheral Blood."

4) FISH: a green dot

In the previous cases, I have gathered observational reports, and attempts to repair them, from published literature. In this section, which considers the method called "Fluorescence in situ hybridization," or FISH, my evidence is from interviews with all of the major participants in a large clinical trial meant to test the technique. The NIH-funded trial, whose acronym was "NIFTY,"[37] began in the early 1990s and it lasted approximately a decade. The outcome of the multi-million dollar study was a disappointing publication in a "low impact" journal announcing a 41% success rate at matching Y cells to male babies, with an 11% false positive rate (matching Y cells to female babies).

The impetus for the project was a few positive reports with small sample sizes that correctly identified, for the first time, fetal cells with chromosomal abnormalities in addition to their Y chromosomes. James Price, Sherman Elias, Joe Leigh Simpson and others, then at the University of Tennessee, had used FISH (which I will describe below) to correctly confirm trisomy 21 in one fetus, and trisomy 18 in another.[38] Bianchi's group also identified trisomy 21 fetal cells from maternal blood, in a case in which trisomy had already been diagnosed by conventional

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[37] The acronym, a bit of a stretch, stands for: National Institute of Child Health and Development Fetal Cell Isolation Study.

[38] S. Elias and others, "First Trimester Prenatal Diagnosis of Trisomy 21 in Fetal Cells from Maternal Blood," *Lancet* 340, no. 8826 (Oct 24, 1992), 1033.

methods.[39] At around the same time, a German lab headed by Wolfgang Holzgreve also began publishing on fetal cell separation. Holzgreve cites the advent of fluorescent probes as the impetus for his group's interest in the field. In 1993, Holzgreve's lab used an enrichment system called magnetic activated cell sorting (MACS) and FISH to detect trisomies 21 and 18 in patients.[40]

At the beginning of the trial, hopes were high. One member of the collaboration told me, "It was very exciting. We thought 'Wow, this is really great. We're all going to have our name in lights and it's going to be wonderful'"[PT]. After a 1993 conference bringing together all the major research groups, "participants left with a clear consensus that fetal cells were indeed not only present but also, with modifications, could be exploited for prenatal genetic diagnosis."[41]

Funding from the NIH was secured after Joe Leigh Simpson and Sherman Elias approached Felix de la Cruz, then chief of the Mental Retardation

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[39] D. W. Bianchi and others, "Detection of Fetal Cells with 47,XY,+21 Karyotype in Maternal Peripheral Blood," *Human Genetics* 90, no. 4 (Dec, 1992), 368-370.

[40] W. Holzgreve, H. S. Garritsen and D. Ganshirt-Ahlert, "Fetal Cells in the Maternal Circulation," *The Journal of Reproductive Medicine* 37, no. 5 (May, 1992), 410-418.

[41] Joe Leigh Simpson, Sherman Elias and New York Academy of Sciences, *Fetal Cells in Maternal Blood: Prospects for Noninvasive Prenatal Diagnosis*, Vol. 731 (New York: New York Academy of Sciences, 1994), xi.

and Developmental Disabilities Branch (MRDD) of the NIH.[42] Simpson, along with a few other collaborators in NIFTY, had previously worked with de la Cruz on a large clinical trial to assess the safety and efficacy of Chorionic Villus Sampling (CVS), an invasive prenatal genetic screening test.[43] The contacts were in place, then, for Simpson and Elias to persuade de la Cruz to fund a similar genetic testing project, though this one had the aim of circumventing risky invasive tests.

NIFTY involved four different labs in order to accumulate a large number of samples, but also because a trial involving several sites would intrinsically test the robustness of the technique. In order to be clinically feasible, the technique would have to be operable in many hands and in many places. The centers involved in NIFTY were tied to particular clinicians, rather than to locales, and in fact several of the centers moved with clinicians during the course of the study. The original teams were those who had published positive results: Joe Leigh Simpson and Sherman Elias at Baylor University in Houston; Diana Bianchi at Tufts University in Boston; Wolfgang Holzgreve and Dorothee Ganshirt at Munster University. Laird Jackson at Thomas Jefferson University (TJU) in Philadelphia joined the collaboration after the NIH put out a call for participants. Although the investigators at TJU had done no work with fetal cells in maternal blood, they had been involved in the CVS study and

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[42] The MRDD is a branch of the National Institute of Child Health and Human Development (NICHD), an Institute within the National Institute of Health (NIH), a U.S. government body.

[43] R.J. Desnick and others. "First-trimester biochemical and molecular diagnoses using chorionic villi: High accuracy in the U.S. collaborative study," *Prenatal Diagnosis*, 12:357-372, 1992.

had contacts with a local company that could separate cells by using magnetically linked antibodies. These four centers both recruited patients and conducted laboratory work on the samples, while a fifth partner, Obstetrician Mark Evans at Wayne State University in Detroit, contributed samples to the study, but did not perform any of the laboratory work.

A final, though integral, participant, was the data management company, DMSTAT, a Boston-area company founded by Kimberly Dukes. DMSTAT is a private company that the NIH hired as an impartial participant to whom the laboratories would report their results. In addition to collecting the data, analyzing it statistically, and reporting on the aggregate results, the company was involved in producing and amending the protocol for the study. They also coordinated and chaired meetings and conference calls, and they did laboratory visits to ensure that participants were following the protocol.

An interim publication by the parties in the collaboration noted that the numbers of fetal cells that cross the placenta seem to be higher when the pregnancy is abnormal. "Since the goal of fetal cell analysis is detection of aneuploidy and not gender, we recommend that ongoing and future studies of fetal cells in maternal blood use sensitivity of detection of aneuploidy in aneuploid cases as the endpoint for analysis."[44]

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[44] D. W. Bianchi and others, "Fetal Cells in Maternal Blood: NIFTY Clinical Trial Interim Analysis. DM-STAT. NICHD Fetal Cell Study (NIFTY) Group," *Prenatal Diagnosis* 19, no. 10 (Oct, 1999), 995.

Nonetheless, the group prioritized "detection of *fetal male gender*"[45] as a means of evaluating, for the first time on a large scale, whether the technique would work.

The centers would collect blood samples from women who already had chosen to undergo an invasive procedure, they would attempt to isolate fetal cells from the maternal blood and then would compare the result with findings from the test.[46] Early in the project, the NIFTY group published a letter in the *American Journal of Obstetrics and Gynecology*, which proposed that "in the initial phase of the study cell separation techniques, monoclonal antibodies, and genetic analytic methods will be compared among centers. A later phase of the study will use a single protocol to analyze collaboratively at least 3000 pregnant women."[47] While the explicitly stated purpose of the collaboration was to develop a common protocol, one never emerged. One investigator reported that "you would hope that there would be a common protocol that would have been developed from that. And that's really, even at the end, we learned a lot but we didn't really have a single product that was developed" [MR].

Major differences in the groups' approaches included whether to use MACS or FACS during the enrichment step, and how many different

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[45] D. W. Bianchi and others, "Fetal Gender and Aneuploidy Detection using Fetal Cells in Maternal Blood," 610.

[46] The participants agreed on nucleated red blood cells (NRBCs) as the candidate cell. Other possibilities included trophoblasts and white blood cells.

[47] F. de la Cruz and others, "Prenatal Diagnosis by use of Fetal Cells Isolated from Maternal Blood," *American Journal of Obstetrics and Gynecology* 173, no. 4 (Oct, 1995), 1354-1355.

chromosomes to look for in the detection stage. Enrichment, the first major step in the technique, aims to raise the ratio of fetal cells to maternal cells. Ideally, one would be able to separate out the fetal cells and end up with a pure sample, but the pragmatic aim in this study was to get a high enough concentration of fetal cells that a human at a microscope could find at least one on a microscope slide in a reasonable amount of time. Each lab group chose to use one of two very different enrichment methods. Boston and Baylor each used the fluorescent activated cell sorter, or FACS, while Basel and Philly used the magnetic cell sorter or MACS. The choice of FACS or MACS, at the beginning, had to do with prior experience. Eventually, though, it would become a point around which social alliances were formed, and "things just ran in two parallel courses": "Right away there was (pause) a discussion at least between the MACS people and the FACS people. And as it went on it kind of became a little bit polarized" [DI].

The second step, which participants call "analysis", follows MACS or FACS. This involves "smearing" the enriched sample onto a microscope slide, and using FISH to look for chromosomal differences between maternal cells and fetal cells. FISH has several steps: First, DNA from the sample is fixed on the microscope slide and non-genetic components of the cell (proteins, membranes) are cleared away with enzymes that digest them. Second, the DNA is "denatured" with heat or unzipped so that it becomes single stranded. Next, "probes" (small pieces of single-stranded DNA commercially made to stick to a particular DNA sequence) are mixed with the DNA on the slide. The probe, outfitted with a fluorescent marker molecule, will bind to the target DNA. In a dark room with a

fluorescence microscope, the probe will be visible as a bright spot on a contrasting-color background. When two kinds of probes are used – for example, one for sequences on the X chromosome and one for the Y chromosome – they can be engineered to emit different colors.

One target for analysis in all 4 laboratories was the sex (XX or XY) of the child. Sex, in this case, was determined by attaching a fluorescent "probe" to both the X and Y chromosomes in a blood sample. In those where the Y chromosome could be seen (as a green spot on a red circle), the particular cell was presumed to be fetal in origin and the pregnancy was predicted to be male. Two of the centers also looked for extra or missing copies of chromosome 21, and one of these laboratories "went after" a total of 5 chromosomes: X,Y,13,18,21.[48] As with enrichment, the labs began with a marked difference, not in their detection method, but in what exactly they were trying to detect.

While FISH is a largely "black boxed" technique,[49] in practice it entails layers of difficulty: in making the cells permeable to particular probes, in making sure the probes stick only to the sequence of interest and not

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[48] These are the chromosomes in which chromosome variations, or "aneuploidies," are most common in live births.

[49] Black boxing is a term used in S&TS, borrowed from engineering, to indicate the taken-for-grantedness of facts and technologies. FISH is black boxed because, unlike when it was being developed, users can talk about it as a transportable, uniform technology; they know what goes into it (cells on microscope slides) and what comes out (fluorescent dots attached to chromosomes). See Bruno Latour, *Science in Action: How to Follow Scientists and Engineers through Society* (Cambridge, Mass.: Harvard University Press, 1987).

others, in seeing and counting "signals" despite ambiguities on the slide introduced by overlapping cells, etc. Investigators also say the results vary because different people handle the equipment with different degrees of skill. FISH is like the "plasmid prep," a common laboratory technique that appears to be stable and formalized. However, when Kathleen Jordan and Michael Lynch watched molecular biologists actually *doing* plasmid preps, they "often encounter a number of persistent problems associated with establishing the coherence and efficacy of the practice, determining whether one practitioner's method for doing it is the same as another's, accounting for discrepant results, and explaining how the technique works."[50]

With FISH, a great amount of "tacit knowledge" is required to elicit results from such finicky material.[51] One lab, for example, took pride in being able to get five-color FISH to work. The PI explained that the lab director in this lab was "really a pro" and "so she's managed to get the cells to be more informative than some other centers" [MR]. Because non-invasive prenatal genetic testing is desired not for sex-selection but for diagnosing aneuploidy (extra or missing chromosomes), ultimately it would have been more useful to get five-color FISH to work, but the extra

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[50] Kathleen Jordan and Michael Lynch, "The Sociology of a Genetic Engineering Technique: Ritual and Rationality in the Performance of the 'Plasmid Prep.'" In *The Right Tools for the Job: At Work in Twentieth-Century Life Sciences*, eds. Adele Clarke and Joan H. Fujimura (Princeton, N.J.: Princeton University Press, 1992), 77-114.

[51] Tacit knowledge is that which is embodied and cannot be formalized or written down. See H. M. Collins, *Changing Order* and Michael Polanyi, "Skills", in *Personal Knowledge: Towards a Post-Critical Philosophy* (Chicago: University of Chicago Press, 1958), 49-65.

"beating up" the cells take for such a feat may have compromised this lab's detection rates, which were low when compared with other labs in which only sex chromosomes were targeted. FISH also entails some observational ambiguities possibly corrected by skilled microscopic work. One report, for example, notes that "the microscopic resolution of contiguous signals and focal planes of a signal that is unclear in one plane may become clear on refocusing the microscope."[52]

At some point during the trial, when results were clearly turning out to be disappointing, the data management company urged the different laboratories to concentrate on detecting the Y chromosome, and to give up on the other chromosomes, which would have more or less than 2 copies (and therefore differ from the mother) only in very rare circumstances. A participant told me:

> If you looked at a … woman who basically, this is her first delivery and you can get 50% of those samples and you're finding a Y, then you know you've got the fetal cell. And then once you've got the technology down and you can get Ys 100% of the time, then go after your aneuploids. It's sort of a proof of concept. [LY]

Several other participants explained to me the obviousness of relying on the Y chromosome as proof of a fetal cell. One interviewee reports that "it's quick and easy,"[BB] and another describes it as "this kind of rapid, dirty way of detecting, you know, male DNA. It misses female cells"

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[52] J. O. Price and others, "Prenatal Diagnosis with Fetal Cells Isolated from Maternal Blood by Multiparameter Flow Cytometry," *American Journal of Obstetrics and Gynecology* 165, no. 6 Pt 1 (December 1991), 1736.

[JM]. Some explained that it is exclusive to males: "The Y chromosome, not only is it obviously different, you know, it's only present in men" [AG]. Another researcher told me "obviously mommy shouldn't have Y chromosomes. If you see a definitive Y chromosomal signal within a cell it should be fetal" [DI].

What went wrong?

Despite the apparent ease of finding Y chromosomes, the report that came out of the trial was, by most accounts, a frustrating disappointment. However there was no single, simple explanation for the apparent breakdown. In their classic study about scientists' discourse, Nigel Gilbert and Michael Mulkay begin by noting that this multivocality in scientists' reports of "what went on" is common. Moreover, discordant accounts of the same experiment or, in this case, the same collaboration can confound sociologists' attempts to recreate a singular story about "what when on." Instead Gilbert and Mulkay examine the variation of scientists' accounts as a topic in itself, and they identify two recurrent repertoires: the empiricist repertoire and the contingent repertoire. In the empiricist repertoire, most common in formal accounts such as published articles, "speakers depict their actions and beliefs as a neutral medium through which empirical phenomena make themselves evident."[53] Unlike the empiricist repertoire, which allows nature to speak for itself, the contingent repertoire introduces any number of variable factors outside the arena of natural phenomenon, such as "speculative insights, prior

[53] G. Nigel Gilbert and M. J. Mulkay, *Opening Pandora's Box,* 56.

intellectual commitments, personal characteristics, indescribable skills, social ties and group membership."[54] These extra-scientific factors, the speakers imply, interfered with nature's voice.

Gilbert and Mulkay argue, with ample evidence, that scientists choose which repertoire to employ in contextually specific ways, and following an asymmetrical structure. Specifically, they tend to use the empiricist repertoire when connecting successful experimental evidence to the correct view or theory, which is most often their own. "Each speaker presents his theoretical position as an unmediated expression of the natural world, in so far as that world has revealed itself in the findings of controlled experiments."[55] Scientists use the other style of discourse, the contingent repertoire, most often when they are accounting for their own error, or the "incorrect" beliefs of colleagues and competitors.

Gilbert and Mulkay's analysis is useful for understanding the accounts produced by NIFTY participants to explain the disappointing results of the collaborative study. In my interviews with fetal cell investigators, they almost exclusively used the contingent repertoire. This would be predicted by Gilbert and Mulkay's model, as the results of the trial were not impressive. The only exception to this was, of course, the 41% of the times when a Y chromosome was detected and a male baby was born. Because the model predicted that the technique should detect Y chromosomes in 100% of the cases where boys were born, this was judged to be a collaborative failure. However, it is implied, in those 530

[54] Ibid., 56
[55] Ibid., 67-68.

cases out of 1292 when the expectation predicted by theory and the experimental result agreed, nature spoke for itself. In the other 762 cases, something social or technical got in the way.

In what follows, we will see examples of from interviews with the NIFTY participants in which they use the contingent repertoire to explain factors contributing to the poor results. Gilbert and Mulkay describe this strategy as "accounting for error": their interviewees used the discursive strategy in order to explain – or explain away – error. The apparent errors, they said, were a function of social factors. This reasoning functioned to protect the scientists' own credibility and theory choices, while calling into question their competitor's reputation or authority. The NIFTY collaborators were in a slightly different situation that the competitors that Gilbert and Mulkay interviewed. Like Gilbert & Mulkay's respondents, the NIFTY teams were in separate labs, and essentially competing to be the first to crack the fetal cell isolation problem. However, unlike Gilbert and Mulkay's scientists, the collaborative set-up of the trial (a condition of their funding) meant that their fates in this project were tied together, and that they established informal, and mostly friendly, relationships. Hence their accounts of error were not as oppositional as those that Gilbert and Mulkay describe. For example, the following interviewee mentions competition and mistrust, contingent factors, but he does not fall into an "us and them" pattern.

> Everyone had their own ideas and approaches. Not until the very end did it become more collaborative. I think it was more of a competitive collaboration early on in that everyone had their own ideas, trusted their own data, but didn't necessarily, I don't want to

> use the word "trust", but didn't see the reliability in others' data as much as in their own data. … they don't want to give away their goldmine if it's really going to work. [AG]

NIFTY participants tended to hedge a bit in describing reasons for error, treating collaborators with courtesy, accepting some portion of the responsibility for not communicating better, and in the end concluding that the project was just too complex for the methods at hand.

When asked to reflect on the success or failure of NIFTY, most interviewees expressed some disappointment. Most vacillated between accounts suggesting that the technique failed, and alternatively that the collaboration failed, and the two failures cannot easily be pulled apart. Almost every one of my interviewees spoke, at some point, about the disappointing results in terms of the difficulty inherent in the natural objects, or research materials. The rarity of fetal cells, and the inadequacy of the techniques featured in these accounts:

> We know that the fetal cells are there but they are very rare. So you've got to have a technology that can pick up one to five cells per milliliter of maternal blood. And flow-sorting and magnetic activated cell sorting, the commercially available technologies are not sensitive enough. [BB]

> And these cells were very very very rare. So exactly as you would visualize the needle in a haystack. This is what we had to deal with. [PT]

Fetal cells, it seems, are like the voice of nature: trickling through an obstacle course of social and technical impediments.

One recurrent theme that came up in interviews is that the gap between expectation and result, which doomed the study, was a result of its mis-description as a clinical trial. The rubric under which the work was generously funded – a "clinical trial" – was judged in retrospect to have been a poor description of what really went on: "So the study got termed a clinical trial which was probably not the best thing to do because everyone expected finalized clinical data and we were all really still doing a lot of R&D" [PT]. Another participant lamented that "It should never have been described as a clinical trial. It wasn't a clinical trial, it should have been described as an R&D, we always say 'study'. I think people went into it very blue-eyed, thinking we were going crack this" [GM]. The incorrect classification as a clinical trial, these participants feel, created inflated expectations. Hence, the disjuncture between expectation and a poor numerical result had material consequences for the field as a whole: "Those results could have been maybe a lot better and it is a bit frustrating from the perspective of the field that that paper is used as the conclusion, it's the end of the line. It's a shame" [TH].

