Title
Teratology Transformed: Uncertainty, Knowledge, and Conflict Over Environmental Etiologies of Birth Defects in Midcentury America

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Publication Date
2016

Peer reviewed|Thesis/dissertation

Teratology Transformed: Uncertainty, Knowledge, and Conflict over Environmental Etiologies of Birth Defects in Midcentury America

by

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DISSERTATION

Submitted in partial satisfaction of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

History of Health Sciences

in the

GRADUATE DIVISION

of the

UNIVERSITY OF CALIFORNIA, SAN FRANCISCO

Acknowledgements

Portions of Chapter 1 were published in an edited volume prepared by the *Western Humanities Review* in 2015.

Abstract

This dissertation traces the academic institutionalization and evolving concerns of teratologists, who studied environmental causes of birth defects in midcentury America. The Teratology Society officially formed in 1960, with funds and organizational support from philanthropies such as the National Foundation (Later known as The March of Dimes Birth Defects Foundation). Teratologists, including Virginia Apgar, the well-known obstetric anesthesiologist and inventor of the Apgar Score, were soon embroiled in public concerns about pharmaceutically mediated birth defects. Teratologists acted as consultants to industry and government on pre-market reproductive toxicology testing for pharmaceuticals. However, animal tests seemed unable to clearly predict results in humans and required careful interpretation of dosage and animal species and strain responses.

By the late 1960s, amidst the popular environmental movement, teratologists grappled with public claims that birth defects resulted from exposure to industrial pollutants in water or air, or from food additives, pesticides, and industrial waste or effluent. In a crowded field of professionals concerned with pharmaceutical or chemical exposures during pregnancy, teratologists proved adaptive and resilient. Despite influences from the environmental movement, teratologists at times tried to contain the substances and outcomes considered relevant and called for greater vetting of chemical claims, amidst rampant journalistic and public accusations about iatrogenic or industrial harm. Both experimental teratology and epidemiology informed these debates but each faced explanatory insecurities in causal inference

that left room for parental anxiety and considerable speculation about uncertain harms to susceptible fetuses.

Concomitantly, environmental scientists and activist geneticists wanted to expand the definition of a teratogen to include more subtle or long-term outcomes and raising concerns about the as-yet-undetected reproductive hazards associated with chemical profligacy. Thus, by the 1960s and 1970s, a more general definition of non-genetic factors influencing mechanisms of developmental defect was overwhelmed by a vision of toxic chemical hazards, often pharmaceuticals, affecting development (particularly cognitive or neurobehavioral effects). I argue that the protectionist experimental science of teratologists in the 1950s, the calculative science of epidemiological risk and environmentalist's neo-eugenic claims of damaged children resulting from corporate negligence and industrial pollution that gained ground in the 1960s and 1970s contributed to a late twentieth-century characterization of pregnancy as a risky state.

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Introduction

Since the 1970s, there has been ongoing debate about the reproductive effects of chemicals: among pregnant women discussing safe medications, by scientists studying reproductive toxicology, in arguments about workplace protection policies for fertile women, and by local activists concerned about miscarriages that appeared to be linked to herbicide spray or toxic waste disposal.[1] This research was animated by key questions about maternal experience: How did the uterus become understood as a site of chemical pollution that could result in deviant infant growth (birth defects)? How did pregnancy become constructed as a risky and pathological state linked to pharmaceutical exposure or occupational or environmental pollution? How did the experiences of pregnancy change as a result of this characterization of chemico-toxic prenatal risks?

Yet, instead of the voices of pregnant women, what I found in the historical record was a wealth of published scientific literature about pregnancy and fetal risk, and advice literature addressing potential parents (mostly mothers). Given the sources, my work emphasizes professional debates and discussion of how controversial and incomplete evidence of environmental risks should be or were communicated to pregnant women amidst negotiations between scientists, women's health activists, the media, and medicine in the 1950s through the 1970s.

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[1] Leslie J. Reagan, "From Hazard to Blessing to Tragedy: Representations of Miscarriage in Twentieth-Century America," *Feminist Studies* 29, no. 2 (2003): 357– 78; Theo Colborn, Dianne Dumanoski, and John Peterson Myers, *Our Stolen Future: Are We Threatening Our Fertility, Intelligence, and Survival?: A Scientific Detective Story* (New York: Dutton, 1996); Sheldon Krimsky, *Hormonal Chaos: The Scientific and Social Origins of the Environmental Endocrine Hypothesis* (Baltimore, MD: Johns Hopkins University Press, 2000).

Some advice literature, such as *What to Expect When You're Expecting*, published starting in 1984, was written by parents for parents, seeking to provide clear explanation of some of the threats to pregnancy that "lurked everywhere: in the air we breathed, the food we ate, in the water we drank, at the dentist's office, in the drugstore, even at home."[2] By the 1980s, as in best-selling author Heidi E. Murkoff's depiction, prenatal environmental chemical dangers were seen as ubiquitous and insidious risks that must be managed by pregnant women for the well-being of children and the future of the human race. In her view, pregnant women needed to become informed citizens who understood and managed the risks of environmental pollution. Therein lies a paradox, that despite the relative comfort and safety of modern life in a wealthy country in the late twentieth century, some people felt that fetuses were being poisoned, and were particularly concerned about environmental developmental risks to children occurring during the prenatal period. Embryos and fetuses were understood as particularly susceptible to exogenous chemical exposures.

Teratology, the study of birth defects, played a role in the modern scientific characterization of pregnancy as susceptible to environmental hazards. In particular, I describe how the discipline and profession of teratology (a medical science rooted in nineteenth-century anatomical and laboratory examination of unusual infants and animals) was transformed, by the modernizing and biomedicalizing impulses of those who organized the Teratology Society in the late 1950s in the context of a rising epidemiological science of chronic diseases, and later by scientific and activist voices of feminists and environmentalists of the late 1960s and early 1970s. Ironically, perhaps, this work

[2] Arlene Eisenberg, Heidi Eisenberg Murkoff, and Sandee Eisenberg Hathaway, *What to Expect When You're Expecting* (New York: Workman Pub., 1984). Also quoted by Marika Seigel, *The Rhetoric of Pregnancy* (Chicago; London: The University of Chicago Press, 2013), 92–93.

privileges professionals, medicine, and the fetus, rather than pregnant women, parental advocates for the disabled, or disabled children. As such, it plays a role in the subsumption of the needs, perspectives, and empirical experience of pregnant women that characterizes fetal patient or personhood. In this history, the academic medical science of teratology proved adaptive and resilient, despite its anachronistic leanings. Teratologists based their knowledge claims on modern techniques of mammalian experiment and epidemiology, in an increasingly crowded professional field addressing prenatal chemical risks. They often relied on laboratory experiment on pregnant animals to understand the mechanisms of abnormal development, experimental teratology, even as epidemiology began to play a greater role in assessing prenatal pharmaco-chemical risks in the 1970s.

This work highlights the evolving role of epidemiology and experimental teratology in these debates. Nineteenth-century experimental teratology was concerned with production, classification, and examination of animals with deviant growth in laboratory-like settings. By the mid-twentieth century, teratology was already informed by epidemiology as medical attention turned to chronic diseases in children, particularly in the work of professors of social or preventive medicine, like Theodore Ingalls, Thomas McKeown, or Brian MacMahon. In the late 1940s, British physician scientists set up large cohort studies of congenital malformation, often within departments of social medicine.[3] Initially, in the early 1960s, organizations such as the National Foundation-March of Dimes privileged clinic and laboratory-based techniques studying congenital malformations as promising research fields for funding, such as experimental teratology and related fields

[3] Salim Al-Gailani, "Making Birth Defects 'Preventable': Pre-Conceptional Vitamin Supplements and the Politics of Risk Reduction," *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences* 47 (2014): 278–89; Ian Leck, "McKeown, Record, and the Epidemiology of Malformations," *Paediatric and Perinatal Epidemiology* 10, no. 1 (1996): 2–16.

studying the biochemistry of congenital malformations and medical genetics. Even so, the history of the Teratology Society is a tale of professional resilience and adaptation in the context of two parallel approaches to examine developmental disability: the growing biochemical and genetic view of life, and medicine's further reliance on human statistical population studies.

Even as the Teratology Society was organizing, a huge cohort study of congenital malformation (nearly 60,000 women were followed)—the Collaborative Perinatal Project—was initiated under the auspices of the National Institute of Neurological Disease and Blindness in the late 1950s to link the "continuum of reproductive wastage" (mostly neurological outcomes) to adverse birth events.[4] In the 1970s, epidemiologists combed through this data in effort to link toxic exposures from substances such as pharmaceuticals to birth defects.[5] In the 1970s and early 1980s, epidemiology assumed preeminence as a methodology for statistically linking specific chemical exposures to human anatomical malformations and functional deficit, even as techniques of genetic toxicology gained ground as a means of pre-market testing of chemical substances for carcinogenicity and mutagenicity, following the introduction of a microbial-based assays for mutagenesis in the early 1970s (the Ames Test is one of the most famous).[6] The issue of resurrecting maternal memories of past exposures to link them to infant or childhood anomaly would prove

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[4] Mark A. Klebanoff, "The Collaborative Perinatal Project: A 50-Year Retrospective," 23 (2009): 2–8; Kenneth R. Niswander, Myron Gordon, and National Institute of Neurological Diseases and Stroke, *The Women and Their Pregnancies; the Collaborative Perinatal Study of the National Institute of Neurological Diseases and Stroke*, DHEW Publication No (NIH) 73– 379 (Washington: U.S. Government Printing Office, 1972).
[5] Olli P. Heinonen, Dennis Slone, and Samuel Shapiro, *Birth Defects and Drugs in Pregnancy* (Littleton, MA: Publishing Sciences Group Inc., 1977).
[6] Scott Frickel, *Chemical Consequences: Environmental Mutagens, Scientist Activism, and the Rise of Genetic Toxicology* (New Brunswick, NJ: Rutgers University Press, 2004); Gary Edmond and David Mercer, "Litigation Life: Law-Science Knowledge Construction in (Bendectin) Mass Toxic Tort Litigation," *Social Studies of Science* 30, no. 2 (2000): 265–316.

challenging, and epidemiology would define a problem of "recall bias," that did much to call into question parental logic of causality of infant anomalies, expanding the chasm between lay and expert epistemologies of birth defects.[7]

Ultimately, this dissertation contrasts the laboratory and clinic-based vision of physicians and teratologists who wanted to contain their disciplinary territory and the definition of teratology, with rising voices in the 1970s of environmental scientists, activist geneticists, feminists, and concerned public health physicians. In this account, teratologists are adaptive to changing public concerns. Teratologists both courted funds raised by attention to pharmacological or chemical environmental reproductive hazards and tried to avoid public controversy and what they saw as sensationalistic accounts of their research. Like many physicians, teratologists were concerned with clinical disease, anatomical anomalies, or obvious functional deficit brought about by high-dose exposures such as those seen from pharmaceuticals, and initially less concerned about elusive prenatal harms interrogated by environmental scientists and some pediatric public health practitioners, particularly with respect to the neurological outcomes of exposure to radiation and heavy metals. They emphasized the natural "background" rates of clinically severe birth defects and asked what medicine could do to prevent or treat severe childhood disability. Nevertheless, teratologists were called upon to arbitrate difficult societal disputes about the environmental origins of developmental disability, particularly pharmaceutical hazards. They often summarized a perspective that there was little convincing evidence that a particular chemical exposure caused birth defects or urged caution about interpreting the data they produced in the laboratory on animal models. Yet, that didn't stop public health physicians and environmental health scientists (and to a lesser extent, informed feminists)

[7] Karen Raphael, "Recall Bias: A Proposal for Assessment and Control," *International Journal of Epidemiology* 16, no. 2 (1987): 167–170.

from raising the question of whether testing systems were appropriate to detect harmful effects of chemical exposures. Environmental health scientists, concerned public-health-oriented physicians, and some feminists in the 1970s asked whether more long-term and chronic industrial exposures and subtle developmental outcomes had been adequately explored, effectively expanding the definition of teratogen.