This theme – that the trial was a failure because such a high profile group of scientists produced such a dismal aggregate success rate in the end – was recurrent in the interviews. For example, these two assessments both came from laboratory directors:

> What was embarrassing was that, you know, the government had spent over 17 million, I don't know the exact number, of dollars on this multicenter trial, and what did we have to show for it, were a

> few papers that gave this multi-center review and really it was hard to say that we had made a lot of progress. [PT]
>
> We were all hoping for a *NEJM* paper at the end of the study, and it finally got published in *Prenatal Diagnosis*. Which a lot of people who weren't involved in the study said this was probably the most expensive paper that has ever been published, it was several million dollars. [GM]

In making the best of a bad situation, some investigators told me that the trial was a mitigated success because the lack of rigid protocol, and the generous funding allowed them to follow up on side projects generated during the course of the trial. One respondent described this methodological capriciousness as a kind of opportunism: "Everybody is moving on to the next best thing, and the next newest idea… It's all driven by funding ultimately, and by what you can get out of it" [TH]. Several thought that this flexibility built into the NIH funding scheme allowed them to follow up on more promising leads than the disappointing fetal cells:

> So there's all of these sideline things that were developed because people had the ability to do them. It allowed us to, you know, the entire plasma DNA work was funded from NIFTY. We would not have gotten into that if we didn't have that money. In fact, they told us, don't stay fixed to one protocol, if it doesn't work, don't stick with it. [GM]
>
> Really the goal as the study progressed was to generate data and different ideas to get additional funding. So our approaches to microchimerism and DNA and RNA work and NIH grants that we've had have come directly from that funding. [AG]

According to some respondents, the "next best thing" approach may have prevented individual laboratories from sticking with a routine for long enough to attain satisfying results. While some labs were quick to focus on new areas altogether, most were tinkering with the methods for isolating fetal cells throughout the trial. One clinician told me "we went through all sorts of bead techniques and separations, you know big beads, little beads - different density gradients before and after. Issues relating to transport of the samples, do you analyze them immediately – do you wait?" [MR]

One investigator, in particular, was dismayed that the other laboratories in the study would neither stick to their own method for very long, nor switch at some point to the method (MACS) which seemed to be getting better results.

> I said "We've tinkered with a couple things – not that it seems to change – they're all bad. Maybe we just should try doing one thing and seeing if consistency slightly improves it." So we did that. And it did. We improved gradually just because the people doing it just were more consistent about what they were doing. [DI]

Of the participants, it was this investigator who was able, eventually, to obtain the most encouraging results. In the last 250 to 300 results of the trial, his lab was able to get 70-72% Y signals for male pregnancies. The methodological promiscuity of his collaborators, he figures, was due less to commercial interests than simply to the novelty of the task: "everybody wanted to do whatever it was that looked like it might be interesting so in case it worked, they wouldn't be left out" [DI].

While some investigators complained that other labs didn't stick to one method long enough to develop the tacit skills to make it work, another common assessment was that other labs were actually too attached to their own methods. As one interviewee told me: "This was a famous expression: 'Well in our hands, we can get it to do this'" [LY]. One researcher in the field who was not part of the collaboration commented: "each group obviously wanted to stick with their method because they thought their method was going to be the best method. And as a result the whole thing is very difficult to draw any conclusions from and it's actually quite amazing that they managed to produce a report at all" [TH].

A member of the data management company, whose job it was to enforce a common protocol, described her efforts to corral the individual labs:

> We did site visits. We needed to make sure that everyone was doing everything in a uniform manner. And even then they weren't. It's not their fault. And it's not the NIH's fault. It's that people, society, and NIH for political reasons, people wanted it to be better than it was. And it wasn't where it was. So what ended up happening is then you've got everybody kind of doing their own thing and not following protocol because they wanted to figure out a way that they could find the fetal cells. [LY]

This rationale, which includes both society and politics, obviously introduces contingent extra-scientific factors to explain why the trial was a disappointment. This speaker showed obvious frustration throughout the interview at the investigators' stubbornness. Yet she also vindicates them personally and points to people and politics as interfering with good

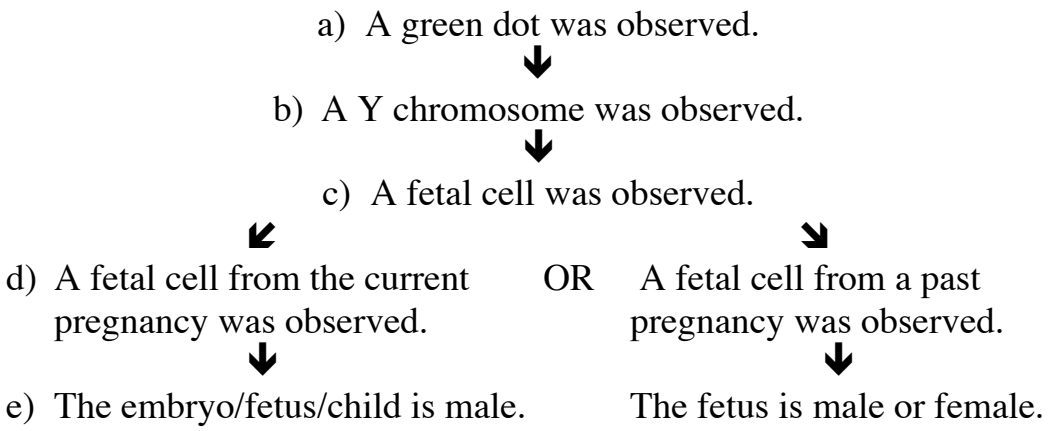
science. While speaking with these scientists, I was struck by the array of contingent explanations for the results that did not live up to expectations. No one, however, suggested that the model is wrong: maybe fetal cells are not there in many pregnancies, or maybe Y chromosomes do not, and should not, always match up to male pregnancies.

Why not Y? Breaks in the chain of inferences

Notably absent in these accounts is any mention of the potential fallibility of the Y chromosome as a tool for detecting fetal cells. In NIFTY, I think that this is partially because the magnitude of "error," if it can be called that, is so large. In other words, the roughly 60% of male pregnancies in which there was no Y signal, and the 11% of female pregnancies in which there was, can obviously not be accounted for just by variations from an XX/XY sex binary. We did occasionally see non-standard sex constitution as a possible reparative explanation for the "false" results when, in the early days of the technique, the sample sizes were much smaller. Nevertheless, I suggest that exceptions and outliers to this rule must account for some of the gap between expected and achieved results in the NIFTY trial.

In order to explore this possibility, I will return to Pinch's model of externality introduced earlier in the chapter. There, I described three potential observational reports, and alleged that fetal cell scientists usually jump to the most distal report in cases where the expected result is achieved, and slip back up the chain to retrospectively repair their "false" results. Because the possibility that fetal cells persist from prior

pregnancies was confirmed during the course of NIFTY, an observed fetal cell could either be from a past or a present pregnancy:



My purpose here is to enumerate those exceptions that violate an absolute adherence to the "binary rule of chromosomal sex."[56] This rule, on which the calibration equipment of almost fifty years of fetal cell research has relied, is thus: *female bodies contain only XX cells and male bodies contain only XY cells, unless a woman is pregnant with a son*. To caution the skeptic, this is admittedly an area of rarities, and my argument is therefore one based on the aggregate possibility that the chain of inferences doesn't hold, rather than relying on any one instance of biological or technological anomaly. Furthermore, the technology itself relies on rarities: one green dot, or one single cell, constitutes a positive result.

The last statement, "the fetus is male," is an inference, rather than an observational report. The accuracy of this inference is, of course, the way

[56] I can, of course, only mention those of which I am aware, though the corpus of biological knowledge is ever-changing.

that the investigators test the functioning of their technique. The observational report against which this inference is compared, in the case of NIFTY, is either a karyotype produced from amniocentesis or CVS, or the sexual anatomy of the child at birth. A break in this step – d) to e) – occurs when a fetal cell from the current pregnancy is truly observed, but the child is not "male." This could be the result of chimerism or mosaicism, in which the fetus has both XX and XY cell lines. If the fetal blood cells are XY, but the amniocytes (cells in the amniotic fluid, derived from the fetus) are XX, the amniocentesis would conflict with the fetal cell results. Additionally, if "girl" is the apparent birth outcome, but the fetal cells are actually XY, the child may have androgen insensitivity syndrome (AIS), where a chromosomal male is a phenotypic female because she is unable to respond to certain hormones, and thus is feminine in her secondary sex characteristics.

The major situation in which d) might not be true, but c) is would be where a fetal cell from a prior pregnancy is detected. This cell could be from a known male pregnancy, or from a termination or miscarriage. It could even be from a pregnancy that the woman was not aware she had because the demise of the embryo occurred so early. Male fetal cells could also be found in a woman who had only given birth to girl children. These cells could come from an XY vanished twin: "A vanished twin is thought to be a relatively common phenomena [sic] resulting from a spontaneous resorption of one sac or embryo in a twin pregnancy."[57] As

[57] Z. Yan and others, "Male Microchimerism in Women without Sons: Quantitative Assessment and Correlation with Pregnancy History," *The American Journal of Medicine* 118, no. 8 (Aug, 2005), 905.

the trial went on, investigators in NIFTY became aware of the potential for false positives from lingering fetal cells, and they attempted to control for it by targeting nucleated red blood cells (NRBCs) instead of white blood cells (lymphocytes). The former are believed to be present during pregnancy, but rapidly cleared after, while the latter can multiply and persist for decades.

The possible detection of a fetal cell from a prior pregnancy breaks the category "fetal cell" into two kinds: fetal cells past and fetal cells present. The object of the prenatal test is to render the former invisible, and to make the latter visible. Interesting ambiguities open up with respect to the categories "fetal cell," "mother," and "chimera." Any woman who has had a previous pregnancy, known or not, could be a chimera either because she was born a chimera or because she has been "chimerized" by prior pregnancies. Fetal cells past can be conceived of as part of the mother, as "her" cells, or they could be considered foreign. Female fetal cells are, of course, not considered at all. Their invisibility renders them part of the mother. The assumptions embedded in the experimental set-up include an imagined mother whose cell composition prior to the pregnancy was purely XX. When the experiment produces false positives or false negatives, the imagined mother can be readily adapted to accommodate prior pregnancies or chimerism. The point here is that, unless complicated genetic profiling is undertaken on individual cells (and it is most often not, particularly in large trials like NIFTY), the classification of results, and the ways in which those results are rationalized, allow numerous resources for retrospective repair work.

The link in the chain from b) "a Y cell was observed" to c) "a fetal cell was observed" requires that the positive identification of a Y chromosome is equivalent to the observation of a fetal cell. It is this link that is most susceptible to breaking as a result of non-conformity to the binary rule of chromosomal sex. The Y chromosome could come from the mother, but be unrelated to her pregnancy history. Small numbers of XY cells could have been introduced externally – via an organ transplant, a bone marrow transplant, or a blood transfusion, although this can usually be ruled out by a thorough medical history. If her cells were all XY because of AIS, for example, it is likely that she would be infertile, and therefore not likely to be in a prenatal testing clinic. However, it is possible that a small proportion of her cells would be XY. The mother may contain non-fetal Y-chromosomes if she is an XX/XY chimera or mosaic. Chimeric women with cell populations of both types can be fertile if their reproductive tissues are mostly or entirely XX. Also, she could be a blood chimera, having absorbed cells from her fraternal twin brother during gestation.

In a surprising recent study (post-NIFTY), Lee Nelson and her colleagues tested women who had never been pregnant to discern whether or not any Y-chromosomes could be found. No one had looked at this before, because of the powerful dogma that women "are" XX throughout, and that bodies are well contained and sealed off from each other. They found that "slightly more than one fifth of all women with no history of a male births had male microchimerism in their peripheral blood."[58] As sources,

[58] Yan, "Male Microchimerism," 905.

they suggest a nonrecognized (male) miscarriage, or a vanished twin, but they raised some other possibilities for this apparently normal phenomenon:

> A third possibility is from an older male sibling transferred by the maternal circulation to the fetus of a later pregnancy. Another possibility that has not been investigated is whether male DNA can be detected in a woman's circulation from sexual intercourse without pregnancy.[59]

These sources would yield very few XY cells, of course, but in the fetal cell studies, a single cell sighting was coded as a positive result.

As mentioned previously, a Y chromosome could come from a contaminating source during the laboratory work. As we saw, experimenters attempted to control for this by excluding males from the laboratory space. This precaution, however, relies on the assumption that we can tell what chromosomes a technician contains just by looking at her. A woman may, however, have only XY cells if, for example, she is transgendered, or if she has an intersex condition like AIS. In these cases, she may not wish to disclose this information because of the potential for stigma. Alternatively, she may have some proportion of XY cells for the reasons mentioned above in relation to the mother: she could be a chimera or a sex chromosome mosaic; she may have had an organ transplant, a blood transfusion; she may be pregnant, or she may have previously had sons, or an abortion or a miscarriage.

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[59] Ibid.

Moving up the chain, the last link is that between a Y chromosome and a green dot. While these could be caused by non-specific binding to the Y, or by visual artifacts, these have little to do with the sex chromosome binary. However, one of my interviewees described a situation in which a green dot would not be equivalent to a whole Y chromosome: "Some women will actually carry a Y, will have parts of their X chromosome which Y bits have translocated onto, so you've got to be kind of careful that you use the right signal, that you go for the right sequence" [TH]. In other words, the probe may have correctly identified part of a Y chromosome, but it might come from a female – the mother, the fetus or the technician.

Notably, none of these threats to the chain of inferences connecting green dots to fetal cells would be disputed, in principle, by the investigators in NIFTY. When I asked one PI about sex chromosome abnormalities, he replied: "Yes, you could have a fetus that had a chromosome abnormality but the majority of the blood samples you would get would be from normal pregnancies" [DI]. Their lack of concern about rarities, exceptions and outliers is a pragmatic matter; the Y is "good enough" for getting results published, and it is a good enough detector of whether or not the system can work. This may well be true, depending on the purpose of the test. In fetal cell research, the Y has been good enough for proof of concept in small-scale experimental settings, but not good enough for the certainty required of a clinical test in a hospital. The resilient expectation that the Y chromosome is the right tool for the job – in the face of evidence to the contrary – hints at a deep cultural commitment to the intransigence of a binary order of sex.

Sex and gender

Joan Scott traces the surprisingly recent history of "gender" as a word and as a concept.[60] Its use, in feminist circles at least is intended to emphasize the cultural, relational and fluid aspects of social distinctions based on sex. Sex, on the other hand, usually refers to the biological differences - chromosomal, hormonal and anatomical - that allegedly separate men and women in some way not reducible to culture. However numerous feminist biologists and critical theorists, such as Nelly Oudshoorn, Anne Fausto-Sterling, and Ruth Bleier have historicized and contextualized a number of presumably biological categories, showing them to be culturally mediated.[61] As Judith Butler writes, "what is 'sex' anyway? Is it natural, anatomical, chromosomal, or hormonal, and how is a feminist critic to assess the scientific discourses which purport to establish such 'facts' for us?" One strategy feminists have used for undermining sex (and the apparently natural gendered characteristics that flow from it), is to point out biological variability:

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[60] Joan W. Scott, "Gender: A Useful Category of Historical Analysis," *American Historical Review* 91, no. 5 (1986), 1053-1075.

[61] See especially Ruth Bleier, *Science and Gender: A Critique of Biology and its Theories on Women* (New York: Pergamon Press, 1984); Sandra G. Harding, *The Science Question in Feminism* (Ithaca: Cornell University Press, 1986); Nelly Oudshoorn, *Beyond the Natural Body: An Archaeology of Sex Hormones* (New York: Routledge, 1994); Donna Jeanne Haraway, *Simians, Cyborgs, and Women*; Anne Fausto-Sterling, *Sexing the Body*; Anne Fausto-Sterling, *Myths of Gender: Biological Theories about Women and Men*, 2nd ed. (New York, NY: BasicBooks, 1992).

> Biologists and medical scientists recognize, of course, that absolute dimorphism is a Platonic ideal not actually achieved in the natural world. Nonetheless, the normative nature of medical science uses as an assumption, the proposition that for each sex there is a single, correct developmental pathway. Medical scientists, therefore, define as abnormal any deviation from bimodally distributed genitalia or chromosomal composition.[62]

Both chimerism and fetal cells in women contribute to this project because they call into question the dogma that people are genetically homogeneous, an assumption that has prevailed even among feminist critics. Indeed, because it would take an inventory of every cell in a body to demonstrate chromosomal purity – an impossible task – *we don't know that anyone is genetically homogenous.*

The assumption that seeing a single Y chromosome in a pregnant woman means that she is carrying a male baby reproduces and reifies the binary economy of chromosomal sex. Ironically, though, it can be re-read as a fundamental challenge to the stability of this tenet. Quite simply, if women's bodies contain Y-chromosomes – because they are or have been pregnant with Y bearing fetuses, or because they have a more diverse chromosomal arrangement than the binary model allows – then the presence of a Y chromosome can no longer mark a body as male. The chromosomal dichotomy breaks down.

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[62] M. Blackless and others, "How Sexually Dimorphic are we? Review and Synthesis," *American Journal of Human Biology : The Official Journal of the Human Biology Council* 12, no. 2 (Mar, 2000), 151.

The inscription of a Y chromosome as a band on an autoradiograph, in the presence of only "female" bodies - the mother, the fetus, the technician - is called a "false positive". Rather than suggesting that it might indicate a true Y chromosome, it is taken to be confirming evidence of the sporadic contamination – by traces of a so-called "male" body - during PCR preparation. The externality of the report is moved back one notch by saying that a Y chromosome was indeed observed, but it was from a male other than the fetus. Contamination is a catch-all for the unexpected in this procedure and it functions to assume, create, and reify binary categories of chromosomal sex. Hypothetically taken to its extreme, discipline of laboratory technicians in the name of anti-contamination readily devolves into absurdity, and comes to seem more of a ritual than a precaution.[63] Women technicians could be prevented from bodily contact with men, for fear that they would carry unwanted cells on their skin or clothing. From this very technology, we have learned that pregnant women can carry Y chromosomes, even in skin rashes likely to flake. As a precaution, pregnant technicians could be barred from this practice, or at least have to undergo prenatal sex determination themselves to make sure that they are carrying females.

My contention is that regulation of lab technicians by their biological attributes is a peculiar practice. It happens here, I suggest, for two simple reasons, both of convenience. First, just as searching for the Y

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[63] For a discussion of the role of ritual in the laboratory, see Michael E. Lynch, "Sacrifice and the Transformation of the Animal Body into a Scientific Object: Laboratory Culture and Ritual Practice in the Neurosciences," *Social Studies of Science* 18, no. 2 (May, 1988), 265-289.

chromosome seemed an obvious place for investigators to start, mandating that technicians be female seemed an obvious precaution. Dividing the world into binary categories of male and female is something we are all accustomed to; it doesn't (seem to) take a complicated vetting process. Of course this assumption excludes or renders invisible anyone who has a non-standard chromosome/gender relationship because of a chromosome abnormality, or mixed XX/XY chromosomes.

The second reason for this apparent precaution is that most cytogenetic laboratory technicians are female anyway. As one of my interviewees described, "We're just a group of women here who tend to keep working in this lab" [PT]. Rayna Rapp suggests that most personnel in cytogenetics labs are women because laboratory work is a service sector which has regularized hours and low pay – hallmarks of 'women's work.'[64] In fetal cell isolation, the appearance of female technicians as an innocent technological precaution based on sex - or on not sloughing off Y chromosomes every time they turn around - encodes a gendered segregation of labor present in the lab anyway.

The Baby Gender Mentor

Finally, I offer the story of the Baby Gender Mentor as a confirmatory postscript to my arguments in this chapter. In the summer of 2005, a small private lab called Acu-Gen Biolab, Inc., based in Lowell Massachusetts, introduced onto the market a kit called "The Baby Gender Mentor" (figure 4). The kit is offered direct-to-consumers over the

[64] Rayna Rapp, *Testing Women, Testing the Fetus,* 199-200.

internet. Designed for "the type of woman who can't wait to open Christmas presents,"[65] it purports to identify the "gender" (technically, the sex) of a baby as early as five weeks gestation, with a 99.9% success rate, and a 200% money-back guarantee. The test requires a woman to prick her finger, dab a few spots of blood on a special paper, and mail it to the Acu-gen lab. This test must be done in the absence of males in order to prevent contamination (figure 5). Within 24 hours, she can log on to their website, enter her special code, and discover the gender of her baby.