Historiographical Context

If this work speaks particularly to the voluminous literature on the history of reproductive health, it is also informed by diverse bodies of historical literature, including perspectives on eugenics and medical genetics, disability history and social theory, and studies of professional groups within biology and medicine. This research seeks to bridge histories of the professional terrain of applied academic pediatrics research with histories of environmental science and women's health in the mid-twentieth century. Much of the historiography specific to teratology addresses debates about Early Modern notions of monstrosity (typically, infants born with severe and obvious anatomical anomalies) as objects of wonder or deviancy from expected norms and the growing interest of medicine in pathological specimens, teratological research, and embryological collection in the latter half of the nineteenth and early part of the twentieth century.[8] Some scholars choose to

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[8] Katharine Park and Lorraine J. Daston, "Unnatural Conceptions: The Study of Monsters in Sixteenth- and Seventeenth-Century France and England," *Past & Present*, no. 92 (1981): 20–54; Caroline Joan Picart and John Edgar Browning, *Speaking of Monsters: A Teratological Anthology* (Basingstoke: Palgrave Macmillan, 2012); Olivier Roux, *Monstres: Une histoire générale de la tératologie des origines a nos jours* (Paris: CNRS, 2008); Dennis Todd, *Imagining Monsters: Miscreations of the Self in Eighteenth-Century England* (Chicago: University of Chicago Press, 1995); Tony Bates, "Emblematic Monsters: Unnatural Conceptions and Deformed Births in Early Moden Europe," *Clio Medica* 77 (2005); Philip K. Wilson, "Eighteenth-Century" Monsters" and Nineteenth-Century" Freaks": Reading the Maternally Marked Child," *Literature and Medicine* 21, no. 1 (2002): 1–25; David Williams, *Deformed Discourse: The Function of the Monster in Mediaeval*

emphasize the gendered disciplinary power of discourses about monsters and maternal impressions, even as others pointed out how much prodigal possibility was ascribed to the wandering minds of pregnant women.[9] Bridging nineteenth-century and early-twentieth-century examinations of "monsters," Salim Al-Galiani's masterful depiction of John Ballantyne's claims to obstetrical expertise on antenatal care and teratology provides insights on early debates about pathological pregnancies and the role of obstetricians in state-based antenatal care.[10] If teratology is often associated with these debates about monsters that pre-date the twentieth century, the Teratology Society that formed in 1960 continues to meet and debate the origins of birth defects into the twenty-first century.

Twentieth-century American teratology can be situated within the professionalization and specialization of pediatrics in the early-to-mid-twentieth century.[11] It speaks also to the history of eugenics and medical genetics.[12] Several technical accounts

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Thought and Literature (Montreal, Canada: McGill-Queen's University Press, 1999); Nina Lykke and Rosi Braidotti, *Between Monsters, Goddesses, and Cyborgs: Feminist Confrontations with Science, Medicine, and Cyberspace* (London: Zed Books, 1996).

[9] Rosi Braidotti, "Signs of Wonder and Traces of Doubt: On Teratology and Embodied Differences," in *Between Monsters, Goddesses, and Cyborgs: Feminist Confrontations with Science, Medicine, and Cyberspace*, ed. Nina Lykke and Rosi Braidotti (London: Zed Books, 1996); Wilson, "Eighteenth-Century 'Monsters' and Nineteenth-Century 'Freaks': Reading the Maternally Marked Child." This observation is based on Philip Wilson's evocation of Roy Porter's work.

[10] Salim Samar Al-Gailani, "Teratology and the Clinic: Monsters, Obstetrics and the Making of Antenatal Life in Edinburgh, c. 1900" (PhD Diss., University of Cambridge, 2010).

[11] John F. Cronin and Robert Aaron Lyon, *Albert Graeme Mitchell* (Cincinnati: Cincinnati Children's Hospital, 1964). Sydney A. Halpern, *American Pediatrics: The Social Dynamics of Professionalism, 1880–1980* (Berkeley: University of California Press, 1988).

[12] M. Susan Lindee, *Suffering Made Real: American Science and the Survivors at Hiroshima* (Chicago: University of Chicago Press, 1994); *Moments of Truth in Genetic Medicine* (Baltimore, MD: Johns Hopkins University Press, 2005). Lily E. Kay, *Who Wrote the Book of Life?: A History of the Genetic Code*, Writing Science (Stanford, CA: Stanford University Press, 2000). Daniel J. Kevles, *In the Name of Eugenics: Genetics and the Uses of Human Heredity*, 1st ed. (New York: Knopf, 1985). Ian R. Dowbiggin, ""A Rational Coalition": Euthanasia, Eugenics, and Birth Control in America, 1940–1970," *Journal of Policy History* 14, no. 3 (2002): 223–60.

have examined the trajectory of mid-twentieth-century teratology in North America, such as Harold Kalter's comprehensive encyclopedic monograph on the history of research on environmental influences on prenatal development. There are also highly detailed internal descriptions of the formation of the Teratology Society.[13] In addition, historians of medicine and science, such as Jane Oppenheimer, have examined the evolving concerns of experimental teratologists and embryologists.[14] Yet there isn't a comprehensive historical examination of the professional organizing of teratologists in midcentury, much less the interface between these birth defects experts and critiques arising from the environmental and women's health movement about iatrogenic or industrial effects on pregnancy and the fetus or newborn.

Because teratologists are ultimately concerned with environmental factors that caused birth defects, their research is implicated in the history of the environment of the womb and subsequent concerns from feminist activists and environmental scientists about toxic hazards to pregnant women and fetuses. I situate this work within a larger framework of the history of environmental health, particularly in accounts that root the history of environmental health sciences on the factory floor, rather than histories of encounters with nature or conservation movements.[15] Anthony Bale's survey on "women's

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[13] Thomas H. Shepard et al., "An Updated History of the Teratology Society," *Birth Defects Research Part A: Clinical and Molecular Teratology* 88, no. 5 (2010); Harold Kalter, "Teratology in the Twentieth Century Congenital Malformations in Humans and How Their Environmental Causes Were Established," (Elsevier); James G. Wilson and Josef Warkany, "The History of Organized Teratology in North America," *Teratology* 31, no. 2 (1985), 285–96.

[14] Jane M. Oppenheimer, "Some Historical Relationships between Teratology and Experimental Embryology," *Bulletin of the History of Medicine* 42, no. 2 (1968): 145–159.

[15] This work owes a great debt to historians of environmental and occupational health, among them Christopher Sellers, Christian Warren, Gerald Markowitz and David Rosner. Christopher C. Sellers, *Hazards of the Job: From Industrial Disease to Environmental Health Science* (Chapel Hill: University of North Carolina Press, 1997). Christian Warren, *Brush with Death: A Social History of Lead Poisoning* (Baltimore, MD: Johns Hopkins

toxic experience," grouped by pharmaceutical, occupational and environment exposures, provided an overview of the diverse arenas in which women encountered the toxic world and laid open teratology as an area with insufficient study.[16]

The effect of the environment on health has long been a concern of healers and physicians. Linda Nash argues that modernist emphasis on bodily disease and defect is a temporary aberration in a larger history of neo-Hippocratic environmentalist conceptions of disease and disability. If health was once seen as a state of balance, of equilibrated rest, diet, and evacuations in a salubrious environment, medical theories of the late nineteenth century directed attention to particular pathogens and diseased bodies. By this line of reasoning, germ theory and forms of scientific medicine shifted sanitarian and miasmatic environmentalist narratives of disease situated in the local terrain away from an unhealthy environment towards contaminated individuals. The environmental movement can be seen as a resurgence of more long-standing environmentalist perspectives on optimum health. Fears of specific toxic harm and chemical exposures from industrial pollution of the air or water were nevertheless part of this resurgence of environmentalist perspectives on disease. If fears of germs had provoked new medical intervention and control of bodies, chemicals claimed a new role in the second half of the twentieth century. By the early 1960s, childhood cancer clusters were reported that hinted of environmental etiologies.[17] Nash cites the exploding of the atomic bomb, poisoning accidents among farm workers

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University Press, 2000). Gerald E. Markowitz and David Rosner, *Deceit and Denial: The Deadly Politics of Industrial Pollution* (Berkeley, CA: University of California Press, 2002).

[16] Anthony Bale, "Women's Toxic Experience," in *Women, Health, and Medicine in America: A Historical Handbook*, ed. Rima D. Apple (New Brunswick: Rutgers University Press, 1992), 403–31.

[17] Epidemic intelligence officers hinted that a virus might have caused an unusual leukemia cluster among children in Cook County, Illinois in the early 1960s. Clark W. Heath, Robert Hasterlik, "Leukemia among Children in a Suburban Community," *Journal of the American Medical Association* 34 (1963): 796–812.

exposed to pesticides (such as parathion) in the Central Valley of California, and environmental activism of communities such as McFarland (a California cancer cluster in the 1980s, attributed to agricultural chemicals in water supplies) and the Love Canal (the chemical-waste-dump-become-suburb near Niagara Falls that was controversial in the mid-1970s) as important incidents that influenced perceptions of risk from chemical exposure and revived discussion of the role of the local environment on health.

Nancy Langston's detailed look at the many faces of the synthetic estrogen diethylstilbestrol (DES) also demonstrates changing approaches to the precautionary principle (the level of caution with which potentially toxic substances are used or controlled when some evidence suggests harmful effects) and the role DES has had in raising concerns about transplacental carcinogenesis and other subclinical or long-term reproductive hazards from prenatal exposures.[18] Likewise, Sarah Vogel's examination of the history of bisphenol A (BPA) research and activism raised questions about crisis management and public fears in response to particular estrogenic substances, relatively toothless chemical regulatory policy that defined many substances as safe merely because of their long usage (known as the GRAS list, as substances were generally recognized as safe), theories of fetal origins of disease and endocrine disruption advanced in the 1990s, and efforts to evaluate the safety of particular estrogenic substances.[19]

My research emphasizes environmentalist narratives in the 1940s and 1950s that privileged the semipermeable uterus as the site of production of individual damaged infant

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[18] Nancy Langston, *Toxic Bodies: Hormone Disruptors and the Legacy of DES* (New Haven, CN: Yale University Press, 2010). "The Retreat from Precaution: Regulating Diethylstilbestrol (DES), Endocrine Disruptors, and Environmental Health," *Environmental History* 13, no. 1 (2008): 41–65.

[19] Sarah Vogel, "The Politics of Plastics: The Making and Unmaking of Bisphenal a 'Safety'," *American Journal of Public Health* 99, no. S3 (2009): S559–S66; Sarah A. Vogel, *Is It Safe?: BPA and the Struggle to Define the Safety of Chemicals* (Berkeley: University of California Press, 2013).

bodies from radiation exposure, pharmaceuticals, or nutrient deficiency (this research can be seen as a rising counter narrative to deterministic eugenics and genetics perspectives subsequent to World War II). This postwar vision of biochemical deficiency or excess causing prenatal damage during pregnancy was accompanied with narratives of protection and responsibility for pregnant women, particularly once the National Foundation became involved in research and prevention of congenital malformations in 1958 (they adopted "birth defects" as a less disturbing term than "monsters" or malformations).

Such environmentalist narratives derived from pediatric medicine, teratology, perinatology, and embryology overlapped with a perspective arising with the environmental movement in the 1960s and 1970s. If teratologists had defined environmental factors to include anything not genetic, environmentalists increasingly focused on specific toxic chemical risks in the environment but framed reproductive hazards and outcomes much more broadly (describing congenital malformations as a crude indicator of developmental damage). They feared not only teratogenesis but also mutagenic effects on both sexes derived from exposure to specific toxic chemical pollutants, or "matter displaced," in the exterior environment.[20] In quasi-eugenic discourse about impairment to the vigor, intelligence, and wellbeing of children and future generations, environmental scientists wanted to interrogate increasingly subtle neurological outcomes, transplacental carcinogenesis and other long-term effects, mutagenesis, or other reproductive harms affecting females and males from hazardous substances, in a more broadly defined and interconnected chemically-polluted environment. Scott Frickel's work on the history of the

[20] This term for pollution comes from anthropologist Mary Douglas, but Mitman, Murphy and Sellers also use this terminology. Mary Douglas, *Purity and Danger: An Analysis of Concepts of Pollution and Taboo*, (Harmondworth: Penguin, 1970). Gregg Mitman, Michelle Murphy, and Christopher C. Sellers, eds., *Landscapes of Exposure: Knowledge and Illness in Modern Environments*, vol. 19, Orisis (Chicago: University of Chicago Press, 2004), 13.

Environmental Mutagen Society has been particularly useful to understand biophysicist and geneticist scientific activists, the evolution of genetic toxicology, and the ways in which narratives about mutagenic damage to future children took up themes from eugenics discourse.[21] Yet genetic toxicology, public health, and much of the historical literature on epidemiological study of environmental factors affecting human health has been particularly engaged with the question of how chemical mutagens affected cancer outcomes.[22] Though at times teratological research seemed a foil against public anxieties about uncertain chemical and radiation-related mutagenic effects on germ cell material (rather than somatic effects), the relationships between chemical mutagenesis and teratogenesis remained scientifically difficult to trace and underrepresented in historical scholarship on environmental science.[23]

In essence, this dissertation addresses two overlapping ways of discussing the prenatal environment: that of the environment as the uterine site of non-genetic factors influencing deviant development and that of the broader environment as a source of toxic

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[21] Frickel, *Chemical Consequences: Environmental Mutagens, Scientist Activism, and the Rise of Genetic Toxicology*. John S. Wassom, "Origins of Genetic Toxicology and the Environmental Mutagen Society," *Environmental and Molecular Mutagenesis* 14, no. S16 (1989).

[22] Alan I. Marcus, *Cancer from Beef: DES, Federal Food Regulation, and Consumer Confidence* (Baltimore: Johns Hopkins University Press, 1994). Robert Proctor, *Cancer Wars: How Politics Shapes What We Know and Don't Know About Cancer* (New York: BasicBooks, 1995); Christopher Sellers, "Discovering Environmental Cancer: Wilhelm Hueper, Post-World War II Epidemiology, and the Vanishing Clinician's Eye," *American Journal of Public Health* 87, no. 11 (1997): 1824– 35.

[23] The Mrak Committee's report on teratogenic risks of pesticides underscored the lack of good studies examining teratogenic effects from pesticides. Emil M. Mrak, "Report of the Secretary's Commission on Pesticides and Their Relationship to Environmental Health, Department of Health, Education and Welfare Publication," in *Food and Drug Administration, Washington, DC* (1969). Efforts to link mutagenesis to teratogenesis and perform conclusive pre-market teratogenic testing were difficult. See the commentary by Anne McLarren in F. M. Sullivan et al., "Congenital Malformations and Other Reproductive Hazards from Environmental Chemicals," *Proceedings of the Royal Society of London. Series B, Biological Sciences* 205, no. 1158 (1979): 109.

pollution and reproductive hazards that nevertheless maintained scrutiny on individual pregnant bodies, particularly due to political and legal conflicts over workplace fetal protection policies. Starting in the 1940s, teratologists and other scientists developed new interest in categorizing and explaining environmental factors affecting development that were not genetic, yet they only included potential toxins as a small, rather insignificant subset of this overarching classification that sought to explain "natural" causes of severe infant disability.[24] For some environmental scientists, parents, and feminists, the toxicity of particular pharmaceuticals and chemicals loomed large as a problem starting in the late 1960s and 1970s. They argued that interacting and overlapping chemical toxins derived from a polluted industrial landscape had been inadequately explored by medical science, including reproductive hazards to men.[25]

Political scientist Cynthia Daniels has turned laser focus to the question of why reproductive hazards and health of men were largely ignored until the 1970s, attributing it to four cultural assumptions about masculinity and fatherhood. She argues that these ideals of masculinity influenced the characterization of male reproductive hazards based on the assumptions that men: 1) had a limited, secondary, role in reproduction, 2) were invulnerable to reproductive harm due to idealizations of the strength of the male body 3) were viral and might be shamed by suggestions otherwise, and 4) were less involved in the nurturing and care of children.[26] Teratological research was equally informed by cultural assumptions about gender and infused with concern for both the protection of pregnant

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[24] For an example of this perspective, see the conclusion to D.A. Beckman and Robert L. Brent's article, Environmental Teratogens: Robert L. Brent and David A. Beckman, "Environmental Teratogens," *Bulletin of the New York Academy of Medicine* 66, no. 2 (1990): 151.
[25] Vogel, "The Politics of Plastics: The Making and Unmaking of Bisphenal a 'Safety'."; Vogel, *Is It Safe?: BPA and the Struggle to Define the Safety of Chemicals*.
[26] Cynthia R. Daniels, *Exposing Men: The Science and Politics of Male Reproduction* (Oxford ; New York: Oxford University Press, 2006).

women and, at times, the need for women to take responsibility for the outcomes of reproduction. Nevertheless, the long fascination with anatomically unusual newborns and the well-established professionals charged with protecting the health of pregnant women and newborns influenced how the science of environmental reproductive risks unfolded. The burgeoning research and medical fields in the 1950s focused on congenital anomalies should also not be discounted in this history.

There are a number of inescapable paradoxes in this history. First, as environmental historian Michelle Murphy has demonstrated with respect to sick-building syndrome, the conditions of possibility of modern life allowed for consideration of more subtle environmental harms: "The very materials and technologies of postwar comfort and success might themselves be sources of subtle and stealthy chemical exposure."[27] In this case, fears of subtle infant deviancy resulting from environmental pollution were possible in part because of the relative safety and comfort of modern life and lower infant, maternal, and childhood mortality rates, which can be linked to higher standards of living and emergency medical care during pregnancy. Indeed, as historian of eugenics Martin Pernick has noted, the abortion of most fetuses thought likely to be severely impaired (observed via technologies of prenatal diagnosis or visualization) might lower risk tolerances for infant disability or turn attention to more subtle types of deviancy.[28]

Second, it wasn't just paternalistic (male) scientists and physicians who pointed to potential environmental fetal harm. Several ground-breaking women professionals and women's health advocates urged greater attention to both prenatal risks to fetuses and

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[27] Michelle Murphy, *Sick Building Syndrome and the Problem of Uncertainty: Environmental Politics, Technoscience, and Women Workers* (Durham NC: Duke University Press, 2006), 3.

[28] Martin S. Pernick, *The Black Stork: Eugenics and the Death of "Defective" Babies in American Medicine and Motion Pictures since 1915* (New York: Oxford University Press, 1996).

greater responsibility and participation in medical decision-making about prenatal risks for pregnant women. At least two popular works in the early 1980s portrayed industrial environmental damage to children as neglected by medicine and underfunded by government.[29] As such, this dissertation engages with a large body of scholarship that examines the history of reproductive health, the women's health movement, and notions of motherhood in twentieth-century America.

This rich scholarship on changing twentieth-century notions of motherhood in North America informs the history of pregnancy.[30] It is well established that before the twentieth century, mothers, particularly poor mothers, managed most of the health needs of families and called for physicians only in grave emergency or severe illness.[31] Early-twentieth-century social welfare programs were often directed at the health and well-being of mothers

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[29] Christopher Norwood, *At Highest Risk: Environmental Hazards to Young and Unborn Children* (New York: McGraw-Hill, 1980); John Elkington, *The Poisoned Womb: Human Reproduction in a Polluted World* (Harmondsworth, Middlesex, England ; New York, NY: Viking, 1985).