Figure 4: the Baby Gender Mentor kit (photo: A. Martin)

[65] Sherry Bonelli, the test's marketer, quoted in Carey Goldberg, "Test Reveals Gender Early in Pregnancy," *Boston Globe,* June 27, 2005.

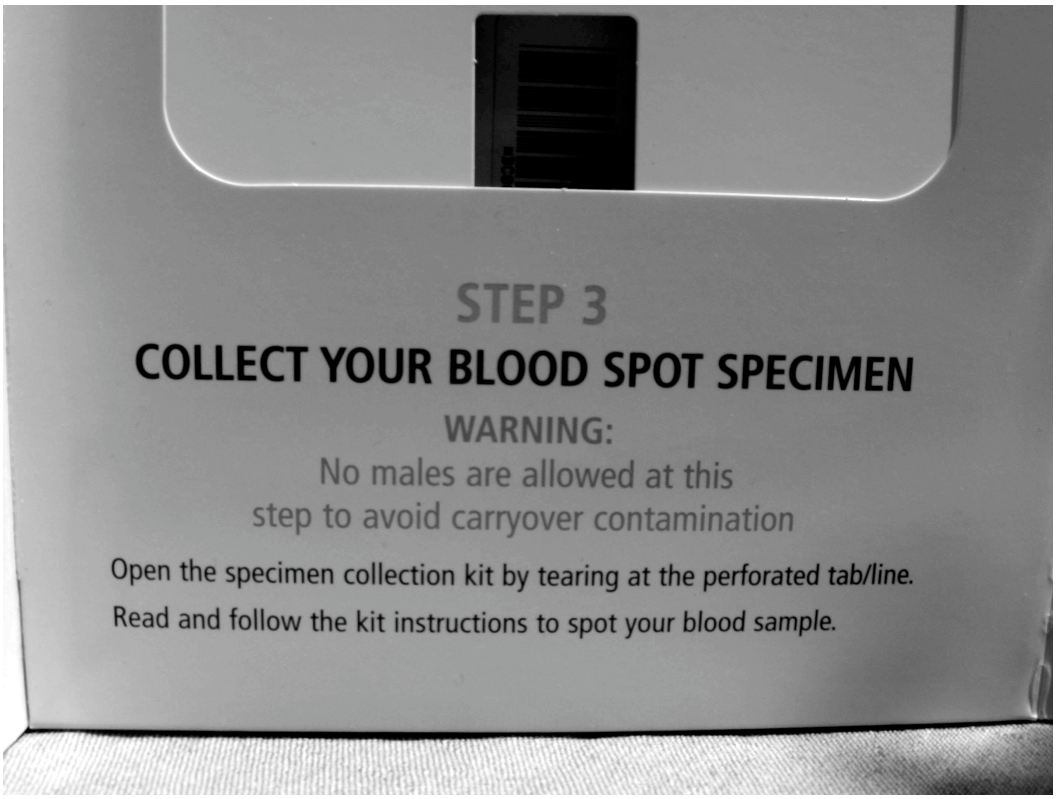

Figure 5: No boys allowed (photo: A. Martin)

I suggest that the BGM is an illegitimate child of the fetal cell research trajectory because it apparently uses cell-free fetal DNA – the presence or absence of bits of Y-chromosomes – to detect sex. I say "illegitimate child," because while the NIFTY scientists are uninvolved with the kit, the "science behind facts" page of the website contains a long list of publications, many of which are by NIFTY participants, and arose from NIH funded research.[66] I say "apparently" because the company is very secretive about its method, and it has not published any evidence of the protocol or accuracy of the technique. The fetal cell investigators, from whom I learned about the kit, are angry both because the test probably

[66] http://babygendermentor.com/information.php?information_id=3, accessed April 3, 2006.

violates their patents, and because they believe it cannot possibly be 99.9% accurate at 5 weeks. Ethicists are worried about the kit because of its potential use for unsanctioned gender-selective abortion (an issue, incidentally, that fetal cell researchers up to now have been laudably sensitive and prohibitive about).

The Baby Gender Mentor, cheerily plugged on *The Today Show,* in newspapers and in women's magazines, was an instant hit with thousands of women, who forked out the steep fee "just for fun." Its heyday was short-lived, though. In its approximately nine months (!) on the market, the kit has become mired in bad publicity and controversy, including, most recently, a class action law suit. Consumers are disgruntled for many reasons, not the least of which is that many women are delivering babies who are the wrong sex. When these women have confronted the company with their false results, they have been told a familiar story. These are posts from a website that is tallying women's complaints:

> EternalSunshine: Acu-Gen tested 4 times (inconclusive, boy, girl, boy). Claims that mother is "chimeric" and has different DNA in blood in "left and right hand". No refund.[67]
>
> MikeysMom: Acu-Gen retested original sample, still came back boy. After her baby girl was born, the mother sent a valid birth certificate requesting a refund, but Acu-Gen requested a blood sample or fingerprints from her baby. Dr. Wang informed the mother she should be very concerned because her baby is not

[67] http://www.in-gender.com/cs/forums/1001/ShowPost.aspx, accessed April 3, 2006.

> genetically female and should be checked to see if she has a uterus or ovaries.[68]

The company's president, Dr. Wang, is apparently relying on presumptive chromosomal anomalies to repair problematic results, and circumvent the 200% money-back guarantee. The possibility of something other than an unequivocal boy or girl result is not mentioned anywhere in the test's literature. Wang, maintaining his claim that the lab does not make mistakes, comments that the test, in practice, has revealed "the inevitable complexity of nature."[69] Nature is not so complex, though, that he has adjusted his 99.9% guarantee. In an ABC News inquiry, the narrator skeptically reports that "For every specific case Linda asked about, Wang had an excuse like embryo fusion or vanishing twins."[70] For verification, the reporter asks expert Diana Bianchi. She replies: "Embryo fusion does exist. Vanishing twins do exist. But they are both very, very rare phenomenon. So I don't think they'd be a common explanation for any discrepancy in the results."[71]

Time will tell whether the Baby Gender Mentor will be judged as a "good enough" tool for parents to decide what color to paint the nursery. In the discourse about the controversy, however, I have not seen a single person question the desire that fuels the marketability of this clearly opportunistic technology. The desire "to know" is based on a commitment to binary

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[68] Ibid.
[69] Carey Goldberg, "Gender Test's Accuracy is Questioned," *Boston Globe,* October 17, 2005.
[70] "Baby gender test leads to great concern for some mothers-to-be," *ABC Action News*, Tampa, FLA, Aired February 20, 2006.
[71] Ibid.

gendered ideals (or else why would it matter?). The premise of the lawsuit is that the test has caused women, whom their own lawyer calls "a vulnerable group, or at least an emotional group,"[72] undue heartbreak. They seek compensation for "the wrenching flip-flop from expectations of one gender to the other, made especially painful for some by the sudden dawning of fears that perhaps the gender confusion meant something was wrong with the baby."[73]

These comments seem resoundingly to confirm Butler's claim that "the mark of gender appears to 'qualify' bodies as human bodies; the moment in which an infant becomes humanized is when the question 'is it a boy or girl?' is answered. Those bodily figures who do not fit into either gender fall outside the human… ."[74] This moment of gendering is happening earlier and earlier. As a consolation, I enjoy some subversive pleasure from imagining the "surprise" babies whose wrong-colored nursery and queer apparel may open up to them some new possibilities for being.

Conclusion

In the case of the Baby Gender Mentor, Dr. Wang and Acu-gen are using the putative and unproveable occurrence of chimerism to repair their results (and avoid giving customers their money back). Simultaneously, they are using the label "chimera" to repair the assumption that "normally" XX=female and XY=male. Any exception, by virtue of being

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[72] Barry Gainey, quoted in Carey Goldberg, "Lowell Firm is Sued on Fetal Gender Test," March 1, 2006.
[73] Goldberg, *Gender Test's Accuracy is Questioned.*
[74] Judith Butler, *Gender Trouble*, 111.

labeled an exception, reifies the norm. Because of their secrecy, we do not know precisely what the personnel at Acu-gen observe before they make the observational report "male" or "female." We do know that when challenged, the company admits a break in the chain of inferences, however it does so in a way that individualizes the mistake, and protects the integrity of the technique. The "error," they imply, is not in the technique, but in the individual body of either the woman or the baby. This potential for variation in the cellular content of bodies is a useful rhetorical resource for researchers to repair their findings or their techniques in the short-run. If we take a longer view of the field, this very same variation – the fundamental instability of sex – seems to doom the project to failure.

CHAPTER 3:

FOREIGN CELLS IN THE MOTHER(LAND): THE LANGUAGE AND PRACTICE OF FETAL MICROCHIMERISM RESEARCH

> My point of departure is that nationality, or, as one might prefer to put it in view of that word's multiple significations, nation-ness, as well as nationalism, are cultural artifacts of a particular kind. To understand them properly we need to consider carefully how they have come into historical being, in what ways their meanings have changed over time, and why, today, they command such profound emotional legitimacy.
>
> ---Benedict Anderson, *Imagined Communities*[1]

Introduction

Barbara Duden employs a historicism that is similar to Anderson's in her account of how the fetus came to be a "modern certainty."[2] She describes her task as one of showing "*historically* that the human fetus, as conceptualized today, is not a creature of God or a natural fact, but an engineered construct of modern society."[3] Anderson's and Duden's arguments are compelling because they begin with objects – nation and fetus – whose existence is now widely taken for granted. Neither is visible to the naked eye; they are made visible with maps and sonograms. Both are entities that, in contemporary America, have a seeming concreteness that commands fierce protection and emotional and political

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[1] Benedict R. O'G Anderson, *Imagined Communities: Reflections on the Origin and Spread of Nationalism*, Rev. and extend ed. (New York: Verso, 1991), 4.
[2] Barbara Duden, *Disembodying Women: Perspectives on Pregnancy and the Unborn* (Cambridge, Mass.: Harvard University Press, 1993).
[3] Ibid. 4.

investment, at least to some portion of the political spectrum. And both, we learn from Anderson's and Duden's skillful accounts, are relatively new. In the 18th Century, a man had a God and a King, but he did not have a nation. A woman had a stagnation, a fruit that may or may not emerge as a child; she did not have a fetus. My project is not historical on the same scale as Anderson's and Duden's, but it has grown from the same kind of sensibility about the emergence of objects. And it concerns a strange and recent convergence of their objects of study. In this chapter I ask: how did the fetus come to be a nation?

In the past decade, several researchers in a handful of laboratories have been characterizing a phenomenon that they call "bidirectional cell trafficking" between fetal and maternal bodies. This research trajectory grew directly out of attempts to use fetal cells in pregnant women's blood as an instrument for prenatal screening (see chapter 2). The empirical material for this chapter begins in 1996 with the first definitive evidence that fetal cells can be found in women's bodies long after the pregnancy is over. The technical term for this phenomenon is "microchimerism"; like chimerism, except the second population of cells is very small in proportion to the major population.

In both the spoken and written technical discourse of the community of (mostly American) microchimerism researchers, metaphors that liken cells to human migrants are ubiquitous. Fetal cells "traffic" into the maternal body, "migrate" to particular organs and "repopulate" them. Sociologist John Torpey writes "rather than ignoring the role of states, studies of immigration policies take them as given and thus fail to see the

ways in which regulation of movement contributes to constituting the very 'state-ness' of states."[4] Similarly, I suggest that trafficking and other geopolitical metaphors in fetal cell research both assume and contribute to the state-ness of bodies. While geopolitical metaphors are not the only set of tropes employed by researchers in this field, I was struck during the course of my research by their prominence.

This story bears out the proposition – suggested by Emily Martin,[5] Evelyn Fox Keller[6] and others – that the ways in which scientists speak and write about the objects they study is embedded in metaphors available from sociocultural frames that are specific to times and places. Keller writes:

> Some of the force of descriptive statements … derives from the role of metaphor in constituting similarity and difference, in defining the "family resemblances" that form the bases on which we categorize natural phenomena and in motivating the performance of particular experiments or the construction of particular technical devices.[7]

Nowhere, but in the late 20th or early 21st Century Anglo-America would cells be trafficking, migrating and repopulating organs, because these are contemporary preoccupations. The question then becomes: Would cells

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[4] John Torpey, "Coming and Going: On the State Monopolization of the Legitimate 'Means of Movement,'" *Sociological Theory* 16, no. 3 (Nov, 1998), 240.

[5] Emily Martin, *The Woman in the Body: A Cultural Analysis of Reproduction* (Boston, Mass.: Beacon Press, 1987), 276; Emily Martin, *Flexible Bodies*.

[6] Evelyn Fox Keller, *Refiguring Life,* 134.; Evelyn Fox Keller, *Secrets of Life, Secrets of Death*, 195.

[7] Evelyn Fox Keller, *Refiguring Life,* xi.

be doing the same things if they were described in different ways? Fetal cell microchimerism is a particularly good phenomenon for showing that the ways in which scientists talk about objects *matters* for the research trajectory and for the ontology of those objects. This chapter begins with a detailed history of the past decade of research in fetal microchimerism, with special attention to the discourse of the field. Later in the chapter, I discuss how language itself traffics in and out of the laboratory to configure and reconfigure identities and ontologies of cells, fetuses and women.

Fetal cell voyages, 1996-2006

Cellular invasions

The presence of fetal cells in women's blood during pregnancy was first noticed over a century ago. Since the late 1960's, a number of persistent groups have tried to recover fetal cells from maternal blood, so that they can be used for prenatal genetic testing (see chapter 2). The "holy grail," as some of them call it, would be a technique for analyzing fetal chromosomes by using only a blood sample from the mother. This would be a less risky, less expensive (and therefore lucrative), earlier and more widely available test than amniocentesis or Chorionic Villus Sampling (CVS), the current options for definitive prenatal diagnosis. Since the beginning of this quest, "fetal cells" have been interchangeably defined by their proxy: cells bearing a Y chromosome, found in a woman who is or was pregnant. In chapter 2, I covered the story of fetal cells, prenatal testing, and misplaced faith in the Y chromosome.

In this chapter, I pick up the story in 1993, at a conference entitled "Fetal Cells in Maternal Blood: Prospects for Noninvasive Prenatal Diagnosis." The conference was in Arlington Virginia, and funded primarily by the NIH, though support also came from the March of Dimes and several genetics corporations. The proceedings from the conference suggest that the driving impetus for the conference was to bring a fetal cell technique to clinical utility and to the market.[8] At the conference, several disparate groups, mostly from the US, but also from Switzerland and the UK, congealed into a field of research. Other invited participants, who were tangentially allied to the core set and have not persisted as key players, included anatomists, immunologists, ethicists and some representatives from the private sector.

I suggest that during the conference two important shifts occurred in the landscape of fetal cell research. The first is that the community of fetal cell researchers was introduced to a new set of metaphors. Prior to this, fetal cells existed entirely as instrumental objects (or would-be instruments for prenatal diagnosis). Things were done to them (they were sorted, separated, isolated, probed, purified), but they didn't do things. When a verb was used in conjunction with their apparent presence in a pregnant woman's blood, it was generally a fairly passive verb: they *passed* across the placental barrier, or they *were transferred* to maternal blood.

[8] Joe Leigh Simpson and Sherman Elias (eds.) *Fetal Cells in Maternal Blood : Prospects for Noninvasive Prenatal Diagnosis*.

At the conference, Kurt Benirschke, an anatomist from outside the core group of fetal cell scientists, described how fetal cells establish contact with the maternal tissues. These cells "invade" and "attach" to the placental floor, and are involved in "cell traffic … between fetus and mother."[9] Other contributors, Beer et al., introduced the notion that the fetus is immunologically comparable to a transplanted organ. Their article begins with the statement that "in any graft-host relationship" there are different ways in which "the host may become aware of foreign solid tissue."[10] They go one to describe that the placenta, "a frontier of immense proportions,"[11] orchestrates many functions including "deportation of living cells into the mother."[12] Like Benirschke, Beer et al. describe fetal cells invading maternal tissues, and refer to fetal cell trafficking, across the placental "barrier".

Thus these nationalistic metaphors – now accepted as the technical language of the field – had a historical beginning in the fetal cell community. It seems plausible that, in a manner akin to Ian Hacking's notion of "semantic contagion,"[13] the language of cell traffic, invasion and

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[9] Kurt Benirschke, "Anatomical Relationship between Fetus and Mother" in *Fetal Cells in Maternal Blood: Prospects for Noninvasive Prenatal Diagnosis*, eds. Joe Leigh Simpson and Sherman Elias, Vol. 731 (New York: New York Academy of Sciences, 1994), 11.
[10] Alan E. Beer, Joanne Y. H. Kwak and Jaime E. Ruiz, "The Biological Basis of Passage of Fetal Cellular Material into the Maternal Circulation" in *Fetal Cells in Maternal Blood: Prospects for Noninvasive Prenatal Diagnosis*, eds. Joe Leigh Simpson and Sherman Elias, Vol. 731 (New York: New York Academy of Sciences, 1994), 21.
[11] Ibid.
[12] Ibid.
[13] Ian Hacking, *Rewriting the Soul,* 336.

the foreign-ness of fetal cells entered the lexicon of the core group of fetal cell researchers at or around the time of the 1993 conference. The vision that they uphold – that organisms are pure collections of immunologically cognizant cells, capable of distinguishing self from other – long pre-dated this discursive contagion.[14] Consequently, I am not suggesting that the package of metaphors I am tracing is *causal* of research theories and practices *per se*. Rather, as Max Black argues in his explication of metaphors as interactive: "The metaphor selects, emphasizes, suppresses, and organizes features of the principal subject by implying statements about it that normally apply to the subsidiary subject."[15] The principal subject in this case would be the cell out of its proper place, and the subsidiary subject would be a traveler between countries. The metaphor *makes sense* to its users because the same relations of self and other seem to apply to both subjects. This makes sense, in turn, because they have been accustomed to thinking, speaking and writing about the two scenarios in the same language.

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[14] The description of immunology as the relation of self and other was introduced by Sir Frank Macfarlane Burnet in 1949. For a thorough history of the self as a central concept in immunology, see Alfred I. Tauber, *The Immune Self: Theory or Metaphor*(Cambridge: Cambridge University Press, 1994). This history of the self in immunology is brought up to date by Tauber in "The Biological Notion of Self and Non-self", *The Stanford Encyclopedia of Philosophy* (Spring 2006 Edition), Edward N. Zalta (ed.),<http://plato.stanford.edu/archives/spr2006/entries/biology-self/>.

[15] Max Black, *Models and Metaphors; Studies in Language and Philosophy* (Ithaca, N. Y.: Cornell University Press, 1962), 44-45.

Cellular residency

A second turning point in the field, also foreshadowed at the 1993 conference, rendered fetal cells less like incidental byproducts of pregnancy and more like immigrants. Diana Bianchi, a central player in fetal cell research for more than twenty years, presented evidence from a study of eight women who were not pregnant, but who had delivered male infants between 6 and 27 years earlier.[16] The non-pregnant women had been included in the study as controls against which to compare women who were carrying male fetuses. Much to their surprise, the Bianchi lab found that most of these non-pregnant women were positive for male DNA. They report: "The fact that women might become permanent low-grade chimeras after pregnancy is a surprising observation that needs validation and extension by other investigators."[17] Bianchi described her reaction to these unexpected results:

> You know, really, it was a disappointment to us to find out that fetal cells circulated from prior pregnancies, because we were focused on isolating fetal cells from the current pregnancy, and we were using … the stem cell antigen, thinking that fetal cells would preferentially have this antigen and it would be a good marker to pull out fetal cells for non-invasive genetic diagnosis. So at first when we found out that it pulled out cells from a prior pregnancy, we were very upset.

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[16] Diana W. Bianchi, "Clinical Trials and Experience: Boston" in *Fetal Cells in Maternal Blood: Prospects for Noninvasive Prenatal Diagnosis*, eds. Joe Leigh Simpson and Sherman Elias, Vol. 731 (New York: New York Academy of Sciences, 1994), 92-102.
[17] Ibid, 95.