[30] The changing relationship between mothers' work inside and outside the house remains an obsession of this literature. Susan Thistle, *From Marriage to the Market: The Transformation of Women's Lives and Work* (Berkeley: University of California Press, 2006); Rebecca Jo Plant, *Mom: The Transformation of Motherhood in Modern America* (Chicago; London: The University of Chicago Press, 2010); Marga Vicedo, *The Nature and Nurture of Love: From Imprinting to Attachment in Cold War America* (Chicago; London: The University of Chicago Press, 2013); Joanne J. Meyerowitz, *Not June Cleaver: Women and Gender in Postwar America, 1945–1960* (Philadelphia: Temple University Press, 1994); Molly Ladd-Taylor and Lauri Umansky, *"Bad" Mothers: The Politics of Blame in Twentieth-Century America* (New York: New York University Press, 1998). Allison L. Hepler, *Women in Labor: Mothers, Medicine, and Occupational Health in the United States, 1890–1980*, Women and Health (Columbus: Ohio State University Press, 2000). Molly Ladd-Taylor, *Mother-Work: Women, Child Welfare, and the State, 1890–1930* (Urbana: University of Illinois Press, 1994). Alice Kessler-Harris, *Out to Work: A History of Wage-Earning Women in the United States* (New York: Oxford University Press, 1982). Ruth Schwartz Cowan, *More Work for Mother: The Ironies of Household Technology from the Open Hearth to the Microwave* (New York: Basic Books, 1983).

[31] Rima D. Apple, *Women, Health, and Medicine in America: A Historical Handbook* (New York: Garland Pub., 1990); *Perfect Motherhood: Science and Childrearing in America* (New Brunswick, NJ: Rutgers University Press, 2006); Rima D. Apple and Janet L. Golden, *Mothers & Motherhood: Readings in American History* (Columbus: Ohio State University Press, 1997).

and children, sometimes with eugenic leanings intended to improve the quality of the race.[32]

The role and status of mothers has changed considerably in the twentieth century, as the average number of children declined and more women earned wages and professional status outside the home (the average number of children was 3.56 at the turn of the twentieth century and 1.86 at its end, though there were waxing and waning demographic patterns such as the well-known demographic boom that followed World War II).[33] There is a strong moral overtone to some of the writing on changing expectations of mothers and motherhood.[34] Rima Apple argues that scientific advice played a larger role in informing the care of infants and children by the nineteenth century, but medical advice gained new authority in the mid-twentieth century, resulting in ubiquitous parental literature about scientific approaches to childrearing that informed expectations about "proper" motherhood.[35] Apple focuses on advice for mothers on the care of children, particularly infant feeding, but some of her arguments could be extended to include advice on prenatal care and maternity.

Historians studying pregnancy, such as Barbara Dudan and Leslie Reagan, have done much to explain the characterization of pregnancy as dangerous and potentially pathological, particularly with respect to the prioritization of the rights and needs of a baby-like fetus that was constructed during debates about fetal life, via medical specialties and technologies of observation and visualization, and in the ways that environmentalist

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[32] Theda Skocpol, *Protecting Soldiers and Mothers: The Political Origins of Social Policy in the United States* (Cambridge, MA: Belknap Press of Harvard University Press, 1992); Alisa Klaus, *Every Child a Lion: The Origins of Maternal and Infant Health Policy in the United States and France, 1890–1920* (Ithaca: Cornell University Press, 1993).
[33] Plant, *Mom: The Transformation of Motherhood in Modern America.*
[34] Ladd-Taylor and Umansky, *"Bad" Mothers: The Politics of Blame in Twentieth-Century America.*
[35] Apple, *Perfect Motherhood: Science and Childrearing in America.*

fears were constructed around the pregnant risks of harm to future generations.[36] Feminist scholarship of pregnancy has emphasized the role of technologies in transforming the experience of pregnancy from one of subjective sensation defined by the pregnant woman (such as quickening or lightening) to a "tentative" experience defined by medical tools of observation and prenatal diagnosis (via stethoscope, amniocentesis, ultrasound, electrocardiogram, prenatal genetic diagnostic tests, etc.).[37] In some accounts, mothers and physicians in the 1970s are depicted as "moral pioneers" as they interacted with and used reproductive technologies, including prenatal testing methods and ultrasound, with the legal right to medical abortion (widespread since 1973).[38] In this scholarship, scrutiny of the fetus for visual abnormality is technologically mediated and contributes to the pathologization and medicalization of pregnancy, potentially leading to unnecessary or dangerous medical interventions.

Other authors have demonstrated how fetal risks, particularly from maternal "vices," such as alcohol or smoking, became conceived as a problem for all pregnant women. The post-1970s imagery of the anti-abortion movement and public awareness campaigns

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[36] Barbara Duden, "The Fetus on the 'Farther Shore:' Toward a History of the Unborn," in *Fetal Subjects, Feminist Positions*, ed. Lynn Morgan and Meredith Michaels (Philadelphia: University of Pennsylvania Press, 1999); *Disembodying Women: Perspectives on Pregnancy and the Unborn* (Cambridge, Mass: Harvard University Press, 1993); Leslie J. Reagan, *Dangerous Pregnancies: Mothers, Disabilities, and Abortion in America* (Berkeley: University of California Press, 2010).

[37] These accounts track a broader medical shift away from the sensation of touch and patient narration towards auditory amplification and optical visualization. Duden, *Disembodying Women: Perspectives on Pregnancy and the Unborn*; "The Fetus on the 'Farther Shore:' Toward a History of the Unborn."; Barbara Katz Rothman, *The Tentative Pregnancy: Prenatal Diagnosis and the Future of Motherhood* (New York: Viking, 1986). Rayna R. Reiter, *Testing Women, Testing the Fetus: The Social Impact of Amniocentesis in America*, The Anthropology of Everyday Life (New York: Routledge, 1999). Malcolm Nicolson and John E. E. Fleming, *Imaging and Imagining the Fetus: The Development of Obstetric Ultrasound* (Baltimore: Johns Hopkins University Press, 2013).

[38] Rothman, *The Tentative Pregnancy: Prenatal Diagnosis and the Future of Motherhood*. R. Rapp, "Moral Pioneers: Women, Men and Fetuses on a Frontier of Reproductive Technology," *Women & Health* 13, no. 1-2 (1987): 101–16.

against alcohol, illicit drug use, or smoking during pregnancy to protect the fetus have in the former case tended to make the pregnant woman invisible and in the latter case often characterized pregnant women as irresponsible.[39]

Historical scholarship on pregnancy has engaged with conflicts over diverse professional approaches to childbirth and the rise of biological metaphors (particularly symbiosis and parasitism) applied to pregnancy.[40] Clare Hanson's cultural history of pregnancy provides a compelling study of how obstetrical texts, advice manuals, and science fiction fantasies demonstrate multifaceted understandings of pregnancy, yet traces an overarching shift in how the relationship between pregnant woman and the unborn were characterized, using biological metaphors and gradually favoring parasitic rather than a symbiotic interaction as the twentieth century progressed.[41] Scholars as diverse as anatomist George Corner and sociologists Aryn Martin and Kelly Holloway have explored the history of the elusive placenta.[42] For Aryn Martin and Kelly Holloway, inaccurate

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[39] Elizabeth M. Armstrong, *Conceiving Risk, Bearing Responsibility: Fetal Alcohol Syndrome and the Diagnosis of Moral Disorder* (Baltimore: Johns Hopkins University Press, 2003); Laury Oaks, *Smoking and Pregnancy: The Politics of Fetal Protection* (New Brunswick, NJ: Rutgers University Press, 2001); Janet L. Golden, "'An Argument That Goes Back to the Womb': The Demedicalization of Fetal Alcohol Syndrome, 1973–1992," *Journal of Social History* 33, no. 2 (1999): 269–98; *Message in a Bottle: The Making of Fetal Alcohol Syndrome* (Cambridge, MA: Harvard University Press, 2005); Rosalind Pollack Petchesky, "Fetal Images: The Power of Visual Culture in the Politics of Reproduction," *Feminist Studies* (1987): 263–92; Ladd-Taylor and Umansky, *"Bad" Mothers: The Politics of Blame in Twentieth-Century America*. Oaks, *Smoking and Pregnancy: The Politics of Fetal Protection*.

[40] Judith Walzer. Leavitt, *Brought to Bed: Childbearing in America, 1750–1950* (New York: Oxford University Press, 1986); Clare Hanson, *A Cultural History of Pregnancy: Pregnancy, Medicine, and Culture, 1750–2000* (Houndmills, Basingstoke, Hampshire ; New York: Palgrave Macmillan, 2004). Wendy Kline, *Bodies of Knowledge: Sexuality, Reproduction, and Women's Health in the Second Wave* (Chicago; London: The University of Chicago Press, 2010).

[41] Hanson, *A Cultural History of Pregnancy: Pregnancy, Medicine, and Culture, 1750–2000*.

[42] George W Corner, "Exploring the Placental Maze. The Development of Our Knowledge of the Relation between the Bloodstreams of Mother and Infant *in Utero*," *American Journal of Obstetrics and Gynecology* 86 (1963): 408–18.

historical resurrections of a supposedly impermeable placental wall were used to reinforce a pregnant woman's responsibility to police their behavior and protect the fetus from environmental hazards.[43]

The history of women's bodies and reproductive capacity also provided a venue for feminists to interrogate scientific interpretations of gender, evident in the work of those who asked questions about how sex was defined by science, such as Ruth Hubburd, Nelly Oudshoorn, or Londa Schiebinger.[44] In Ann Oakley's account from 1984, the rise of antenatal care and medical surveillance of pregnancy is an exercise in the control of women, as male obstetricians expanded their professional territory into "normal" physiological pregnancy, marginalizing a more community-based, lay, and women-centered approach characterized by midwives.[45] Yet other scholars demonstrated the agency and negotiations of pregnant women in their search for safer and less painful childbirth.[46]

Writings on fetal person- and patient-hood are numerous. Historians and anthropologists who studied the embryo or fetus, such as Sarah Dubow or Lynn Morgan, argued that the fetus was a point of conflict over cultural anxieties and diverse visions of