While Bianchi and her lab presented these findings in 1993, the paper was rejected three times in her attempt to get it published. The resistance, she says, was because the findings "challenged a lot of paradigms":

> I think it just was, people just, it wasn't that they had concerns about the technical aspects, it was just the idea. Why weren't these cells rejected? It didn't make sense to them, you know, it was counter-intuitive that a foreign cell would live in somebody for that long.

Another member of the Bianchi lab described the resistance in similar terms: "And why would a cell not be eventually destroyed. Eventually a foreign cell should be, or bacterial cell, should eventually be killed off after 27 years" [AG]. Note that both of these descriptions use the word "foreign" and imply that, in keeping with the premises of immunology, one would expect a hostile reception for cells outside of their proper self.[18]

The full article was finally published in 1996 in the *Proceedings of the National Academy of Sciences USA*.[19] It has since become Bianchi's most cited publication, and somewhat of a touchstone in the field. This article is the first to use the term "microchimerism" to characterize the presence, in humans, of fetal cells in maternal bodies. Bianchi cites Liegeois, a mouse

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[18] On military metaphors in immunology, see especially Martin, *Flexible Bodies: Tracking Immunity in American Culture from the Days of Polio to the Age of AIDS*, 320.

[19] D. W. Bianchi and others, "Male Fetal Progenitor Cells Persist in Maternal Blood for as Long as 27 Years Postpartum," *Proceedings of the National Academy of Sciences of the United States of America* 93, no. 2 (January 23, 1996), 705-708.

researcher from Paris, who coined the phrase in 1977.[20] Aside from Liegeois, transplantation researchers were the only others to use the term "microchimerism," beginning in 1992. This connection between fetal cell research and organ transplantation is more than incidental. One researcher told me: "Because the fetus essentially is a foreign antibody, or antigen, whatever you want to call it. It's a foreign thing that's … you've got to consider it an organ transplant. You know, it's there, it can do all these, it's like a little entity on it's own" [JM]. Thomas Starzl, a renowned transplant surgeon from Pittsburgh, referred to chimerism and microchimerism to describe cells from the donor that circulate in the recipient's body after organ transplants. Starzl championed (and continues to promote) the idea that microchimerism prevents the organ recipient from rejecting the organ and therefore should be strategically encouraged in patients.[21]

Notably, the discussion in Bianchi's 1996 paper is the first to make an explicit link between the maternal/fetal relationship and that between an organ recipient and the donated organ. In Bianchi's analogy:

> It is tempting to hypothesize that *active cellular traffic* across the placenta early in gestation is important and perhaps necessary in inducing tolerance to the human fetus. … Starzl and his coworkers

[20] A. Liegeois and others, "Microchimerism: a stable state of low-ratio proliferation of allogeneic bone marrow," *Transplant.Proc.,* 1977, 9, no. 1, 273-276.

[21] T. E. Starzl, "Chimerism and Tolerance in Transplantation," *Proceedings of the National Academy of Sciences of the United States of America* 101 Suppl 2 (Oct 5, 2004), 14607-14614.; T. E. Starzl and others, "Cell Migration, Chimerism, and Graft Acceptance," *Lancet* 339, no. 8809 (Jun 27, 1992), 1579-1582.

> have demonstrated chimerism resulting from widespread seeding of donor cells that emanate from whole organs being transplanted. … They have postulated that *bidirectional cell migration and repopulation* is the first step in the acquisition of donor-specific tolerance, and, ultimately, successful graft acceptance. The human pregnancy may also benefit from similar *one-way or even two-way traffic*.[22]

This passage is, as far as I can tell, the first adoption of the language of migration in any publication by researchers in the fetal cell community. Dennis Lo followed up Bianchi's article with a paper titled "two-way cell traffic between mother and fetus," also in 1996.[23] From this point on, "trafficking" becomes the standard technical descriptor for movement of cells between mother and fetus, especially when those cells are found to persist after pregnancy, miscarriage or termination. It is used in formal technical and popular publications, and it is how researchers describe the phenomenon in interviews: "so few trafficked over that all the procedures to try and find them reduced them even more" [TH]. And so, by the end of the conference, or at least by the time that Bianchi's results had been accepted as valid, fetal cell researchers had a new, more active, language to describe fetal cell movement, and they had a new, promising, research problem: What were these cells "doing" in women?

Cellular insurgency

Around this time, Lee Nelson, a rheumatologist in Seattle, and Carol Artlett, an immunologist in Philadelphia, independently became interested

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[22] Bianchi and others, *Male Fetal Progenitor Cells Persist in Maternal Blood for as Long as 27 Years Postpartum*, 707-708 [emphasis mine].
[23] Y.M. Lo and others, "Two-way cell traffic between mother and fetus: biologic and clinical implications," *Blood*, 1996, 88, no.11, 4390-4395.

in fetal cell microchimerism. Nelson published a theoretical piece in *Arthritis and Rheumatism* proposing that, since women have a significantly higher incidence of autoimmune diseases than do men, and since they tend to occur after women's childbearing years, maybe persistent fetal cells are causing diseases in women.[24] She described to me the genesis of this idea:

> I work in a transplant center where colleagues are often talking about graft-vs.-host disease…One colleague shared my interest in fetal-maternal cell exchange during pregnancy as he thought it might influence transplantation success. I asked him if it was known how long it takes fetal cells to disappear from the mother's circulation after pregnancy. One day he called me up and said he had talked with another colleague who studied fetal cells in the mother's blood, that they had tested one of their technicians and found fetal cells were still there are year after delivery. When he told me this it was like the lights went on. I thought - scleroderma looks like graft-vs-host disease, it occurs more in women and usually after childbearing years (by 5-15 years), the fetal cells persist, maybe the foreign fetal cells play a role in scleroderma. Later I talked with the researcher who had studied the technician and he told me that Diana Bianchi had a similar finding and sent me an abstract she'd presented - at that time she hadn't yet published a paper.

Like Nelson, Artlett told me that her research direction was stimulated both by Bianchi's findings, and by an analogy to transplantation immunology:

> See scleroderma is very much like a graft vs. host disease. It has similarities; it doesn't mean that it is graft-vs.-host disease. But our

[24] J. L. Nelson, "Maternal-Fetal Immunology and Autoimmune Disease: Is some Autoimmune Disease Auto-Alloimmune Or Allo-Autoimmune?" *Arthritis and Rheumatism* 39, no. 2 (Feb, 1996), 191-194.

> assumption was that it looked so similar to it, lets go and look for a foreign cell population and see if fetal cells, those fetal cells are actually in the lesions.

How would one look for fetal cells in women's tissues? The techniques for finding Y-containing cells – already accepted as proxies for fetal cells – were readily adopted from prenatal testing labs, including Bianchi's.[25] Both the Nelson lab and the Artlett lab immediately went to work to find Y-containing cells in women with scleroderma, a fatal autoimmune disease, who also had given birth to sons. And they found them, in the blood, kidney, lungs and skin of women with the disease.[26]

Following a spate of publications associating fetal microchimerism with scleroderma, the main research groups, as well as new ones, began looking for, and in most cases finding, fetal cells in a range of other autoimmune disorders. These included skin rashes common during pregnancy,[27] autoimmune liver disease,[28] autoimmune thyroid disease[29]

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[25] See Chapter 2 for a description of PCR and FISH, the main techniques for finding Y chromosomes.

[26] See, for example, J. L. Nelson and others, "Microchimerism and HLA-Compatible Relationships of Pregnancy in Scleroderma," *Lancet* 351, no. 9102 (Feb 21, 1998), 559-562; J. L. Nelson, "Microchimerism and the Pathogenesis of Systemic Sclerosis," *Current Opinion in Rheumatology* 10, no. 6 (Nov, 1998), 564-571; S. E. Kaal and others, "Systemic Sclerosis: New Insights in Autoimmunity," *Proceedings of the Society for Experimental Biology and Medicine. Society for Experimental Biology and Medicine* 222, no. 1 (Oct, 1999), 1-8; C. M. Artlett, J. B. Smith and S. A. Jimenez, "New Perspectives on the Etiology of Systemic Sclerosis," *Molecular Medicine Today* 5, no. 2 (Feb, 1999), 74-78.

[27] S. Aractingi and others, "Fetal DNA in Skin of Polymorphic Eruptions of Pregnancy," *Lancet* 352, no. 9144 (Dec 12, 1998), 1898-1901.

and lupus[30]. By 2000, evidence of the presence of male cells in women with diseases was mounting and the "bad fetal cell" hypothesis was gaining momentum. The primary labs were publishing reviews and opinion pieces in prestigious journals,[31] and disease support groups were funding microchimerism research and inviting speakers to their meetings.

This was a remarkably prolific publishing period for the three key labs (Artlett, Bianchi, Nelson) and it has all the hallmarks of what sociologist of science Joan Fujimura calls a "doable" research problem: a standardized and relatively easy technique that graduate students and postdocs can use, a relatively short experimental time frame, and the

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[28] For example: P. Invernizzi and others, "Blood Fetal Microchimerism in Primary Biliary Cirrhosis," *Clinical and Experimental Immunology* 122, no. 3 (Dec, 2000), 418-422; D. E. Jones, "Fetal Microchimerism: An Aetiological Factor in Primary Biliary Cirrhosis?" *Journal of Hepatology* 33, no. 5 (Nov, 2000), 834-837; C. Corpechot and others, "Fetal Microchimerism in Primary Biliary Cirrhosis," *Journal of Hepatology* 33, no. 5 (Nov, 2000), 696-700.

[29] For example: B. Srivatsa and others, "Microchimerism of Presumed Fetal Origin in Thyroid Specimens from Women: A Case-Control Study," *Lancet* 358, no. 9298 (Dec 15, 2001), 2034-2038; M. Klintschar and others, "Evidence of Fetal Microchimerism in Hashimoto's Thyroiditis," *The Journal of Clinical Endocrinology and Metabolism* 86, no. 6 (Jun, 2001), 2494-2498; T. Ando and others, "Intrathyroidal Fetal Microchimerism in Graves' Disease," *The Journal of Clinical Endocrinology and Metabolism* 87, no. 7 (Jul, 2002), 3315-3320.

[30] For example: D. W. Bianchi, "Fetomaternal Cell Traffic, Pregnancy-Associated Progenitor Cells, and Autoimmune Disease," *Best Pract Res Clin Obstet Gynaecol* 18, no. 6 (Dec, 2004), 959-975.

[31] D. W. Bianchi, "Fetomaternal Cell Trafficking: A New Cause of Disease?" *American Journal of Medical Genetics* 91, no. 1 (Mar 6, 2000), 22-28.

ability to generate both publications and further funding.[32] One lab director told me the goal of the lab in the heart of the microchimerism research was to "publish the hell out of this thing and lets just get the papers out there" [AG]. The height of fetal microchimerism research was the late 1990's and the early 2000's.

Concurrently, it had become apparent that fetal cells were not going to be the prenatal screening panacea that many investigators had hoped (see chapter 2). Microchimerism, therefore, was a timely research avenue for those laboratories and researchers who had honed their skills by searching for Y chromosomes in women. One such researcher told me: "It became obvious, I suppose, that prenatal diagnosis wasn't going to be a winner, and we were really, there was a lot of time sitting around discussing what these cells might actually do. What other useful things could we draw from the research?"[TH]

Cellular relief work

While the "bad fetal cell" theory was on its way to becoming a fact, some peculiar things began to happen, mostly in the Bianchi lab. Diana Bianchi described to me two unexpected "AHA! moments" which came from control subjects in autoimmune microchimerism research. In the first experiment investigators were looking for fetal cells in patients with autoimmune thyroid disease, and comparing them to healthy thyroid tissue from women who had also had sons:

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[32] Joan H. Fujimura, *Crafting Science: A Sociohistory of the Quest for the Genetics of Cancer* (Cambridge, Mass.: Harvard University Press, 1996), 322.

> There's one woman … part of her thyroid is entirely male and part of her thyroid is entirely female. And she's healthy, she just has this benign thyroid adenoma that's been removed, never been transfused, I mean those are definitely her son's cells in there. But that turned into a thyroid. I mean the male cells have follicles and it looks like a normal thyroid.

In the second experiment, Bianchi's lab was looking for fetal cells in an autoimmune liver disease. Every study needed a control population, but it is rare that a healthy woman would have a liver biopsy. And so in this study, they used as controls the biopsies from some women who had infectious hepatitis C, which is not an autoimmune disease. In one woman who had been diagnosed with hepatitis C, cells from a male fetus populated almost an entire lobe of her liver. The lab used genetic markers from the woman and her former boyfriend to prove that the cells originated from a pregnancy she had terminated years ago.[33]

Importantly, in both of these cases the male cells seemed to have differentiated from some kind of stem cell into tissue cells – thyroid and liver – that were indistinguishable morphologically from their "host" counterparts. In their report of the hepatitis case, Bianchi and colleagues proposed an altogether new hypothesis:

> This finding, if replicated, has significant implications. It suggests that endogenous fetal stem cells may be an alternate source of tissue repair in the [post-pregnant] woman. Taken together, these 2

[33] K. L. Johnson and others, "Significant Fetal Cell Microchimerism in a Nontransfused Woman with Hepatitis C: Evidence of Long-Term Survival and Expansion," *Hepatology* 36, no. 5 (Nov, 2002), 1295-1297.

> cases imply that fetal cells can migrate to diseased maternal tissue and differentiate into functional tissue.[34]

After these findings, the Bianchi lab retrenched from the position that fetal cells were likely disease agents, and started looking for them everywhere. The scope of doable research problems expanded. They changed their IRB application and consent forms to reflect the change from autoimmune disorders to anything that affects women, including ovarian and cervical cancers.

In their most recent work, the Bianchi lab is championing this "stem cell repair" model: "So our theory is that the cells go in as blood cells or stem cells and then they encounter the diseased tissue and in that setting they differentiate into the host organ, whatever that is." This hypothesis – with its tantalizing implications that fetal cells could be used therapeutically instead of embryonic stem cells – has garnered some media publicity, particularly in the United States.[35] Lee Nelson also modified her position, in light of the new evidence, to allow that fetal cells may either be "insurgents" or they may be "protectors."[36] At present, the research community is ambivalent about what fetal cells are doing in women. And with this question – "What the heck are they doing there?"[37]– I will end

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[34] Ibid., 1296.

[35] Bruce Morgan, "Profile: Diana Bianchi," *Tufts Medicine* June 20, 2005, http://www.tufts.edu/home/feature/?p=bianchi (accessed April 7, 2006); Gina Kolata, "Stem Cells: Promise, in Search of Results," *The New York Times*, sec. Science, August 24, 2004.

[36] J. L. Nelson, "Pregnancy and Microchimerism in Autoimmune Disease: Protector Or Insurgent?" *Arthritis and Rheumatism* 46, no. 2 (Feb, 2002), 291-297.

[37] Morgan, "Profile: Diana Bianchi."

the empirical story and turn to some analysis of the language and guiding metaphors in the field.

Ontologies

Ian Hacking's *Historical Ontology* is a collection of essays "concerned with objects or their effects which do not exist in any recognizable form until they are objects of scientific study."[38] If ontology is the study of being, then historical ontology is the study of things coming into being, in a gradual and time-dependent process. This approach to the study of things – like nation and fetus – owes a clear debt to Michel Foucault, and to his genealogical method. In this section, I contemplate what the package of geopolitical metaphors, discussed above, has meant for the ontology of fetal cells in women. My concern is not metaphysical but practical; in other words, I make no distinction between what the fetal cells are "really" like, or "really" doing, and how scientists describe or depict them. As Annemarie Mol writes, "ontology is not given in the order of things … instead, ontologies are brought into being, sustained, or allowed to wither away in common, day-to-day, sociomaterial practices."[39]

By focusing on discourse about trafficking and state borders, I run the risk of overdetermining one particular set of metaphors to the exclusion of others that researchers also use. Such a single-minded approach oversimplifies the ways in which overlapping packages of metaphors are

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[38] Ian Hacking, *Historical Ontology* (Cambridge, Mass.: Harvard University Press, 2002), 11.

[39] Annemarie Mol, *The Body Multiple,* 6.

mutually constitutive, though not always consistent. Speakers and writers have some agency in selectively deploying one set of images over another, depending on their rhetorical purpose; metaphors operate more like tools than cages.[40] In this community of fetal cell researchers, alternatives to immigrant-talk include graft versus host metaphors and more militaristic images common to immunology and cell biology. Thus, metaphors co-exist in a web of meanings which are interconnected. For example, whether cells are imagined as immigrants or soldiers, they have in common that they are people invested in nationhood.

Cells are people, too

Hacking makes a well-known distinction between social and natural kinds, and he argues that the former – like gloves and multiple personality – are liable to change in response to our description of them, while the latter – like planets and horses – are not.[41] Although this distinction would be contested by many in science in technology studies, it becomes especially murky when the so-called natural objects are personified. A number of sociologists and anthropologists of science have identified the tendency for scientific researchers to personify cells. Jackie Stacey writes that:

> Cells are endowed with more than just a physiological identity in scientific discourse. These supposedly biological units are, in fact, being increasingly "endowed with personhood"… the

[40] Thanks to Stephen Hilgartner for this excellent metaphor about metaphors.

[41] These examples are from Ian Hacking, "Making Up People."

> conceptualization of the cell as the microcosm of the self has permeated all kinds of medical practice in recent years.[42]

In her work on the history of cell culturing, Hannah Landecker notes: "the synecdoche between cell and person functioned to make the cell populations of Petri dishes analogous to populations of people. The scientists moved readily between the language of cells in culture to that of people in culture."[43] Emily Martin also drew our attention to characterizations of the egg cell and sperm cells in predictably gendered motifs, and more recently she has traced the discourse of immunology in which cells have jobs ranging from housekeeping to garbage collecting to police work.[44] Sarah Franklin and Margaret Lock note that "cell lines acquire powerful social identities with high stakes in terms of individual, familial, professional, and community futures."[45] From what I have observed and read, it is the rule rather than the exception for cells to be personified in fetal cell research as well. In addition to the obvious likening of cells to travelers, traffickers and immigrants, one pediatrician told me: "Cells are pretty smart … They know where to find their home

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[42] Jackie Stacey, *Teratologies: A Cultural Study of Cancer* (New York: Routledge, 1997), 146. The term "endowed with personhood" comes from Emily Martin, "Body Narratives, Body Boundaries" in *Cultural Studies*, eds. Lawrence Grossberg, Cary Nelson and Paula A. Treichler (New York: Routledge, 1992), 15.

[43] Hannah Landecker, "Immortality, in Vitro: A History of the HeLa Cell Line," 64.

[44] Martin, *Flexible Bodies,* 320.

[45] Sarah Franklin and Margaret M. Lock, "Animation and Cessation: The Remaking of Like and Death," in *Remaking Life & Death: Toward an Anthropology of the Biosciences, eds*. Sarah Franklin and Margaret Lock (Santa Fe; Oxford: School of American Research Press; James Currey, 2003), 18.

and how to interact" [BL]. While I was observing routine practice in a clinical lab, a technician told me that cells get "depressed" when they are alone.

That cells are personified in contemporary biology and medicine seems beyond doubt. However, few analysts have grappled with the question of why this is so. I have three speculations, which I'll call the biological, phenomenological and historical explanations, and I suspect that they all contribute. The biological explanation is that gametes and early embryonic cells are the literal precursors of full-blown persons. We each came from one fertilized egg cell, as everyone familiar with the birds and the bees knows. Stem cell politics in the U.S. makes the slippage from a cell to "a life" seem frighteningly self-evident. However, this feature of embryonic stem cells doesn't so easily explain why a blood cell or kidney cell acts remarkably like a human.

The second hypothesis I offer is that cells are phenomenologically like people. This, of course, could also be a product rather than a cause of their personification, and it is more likely a case of co-construction. Nonetheless, cells and humans share some characteristics. They are both, in most cases, understood as "living,"[46] and as atomistic, discrete or individual. They have discernable boundaries and are usually perceived as separate from each other. An affinity that cells and people share is that

[46] In biological terms, cells and people are alive (except when they're dead). Like people though, cells are sometimes seen as objects, particularly when they are outside bodies and in laboratories, or when they are stained and fixed on microscope slides.

they can be, and often are counted. People are counted by censuses and votes, for example, and cells are counted in disease treatment and monitoring – CD4 counts in HIV/AIDS and white blood cell counts in leukemia for example. This operation both measures the discreteness of objects, and makes them discrete.[47] Another characteristic that likens cells to people is that they are motile. This feature seems particularly prescient in my story where movement across boundaries is key to the analogy. Another way of making this point about phenomenological similitude is to ask the family resemblance question: What "kinds" of things are most often personified? I suggest that discrete, mobile things are more likely to be anthropomorphized than are stationary, amorphous or fluid things.

My third suggestion, which most explains how cells became not just people, but citizens, is historical. A thorough history of the metaphor and meaning of "the body politic" exceeds the scope of this chapter and my own expertise. However, it is clear that an analogical relationship between the body and the state has been compelling, at least to philosophers, political theorists, and authors since the ancient Greeks. Its proponents included Plato, St. Augustine, King Henry VIII, Shakespeare and Hobbes, to name just a few. Several commentators have recently called "the body politic" a "dead" and/or misused metaphor.[48] To be

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[47] For my more fully developed thesis about the individualizing function of counting, see Aryn Martin, "Can't any Body Count? Counting as an Epistemic Theme in the History of Human Chromosomes," *Social Studies of Science* 34, no. 6 (Dec, 2004), 923-948.

[48] David G. Hale, "Analogy of the Body Politic" in *The Dictionary of the History of Ideas*, Vol. 1 (Charlottesville: The Electronic Text Center, The

clear, I don't think that when my informants use the phrases "cell trafficking," "migration" and "immigration," they are self-consciously proposing that the state is or should be like a human body in the same way that many of their predecessors were. However several American biologists in the 1930's were doing exactly this. *The Scientific Monthly* published several essays expounding the virtues of the human body as a model for governmental organization. These include "Body Anatomic and Body Politic," by cytologist E.V. Cowdry[49]; "Organic Theory of the State," by Stanford bacteriologist W.H. Manwaring[50]; and "The Body Physiologic and the Body Politic," by Harvard physiologist Walter B. Cannon.[51] Some particularly germane excerpts include:

> I, therefore, venture the opinion that the most reliable guide to an impartial and successful overhauling of our democratic institutions would be the political ideals deduced from the economic perfections of the human body.[52]

> Let us compare some types of cells with the millions of individuals which constitute a fairly self-contained nation …The nerve cells are the oldest and wisest. They constitute the ruling class and have special means of gathering information; domestic, from within the community, and foreign, from the outside world … Order is enforced by the leucocytes or policemen.[53]

University of Virginia, 2003), 67-70, http://etext.virginia.edu/cgi-local/DHI.

[49] E. V. Cowdry, "Body Anatomic and Body Politic," *The Scientific Monthly* 42, no. 3 (March, 1936), 222-229.

[50] W. H. Manwaring, "Organic Theory of the State," *The Scientific Monthly* 47, no. 1 (July, 1938), 48-50.

[51] Walter B. Cannon, "The Body Physiologic and the Body Politic," *The Scientific Monthly* 79, no. 1 (July, 1954), 20-26.

[52] Manwaring, "Organic Theory of the State," 48.

[53] Cowdry, "Body Anatomic and Body Politic," 223.

My objective is not to explore the intricacies of these authors' political-anatomical arguments, although these are truly fascinating, but to suggest that they (among others, no doubt) made the idea of the cell as citizen available to twentieth century biologists.

Intentionality

In this area of research, though, cells are not just citizens. They are citizens of the world. They have exceeded the boundaries of one body and entered another, perhaps illicitly. The conflation between cells and persons implies some peculiar consequences. One is that cells, like people, are intentional actors. As Stacey puts it, "cells are given individual identities: like us, they desire, they fear, they have intentions, they triumph, and they are satisfied."[54] In written and spoken language of fetal cell scientists, fetal cells only became intentional when they were found to outlive the birth of the child or termination of the fetus.

And their intentions, it seemed, were malevolent. Daniel Nordman wrote "the vagabond is, by definition, a suspect."[55] Like the always-suspicious vagabond, fetal cells were immediately suspect. Worse than travelers, they were traffickers. For at least five years, the prevailing hypothesis was that fetal cells were attacking women's bodies. That investigators followed this particular research trajectory, I suggest, is entwined with the package of nationalistic metaphors in which the fetal-maternal

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[54] Stacey, *Teratologies: A Cultural Study of Cancer*, 148.
[55] Daniel Nordman, 1987, quoted in Torpey, "Coming and Going," 239.

relationship was and is framed. This implication is supported by the reports of various investigators I interviewed. One, for example, said:

> The microchimerism, we knew, that first paper was '97, but then, as you probably know, the whole field went off on a tangent down the autoimmune disease line, and it wasn't really until probably 2001 that Lancet, the Srivatsa paper, that people began to sort of say well hold on a minute now, are we just finding it because we're looking for it, or does it actually mean anything? [TH]

Also with the benefit of hindsight, another explained:

> The rheumatology community was sending us down the autoimmune pathway and everyone went that way cause that's where everyone's going – lets go that way. Then all of a sudden we said hold on a second, wait a second. Lets just take a step back and look at this. [AG]

This trip down the garden path, so to speak, is much like the story Evelyn Fox Keller tells about "the pacemaker concept" in developmental biology.[56] Keller was involved in a line of research in which her theory that favored complex and interactive explanations was marginalized while theories that favor causal explanations were foregrounded. "In our zealous desire for familiar models of explanation," Keller writes, "we risk not noticing the discrepancies between our own predispositions and the range of possibilities inherent in natural phenomena. In short, we risk imposing on nature the very stories we like to hear."[57]

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[56] Keller, Evelyn Fox. "The Force of the Pacemaker Concept in Theories of Aggregation in Cellular Slime Mold," In *Reflections on Gender and Science* (New Haven, CT: Yale University Press, 1985), 150-157.
[57] Evelyn Fox Keller, *Secrets of Life,* 157.

Using Max Black's language, researchers assumed that when they cross a border, both cells (principal subject) and people (the subsidiary subject) move from a safe territory of recognition and protection to a foreign and hostile territory. As Gloria Anzaldua writes, "borders are set up to define the places that are safe and unsafe, to distinguish us from them."[58]

A comparison to rhetoric about immigration is potentially telling about the kinds of latent associations that may be embedded in the immigration metaphors. Lauren Berlant writes:

> This panic of mistrust in the viability of a non-European-dominated "America" almost goes without saying in any contemporary mainstream discussion of the immigrant effect: it is expressed in the chain of almost equivalent signs "immigrant," "alien," "minority," "illegal"; it is expressed in the ordinary phrase "wave of immigrants," which never quite explicitly details the specter of erosion and drowning it contains, a specter that has long haunted American concerns about the solidity of national economic and cultural property.[59]

The xenophobia described by Berlant could be an implicit feature of the concept of cell trafficking. What exactly is trafficking or being trafficked in maternal/fetal cell exchange? The notion of "cell trafficking" is not particular to the fetal cell community. As I described above, it entered the

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[58] Gloria Anzaldua, *Borderlands: The New Mestiza = La Frontera*, 1st ed. (San Francisco: Aunt Lute Books, 1987), 5.

[59] Lauren Gail Berlant, *The Queen of America Goes to Washington City: Essays on Sex and Citizenship* (Durham, NC: Duke University Press, 1997), 197.

lexicon of the core set of human fetal cell researchers around 1996 via transplant immunology, and pregnancy cell biology more broadly. As a very rough gauge of its history in cell sciences, I did a Medline search for "cell" and "trafficking" together. Its first use was in 1983 (roughly around the beginning of Nancy Reagan's "war on drugs"), and it has had a steady incline since then. In many cases of its broader usage in biology, some kind of marker or tracer has been affixed to the cells, such as a fluorescent marker, and this may, in fact, be the commodity that is trafficked. As far as I can tell, the word does not have a terribly precise meaning in microchimerism research, but it is always invoked to imply movement across a border from one immunologically or genetically defined "self" to another, where the smaller self is a transplanted organ or a fetus.

In its colloquial or political sense, trafficking usually implies that commodities – drugs, babies, organs, persons – are being carried across borders illegally by a third party. In microchimerism literature, the cells seem to be trafficking themselves; there isn't an implicated third party. In some uses, the "products" being trafficked by cells are conceivably the fetus's DNA, or more precisely the half of it that derives from the father, and is therefore "foreign" and immunologically suspect. I do not think that the ways in which my informants use the verb "trafficking" is a deliberate, precise and fully reflexive reference to trafficking in the illicit political sense. I do think they deliberately imply movement of cells from a safe territory of to a foreign territory. They inherited this view of cognizant and hostile cells from immunology. However the fundamental premise of immunology, that cells "know" the difference between self and

other is undermined by the very findings coming out of this research, and in other areas of immunology. Cells do not know always where they belong, or at least do not always reject others:

> [T]his dominant model has recently been challenged, for the self is polymorphous and ill-defined. Contemporary transplantation biology and autoimmunity have demonstrated phenomena that fail to allow strict adherence to such a dichotomy of self/non-self, and as new models are emerging, "the self" has been left exposed as a metaphor, whose grounding — philosophically and scientifically — is unsteady and thus increasingly elusive as the putative nexus of immunology's doctrines.[60]

As indicated in this passage by Alfred Tauber, the inadequacy of a strict self/nonself divide is also being questioned in subspecialties other than fetal microchimerism.

The productive immigrant

Hans Jorg Rheinberger describes that: "The sciences are characterized by a permanent process of reorientation and reshuffling of the boundary between what is thought to be known and what is beyond imagination."[61] And so adaptations and reorientations of metaphors of immigration continue to be productive in the field of fetal cell research. While fetal cells were originally presumed to be ill-willed, they now, one interviewee described, have a somewhat broader range of potential intentions:

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[60] Alfred Tauber, "The Biological Notion of Self and Non-self," *The Stanford Encyclopedia of Science,* 2006. <http://plato.stanford.edu/archives/spr2006/entries/biology-self/>.

[61] Hans-J_rg Rheinberger, *Toward a History of Epistemic Things: Synthesizing Proteins in the Test Tube* (Stanford, Calif.: Stanford University Press, 1997), 11.

> There's three potential consequences of a fetal cell being present in maternal tissue. It's bad, causing an immune response. It does nothing, it's just sitting there, an innocent bystander. Or three, it's doing something good. So those are the three. It's almost like poetry. It has nothing to do really with the biology. It's just saying it's good, bad or indifferent. [AG]

In the process of the research I've described, fetal cells have gone from being suspicious vagrants to productive immigrants, naturalized – in the political sense of the term – to their new home. One newspaper reports on the good cell theory: "If a woman's tissues or organs are injured, fetal cells from her baby migrate there, divide and turn into the needed cell type, be it thyroid or liver, intestine or gallbladder, cervix or spleen."[62] These cells are less like insurgents, and more like 'Doctors Without Borders', or at least good citizens. This too, is a trope of immigration policy, but a more liberal assimilationist one. The vagabond has become a productive worker.

Lately, the traffic in cells between women and their children seems to be bi-directional, so mothers' cells can be found in their children. In a spontaneous use of the immigration discourse that permeates this field, an immunologist recently described the following scenario to me about the sub-population of my mother's cells presumed to be living in my body, and she invited me to be part of an experiment:

> If a Turk was born in Turkey but he moved over here and lived here thirty years, he's not going to be the same as if he stayed in his

[62] Kolata, "Stem Cells: Promise, in Search of Results."

> parent country. And then you could also look at this issue of, by analogy, was the nation formed at the time that the cell emigrated. So, your mother's cells coming in to you are coming in at a time when the nation is not yet formed. The nation is just at a time of becoming, you know, a federation … So I can't wait to do that experiment. [RD]

It's a bit confusing, but Turkey, in this scenario, is my mother, and the Turk is her cell that "emigrated" to my body during gestation. The planned experiment would isolate my mother's cells from my body now and compare them to my mother's cells from her body, to see if there were differences. Importantly, this researcher was not using the metaphor to explain the hypothesis to me, it was, she said, the immigrant metaphor that gave her the idea for the experiment. This application of the metaphor takes into account such complex social and temporal factors as enculturation and assimilation. When, in a previous quote, Bianchi said: "I mean those are definitely her son's cells in there. But that turned into a thyroid… The male cells have follicles and it looks like a normal thyroid" she was, I think, being jarred by the material to change the frame of reference: what, because of its fluorescent Y chromosome looked remarkably like "other" or "foreigner" had come, under different staining and lighting, to look a lot like "self" or "citizen."

In more recent work these same researchers are finding microchimerism wherever they turn their microscopic gazes: twins, women who have never been pregnant, men, children.[63] The epistemic interest in fetal cells, and therefore the funding, was sustained by the notion that bodies are,

[63] Z. Yan and others, "Male Microchimerism in Women without Sons."

with few exceptions, pure collections of genetically identical, self-same cells. In nationalistic terms, the overwhelming sameness of the population is what enabled one to spot the outsider, and a fetal cell was conceived of as just that: matter out of place,[64] hostile, pathological, and therefore potentially interesting. However, if small numbers of cells from our encounters with other human beings can be found in all bodies, they lose their epistemic interest. One investigator told me that funding for this research is now hard to get "because most people say: So what? You know, its like they're there, so what" [JM].

So what, indeed. I've just described in detail the changing metaphors of a research trajectory that didn't really get very far. Was it because the metaphors were misleading? I would argue no, that this is just a particularly intriguing example of science as usual – some representations work with the material, others less so. However, it is also a good example for looking at the ways in which scientific characterizations of bodily phenomena fold back on people's conceptions of themselves. As Emily Martin writes, "The imagery and metaphors that are the organizing features of scientific accounts are as real in their effects on the way doctors and patients act in the world as the effects of an antibiotic or a scalpel."[65] In the following section, I consider the ways in which the characterizations of fetal cells by fetal cell researchers traffic out of the laboratory and come to mean something to particular people and publics.

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[64] Mary Douglas, *Purity and Danger,* 244.

[65] Emily Martin, "The Fetus as Intruder: Mother's Bodies and Medical Metaphors" in *Cyborg Babies: From Techno-Sex to Techno-Tots*, eds. Robbie Davis-Floyd and Joseph Dumit (New York: Routledge, 1998), 125.

Conclusion: Traffic beyond the lab

In this, the final section of the chapter, I explore what peripatetic cells imply about the "territories" they move from (fetus) and to (mother). As in previous sections, I am attempting to stay close to the discourse used by the actors in my study rather than to blithely spin out these metaphors and their cultural resonances.

Fetal Sovereignty

Geopolitical metaphors, as they are mapped onto pregnant and post-pregnant bodies, may be, or may become, a resource for constructing claims of fetal sovereignty. Without a border, there can be no distinct fetal entity. Torpey, whom I quoted at the beginning of the chapter, claims that "states' monopolization of the right to authorize and regulate movement has been intrinsic to the very construction of states."[66] Torpey adapts and augments Weber's argument that modern states monopolized the legitimate use of violence. In Torpey's view, "modern states have also expropriated the legitimate means of movement within and across their borders."[67] In fact, control of entry and exit is one of the defining features of a state, and physical borders are necessary to the ontology of nations. Similarly, the border or barrier that is seen to separate woman and their fetuses, and that regulates the movement of cells, renders the fetus and mother separate states. Like nations' borders, the placental "barrier" is simultaneously seen to be secure and, in light of new evidence, permeable.

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[66] Torpey, Coming and Going, 240.
[67] Ibid., 239.

Several feminist commentators on reproductive sciences have pointed out a recent and intensifying tendency to depict the fetus as autonomous and in control of pregnancy: "the emphasis is not only on fetal separateness and fetal independence, but on its ability to control the mother, rather than be controlled by her."[68] Fetal cell scientists share this tendency when they suggest that what fetal cells are "doing" in women is ensuring that the fetus is not rejected but "tolerated." Many people in the field believe that fetal cells are sent across the placental barrier as emissaries, signaling to the mother that she should not reject the fetus [e.g.,BB,MR].

While it is tempting to suggest that the fetal independence implied by the language in this field plays into or comes from pro-life politics, it seems that the phenomenon does not map onto abortion politics in any obvious way. I have found that several pro-life and Christian websites post links to research and newspaper articles about microchimerism, often without comment. On one such site, a post following an article about microchimerism is explicit: "This also puts the lie to the feminist claim that a fetus is just a lump of flesh, for the unborn baby not only is its own being, but mother and baby each affect each other (share stem cells) in a way that carries on for decades."[69]

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[68] Sarah Franklin, "Fetal Fascinations: New Dimensions to the Medical-Scientific Construction of Fetal Personhood" in *Off-Centre: Feminism and Cultural Studies*, eds. Sarah Franklin, Celia Lury and Jackie Stacey (Hammersmith, London, UK ; New York, NY, USA: HarperCollins Academic, 1991), 193-194.

[69] http://www.stormfront.org/forum/showthread.php?t=128089 posted May 10, 2004, accessed January 2, 2006.

On the flip side, however, one microchimerism researcher told me that she is regularly contacted by a national pro-choice group who expressed that their clients are very interested in fetal cell research: "in resolving their feelings about abortion, it is very important … that they have retained cells from this pregnancy, that in a way is a gift to them" [BB]. In both pro-life and pro-choice discourse, the "traces" that a fetus leaves in a woman are considered relevant to fetal status. However the social meanings of fetal cell microchimerism are not yet stabilized or successfully mobilized by one particular political interest group, and I don't think the language comes from specific political interests, except insofar as they may be deeply embedded in the culture.

Motherland

What does it mean to women that fetal cells take up residence in their blood and organs?[70] In 1991, Donna Haraway suggested that "women have had so much trouble counting as individuals in modern Western discourses" because "their personal, bounded individuality is compromised by their bodies' troubling talent for making other bodies."[71] In 1998, Emily Martin wrote that "compared with the internal purity of the self, women fall far short. When they are pregnant, they are truly hybrid, uneasily 'tolerating' the foreign fetus."[72] Both of these comments seem to foreshadow the characterizations of microchimerism as a

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[70] Thanks to Rachel Prentice for encouraging me to think more about maternal subjectivity, thereby avoiding a replication the fetus-focus of much discourse in this field.

[71] Donna Jeanne Haraway, *Simians, Cyborgs, and Women,* 253(fn8).

[72] Martin, "The Fetus as Intruder," 133.

condition of multiplicity, however with microchimerism, women's compromised individuality lasts much longer than pregnancy: "'A pregnancy lasts forever,' Bianchi suggests, 'because every woman who has been pregnant carries these little souvenirs of the pregnancy for the rest of her life.'"[73] Women's "troubling talent" now extends well beyond the nine months of pregnancy. Post-pregnant women become inhabited by their children's cells (and apparently by their children, as I will discuss in chapter 4). Arguably, this differentiates women from men, whose individuality is contained and uncompromised.[74]

Thus far I have been speaking of cells as personified in very general terms, which is how scientists speak about them at the level of publication, in newspaper accounts, and for the most part in interviews. However, the tissues – blood, skin biopsies, thyroid – have come from actual women, in whom the Y-bearing cell is personified in a specific sense: it originated from a pregnancy which she experienced, and in many cases a son who is living. In fact, this cell has no meaningful signification for the researchers unless it is tied to a story from a speaking subject. This necessity for accurate information about pregnancy history, and in some cases access to tissues from other people in a woman's life, introduces a degree of methodological uncertainty for the scientists, and a degree of intimacy for the women. One researcher describes this confessional moment:

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[73] Morgan, "Profile: Diana Bianchi."