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[43] Aryn Martin and Kelly Holloway, "'Something There Is That Doesn't Love a Wall': Histories of the Placental Barrier," *Studies in History and Philosophy of Biological and Biomedical Sciences* 47 (2014): 300–10.
[44] Londa L. Schiebinger, *The Mind Has No Sex?: Women in the Origins of Modern Science* (Cambridge, MA: Harvard University Press, 1989); Ruth Hubbard, *The Politics of Women's Biology* (New Brunswick, NJ: Rutgers University Press, 1990); Ruth Hubbard, Mary Sue Henifin, and Barbara Fried, *Biological Woman—the Convenient Myth: A Collection of Feminist Essays and a Comprehensive Bibliography* (Cambridge, MA: Schenkman Pub. Co., 1982). Nelly Oudshoorn, *Beyond the Natural Body: An Archaeology of Sex Hormones* (New York; London: Routledge, 1994).
[45] Ann Oakley, *The Captured Womb: A History of the Medical Care of Pregnant Women* (Oxford Oxfordshire; New York, NY: B. Blackwell, 1984).
[46] Leavitt, *Brought to Bed: Childbearing in America, 1750–1950*. Wendy Kline, "Communicating a New Consciousness: Countercultural Print and the Home Birth Movement in the 1970s," *Bulletin of the History of Medicine* 80, no. 3 (2015): 527–56; Kline, *Bodies of Knowledge: Sexuality, Reproduction, and Women's Health in the Second Wave*.

personhood, family, motherhood, and national identity in modern America.[47] Feminist cultural scholars such as Rosalind Petchesky have shown how, since the mid-1960s, imagery of a baby-like fetus floating alone like an astronaut in a space divorced from maternal context changed the way the fetus was understood, amid the contentious politics of abortion in which such images of fetuses were wielded for specific political purposes.[48] Journalists and sociologists, among them Monica Casper, turned their gaze towards the relatively new professional terrain of fetal surgery and their construction of the fetal patient.[49] I build on their work to examine the ways in which teratologists, advocates, and environmentalists characterized pharmaceutical or environmental dangers to the fetal patient amidst an evolving laboratory-based and epidemiological science of prenatal risks.

Bodies of historical literature arose in tandem with the social movements of the 1970s, such as efforts to interpret and examine histories of women's health or people living with disabilities. Disability history was initially concerned with examination of the education and self-empowerment of particular communities, such as those with hearing impairment.[50] Disability scholars are also interested in the changing status of "monsters," as they shifted from objects of awe, wonder and curiosity, to become *terata,* or pathological specimens (or, alternatively, remained a spectacle and sometimes some level of self-

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[47] Sara Dubow, *Ourselves Unborn: A History of the Fetus in Modern America* (Oxford; New York: Oxford University Press, 2011). Lynn Marie Morgan, *Icons of Life: A Cultural History of Human Embryos* (Berkeley: University of California Press, 2009).
[48] Petchesky, "Fetal Images: The Power of Visual Culture in the Politics of Reproduction."; Rosalind P. Petchesky, *Abortion and Woman's Choice: The State, Sexuality, and Reproductive Freedom*, Longman Series in Feminist Theory (New York: Longman, 1984).
[49] Monica J. Casper, *The Making of the Unborn Patient: A Social Anatomy of Fetal Surgery* (New Brunswick, NJ: Rutgers University Press, 1998). Gina Bari Kolata, *The Baby Doctors: Probing the Limits of Fetal Medicine* (New York, NY: Delacorte Press, 1990).
[50] Beth Linker, "On the Borderland of Medical and Disability History: A Survey of the Fields," *Bulletin of the History of Medicine* 87, no. 4 (2013): 499–535; Catherine J. Kudlick, "Disability History: Why We Need Another 'Other,'" *American Historical Review* 1083 (2003): 763–93.

determination and income as "freaks" or side-show performers).[51] They helped illustrate the cultural associations of disability with rehabilitation of veterans since the U.S. Civil War, and the rehabilitative philanthropic efforts to address childhood disability in the 1950s, followed by the mobilization of people with disabilities for greater rights, self-actualization, and transformations of the built landscape and public policy to better accommodate difference.[52] Yet disability historians at times have struggled with how to include voices and tell stories of the most severely disabled, who didn't often join marches or write down their experiences. With respect to pregnancy and severe, life-threatening, neonatal impairments or anatomical anomalies, historians of eugenics and prenatal diagnosis engage with the concerns of disability scholars. [53] They raise ethical questions that haunted

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[51] Marlene Tromp, *Victorian Freaks: The Social Context of Freakery in Britain* (Columbus: Ohio State University Press, 2008); Nadja Durbach, *Spectacle of Deformity: Freak Shows and Modern British Culture*, 1 ed. (University of California Press, 2009); Rachel Adams, *Sideshow U.S.A: Freaks and the American Cultural Imagination* (Chicago: University of Chicago Press, 2001); Stephen T. Asma, *On Monsters an Unnatural History of Our Worst Fears* (Oxford: Oxford University Press, 2009); Jack. Hunter, *Freak Babylon: An Illustrated History of Teratology and Freakshows* (London: Glitter Books, 2005); Wilson, "Eighteenth-Century 'Monsters' and Nineteenth-Century 'Freaks': Reading the Maternally Marked Child," 1–25; Jan Bondeson, *The Two-Headed Boy, and Other Medical Marvels* (Ithaca, NY: Cornell University Press, 2000); *A Cabinet of Medical Curiosities* (Ithaca, NY: Cornell University Press, 1997).

[52] Paul K. Longmore, *Why I Burned My Book and Other Essays on Disability*, American Subjects (Philadelphia: Temple University Press, 2003); "Uncovering the Hidden History of Disabled People," in *Why I Burned My Book, and Other Essays on Disbility*, ed. Paul K. Longmore (Philadelphia: Temple University Press, 2003); Paul K. Longmore and Lauri Umansky, *The New Disability History: American Perspectives*, The History of Disability Series (New York: New York University Press, 2001).

[53] Ruth Schwartz Cowan makes the case that prenatal genetic screening was introduced as a pronatalist effort for families with severe inherited illnesses and is not eugenic. While that may be true, the more broad application of antenatal surveillance and screening for potential infant disability is nevertheless a charged topic and in some cases may be ethically problematic. Such debates often hinge on how eugenics is defined (e.g. as coercive state policies controlling reproduction or as more complex, ambivalent, and diverse desires to improve the quality of the population). Ruth Schwartz Cowan, *Heredity and Hope: The Case for Genetic Screening* (Cambridge, MA: Harvard University Press, 2008).

Hannah Arendt, among other philosophers and bioethicists, about who has a right to decide who can and who cannot exist in the world.[54]

Changing perceptions of prenatal harm are inherently linked to the women's health movement, what sociologist Susan Bell calls "an embodied health movement" that arose as part of second-wave feminism in the late 1960s. Although the women's health movement is often distilled in broader historical surveys into the elite Northeastern experiences of The Boston Women's Health Collective and their 1969 course and publication, *Our Bodies Ourselves*,[55] the movement is more aptly understood as an incredibly varied and distributed grassroots network of women's groups and clinics that emphasized the value of epistemological claims derived from women's bodily experiences and wanted to increase women's reproductive autonomy as well as their access and engagement in their own medical care.[56] By 1973, there were at least 35 health projects and 116 women's centers in the United States.[57]

The link between the contested politics of abortion and such visions of greater reproductive autonomy for women helped make the fetus into the subject of considerable

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[54] Pernick, *The Black Stork: Eugenics and the Death of "Defective" Babies in American Medicine and Motion Pictures since 1915*; Dowbiggin, "A Rational Coalition": Euthanasia, Eugenics, and Birth Control in America, 1940–1970."; Philip Reilly, *The Surgical Solution: A History of Involuntary Sterilization in the United States* (Baltimore: Johns Hopkins University Press, 1991); Suzanne Elizabeth Evans, "Parental Eugenics: Congenitally Anomalous Newborns and the Continuing Debate over Selective Non-Treatment and Neonatal Euthanasia in the United States" (University of California, Berkeley, 2008); Cowan, *Heredity and Hope: The Case for Genetic Screening*; Diane B. Paul, *Controlling Human Heredity, 1865 to the Present*, The Control of Nature (Atlantic Highlands, NJ: Humanities Press, 1995).
[55] Boston Women's Health Collective, *Our Bodies, Our Selves: A Course by and for Women* (Boston, MA: Boston Women's Health Collective, 1971).
[56] Sheryl Burt Ruzek, *The Women's Health Movement: Feminist Alternatives to Medical Control* (New York: Praeger, 1978); Sandra Morgen, *Into Our Own Hands: The Women's Health Movement in the United States, 1969–1990* (New Brunswick, NJ: Rutgers University Press, 2002); Michelle Murphy, *Seizing the Means of Reproduction: Entanglements of Feminism, Health, and Technoscience* (Durham, NC: Duke University Press, 2012).
[57] Ruzek, *The Women's Health Movement: Feminist Alternatives to Medical Control*.

public scrutiny and attention. Subsequently, feminist and environmentalist narratives of industrial or iatrogenic harm often used this public fetus as a political tool. Susan Bell emphasizes how the scientific identification of a relationship between diethylstilbestrol (DES) and cancer and characterization of DES daughters overlapped with and inspired considerable activism from within the women's health movement, helping to change medical practices related to sex hormone usage during pregnancy and the status of women as informed patients.[58]

In the women's health and environmental movement, voices of criticism called for more attention and research on chemical risks to the pregnant body and fetus, asserting that such research concerns had been neglected or de-emphasized by medicine. However, these voices often encouraged research from within teratology and related biomedical fields (pharmacology, dysmorphology, toxicology, environmental science, etc.) that further emphasized fetal or infant deviancy. Such characterization of maternal responsibility for protecting the fetus from prenatal harms resulted in the perception of numerous and ubiquitous risks to pregnancy and high risks of potential infant deviancy (birth defects) from insidious toxic exposure that is evident in advice manuals starting in the 1960s but which becomes particularly strident by the 1970s. Thus, fears of the unknown effects of chemicals on fetuses could be viewed as a more complex and mixed legacy of the women's health movement, which not only empowered women to be more involved in their own care and informed medical approaches to women's healthcare, but also animated fears and anxieties about uncertain harms.

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[58] Susan E. Bell, *DES Daughters: Embodied Knowledge and the Transformation of Women's Health Politics* (Philadelphia: Temple University Press, 2009), 42–43.

Structure of the Dissertation

This dissertation examines the evolution of teratology and the characterization of the fetal environment in four chapters. Chapter 1 addresses the origin story of teratology, including its historical roots in anatomical studies and medical examination of 'monstrous' embryos and births. It traces the evolving research concerns of pediatric physician scientists who helped form assemblages that brought together pregnant animals and chemicals as research tools to study anomalies and mechanisms of abnormal development in laboratory settings in Cincinnati, Pennsylvania, Boston, and Rochester. Concerns of harmful prenatal exposures (primarily radiation-related) and narratives about eugenic degeneracy or deficiency informed this research, even as many researchers chose to emphasize hopeful narratives of simple biomedical solutions that might be obtained through basic research on topics such as prenatal nutrition.