[74] This view doesn't hold up, however, to more recent (and much less publicized) findings that men, too, contain cells from their mother, as traffic appears to be bidirectional.

> One of the criticisms in the microchimerism studies, especially the ones on autoimmune disease is that they didn't spend enough time checking histories, or it was only chart based. Whereas what I did was spend about an hour talking with these women. And therefore we certainly got a much more detailed history. One woman told me about a miscarriage maybe 50 years ago during the war. I got the feeling that was something that wasn't talked about very much, and it certainly didn't appear anywhere in her chart, it wasn't in her records that she'd ever been pregnant, yet she had. [TH]

Moreover, once cells have been identified as belonging *not* to a particular self – the woman – but are visiting, borrowed or harbored from someone else, this knowledge re-enters the woman's story or those told about her.

To some, apparently, the knowledge that they carry cells from their children is heartening. About the woman mentioned above, the researcher reported: "It seemed to be quite a comforting thing for her, its kind of silly. Definitely the fact that there could still be something there didn't seem frightening to her" [TH]. For those who learned about the phenomenon in the context of research about potential causes of their disease, the knowledge was less likely to be reassuring: "I had one patient say to me, I want to know which of my sons gave me scleroderma."[JM] In both cases, patients adopted the slippage from cell to person that permeates the language of researchers, but it implied a complication or reorientation of actual relationships between people in the world.

The apparent colonization of women by cells that are "not theirs" sometimes colors, in peculiar and alarming ways, how others see her.

Investigators would occasionally tell me that women had complicated pregnancy histories, which meant more work for them to sort out whose cells "belong" to whom. Researchers also worried that their patients weren't always telling them the whole story. Couched in these complaints was an unmistakable moral judgment about the woman's sexual past, and the traces it left on her body. The difficulty with controlling women's reproduction, one investigator told me, is the reason that they are switching to mice: "We can't tell women to become pregnant or have miscarriages or whatever else" [AG].

Finally, in an alarming appropriation of this research, I found that an article about microchimerism had been posted on a white supremacist website called "Stormfront". The phenomenon of cell exchange was taken up as proof that white women who had mixed-race children were "defiled," and the cells left behind posed a contaminating threat to subsequent pregnancies. Moreover, the presence of these cells – like the "one drop of blood" rule – was presumed to change the woman's racial status: "As that non-white bloodline courses through the (Formerly) white female's body, her own physiology becomes irreversibly altered to perpetuate the blood structure produced in the womb."[75] The tagline for this commentator was "For God, Race and Country." While this example is admittedly extreme, it illustrates that the slippages between body and nation, between bloodline and cells, traffic beyond the borders of the laboratory.

[75] http://www.stormfront.org/forum/showthread.php?t=128089 posted August 26, 2005, accessed January 2, 2006.

CHAPTER 4: THE SOCIAL LIVES OF CELLS

> Our ideas and attitudes seep into the functioning of the body itself, making up the realm of its possibilities or impossibilities.
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> ---Elizabeth Grosz, Volatile Bodies[1]

Chimerism has a biological and a psychological analog, both of which have been studied by historians and anthropologists of science and medicine. The first, organ transplantation, creates an almost identical biological scenario, and, like chimerism, it raises complicated questions about identity and boundary-crossing. It is from Margaret Lock's chapter "The Social Lives of Organs," in her exemplary ethnography of organ transplantation, that I borrow the title for this chapter. The psychological analog, multiple personality disorder, provides a foil for thinking about the legal and social imperative to be singular, unitary, one.

I begin this chapter with Paul Rabinow's deliberation on the peculiarly Western linkage of the body and the person, a preoccupation he identifies in both mediaeval Christian Europe and in the late 20th Century California Supreme Court.[2] Following Rabinow, I suggest that many of the identity questions raised by chimerism are not particularly new, though the cell has taken on a fairly recent and important role as a meaningful and quasi-sacred part of the body. Next, I turn to organ transplantation as an already well-studied biological phenomenon in which identity is seen to inhabit

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[1] Elizabeth A. Grosz, *Volatile Bodies,* 190.

[2] Paul Rabinow, "Severing the Ties: Fragmentation and Dignity in Late Modernity" in *Essays on the Anthropology of Reason* (Princeton, NJ: Princeton University Press, 1996), 129-152.

human tissue, and the relocation of tissues invites both lay people and medical specialists to ponder fragmentation and multiplication of personhood. Transplantation provides a germane introduction to issues of identity raised in my ethnographic study of chimerism and microchimerism. In some cases, insights and speculations about identity were offered to me in the course of my research, and in others, I specifically asked researchers to reflect on questions of selfhood and identity. In media accounts of chimeras, quandaries of multiplicity, fragmentation and confused kinship are almost always foregrounded; indeed they seem to be the main reasons for journalistic and popular interest in the topic. Rather than simply taking these tidbits of conversation and news as revelatory of what commentators think about chimeras, I will use them as analytic levers into larger questions about individuality, relationship and intercorporeality. For this final task, Ian Hacking's concept of "making up people," and on the history of multiple personality disorder provides a frame for my analysis.[3]

The body and the person

In his essay "Severing the Ties: Fragmentation and Dignity in Late Modernity," Rabinow relates a late 20th century court case about ownership of cells to a grander context of Western preoccupations with the relations between body, soul and person.[4] He opens with the assertion

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[3] Ian Hacking, "Making Up People"; Ian Hacking, *Rewriting the Soul*.

[4] Rabinow, "Severing the Ties." I take Rabinow's discussion essay and his cases as exemplars of cultural and scientific communities conflating the body and the person. Because it is such a predominant Western preoccupation, this is one of many texts I could have chosen that make this connection salient. Ruth Richardson, for example, does an excellent

that "the intimate linkage between the two key symbolic arenas, 'the body' and 'the person,' would have to figure prominently on any list of distinctively Western traits."[5] Attention to the "oldness" of this linkage helps to "isolate elements of the unarticulated uneasiness that many feel over late modern culture."[6] He invokes medieval Christendom (via the work of Caroline Walker Bynum[7]) to illustrate that both theologians and the masses were deeply concerned about the materiality of the body and its spiritual status. The doctrine of resurrection, that "God will assemble the decayed and fragmented corpses of human beings at the end of time and grant them eternal life,"[8] was taken literally; corporeal minutiae such as hair and fingernail clippings, were the subject of scholarly debate. Thomas Aquinas attempted to divest the body of some of its spiritual significance by insisting that only the soul would be resurrected. As evinced by relic cults, reverence for the fragments of the body persisted in the Middle Ages. "A belief in the fundamental identity between the body and the person was embedded in these popular beliefs and practices and was not to be shaken by theological finesse."[9]

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job of describing how peasants in nineteenth century Britain endowed corpses with spiritual and cultural significance. See Ruth Richardson, *Death, Dissection, and the Destitute*, 2nd ed. (Chicago: University of Chicago Press, 2000).

[5] Rabinow, 129.

[6] Ibid., 130.

[7] Caroline Walker Bynum, *Fragmentation and Redemption: Essays on Gender and the Human Body in Medieval Religion* (New York; Cambridge, Mass.: Zone Books; Distributed by the MIT Press, 1991), 426.

[8] Ibid, 239. Quoted in Rabinow, "Severing the Ties," 147.

[9] Ibid., 148-149.

Rabinow demonstrates that the same tension (whether the body is the locus of humanity or mere matter), was a central concern in the 1990 court case, *John Moore v. the Regents of the University of California.*[10] At issue, very broadly, was whether John Moore had a legal claim to the profits garnered by researchers who had, unbeknownst to him, commercialized cell products derived from a cell line that was developed from cells taken from Moore's body. Excerpts from both concurring and dissenting opinions in the case are relevant to Rabinow's argument. Justice Arabian wrote:

> Plaintiff has asked us to recognize and enforce a right to sell one's own body tissue for profit. He entreats us to regard the human vessel – the single most venerated and protected subject in any civilized society – as equal with the basest commercial commodity. He urges us to commingle the sacred with the profane. He asks much.[11]

Justice Mosk, in his dissenting opinion, states: "Our society acknowledges a profound ethical imperative to respect the human body as the physical and temporal expression of the unique human persona."[12] These judges, differing in their political leanings and ultimate decision in the case, agreed that the body and the person are one. Moreover, Moore's cells, excised and physically remote from his phenomenological body, are *one and the same as his body*. [13] As Rabinow writes, "part is whole."[14] Like

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[10] *John Moore v. the Regents of the University of California,* 793 P.2d 479 (Cal. 1990).
[11] Court Transcript, quoted in ibid., 144.
[12] Ibid., 145.
[13] Perhaps ironically, the court ruled that for this reason, Moore did *not* have a legal monetary claim to his own cells.

medieval relic cults, these judges exhibit "the enduring cultural understanding that the 'person' is inextricably tied to the sheer materiality of the body."[15]

Transplanted identities

Rabinow mentions organ transplants as an example of contemporary popular beliefs in the embodiment of identity, but he does not develop the theme. Other ethnographic studies, notably those by Margaret Lock[16] and Lesley Sharp,[17] have grappled with the repercussions of identity for organ recipients who literally incorporate other into self. Organ and bone marrow recipients are technically chimeras or at least microchimeric, according to the definition of the term, which specifies that the chimeric organism contains cells from more than one genetically distinct embryo. However, chimera terminology is rarely used in transplant communities to refer to patients. It does occasionally appear as an emblem. For example, the Chimaera of Arezzo[18] is the icon of the American Society of Transplant Surgeons, and their newsletter is titled *Chimera*. In the first issue of *Chimera*, the ASTS President explained the significance of the logo:

> And what is a more fantastic idea than clinical transplantation, particularly in its multiple manifestations of our present

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[14] Ibid., 145.
[15] Ibid., 149.
[16] Margaret M. Lock, *Twice Dead*.
[17] Lesley A. Sharp, "Organ Transplantation as a Transformative Experience: Anthropological Insights into the Restructuring of the Self," *Medical Anthropology* 9, no. 3 (Sept, 1995), 357-389.
[18] An Etruscan Statue from 5th Century B.C. See chapter 1.

> armamentarium? Thus, the Chimera as the logo of the American Society of Transplant Surgeons not only embodies the substance (multiple diverse body parts) but also the spirit of our specialty.[19]

Beyond its use as an icon, chimerism has a more specific meaning in transplant communities. A small number of transplant physicians use the term chimerism, or "macrochimerism" to emphasize their novel therapeutic strategy for improving organ acceptance in recipients.[20] They aim to induce organ tolerance by transplanting, along with the required organ, bone marrow from the same donor. Ideally, this would create an eternal population of donor's cells in the recipient's blood, enabling them to tolerate the organ (i.e., not reject it), preferably without the use of life-long immunosuppressants. Therapeutic macrochimerism creates a situation akin to the twin blood chimeras who were found to tolerate skin grafts from each other (see chapter 1).

Nonetheless, "chimera" is not a common term in transplantation, and it is not an identity description that organ or bone marrow recipients can expect to encounter. However, the quandaries of identity that are raised

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[19] American Society of Transplant Surgeons, "The Chimera," August 1989, 1.

[20] See, for example, T. E. Starzl, "Chimerism and Tolerance in Transplantation"; T. E. Starzl and others, "Cell Migration, Chimerism, and Graft Acceptance"; M. T. Millan and others, "Mixed Chimerism and Immunosuppressive Drug Withdrawal After HLA-Mismatched Kidney and Hematopoietic Progenitor Transplantation," *Transplantation* 73, no. 9 (May 15, 2002), 1386-1391; E. H. Field and S. Strober, "Tolerance, Mixed Chimerism and Protection Against Graft-Versus-Host Disease After Total Lymphoid Irradiation," *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences* 356, no. 1409 (May 29, 2001), 739-748.

by transplantation are analogous to those in genetic chimerism, except insofar as the first is "man-made" and the second is "an experiment of nature" (a distinction that may or may not be relevant to identity). Lock and Sharp have used interviews and other ethnographic methods to explore identity in transplant patients, and their findings foreshadow the implications of chimerism for identity. In particular, they describe the frequent disjuncture between people's experiences of identity transformation post-transplant and the medical advice they receive, which downplays or derides any suggestion that the human tissues embody and convey personal, animistic qualities.

Sharp writes that "[t]ransplant professionals, organ donors, and recipients alike appear on the surface to embrace the idea of organ-as-thing, yet underneath all struggle with the larger cultural constructions that personalize body parts."[21] The specific contours of this struggle are culturally specific, as Lock demonstrates so thoroughly in *Twice Dead*, a comparative study of organ transplantation in North America and Japan.[22] Even within cultures, though, the emotional, psychological and spiritual responses among individuals are highly variable. Both Sharp and Lock emphasize the contradictions and paradoxes inherent in this experience. On the one hand, donors and their loved ones are encouraged by nurses, physicians, and eager transplant personnel to "give the gift of life," to enable the deceased to "live on" in another. On the other, they are discouraged or prohibited from incorporating recipients into their social lives, and from imagining visceral connections. Usually the recipients

[21] Sharp, "Organ Transplantation as a Transformative Experience," 361.
[22] Lock, *Twice Dead*, 429.

and donors are told very little about each other, and the only facilitated contact is a letter of gratitude delivered through the transplant co-ordinators. Hence the organ – when solicited – is to be seen an entity of inordinate personal value; once given up, it is to be seen as an inanimate object: "the rhetoric that transplant specialists use among recipients insists … organs should be reified: they are mere muscles, pumps, filters or bits of flesh."[23]

While it is not inevitable, it is certainly common for recipients to identify with their donors, and to feel that they have received some of the donor's traits along with the organ. This is the subject of many "psychosocial" studies, as well as anthropological enquiries. For example, Sharp tells about a black man who was worried that a white woman's kidney would reject him.[24] Lock excerpts this story from an interview:

> I still think of it as a different person inside me – yes I do, still. It's not all of me, and it's not all this other person either… You know, I never liked cheese and stuff like that, and some people think I'm joking, but all of a sudden I couldn't stop eating Kraft slices.[25]

Furthermore, Lock discusses a psychiatrist who works with organ recipients, who tells her that he asks patients what they call their new organ: "And they're always surprised when I ask that, because they didn't think anyone else had given their organ a name! They've given it a persona, a story, and they have a whole relationship with it."[26] He also

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[23] Sharp, "Organ Transplantation as a Transformative Experience," 377.
[24] Ibid., 365. Refers to a study by Veiderman in 1974.
[25] Lock, *Twice Dead*, 323.
[26] Ibid., 327.

told her about a teenager who received a kidney from an Italian donor, and he was trying to make a good home for it, by eating Italian foods. In another study, recipients reported having become "kinder" and "more tolerant" post-transplant, perhaps because the donor had had different opinions than the recipient, or when a man receives a woman's heart.[27] In short, since organ transplants have been practiced, qualitative researchers have reported that many recipients perceive some sort of conveyance of traits.

Sharp describes that transplant recipients are discouraged from these kinds of ideas:

> [Psychiatric and psychological specialists] voice a common concern: it is pathological and thus unnatural when recipients identify with their donors. They alert other professionals to the psychological dangers of such identification, formulating guidelines on how to help recipients extinguish their delusions and build a healthier sense of self.[28]

As a subtle example of this, the psychiatrist whom Lock interviewed told her: "men who get kidneys from women often feel feminized – although I haven't noticed a problem the other way around."[29] His coding of this as a "problem" corroborates Sharp's finding. In the 1970's, psychiatric professionals' concerns tended to have a psychoanalytic flavor: "Although

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[27] M. A. Sanner, "Transplant Recipients' Conceptions of Three Key Phenomena in Transplantation: The Organ Donation, the Organ Donor, and the Organ Transplant," *Clinical Transplantation* 17, no. 4 (Aug, 2003), 391-400.
[28] Sharp, "Organ Transplantation as a Transformative Experience," 359.
[29] Lock, *Twice Dead*, 327.

most transplantation patients make a satisfactory adjustment, some have serious difficulties integrating the new organ into their body image, and pathologic introjections, denial and other ego disruptive sequelae may follow."[30]

In a more recent psychological study of organ transplantation and identity, Swedish researcher Margareta Sanner distinguishes between "rational and 'modern' reasoning" and "primary process thinking."[31] The latter, typical of young children's thinking, includes "archaic symbolism and illogical, instinct-ridden, wishful and magical thinking."[32] Sanner's methodology entails lengthy and repeated interviews with organ recipients. She explores patients' explanations of the causes of their perceived changes in personality post-transplant, and identifies three categories of such explanations. The first is "transmission, which is a kind of magical thinking" in which "a contamination through an unspecified 'essence' from the donor to the recipient occurs via the transplant."[33] Unlike this primary process rationale, the other two kinds of explanations are coded by Sanner as "rational." The first of these is, to quote a patient, that "a gene would slip over" from the donor. The second "rational" explanation is "analogy thinking": "It is, for instance, an empirical fact that a mixed substance usually shows traits from all components comprising that

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[30] S. H. Basch, "The Intrapsychic Integration of a New Organ. A Clinical Study of Kidney Transplantation," *The Psychoanalytic Quarterly* 42, no. 3 (1973), 384.
[31] Sanner, "Transplant Recipients' Conceptions of Three Key Phenomena in Transplantation," 397.
[32] Ibid., footnote 2.
[33] Ibid.

substance. Thus, one might expect that such laws also apply to transplantation where 'people are mixed.'"[34]

Professional discourses about patients' beliefs in the transmission of personality traits from donors to recipients inevitably cast the problem in terms of an expert/lay person dichotomy. The rational (secular) doctor knows that the body and its parts are devoid of animistic qualities. The superstitious and unscientific patient believes she has been infected with a desire to eat cheese. However both Sharp and Lock point out that the divide is not so clear-cut. Doctors themselves occasionally betray signs of, as Rabinow would say, their own "enduring cultural understanding that the 'person' is inextricably tied to the sheer materiality of the body [and] its parts."[35] Lock tells a story of a surgeon who was uncomfortable with the proposition that organs might be procured from death row. His chagrin was not because of ethical problems, but because, he says "I wouldn't want to have a murderer's heart put into my body."[36] Sharp describes that clinicians who are all business in the presence of patients speak more figuratively in each others' company: "Monstrous images of Frankenstein and the chimera haunt the literature that appears in professional and technical journals, even while these same authors scold their patients for referring to themselves in this fashion."[37]

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[34] Ibid.
[35] Rabinow, "Severing the Ties," 149.
[36] Lock, *Twice Dead*, 320.
[37] Sharp, "Organ Transplantation as a Transformative Experience," 381-382.

Microchimerism and identity

In chimerism research, clinicians and molecular biologists talk about cells as representatives of the people – even *as the people* – to whom they "belong." This synecdoche is in keeping with the enduring cultural linkage between body and person detailed by Rabinow and expressed by transplant recipients. It is also further evidence that the conflation is not limited to non-scientists. When microchimerism researchers talk about identity, they often describe the cellular phenomenon as a literal embodiment of the mother-child relationship. Their comments are rife with cultural assumptions about motherhood. One informant was particularly loquacious about the mother-child bond, and related cell exchange to his own relationship with his recently deceased mother. A fairly lengthy excerpt from the interview demonstrates that for him, this is more than a fleeting reflection.