In this vision, abnormal infant growth might occur as a result of either mutagenesis (damage to genetic material, or germ cells) or teratogenesis (damage to the developing embryo or fetus resulting in infant anomalies), but teratogenesis was a more tangible and reproducible object of study, in contrast to public fears and elusive evidence of the effects of low-level exposures to radiation on human genetic material. Yet the information obtained from animal experiments proved complex, which required nuanced interpretations and resisted simple explanations or extrapolations to humans. In the face of public concern about environmental exposures and publicity about severe infant disability among children in Germany and around the world in 1962 as a result of thalidomide exposure, the expertise of teratologists was much in demand, and their interests became much more intertwined with the pharmaceutical industry and efforts to produce useful mammalian tests for reproductive toxicology.

Chapter 2 addresses the popularization of teratological research in midcentury, including the shifting priorities of the National Foundation for Infantile Paralysis to congenital malformations (and juvenile arthritis) and the career and advocacy of the anesthesiologist-cum-perinatologist, Virginia Apgar. The National Foundation-March of Dimes helped define, fund, and publicize the study of birth defects starting in 1958, initially highlighting crippling neural tube disorders such as spina bifida as their area of primary arena for medical support and advocacy. Popular literature at the time used metaphors of biological organisms, leaky barnyard fences, and space exploration and pioneers to help lay readers imagine the still relatively inaccessible uterine environment; understand teratology and the permeable relationship between the maternal environment and the developing fetus; and recognize the apparent heroism of exploratory efforts by fetal surgeons and other perinatal specialists.

Chapter 3 addresses the career trajectory of Vilma Hunt, an environmental scientist who became involved in debates about occupational hazards and fetal protection in the 1970s. Hunt's research shifted from polonium-210's presence and effects on lung tissue, smoking, and air pollution research to examination and debate about reproductive exposures during pregnancy and fertile women's right to work in hazardous settings in the 1970s. Hunt's report on the occupational hazards, particularly teratogenic risks, to pregnant women, provoked many debates about fetal protection policies that bled into a much broader framing of chemical reproductive hazards encompassing threats to reproduction (mutagenesis and teratogenesis) in men and women from industrial pollution and diverse occupational settings.

Chapter 4 traces epidemiological and toxicological debates about prenatal heavy metal poisoning in the 1960s and 1970s, extending to worldwide incidents of acute

congenital poisoning from fungicide-treated seed grain and large cohort studies of mercury exposure from fish consumption among pregnant women in indigenous populations in North America and far-flung island nations in the 1980s and 1990s. Congenital Minamata disease in Japan became an archetype of industrial environmental damage and provided iconic images of damaged children by the 1960s. Mercury poisoning evoked long-standing debates about iatrochemical harm, yet teratologists played a relatively small role in them. Congenital mercury poisoning was a topic that was of great concern to the media, environmental scientists, toxicologists, neurologists and some pediatricians and parents in North America in the 1970s but seemed to lie outside of the disciplinary purview of teratologists. In many respects, teratologists viewed congenital heavy metal poisoning from industrial sources as a rare and unlikely scenario, and urged greater attention to understand the basic mechanisms of a vast range of apparently "naturally occurring" developmental disorders. In the 1980s, studies of prenatal effects of dietary consumption of fish in the Seychelles and Faroe Islands studies pitted concerned public-health-oriented physicians, who emphasized low-level chronic effects of methylmercury exposure on intelligence, with other biochemists and toxicologists, who characterized a more adaptive and resilient fetus in the face of exposure to environmental hazards. These debates about the fetus are thinly veiled metaphors about the resilience of the human race in the context of environmental pollution and degradation.

This is a complex story, not necessarily one of professional dominance and satisfactory medicalization of pregnancy and infant disability, but rather a contested history with women and professionals, sometimes one and the same, at times emphasizing and at times deemphasizing clinical or subclinical environmental prenatal risks, informed by the evolving sciences of experimental teratology and human epidemiology. Indeed,

midcentury perinatal research advocacy of teratologists and other professionals about insidious chemico-environmental risks and prevention during pregnancy was reinterpreted and sometimes remobilized by lay audiences in 1970s. A relatively common parental anxiety about the uncertain outcomes of pregnancy, manifested in myths about monsters and marked children, was translated in the 1950s and 1960s to anxieties about birth defects, due to specific chemical exposures. By the 1970s, in the context of an evolving epidemiological science of prenatal risks, the word *teratogen* became more broadly defined as the agent not only of severe congenital malformation at birth (the disciplinary terrain of experimental teratologists) but also more subtle or long-term outcomes.

Chapter 1: Teratology Transformed: Medicalizing Monsters and Environmentalizing the Womb in Midcentury America (1940–1975)

Introduction

On May 14, 1954, in Cincinnati, the pediatrician Josef Warkany and the embryologist James G. Wilson wrote a letter to twenty-one scientists seeking to organize a society of researchers interested in the field of teratology. Later that year, they expanded this select group, and fifty-three people gathered for the first meeting in 1956. In their view, teratology had languished since the early part of the twentieth century and they were reaching out to fellow researchers to solicit interest in forming a professional group and annual conference dedicated to "causation, mechanisms, and manifestations of abnormal embryonic development."[1] Included in their list of interested parties were geneticists such as James V. Neel, and Curt Stern, who worked on the human health effects of radiation, along with embryologists, developmental biologists, zoologists, and anatomists. In addition to

[1] Josef Warkany and James G. Wilson to Dr. Salome G. Waelsch, 14 May 1954, Box 1, Folder 1, Series 1.1, Teratology Society Records, College of Physicians of Philadelphia, PA. The letter appears to have been sent to the following people: Salome Waelsch, Curt Stern, John G. Sinclair, Paul B. Sawin, Meredith N. Runner, Liane B. Russell, Bradley M. Patten, Ronan O'Rahilly, James V. Neel, Walter Landauer, Sewall Wright. Attendees at the first meeting in 1956 included a broader complement of advocates for infant and child welfare and few geneticists (save for James V. Neel): W.F. Windle, Ethel Dunham, Katherine Blaine, Elsa Orent Keiles, Leonard Mayo, Alice Fitzgerald, S. R. M. Reynolds, Richard Masland, Hermann Yannet, Alfred Shands, James V. Neel, Marjorie Nelson, Bradley M. Patten, Douglas P. Murphy, Theodore Ingalls, Meredith Runner, Paul Sawin, Lester Sontag. Richard Masland was director of the National Association for Retarded Children and would go on to be involved at the Collaborative Perinatal Project at the National Institute of Neurological Diseases and Blindness.

academics, the initial meeting was attended by representatives of the U.S. Children's Bureau, the National Institute of Neurological Diseases and Blindness (NIDB), one representative of the Dupont Institute, and representatives from the Association for the Aid of Crippled Children (AACC) and the National Association for Retarded Children (NARC).

As part of their efforts to organize a conference and a professional society dedicated to teratogenesis, Warkany and Wilson also asked for funds from Metabolism & Nutritional Study Section and the Human Embryology and Development Study Section (HED) of the NIH, and the AACC. The HED was formed in 1955 and would help coordinate these networks of researchers. The AACC (now known as the Foundation for Child Development) was particularly instrumental in initiating scientific meetings that emphasized childhood disability originating in the prenatal period. It was a charitable organization, founded in the early part of the century in New York City, that had gradually expanded its efforts from education, charity, and support for families with crippled children to funding scientific research activities emphasizing the prevention of prenatal causes of disabling disorders of children (the charity used a bequest in the 1940s from the estate of the silk merchant Milo M. Belding).[2] By 1952, the association sponsored a conference and decided to "give major attention to the development and support of basic research in

[2] "Foundation for Child Development Annual Report: 1979–1980," 2, Box 2, Folder 56, Foundation for Child Development Records (FA019), Rockefeller Foundation Archives, Tarrytown NY. http://storage.rockarch.org/93cab944-e501-462d-ab22-9920cda196ea-FCD001_033_00785.pdf [Accessed June 26, 2015]; See letters requesting conference funding: Josef Warkany and James G. Wilson to Elsa Orent Keiles and Leonard Mayo, 7 June 1955, Box 1, Folder 1, Series 1.1, Teratology Society Records.

prematurity, congenital malformations, and birth injuries."[3] Likewise, the National Foundation for Infantile Paralysis refocused their activities in 1958 beyond the apparently vanquished polio to other "crippling" diseases such as juvenile arthritis and congenital malformation, funding some of these researchers and the costs of incorporation of the Teratology Society in 1960 (By 1958 they had changed their name to simply the National Foundation. In 1976, they changed their name to the March of Dimes Birth Defects Foundation. Henceforth, I will use NFIP for the organization before 1958 and NF or NF-March of Dimes after).[4]

The Teratology Society attempted to combine a diverse mix of anatomists, pediatricians, experts in maternal and child health, and human geneticists to address the topic of abnormal infant morphology. With origins in pediatric nutritional research and radiation safety, this seemingly rather academic and anachronistic interdisciplinary professional group was drawn into contentious debates about environmental causes of birth defects. One early proponent of collective preventative action to prevent congenital malformations acquired during the prenatal period was a professor of preventative medicine, Theodore Ingalls, who did not join the Teratology Society.[5] Research on congenital malformation was also

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[3] Association for the Aid of Crippled Children, University Committee on Research in Congenital Malformations, Prematurity, and Birth Injuries, "Plan," January 1955, Box 1, Folder 1, Series 1.1, Teratology Society Records; S. R. H. Reynolds to Josef Warkany. "Conference on Congenital Malformation, June 15 and 16, 1954: Proposed Agenda," 13 May 1954, Box 1, Folder 1, Series 1.1, Teratology Society Records.

[4] Leonard W. Mayo to Gilbert Dalldorf, 15 September 1958, Box 7, Folder: "Public Relations: Association for the Aid of Crippled Children, 1955–1958." Series 6: "Expanded Program," Medical Program Records, March of Dimes Archives, White Plains, NY.

[5] Theodore Ingalls was an early and avid proponent for using epidemiology and laboratory experiment to examine the origins of congenital malformations in the interests of preventative medicine. Theodore H Ingalls, "The Study of Congenital

part of a postwar reframing of human genetics and was influenced by rising popular concern about toxic prenatal harm from pharmaceuticals and environmental pollution in the 1960s and 1970s. After the 1962 exposé of birth defects linked to an anti-nausea medication, thalidomide, this rather obscure group of teratologists was consulted as experts on birth defects and was asked by industry and government to take on questions of reproductive toxicology.

To some extent, the Teratology Society was representative of postwar research interest on chronic diseases of children. Cofounders Warkany and Wilson's efforts were part of a broader shift within philanthropies and research communities that placed new attention on science-based prevention of congenital malformation. Concomitantly, pediatrics was growing as a profession and becoming more specialized, even as childhood infectious disease and micronutrient malnutrition appeared to be less of a threat due to modern therapeutics and dietary or nutritional supplementation. Tools of medical observation, such as x-rays, made hidden anatomical anomalies of infants were more evident by midcentury, and congenital

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Anomalies by the Epidemiologic Method: With a Consideration of Retrolental Fibroplasia as an Acquired Anomaly of the Fetus," *New England Journal of Medicine* 243, no. 3 (1950): 67–74; Ingalls, "The Strange Case of the Blind Babies," *Scientific American,* December 1955 40–44; Ingalls, F. L. Babbott, K. W. Hampson, and John E. Gordon, "Rubella: Its Epidemiology and Teratology," *American Journal of Medical Sciences* 239, no. 3 (1960): 363–83; John E. Gordon and Ingalls, "Preventive Medicine and Epidemiology," *The American Journal of the Medical Sciences* 225, no. 3 (1953): 320–344; Ingalls, "Mongolism," *Scientific American* 186, no. 2 (1952): 60–66; Ingalls, "Modern Concepts of Communicable Disease," *American Journal of Public Health and the Nation's Health* 43, no. 12 (1953): 1586–87; Gordon and Ingalls, "Death, Defect, and Disability in Prenatal Life. An Epidemiologic Consideration," *American Journal of Public Health and the Nations Health* 38, (1948): 66–74; Ingalls, "Congenital Malformations: Environmental Influences That Act to Cause Them," *Yale Journal of Biological Medicine* 32, no. 1 (September 1959): 51–7.

malformations comprised a larger share of infant mortality.[6] Originating in morphological embryology studies within departments of anatomy and influenced by burgeoning laboratory-based disciplines of biology, experimental teratology had one foot in the older anatomical medico-scientific traditions yet was also linked to newer fields such as genetics, biochemistry, physiology, and development.[7]

This chapter examines the academic professional organization of teratology researchers, who were seeking to reframe the nineteenth-century discipline of teratology as a new laboratory- and epidemiology-based science. Teratology as a professional field was characterized by two developments. First, teratology arose in dialogue with, but often as a counter narrative to, the study of human inheritance. Teratologists were instead interested in elaborating environmental (non-genetic) causes of malformations that influenced obvious morphological or functional anomalies evident shortly after birth. They characterized the womb as the site of maldevelopment. As such, they were forerunners to concerns in the 1960s and 1970s about industrial-pollution-related exposures occurring during the prenatal period, but advised cautious interpretation of data obtained from pregnant animals in the laboratory to apply to humans. Teratologists wanted to transform teratology into a modern academic science, yet they often wanted to emphasize naturally occurring

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[6] In his description of the evolution of clinical approaches to congenital malformations, Warkany emphasized that many infants born with severe internal anomalies in the early twentieth century perished or were misdiagnosed and that surgeons were typically called in for cases of cleft palate, spina bifida, and "gross malformations of the extremities." Josef Warkany, "The Medical Profession and Congenital Malformation (1900–1979)," *Teratology* 20 (1979): 202.

[7] At the time, medical genetics, focused on diagnosing rare familial disorders, was still in its infancy, a medical backwater with little hope for successful treatments. It did not yet dominate the diagnosis and classification of childhood disability and was being re-invented as a clinical and statistical science after eugenics had begun to take on its pejorative meanings due to the apparent shoddiness of associated science and the atrocities of the war committed in the name of biological racial superiority.

severe infant disability as the outcome of most relevance. Even as concerns about radiation safety animated their research in the 1950s, ambivalence characterized their response to the environmental movement's approach to prenatal chemical hazards. Teratologists were influenced by, but sometimes skeptical of, claims made during the 1970s by journalists and the popular environmental movement that raised questions about more subtle, often neurological, and long-term outcomes of prenatal exposures to pollution from industrial chemicals and other widely dispersed synthetic products.

Second, there were differing perspectives among statistically oriented medical researchers who were informed by their observations of patient populations and concerned about social determinants of disease and the laboratory-based scientists who based their findings on animal experiment. Those who wanted to publicize prenatal environmental risks often came from public health, social medicine, and environmental health perspectives and were sometimes in conflict with scientists practicing experimental teratology research on animals who formed the core of the Teratology Society. If teratologists at times were driven by the impetus to influence public policy in order to prevent future birth defects, experiment-driven teratologists insisted on defining "true" causes of birth defects and producing "good" science. They often advocated for a moderate or skeptical approach that emphasized careful vetting of conclusions about human exposures obtained from animals, and tended to focus on the apparently high rate of spontaneously occurring severe infant anomalies (2–3% of births).[8] Sometimes

[8] In the preface to the first volume of *Issues and Reviews in Teratology* in 1983, Harold Kalter described the divide between teratologists and environmentalists as follows: "Fetal maldevelopment has become the concern of environmentalists,

researchers used both methodologies but differed in their perspectives on how to inform public policy, the media, and pregnant women.

Teratologists both responded to concern over the prenatal impacts of chemical pollution, pharmaceuticals, and radiation in the 1960s–1970s and were dismayed by how their research was represented in some environmentalist and media accounts. The worldview and institutional commitments of pediatric researchers who created knowledge about birth defects had a significant effect on the outcomes they considered relevant and how they defined environmental etiologies. In general, they wanted to narrow the scope of the field to their own disciplinary terrain and interests, despite claims from concerned parents and environmentalists that served to expand the definition of what counted as teratogenic. Some teratologists were pediatric clinicians who tended to underscore the importance of delineating the diverse, multifactorial mechanisms of severe congenital disabilities of childhood, which made them question the priorities and emphasis of environmental health researchers on prenatal industrial chemical exposures; toxic exposures composed a small fraction of the environmental etiologies they had helped define. Many teratologists portrayed their work as an overarching counter narrative to research on deterministic genetic factors, yet were nevertheless in dialogue with geneticists about mechanisms of abnormal development. Aware of multifarious environmental factors interacting with genetics to cause infant

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activists of various persuasions, industrial organizations, government agencies, ethicists, parents—i.e., individuals and groups whose actions are impelled by apprehension... For still others—clinicians, academics, experimentalists—the upsurge in the interest in fetal maldevelopment is at a different level, and their pursuits are broad, taking external agents as but one of the causes of defective development." Harold Kalter, ed. *Issues and Reviews in Teratology*, vol. 1 (New York: Plenum Press, 1983), ix.

disability (viral, mechanical, physical, chemical), they tended to see prenatal toxins as exceptional or insignificant. Even as environmental scientists worried about the less obvious impacts of chemical pollution, teratologists tended to emphasize measurable and severe anatomical anomalies and clinical conditions over subtle or long-term outcomes.

Josef Warkany, F. Clarke Fraser, and James G. Wilson founded the Teratology Society amid postwar preoccupations about nutritional deprivations and the effects of the atomic bomb and other radiation exposures. Though they acknowledged complex relationships between genes and the environment, these scientists often based their careers on specific disabilities and the environmental factors they thought were most important or actionable. Fraser studied the genetics of cleft palate, Warkany was interested in prenatal nutritional deficiencies, and James G. Wilson was an embryologist who had studied radiation effects on embryos in the 1950s and later led workshops and training exercises on teratology in the 1960s to aid with pre-market reproductive toxicology testing of pharmaceuticals. Despite concern for the effects of the local environment on human health, and experiences in nutritional and radiation safety research, the factors they considered as environmental were influenced by assumptions about origins of infant disability, what would be ameliorable using biomedicine, and the appropriate outcomes to study based on clinical practice, laboratory experiences, and the long history of medical research on unusual infant and animal anatomy. Their ecological thinking helped defined the womb as the fetal environment and as a source of harm in opposition to eugenic policies and genetic determinism. Yet in the face of the apparent intractability of influencing some environmental factors and the range and

diversity of spontaneously occurring and severe clinical infant anomalies, they made assumptions about what counted as 'environmental' that tended to emphasis severe disabilities, scrutiny of the personal behaviors of pregnant women, and biomedical solutions.

This chapter now lays out a bit of background on nineteenth-century experimental teratology, and describes the initial meetings and foundation of the Teratology Society 1956-1960. It defines the epistemic communities surrounding two methodological approaches to studying environmentally mediated congenital anomalies: experimental teratology and epidemiology. Those who used epidemiology usually expressed concern for social determinates of disease (social medicine) and public health. The broad historical shift in thinking about prenatal environmental exposures begins with mid-twentieth-century research on the prenatal environment based on embryology and eugenics that was informed by concerns about radiation safety, oxygen deprivation, and nutrition. By the early 1960s, growing concern about the safety of pharmaceuticals during pregnancy informed this research, but by the late 1960s and 1970s a new vision arose from the environmental movement that interrogated a more expansive set of outcomes and directed attention to uncertain prenatal effects from environmental pollutants and accidental exposures to pesticides, chemical pollutants, and toxic waste. The pediatricians, epidemiologists, and biomedical researchers of the Teratology Society attempted to answer questions about the origins and meanings of anomalous infants based on their empirical experiences in the lab and clinic, carving a professional niche for themselves in an increasingly crowded terrain of professionals with expertise on pregnancy and prenatal pharmaceutical and other chemical exposures.