> I'd say probably 99% of the people I talk to find some kind of… I don't know if it's poetic justice or something… But it's the whole thing of mother and their children. You know how society is, different societies, but you know, and working women and stuff like that, and trying to balance career and family and stuff like that, but when it comes down to it, your mom is your MOM. And that's the one person – you could be a murderer and your mom will still come and visit you in jail. And the thing about – there's a saying of something like – the mother holds their children's hand for only a short time, but holds their hearts forever. And there's a certain almost like a physical manifestation of that idea.
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> I have my mother's cells in me and my mother, although she recently passed away, but she had my cells in her and it was almost that kind of nonverbal relationship…. So even if I'm on the other side of the world, I'm doing my post-doc here or whatever, there's still part of me in her and vice versa … I don't want to get into the

> difference between mothers and fathers, but there is differences. And you know, your father is, my father was a disciplinarian, he was like OK, I don't want you to get thrown in jail, I don't want you to get anyone pregnant, don't do drugs, all these things … but your mom, is like your MOM, you know. And there's that part of it that's like – well it almost allows you to write it down on paper. Well what is it like to be a mother and a child. Well it's the exchange of cells… I haven't encountered anyone who has been kind of creeped out about it. Who said – well I'm not me. Are you telling me I'm not me, I'm part her.
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> If anything, it's almost more like poetry than science, but it's like… there's all these sayings about mother and children relationships that it's almost like this phenomenon is perfectly suited to that. It's like your mom's always watching you. No she's not watching you, she's right here. You think, your mother tries to instill caring and honesty and having a heart. Maybe that's because some of her cells are in my heart. And it's just kind of a fun thing. Completely outside the research that we do. It gives some kind of humanity to it, or some, you know like a moral justification to say well this is good. [AG]

While this respondent begins with a gesture towards the ways that society is changing to reflect shifts in parental responsibility from women to men – "working women and stuff like that" – he clearly sees cell exchange as a return to a deeper biological connection between mother and child. There is something essential and universal about motherhood, he implies, and microchimerism is not necessarily the cause of this, but it is a "poetic" and corporeal instance of it.

This respondent ends his lengthy reflection on motherhood with an explicit demarcation between "the research" and "fun." The literal and heretofore unknown mother-child connection gives him a way to talk

about his work to the media and to his family and friends, and it makes him feel good about his research. As countless careful studies in science and technology have shown, there is no such boundary between the inside and the outside of the laboratory.[38] Extra scientific factors – the "fun" – inevitably, even necessarily co-constitutes the research. This way of thinking about cells not as representatives of people, but actually *as people* cannot be separate from "the research."

Several researchers are clear that their scientific theorizing is informed by the biological (and cultural) relationship of mother and child. The following excerpt is from an interview with a pediatrician who does not do laboratory research in the field but who does watch it closely, and she writes and speaks about the implications of the phenomenon.

> And you know there really is this kind of philosophical phenomenon. Which is just really cool. See I have this sort of loose brain so I think about these things. The two cells that have memory are our brain cells and our immune system, I mean immune cells have memory. So we've also got the memory of our mom in those immune cells that hang around … I did not choose the title of that editorial loosely ("So you think your mother is always looking over your shoulder? She may be IN your shoulder!") It seemed to me that the role of our parents, we've always thought of it as environmental, and yeah, we have their genes. But now we're talking about it as being internal as well. Mom being internal. Dad not ... which is really interesting.

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[38] See, for example, Michael Lynch and Samuel Y. Edgerton, "Aesthetics and digital image processing: representational craft in contemporary astronomy," in G. Fyfe and J. Law (eds.), *Picturing Power: Visual Depiction and Social Relations* (London: Routledge and Kegan Paul, 1988): 184-220.

> So then, when you come to, what's your sense of self and why would you have, what would having more mom's cells do? Well for the first seven years of your life, you need to be empathetic with mom, she needs to be empathetic with you. She needs to understand what's your behavior because you're spending time with her and she's directing you. So that's on a behavioral, basic behavioral level. But she's also teaching you about society. You get socialized by mom in every culture. So the fact that you might have some of mom's cells that have memory is very appealing to me. [BL]

Her reference to her "loose brain" is a subtle cue that she knows she is wading into territory that, while not exactly non-scientific, is at least pushing the envelope. However, she is obviously speaking quite literally, and not just symbolically, about the cells containing a biological essence, or "memory" of a person. The cells are biologically doing something that is related to the interests of the person from whom they came.

Another clinical geneticist had a similar take on the evolutionary role of microchimerism:

> I'd like to believe that [fetal cells] are there because the fetus has a vested interest in keeping its mother healthy. So if they are a generation younger, and they are more plastic, and they have better regenerative properties, you know, the fetus, the neonate at that point wants its mother to be healthy. So in a pre-antibiotic era, for example, it would make sense to me that the fetus is going to do whatever it can to keep its mother alive because if the mother dies, the baby is going to die too. You didn't have bottle-feeding in those days. [BB]

This clinician was clearly in favor of the hypothesis that fetal cells repair rather than do harm. It is difficult to know which came first, what she'd "like to believe," or her observations. In any case, the fetal cells are acting with the child's interests in "mind."

The researchers did make a distinction between what they saw as appropriate conclusions for patients and lay people to draw from the embodied cellular relationship (usually ones that were positive), and those that were inappropriate (usually negative). These are examples of responses that my interviewees seemed to enjoy and encourage:

> The most heart-rending response I've ever had is that this young woman came up afterwards and she said, you know, I can't tell you know much this means to me. My mom died earlier this year. And to know she's with me is just so incredible. [BL]

> A lot of people find humor in having their mother's cells, which I do too. One woman came up when we started working early on on this and said "Please, draw my blood, tell me that his cells are there, he's going off to college, I can't stand it." So a lot of people find it comforting and like the sense of connectedness in it. I think there are probably other people out there who don't like the idea. I do remember one person saying it gave them the creeps. [RD]

And, on the flip side, investigators who were following up on the autoimmune disease hypothesis, thought it was inappropriate, and a little bit ridiculous, for women to jump to the conclusion that their son's (and not just their son's cells) caused their disease:

> Actually, I had one patient say to me, "I want to know which of my sons gave me scleroderma." Do you think we told her the results? I don't think so … To me, it's just like, to give that sort of information to somebody who would make a comment like that is really unethical. [JM]

Another researcher gave an example of someone who made this deduction about causation in the reverse scenario (maternal cells in a child):

> And another kind of sensitive area is the potential for people to say, you know, this is my fault then. So particularly if you have a woman who has a child that has some kind of disease. And then on top of it, draws the inappropriate conclusion, "Oh my cells caused this disease." [RD]

The researchers seem to be making subtle and somewhat contradictory distinctions about the extent to which cells are people, are representatives of people, or are "mere matter." They were more likely to embrace the cell/person synecdoche when it placed their research in a positive, or at least benign, light.

Kinship was a final theme recurring in fetal cell researchers' comments on identity.[39] Several expressed the opinion that maternal/fetal microchimerism would be less unsettling for someone than containing cells from a stranger: "Now if it were to be like you shook hands with

[39] For further analysis of kinship and new reproductive and genetic technologies, see Charis Thompson, *Ontological Choreography*; Sarah Franklin and Helene Ragon_. *Reproducing Reproduction* and Marilyn Strathern, *After Nature*.

someone and you acquired cells that way from a complete stranger or something or you kiss someone and you got cells and you're like 'Oh my god I've still got that person's cells'… that's a little disgusting" [AG]. Even here though, it was unclear whether they thought that biologically related cell sources were easier to fathom because of genetic similitude, or because of social familiarity. When comparing people's reactions to transplants to their reactions to microchimerism, one researcher said:

> I guess the difference in pregnancy is that you're not talking about something foreign, you're talking about somebody who you know. An awful lot of transplants don't take place among family ... [but from a] strange donor we don't know about ... [Maybe there is] less of a freaking out possibility about it [with family]. Maybe it's more easy to accept what you know than what you don't know.

For one doctor, the relevant distinction was not whether you were related to someone, but whether you liked them:

> I actually think you know, it depends on whether you like your mom or not. But I think that even … philosophically the idea that we have more transgenerational connection than we thought, it's kind of a nice thought, actually. You know that we could be learning things that we carry on on an immune level, or whatever level. I think it's a very nice thought. Now I guess that's cause I'm OK with my mom. I mean if I hated my mom, and I hated the idea that she's helping me out when I cut my finger. But I don't think most people are going to feel that way. I think most people are going to be very philosophically comforted by the idea that there are transgenerational messages. [BL]

In these examples, it is easy to see how culturally and historically specific ideas – about motherhood for example – become written into bodies in the

language of science. To return to the chapter's epigraph by Elizabeth Grosz: "Our ideas and attitudes seep into the functioning of the body itself, making up the realm of its possibilities or impossibilities."[40] These scientists clearly conceive of cells as maintaining something of the person – you could call it spirit, identity, interests, or self.

Fifteen minutes of fame

Only recently, because of a few well-publicized cases and TV episodes, chimeras have entered the popular arena, and they have generated much speculation about the materiality of identity. For most people initial exposure to the existence of chimeras is curious and intriguing. Perhaps "cool," perhaps "creepy," it provokes an ephemeral awareness, probably not deeply transformative. Inevitably, media coverage and response to chimerism highlights multiplicity, monstrosity, or both.

A recently reported case of same-sex chimerism has garnered media attention including numerous newspaper articles and an NPR interview. This case, along with another one, were profiled on a Discovery Health Channel special entitled "I am my own twin." Karen, a woman in her early fifties living near Boston, needed a kidney transplant and so she was tissue-typed in order to match her to a potential donor.[41] She has three sons, all of whom were tested to see if their tissue matched hers. It turns

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[40] Grosz, *Volatile Bodies*, 190.

[41] N. Yu and others, "Disputed Maternity Leading to Identification of Tetragametic Chimerism"; "Sophisticated DNA testing turning up more cases of chimeras, people with two sets of DNA," National Public Radio, 11 August 2003, Morning Edition.

out that not only were Karen's sons not a good tissue match, but two of them could not possibly be her sons. The nurse called and told her:

> "You know, Karen, something very unusual has happened here. We've tested your sons because they were possible donors. Your sons' blood does not match your blood. And that's an impossibility. So they couldn't be your children," is what she said to me on the phone. "These could not be your children."[42]

Upon testing biopsies of other bits of Karen's tissue – bladder, skin, hair, cheek – her doctors decided that she is a tetragametic chimera. The case was published in May 2002 in the *New England Journal of Medicine*, and Karen decided to "go public" with an NPR interview in August 2003. The interviewer explains:

> Karen's blood contains the genes from one of those original twin sisters, whereas other parts of her body--her thyroid, skin, bladder, hair--contain the genes from the other sister, or a mixture of both. That explains why two of her sons appeared not to be her sons. They inherited the set of genes not present in her blood.[43]

Newspapers picked up on Karen's story.[44] Followers of the popular televisions show CSI (Crime Scene Investigation) suggested, on more than one website, that it would be a good story line for an episode. Indeed, the season finale of CSI in 2004, "Bloodlines," featured a chimera

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[42] "Karen", Ibid.
[43] Margot Kruskall, Ibid.
[44] Roger Highfield, "Sons I Gave Birth to Are 'unrelated' to Me" *The Daily Telegraph (London)*, 13 November 2003, 14; "When Two Become One in the Womb," BBC News, 13 November 2003; Claire Ainsworth, "The Stranger Within," *New Scientist* 180(2421) (2003): 34.

whose genetic multiplicity initially gets him off a rape charge because his blood and semen do not match.[45] Grissom, the clever forensic scientist, has a eureka moment and the camera pans to an actual article about chimeras that appeared in *Nature* in 2002, the same month as Karen's case was published. When confronted, the suspect confesses his crimes, and also his self-knowledge:

> Grissom: You know that bone marrow donation you gave your brother? 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.
>
> Villain: 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.

Bloggers and fans, fascinated and "creeped out" by the possibility of genetic chimeras, enthusiastically sought and shared information, often referencing the NPR interview, media reports, or scientific articles about Karen. In 2005, U.S. Olympic cyclist Tyler Hamilton was accused of blood doping because testing found that he carried blood other than his own. His defense? He's a chimera.[46]

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[45] CBS, *CSI: Crime Scene Investigation*, "Bloodlines", Episode 423. Eli Talbert and Sarah Goldfinger, writers. Directed by Kenneth Fink. First aired May 20, 2004.

[46] Gina Kolata, "Cheating, or an Early Mingling of the Blood?", *New York Times*, May 10, 2005, Health and Fitness, p. 1. This defense was suggested to Hamilton by a M.I.T. molecular biologist, David Housman. So far, adjudicating bodies are not convinced by Hamilton's claim.

Discourse about these recent cases of chimerism confirms that genomes have come to bear some deeper meaning about the essence of personhood, like psyches or souls did at particular historical moments. For example, each of the following media accounts clearly draws the conclusion that *two cell lines are two people*. The *Nature* article begins with this statement about another recent chimera, a child who was conceived after in vitro fertilization: "Eight years ago in Britain, a boy was born who, genetically, was two people."[47] An article in *New Scientist* describes Karen (pseudonym "Jane"):

> In the end they discovered that Jane is a chimera, a mixture of two individuals - non-identical twin sisters - who fused in the womb and grew into a single body. Some parts of her are derived from one twin, others from the other. Jane's body was made up of two genetically distinct types of cells. There was only one conclusion: Jane was a mixture of two different people.[48]

What does it mean to be "genetically, two people"? In the NPR interview, Karen herself describes some new anxieties about her relationship to her sons:

> Karen: Telling my sons about this was the hardest part, because I felt that part of me hadn't passed on to them. I thought, "Oh, I wonder if they'll really feel that I'm not quite their real mother somehow because the genes that I should've given to them, I didn't give to them."[49]

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[47] Helen Pearson, "Human Genetics: Dual Identities," 10-11.
[48] Ainsworth, "Stranger".
[49] "Karen", NPR, "Sophisticated DNA testing"

The worry that Karen articulates is perhaps not as new as it seems. The language of genes dresses up old concerns about heredity and "blood" in new clothing. However chimerism presents an entirely new way to sever this hereditary chain.

In each of these excerpts, the language available to talk about chimerism invokes a complication of the boundaries of properly individuated persons. What to make of this? It is clear that chimerism causes people to flirt with notions of multiplicity and fragmentation in a more than trivial way. Karen's interviewer in the NPR segment, for example, ominously posits that "the biggest impact of chimerism is not practical, but philosophical, existential, psychological. For Karen, who began life as twins, learning of her unusual past required some adjustment."[50] It is not entirely clear yet whether this adjustment is superficial, or strikes a deeper chord. In the following section, I draw on Ian Hacking's exploration of another kind of multiplicity to explore this question. We will also see that for a small community, the experiences of multiple personality and of chimerism converge.

Rewriting the Genome

In *Rewriting the Soul*, Ian Hacking describes multiple personality as an historically transient mental disorder.[51] What does Hacking's analysis lend to our consideration of chimeras and the multiplication or fragmentation of selves? Chimerism shares many features with multiple

[50] David Baron, NPR host, "Sophisticated DNA testing"
[51] Hacking, *Rewriting the Soul*.

consciousness, the first of which is that they have both been "made up." Multiple personality came into being, with a patient named Felida X, in late 19th Century France, and it has achieved immense popularity in the United States since the 1970's. Multiple personality disorder is an example of "making up people", an idea that Hacking describes thus: "Inventing or molding new kind, a new classification, of people or of behavior may create new ways to be a person, new choices to make, for good or evil. There are new descriptions, and hence new actions under a description."[52] People are made up through a number of avenues, in Hacking's account. Sometimes official statistics that record births, deaths and diseases create new kinds of people, stored in ledgers and files. Sometimes it involves "semantic contagion", where ways of talking about things or imposing narratives retrospectively are disseminated through official and unofficial channels, and are adopted by people as possibilities for being.[53] Furthermore, multiples were (and are) made up through situated interviews, interactions and therapies with experts who already conceive of the possibility of being multiple or split.

Hacking gives the following example of a person being made up in such an interaction. Pierre Janet is a late 19th Century French psychiatrist, and Lucie is his patient:

> Janet: Do you understand me?
> Lucie (writes): No.
> J: But to reply you must understand me!
> L: Oh yes, absolutely.

[52] Ibid., 239.
[53] Ibid., 238, 256-257.

J: Then what are you doing?
L: Don't know.
J: It is certain that someone is understanding me.
L: Yes.
J. Who is that?
L. Somebody besides Lucie.
J. Aha! Another person. Would you like to give her a name?
L. No.
J. Yes, It would be far easier that way.
L. Oh well. If you want: Adrienne.
J. Then, Adrienne, do you understand me?
L. Yes.[54]

In this example, two sorts of people are made up. One new "person" is Adrienne, who is conjured in the interaction between doctor and patient. The simple practice of naming gives Adrienne an anchor for future characteristics and behaviors. She can now appear and reappear in Janet's notes and in Lucie's mind. The other kind of "person" made up in this exchange, and in ongoing treatment, medical records and Janet's publications, is Lucie, a patient with a disorder called "dédoublement," (the nomenclature for what later became multiple personality disorder). This second meaning, the historical coming and going of categories, and consequently people who "are" that kind of person, applies also to Hacking's examples of consumptives, homosexuals, perverts, anorexics and hysterics. Does it apply to chimeras?

Recall Mrs. McK, who, in 1953, donated blood at a Northern England clinic.[55] Her blood appeared to be a mixture of two types of blood, O and

[54] Pierre Janet, "Les Actes inconscients et le dedoublement de la personnalite pendent le somnambulisme provoque," *Revue Philosophique*, 22 (1886), 581. Quoted in Hacking, "Making Up People," 224-25.

A. The investigators determined that Mrs. McK had been a twin, and proposed that the twin's blood had crossed over during gestation and circulated in Mrs. McK even now, thirty-three years later. His twin hypothesis was correct; Mrs. McK's twin brother had died at the age of three. At this point in the investigation and in the laboratory notes, Mrs. McK's blood went from being her own, though classed into "Mrs. McK I" and "Mrs. McK II," to being hers and her brother's, both in pedigrees and in the ways in which doctors talked about her/them. The next series of techniques were aimed at finding out which blood was her "truly begotten blood," and which was his. Race writes, in a letter to Peter Medawar, "isn't it extraordinary to be able to group fully a person who has been dead for 30 years!"[56]

Like Adrienne in the example above, Mrs McK's brother was newly made up. He existed again, in the blood (if not in the flesh), and was given a number of biological attributes that were not assigned to him when he was alive (e.g. blood type). He was more or less conjured from Mrs. McK's body, without any access to his 3-year-old corpse. In Hacking's second sense, in which "making up people changes the space of possibilities for personhood,"[57] a new category was invented. Mrs McK's case was

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[55] See Chapter 1 for Mrs. McK's story in more detail. The case notes, correspondence and laboratory notes for the Medical Research Council (MRC) Blood Group Unit are at the Wellcome Library for the History and Understanding of Medicine, London, UK. The case files for Mrs. McK are indexed as SA/BGU/F20/1 Parts 1 and 2. The details of Mrs. McK's story are gleaned from these files.
[56] Robert R. Race to Peter B. Medawar, 25 April 1953, SA/BGU/F20/1 Part 1, Wellcome Library, London.
[57] Hacking, "Making up People," 229.

published in the *British Medical Journal* and she became the first human "blood group chimera."[58] Mrs. McK's story highlights the historicity of the category "human chimera." In Hacking's terms, "… a kind of person came into being at the same time as the kind itself was being invented. In some cases, that is, our classifications and our classes conspire to emerge hand in hand, each egging the other on."[59]

Looping effects and vanishing twins

One of Hacking's recurrent themes in several decades of writing about "making up people" is that classifications have what he calls "looping effects" on the people so-described. New descriptions of people provide new ways for people to act under that description. As Michael Lynch points out in his review of Hacking's work, this may be a variation on a long-studied sociological theme, often called "labeling", and also "looping," by interactional sociologists like Erving Goffman.[60] I suggest that chimeric conditions are susceptible to looping and labeling effects. It is this feature that makes chimeras the same "kind" of entities as multiples, although Hacking himself may disagree. Looping effects, in his estimation, happen to "interactive kinds," though not to "indifferent kinds."[61] Very basically, categories of people are the former because they

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[58] I Dunsford, CC Bowley, AM Hutchison, JS Thompson, R Sanger, and RR Race, "A Human Blood-Group Chimera," *British Medical Journal* 2(4827) (1953): 81.

[59] Hacking, "Making up People," 228.

[60] Michael Lynch, "The Contingencies of Social Construction," *Economy and Society* 30, no. 2 (May, 2001), 240-254.

[61] Although he mentions it throughout his writing, Hacking elaborates this distinction in Ian Hacking, *The Social Construction of What?* (Cambridge, Mass.: Harvard University Press, 1999).

can reflexively interact with classifications of themselves. Most other "things" are the latter, "indifferent" (a.k.a. "natural") kinds, like quarks and horses. In Hacking's view, multiple personality disorder and anorexia belong to the first kind and schizophrenia and autism to the second kind. The distinction, for him, turns on the question of whether there is an underlying pathological agent that is "indifferent" to the description of it. (Though his latter examples, schizophrenia and autism, and their biological causes, have themselves been contested.)

Hacking would, I suspect, argue that cells are indifferent kinds. A cell either has a Y chromosome or it does not. Such an identification requires techniques of visualization – microscopes, fluorescent cameras, autoradiographs, etc. In chapter 2, I looked closely at the techniques for finding Y chromosomes, and problematized the unequivocal identification of Y-bearing cells. Nonetheless, let us assume that one can unproblematically identify more than one cell population in a single human being. Doesn't that then make a chimera an indifferent kind? An important point to raise here is that chimerism is not as far as we know, a disease. Cells do not seem to be underlying pathological agents (although they have been candidates for autoimmune disease causation, as we saw in chapter 3). Chimeras are undoubtedly coded as medical anomalies, as demonstrated in chapter 1. However many who study the phenomena believe that both chimerism and microchimerism are much more common than we know, and perhaps ubiquitous. Whether cells "out of place" have any "real" effects is an open question.

Despite Hacking's anticipated protestations, ethnographic evidence from contemporary characterizations of and by chimeras suggests that looping effects abound. This is true, I suggest, because cells have come to be seen as tiny selves, as sites and transporters of identity, as explored in the first part of this chapter. Whether or not they "really do" convey identity in ontologically or biologically relevant ways is a point that I wish to remain agnostic about. However, in a way remarkably analogous to Hacking's multiples, members of a small but growing group of people, allied mostly through internet communities, support groups, and through particular psychotherapeutic approaches, conceive of themselves as multiple because of an early loss and/or absorption of their twins.

These people describe themselves as "wombtwin survivors" or "twinless twins." They are singletons who believe or know themselves to be surviving siblings of the *in utero* death of their twin. The "Vanishing Twin Syndrome" is increasingly well known since the routinization of ultrasound, and the existence of early twin loss is accepted by obstetricians and gynecologists as a relatively common happening. I have often seen the statistic that one in eight pregnancies begin as twins. A medical article on the topic describes the impact on the remaining fetus as follows:

> In addition to loss of a twin, the surviving fetus has an increased risk of cerebral palsy, particularly if vanishing twin syndrome occurred during the second half of pregnancy. Other forms of morbidity reported in the surviving twin are aplasia cutis or areas of skin necrosis. Researchers hypothesize that, in twins connected through vascular connection by placental anastomoses, temporary

> hypotension in the surviving twin at the time of fetal demise of the vanishing twin leads to poor perfusion and skin necrosis.[62]

The medical community is, however, reluctant to affirm that the loss of a twin *in utero* can have psychological and emotional sequelae. Survivors and sufferers have established their own support communities and are collecting anecdotes and observations to get the disorder recognized and to share strategies for healing.[63]

My evidence of this community comes from websites, booklets that survivors have published, and an archived email group called vanishingtwins@yahoogroups.com. In these forums, survivors describe, and share, emotional repercussions of their early loss:

> Due to a deep longing for some undefined, missing part of themselves that, it seems, no mate can quite fulfill, single twins may experience problems with relationships and/or even with their

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[62] Ann L. Anderson-Berry and Terence Zach, "Vanishing Twin Syndrome," published online at http://www.emedicine.com/med/topic3411.htm, last updated August 8, 2005, accessed April 17, 2006.

[63] Their alliance around their (real or imagined) genetic condition has become a key to their personal and group identity, and they seek to shape biological knowledge about vanishing twins. This is an example of biosociality, as described by Paul Rabinow, "Artificiality and Enlightenment: From Sociobiology to Biosociality." In *Essays on the Anthropology of Reason* (Princeton, NJ: Princeton University Press, 1996), 91-111. For further literature on patient identity and activism in biomedicine, see also Steven Epstein, *Impure Science*; Michel Callon and Vololona Rabeharisoa, "Research 'In the Wild'"; Vololona Rabeharisoa and Michel Callon, "The Involvement of Patients' Associations in Research."

> sexual identity. They often suffer from feelings of guilt. They may be haunted by feelings that they're "parasites."[64]

The first step in treatment, a self-proclaimed specialist in the field writes, "… is to create a distinct entity in your mind that is completely separate from you. This tiny little person may be named. Giving a name is a very important step because it marks the fact that your wombtwin and you were separate little people."[65] As with multiples, naming creates a node around which a person can be made up. Another similarity is that knowledge of the disorder travels by semantic contagion. Those who identify as womb twins report that they began to suspect the cause of their psychological distress after hearing of VTP in a psychology class, or after a practitioner of a chiropractic therapy called Neuro-Emotional Technique (NET) uncovered their twin.[66]

While the groups and the phenomenon are not formed around genetic chimerism per se, the survivors embrace the genetic phenomenon as further proof of their predicament, and include information about chimerism in basic overviews of the syndrome. One survivor writes:

> A team was invited in to view me, pictures were taken, and the team determined that the pigment is not vitiligo (as I had previously thought), but the skin of a completely different person, with its own

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[64] Althea Hayton, *Wombtwin Survivors: An Introduction*. *(*St. Albans: Wren Publications, 2005).

[65] Ibid.,15. The community's discourse and its commitments to prenatal experience resonate with "right to life" discourse, and there may be important overlaps.

[66] This is a peculiar variant of the recovered memory movement, also discussed by Hacking in *Rewriting the Soul*.

> DNA and cell properties. Basically, I am literally two people walking around as one.[67]
>
> My conclusion, after many months of pondering, is that I am a chimera, and that in the womb I had a girl-twin with whom I fused so completely that we share physical as well as emotional and spiritual characteristics. Since admitting the possibility I have begun to feel her presence very strongly - in retrospect I have done so my whole life, but could never bring myself to admit it.[68]

The discovery of a second cell population legitimates their claim to the protracted existence of their twin, both to themselves and to skeptics around them. Some ask how they can get tested to determine if they are chimeras. Promoters of the Vanishing Twin Syndrome use the very existence of chimerism to move this psychological phenomenon from an interactive kind to an indifferent kind, and the latter has more cultural power. Unlike Hacking, I am not preoccupied with the ontological reality of the underlying phenomenon, but rather I am interested in the rhetorical moves that people make to legitimize or refute the biological reality of disorders.

Conclusion

As Hacking traces, the sciences and scientists of memory played a fundamental role in enabling and constraining the very possibility for multiples to exist when and where they did. Empirical examination of multiples and their networks sheds light on the historical peculiarity of

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[67] Posted on vanishingtwins@yahoogroups.com, June 29, 2005. Incidentally, my spellcheck objects to this sentence because the subject does not agree with the verb.

[68] Posted on vanishingtwins@yahoogroups.com, January 22, 2006.

their "illness," but it also reveals the historical peculiarity of the "normal" condition: having one memory, one biography and one soul. Chimeras similarly call into question the naturalness of genomic uniformity. That DNA can, to everyone's surprise, reveal many within one (body, person, individual, citizen) threatens to loosen the political glue which links one genome to one person. "But they are so rare," many say, or "what is one cell in millions?" As Nicholas Rose points out, rare individuals often shape common knowledge in the human sciences:

> Our vocabularies and techniques of the person, by and large, have not emerged in a field of reflection on the normal individual, the normal character, the normal personality, the normal intelligence, but rather the very notion of normality has emerged out of a concern with types of conduct, thought, expression deemed troublesome or dangerous.[69]

Are chimeras disruptive or dangerous? On one level, not especially. Despite the constant invocation of the monstrous Chimera in clinical literature, to be a chimera is benign. In other words, people do not seek "diagnosis" of chimerism, because it is by and large irrelevant to their health and self-knowledge.[70]

Chimeras only become disruptive when one invests in a genome, or in a cell, some essence of being human, of being oneself. For example, the following exchange featured on an online discussion forum after the CSI episode:

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[69] Nikolas S. Rose, *Inventing Our Selves,* 26.

[70] Except, perhaps, where intersex conditions are involved. Even then, though, there is an increasingly vocal lobby aiming to dispute the marking of intersex conditions as pathological.

> What if this happened to a Jewish person?
>
> I don't think it would matter, because the genetic material is still a blood relative. It would still be "Jewish DNA" so to speak. The children she would bear would still be Jews, because she is Jewish (and her genetic material is Jewish). In the case of a conversion, I would assume that any genetic material she would have would also be considered Jewish, and any children she would bear would also be Jewish.[71]

And in another discussion of chimeras:

> I know this may be a long shot but I'm wondering if that may be a reason for some people being homosexual. Two people one body… could it be that both male and female embryos merged and now both characteristics live in one human?[72]

In both of these cases, people confronted with the existence of chimeras extrapolated from cells to deeply social identities. These statements seem absurd at first pass, but they are not far from the "rational" discourses we have seen scientists adopt in the course of this chapter.

With recent research in microchimerism, cellular and genetic multiplicity is moving from the margins to the norm. The more scientists and administrators poke around in people's cells, the greater is the ascertainment of microchimerism. Interventions such as fertility drugs

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[71]http://www.beliefnet.com/boards/message_list.asp, posted May 21, 2004; accessed May 31, 2004.
[72] http://www.jellykiss.com/blog/archives/002337.html posted August 14, 2005; accessed August 20, 2005.

that increase multiple births, and of course transfusions and transplants, also increase the incidence. One pediatrician told me:

> It's pretty striking that we've all got Mom's cells and all fraternal twins will have their cells. It's just how many? Probably only one in eight twins that's conceived actually comes to term and so you'd expect those to have cells in the surviving twin, and we know that Mom carries cells from her miscarriages, so there is a lot of that going on. [BL]

At least for this group of "loose-brained" researchers, "the self's not a clone of one. It's actually, intrinsically, the thing we call a self has these minor populations" [RD]. The attribution of personhood to cells may seem to be an absurd leap that effaces all the non-cellular elements of being human. It is certainly a peculiar and literal form of essentialism. On the other hand, maybe it is visionary. The persistent surprises and liveliness of bodies should at least give us pause before we invest too much in individualized genomes.

CONCLUSION

Individualism, a powerful strain in Western political ideology and politics, renders human being as contained, autonomous, independent, liberal. Postmodern and poststructural critical theories posit that human subjects are multiple, fluid, relational, uncontained. These theoretical literatures are complex, esoteric and operate in generalities of which I am wary. Nonetheless, they importantly diagnose some broad features of modernity and they constitute one literature to which this project can contribute. Postmodern theorists have dismantled the modern human subject, showing it (us) to be historically constituted, often in the service of particular political or institutional aims. Many point out that the abstract subject implied in political philosophy is implicitly male, white, able-bodied, enfranchised.[1] As critical feminist theorists have illustrated, attention to the specificities of embodied subjects demands that there is no "subject," only subjects; no "body," only bodies.

As compelling as the idea of a fragmented subject is to some of us, it is hard to hold in one's head, to imagine in real life. Sherry Turkle summarizes her own recalcitrance to reading theorists such as Gilles Deleuze and Michel Foucault in the 1970's. These cultural theorists taught that the self is constituted through language, and that "each of us is

[1] For feminist contributions to the study of "the person" and bodies, see especially E. A. Grosz, *Volatile Bodies*; Judith Butler, *Gender Trouble*; Judith Butler, *Bodies that Matter;* Donna Jeanne Haraway, *Simians, Cyborgs, and Women*.

a multiplicity of parts, fragments, and desiring connections."[2] These abstract formulations are like a secret language, opaque to the uninitiated, and contrary to common sense. Turkle writes:

> While in recent years, many psychologists, social theorists, psychoanalysts, and philosophers have argued that the self should be thought of as essentially decentered, the normal requirements of everyday life exert strong pressure on people to take responsibility for their actions and to see themselves as intentional and unitary actors. This disjuncture between theory (the unitary self is an illusion) and lived experience (the unitary self is the most basic reality) is one of the main reasons why decentered theories have been slow to catch on – or when they do, why we tend to settle back quickly into older, centralized ways of looking at things.[3]

Turkle, however, found an entrée into poststructuralist theory twenty years later, while studying "multiple user domains," or MUDs, where computer users experience multiple identities, where real life, or RL, is just one parallel life among many. Turkle writes: "In my computer-mediated worlds, the self is multiple, fluid, and constituted in interaction with machine connections; it is made and transformed by language."[4]

Chimerism is, I suggest, a potential exemplar of the kind of fragmentation and heterogeneity celebrated by poststructuralist theory. However unlike personalities, digital selves, social roles, or names, cells are in the body, of the body. Hacking writes "Some thinkers find atomistic versions of

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[2] Sherry Turkle, *Life on the Screen: Identity in the Age of the Internet*, 1st Touchstone ed. (New York: Simon & Schuster, 1997), 14.
[3] Ibid., 15.
[4] Ibid.

human nature to be obviously false. Rather we are born into a society, educated by it, and our 'selves' are sculpted out of biological raw material by constant interaction with our fellow humans."[5] In chimerism, our "biological raw material" is itself sculpted by interactions with our fellow humans (mothers and their children, for example). A further novelty of this case is that the challenge to intact and inviolable personhood is coming from the work of biologists, rather than from critical social theorists. The cell scientists quoted throughout this dissertation seem to envision a radical reconceptualization of personhood that breaks down the individual in its last bastion: the material of the body.

Citing Darwin's detailed studies of the peculiar arrangements of sex and reproduction among barnacles, Elizabeth Wilson writes, "it seems to me that scientific material contains schemes and wonders that are of immense significance for feminist theories of subjectivity, embodiment, and sexed and gendered identities."[6] Likewise, it seems to me that chimeras can provide food for feminist thought. The literal embodiment of others (by all people, not just women) gestures to an ethics of care that is internalized. It is not just that we are shaped by other people; we are partly composed of them. Wilson argues that attention to the empirical details of biological sciences can challenge the orthodoxy in contemporary feminist studies that "the biological sciences are politically and conceptually inept, and that the goal of feminist analysis of science is

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[5] Hacking, *Rewriting the Soul,* 16.
[6] Elizabeth Wilson, "Biologically inspired feminism: Response to Helen Keane and Marsha Rosengarten, 'On the biology of sexed subjects.'" *Australian Feminist Studies* 17 no. 39 (2002), 284.

to correct ideological error."[7] While I am sympathetic to this formulation, it risks both romanticism of nature *qua* biology, and the hubris that we feminists and social scientists can tell the sheep of inspirational biology from the goats of ideology.

Cynthia Von Buhler, the artist who created the painting in the Introduction of this work, told me this about images she has seen of the Chimaera: "I think they are quite beautiful. I'd like to have one as a pet."[8] I must confess that I, too, like chimeras and those who study them. It is because chimeras seem prodigious and challenging to doctrines of individuality that I chose to undertake this study. However, as a scholar of the social studies of science, I am in an awkward position vis-à-vis my subject matter. While we in some quarters of S&TS are urged retain a symmetrical approach to scientific representation, the field exists as a critical response to simplicity and reductionism. Sometimes the object of our study (about which we are indifferent) is reductionist (about which we are less than indifferent).

Lucy Suchman articulated this dilemma succinctly in relation to her own research on artificial intelligence.[9] The scientists she observed used embodied, situated, complex means to go about reasoning, and then they arrived at a definition of "reasoning" that used abstract, rational constructs very different from those used by the scientists themselves. This passed

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[7] Ibid., 285.
[8] Email communication, November 16, 2005.
[9] Lucy Suchman, "Representing Practice in Cognitive Science," in *Representation in Scientific Practice*, eds. Michael Lynch and Steve Woolgar (Cambridge, Mass.: The MIT Press), 301-322.

as "intelligence" in the realm of computers, but it is very different than the embodied intelligence that ethnographers of scientific practice observe. Suchman writes:

> In particular, science studies recommend indifference toward the relation of representation to phenomenon, in favour of a focus on the practices by which representations of phenomena are produced and reproduced. In the case of cognitive science, however, the phenomena is one on which our studies take a stand.[10]

I began this project with an expectation that I would take a stand against genetic reductionism, as do many other social researchers of genetics. An account of the genetics of a cell that equates it to a person eclipses everything else that constitutes a person. Most notably this includes the social environment of both the person and the cell. However, when I bracket my suspicion of reductionist accounts, a far more interesting and provocative story of cells and persons emerges, which is anything but simple.

How far can I, as an analyst, push my observation that some cell scientists and some journalists speak as though cells are people and people are cells? There are obvious limits to this quasi-serious, quasi-playful discourse. For example, the very existence of chimerism throws doubt on the fundamental premise of forensic testing, a point that public commentators often note.[11] When confronted with chimerism, people are

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[10] Ibid., 318.

[11] Thus far, this does not seem to be causing a great deal of concern among lawyers, judges and forensic scientists. However publicity of recent cases, including Tyler Hamilton's blood-doping defense, and an alleged case where a court challenged a chimeric woman's maternity, may be harbingers of growing concern in legal circles.

readily able to imagine blood being passed through the machineries of DNA identification and being resolved into two different people, two profiles, two entries in a forensic database. But – and this is an important caveat – we cannot say that cells have achieved full-blown political personhood. While I have shown that people speak and write about chimeras as though they are "two people in one body," no one seriously proposes that chimeras be given more than one vote. Rather than causing a dramatic revision of selfhood that would have us all biologically – and politically – interspersed or distributed, it seems likely that in political contexts, the centuries old coherent subject will hold sway, and chimeras will become a footnote to biological complexity.

Currently, though, the personification of cells in chimerism research demonstrates that the move from DNA to person and back again has been made to seem self-evident. Curiously, though, this iteration of genetic reductionism is creating more and more hybrid and heterogeneous people. Karen, the chimeric woman who needed a kidney transplant, was biologically compatible with twice as many potential donors as she would have been if she were, "genetically speaking," only one person. While these phenomena have thus far been managed by discourses of pathology, pollution, and monstrosity, more fruitful visions of interconnectedness may take their place.

APPENDIX

Interview Details

(all interviews conducted by Aryn Martin)

Date	Interviewee	Place
6/19/04	Colleen Jackson-Cook	Richmond, VA
9/15/04	Wendy Robinson	Vancouver, BC
9/15/04	Judith Hall	Vancouver, BC
9/18/04	Lee Nelson	Seattle, WA.
10/13/04	Carol Artlett	Philadelphia, PA
10/28/04	Diana Bianchi	Toronto, ON
2/01/05	Kirby Johnson	Boston, MA
2/17/05	Joe Leigh Simpson	Houston, TX
2/18/05	Farideh Bischoff	Houston, TX
3/15/05	Norbert Gleicher	New York, NY
3/3/05	Sherman Elias (telephone)	Chicago, IL
3/30/05	Samuel Strober	San Francisco, CA
4/13/05	Laird Jackson	Philadelphia, PA
4/14/05	Mark Evans	New York, NY
5/11/05	Anne McLaren	London, UK
5/15/05	Keelin O'Donoghue	Manchester, UK
5/19/05	Claude Diesch & Carolyn Troeger	Basel, Switzerland
5/19/05	Wolfgang Holzgreve	Basel
5/20/05	Sinuhe Hahn	Basel
6/10/05	Lola Cartier	Montreal, QC
6/10/05	Alessandra Duncan	Montreal, QC
6/10/05	Maryann	Montreal, QC
9/6/05	Dennis Lo	London, UK
3/3/06	Kim Dukes	Boston, MA

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