Teratology's Origin Story

Fascination with unusual progeny has ancient roots, when exceptional births were often understood as omens or portents, the result of interspecies procreation, or as manifestation of God's wrath or punishment. The term *teratology* is derived from the Greek word for monster or marvel, *teras*; and infants born with dramatically unusual form were commonly referred to as monsters until at least the early part of the twentieth century.[9]

The science of teratology originated in the discussion and collection of natural curiosities as a demonstration of erudition, wealth, and power. This propensity demonstrated elite ability to overcome visceral reactions and observe such rare or exceptional objects as jokes of nature or intellectual curiosities rather than viewing them as strange, repugnant, or evil.[10] Though continuities persist, some argue that monsters had already moved out of the realm of portents or prodigies by the seventeenth century, into the realm of medical pathology.[11] In the eighteenth century, exceptional infants and animals were increasingly involved in debates among naturalists about anatomy and regeneration. Historical studies of natural philosophy examine discourses about monsters to emphasize the display and exhibition of unusual bodies as part of collections of pathological anatomy or for

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[9] John Nicholas Walton et al., *The Oxford Medical Companion* (Oxford; New York: Oxford University Press, 1994), 955; Douglas Power Murphy, *Congenital Malformations: A Study of Parental Characteristics with Special Reference to the Reproductive Process*, 2nd ed. (Philadelphia: Lippincott, 1947), 3.
[10] Michael Hagner, "Enlightened Monsters," in *The Sciences in Enlightened Europe*, ed. William Clark, Jan Golinski, and Simon Schaffer (Chicago: University of Chicago, 1999); Bates, "Emblematic Monsters: Unnatural Conceptions and Deformed Births in Early Moden Europe." Park and Daston, "Unnatural Conceptions: The Study of Monsters in Sixteenth- and Seventeenth-Century France and England." Bondeson, *A Cabinet of Medical Curiosities*.
[11] Park and Daston, "Unnatural Conceptions: The Study of Monsters in Sixteenth- and Seventeenth-Century France and England," 23.

popular entertainment. Deviant infant bodies evoked amusement, awe, wonder, and curiosity. At the same time, physicians and naturalists moved to classify and dissect monstrosity, increasingly understood to be on a continuum with normal anatomy, as a means to impose order on nature's complexity and variability. Historian of science Michael Hagner attributes this shift towards dissecting deviance and viewing it as a threat to patterns of order as one of the more disturbing legacies of the Enlightenment, describing "radical change in the epistemic foundations of understanding life as a process and human beings as results of that process…[which] led to attitudes toward deviation and otherness that constituted the dark side of the Enlightenment and outlasted the Age of Reason, casting a huge shadow on modernity."[12]

Monsters were also central to debates within natural history and theology in the seventeenth and eighteenth centuries about preformation, a theory that the seed of a child was implanted whole and complete, which emphasized the fixed and unchanging nature of reproduction, in opposition to theories of epigenesist, which emphasized developmental malleability.[13] The physician and anatomist William Harvey, among others, published in the mid-seventeenth century about the nature of development, based on observations on eggs or early embryos from animals such as deer.[14] For theologians and early naturalists, monsters represented a threat to the infallibility of God (for how could he create something imperfect?) and divisions

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[12] Hagner, "Enlightened Monsters," 178.
[14] Clara Pinto Correia, *The Ovary of Eve: Egg and Sperm and Preformation* (Chicago: University of Chicago Press, 1997). Joseph Needham, *A History of Embryology*, 2nd ed. (New York: Abelard-Schuman, 1959), 133–34.

drawn between man and animals. Such liminal creatures challenged efforts to categorize and understand.[15]

In the words of the anthropologist Mary Douglas, the science of teratology represented a means to maintain anthropocentricism: "[W]hen a monstrous birth occurs, the defining line between humans and animals may be threatened. If a monstrous birth can be labeled an event of a particular kind, the categories can be restored."[16] Infants born with unusual anatomy defied categorization and raised many questions for both lay and expert audiences.

These early interpretations of unusual births often emphasized wonder and curiosity, which scientific rationalism's emphasis on defect and deviancy over the awe of the extraordinary or exceptional seemed to diminish. In addition to providing evidence about the relationships between humans and animals and how regeneration occurred, discussions of monsters often centered on questions of how they came to be. As the feminist philosopher Rosi Braidotti reminds us, "[d]iscourses about monsters are fundamentally 'epistemic,' in that they express and explore a deep-seated curiosity about the origins of the deformed or anomalous body."[17] The broad historical trajectory that disability scholar Rosemarie Garland-Thomson traces, from wonder to error, ominous marvel to freak or curiosity, from "astonishing corporeal extravagance into the pathological specimen of the *terata*," is linked to the standardizing and normalizing processes of modernity and industrialization,

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[15] Hagner, "Enlightened Monsters."
[16] Quoted in Picart and Browning, *Speaking of Monsters: A Teratological Anthology*, 260.
[17] Lykke and Braidotti, *Between Monsters, Goddesses, and Cyborgs: Feminist Confrontations with Science, Medicine, and Cyberspace*, 139.

divorcing identity from kinship or local membership and locating it in bodily difference.[18]

By the nineteenth century, the effort to understand nature's complexity and the range of human and animal morphological variability was characterized by description, systemization, and classification of both unusual human and animal form. Specimens of exceptional infants in glass jars became a commonplace part of collections of pathological anatomy that were the mainstay of medical education and science. However, there was longstanding tension over displays of human oddities for popular amusement and profit and ostensibly more noble uses as part of medical education and collections of morbid anatomy.[19]

By 1830, a few French naturalists began to encourage experimentation on animals as a way of understanding the processes of abnormal embryonic development and the relationships between animal species. Isidore and Etienne Geoffroy Saint-Hilaire, father-and-son investigators credited with naming teratology, performed early experiments (applying heat, varnishing, or shaking hen's eggs, which were an appealing and readily available object of study) and participated in debates about development and comparative anatomy.[20] In 1832, the son, Isidore Geoffroy Saint-Hilaire, published an encyclopedic work classifying monstrous bodies, both human and animal, *Histoire générale et particulière des*

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[18] Rosemarie Garland-Thomson, *Freakery: Cultural Spectacles of the Extraordinary Body* (New York: New York University Press, 1996), 4.
[19] Samuel J. M. M. Alberti, *Morbid Curiosities: Medical Museums in Nineteenth-Century Britain* (Oxford; New York: Oxford University Press, 2011).
[20] Oppenheimer, "Some Historical Relationships between Teratology and Experimental Embryology."

anomalies de l'organisation, also known as *Traité de teratologie.*[21] In these volumes, Saint-Hilaire classified the different forms of anomalies by severity into four main types: anomalies (though he preferred the word *hèrmitéries*), hermaphrodites, and single or double monstrosities.[22]

The overarching trajectory of early experimental studies of teratology was an effort to make something that had been viewed as mythical, magical, fate driven or fantastical explainable by mechanistic laws of nature. The French naturalists who named teratology saw monsters as one manifestation of normal development rather than a joke of nature, emphasizing rational order over playful complexity. Paraphrasing his father, Isidore Geoffrey Saint-Hilaire noted: "Monsters are not sports of nature; their organization is subject to rules, to rigorously determined laws, and these rules, these laws are identical with those that regulate the animal series; in a word, monsters are also normal beings; or rather, there are no monsters, and nature is one whole."[23] Despite this declaration that there were no monsters, it's tempting to emphasize the continuity of subsequent research science and continued emphasis on obvious and dramatic anatomical anomaly.

French scientists Camille Dareste and A. Lereboullet continued a tradition of attempted artificial manipulation of embryos on various animal specimens, such as hen's eggs, fish, lizards, snails, and crayfish in effort to produce morphological changes and study development.[24] The work of German embryologists Wilhelm His

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[21] Isidore Geoffroy Saint-Hilaire, "Histoire générale et particulière des anomalies de l'organisation" (Paris: J.B. Baillière, 1832). There were actually three volumes, Volume 1 published in 1832, two volumes in 1836 and an atlas published in 1837.
[22] Ibid., 78–79.
[23] Quoted in Oppenheimer, "Some Historical Relationships between Teratology and Experimental Embryology," 147.
[24] Ibid.

and Ernst Haeckel in the late nineteenth century, introduced changes in laboratory practice that involved detailed cross sectioning, drawing, and preservation of embryonic samples. Their fierce debates about the meaning of embryological research are typically linked to the rise of modern biology, particularly genetics.[25]

By the early twentieth century, access to human embryos became more widespread and networks of exchange, distribution, and collection of embryos among embryologists and obstetricians more commonplace.[26] As historian of embryology Nicholas Hopwood describes it, embryologists worked "at nodes in circuits of production and communication, and… interact[ed] with a host of other actors," such that their intellectual concerns remain relevant to broader histories of social and cultural history.[27] Human embryo collection peaked in the early part of the

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[25] Haeckel is also credited with coining the term ecology, popularizing Darwin, and promoting his own version of Social Darwinism, termed "monism." This is often seen as the precursor of German archconservative environmentalism that combined a desire to reject cosmopolitanism, urbanism, and rationalism in search of non-alienated and a more harmonious relationship to nature that was combined with authoritarianism and anti-Semitism. Ideas of racial purity were combined with ideas of natural purity. See Janet Biehl and Peter Staudenmaier, *Ecofascism: Lessons from the German Experience* (Edinburgh; San Francisco: AK Press, 1995).
[26] These embryo exchange networks are elaborated upon in Lynn Morgan's work, but also recall Warwick Anderson's analysis of networks of Kuru scientists and their use of brain tissue samples for "gift exchanges" that evoke anthropological encounters with isolated indigenous populations (in this case, the function of gift exchange among scientists was not unlike that in indigenous communities). Morgan, *Icons of Life: A Cultural History of Human Embryos*. In particular, the Boston embryo collection project under Arthur T. Hertig, initiated in 1938, has received considerable attention. Naomi Pfeffer, *The Stork and the Syringe: A Political History of Reproductive Medicine*, Feminist Perspectives (Cambridge, MA: Polity Press, Blackwell Publishers, 1993). Loretta McLaughlin, *The Pill, John Rock, and the Church: The Biography of a Revolution*, 1st ed. (Boston: Little, Brown & Co., 1982). See also, Adrianne Noe, "The Human Embryo Collection," *Centennial History of the Carnegie Institution of Washington, Volume V, The Department of Embryology*, eds. Jane Maienschein, Marie Glitz, and Garland E. Allen, (Cambridge, UK: Cambridge University Press, 2004), 537–40.
[27] Nick Hopwood, "Producing Development: The Anatomy of Human Embryos and the Norms of Wilhelm His," *Bulletin of the History of Medicine* 74, no. 1 (2000): 79.

twentieth century, between 1913 and 1944.[28] In the U.S., embryological studies at the Carnegie Institute of Washington, Department of Embryology, helped launch new fields of biology, such as the reproductive sciences and genetics.[29] Franklin P. Mall, in particular, tried to understand the origins of anomalous embryos, seeing the characteristics of monsters as "acquired" due to faulty implantation.[30] His contemporary, the zoologist Charles Stockard at Columbia University, performed a number of experiments using alcohol and fish, producing cyclopia, though he later became preoccupied with his eugenic dog farm, funded with a grant from the Rockefeller Foundation.[31]

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[29] Adele E. Clarke, "Reproductive Science, 1913–1971," in *Centennial History of the Carnegie Institution of Washington: Volume V, the Department of Embryology*, eds. Jane Maienschein, Marie Glitz, and Garland E. Allen (Cambridge, UK: Cambridge University Press, 2004).

[30] Franklin P. Mall, "A Study of Causes Underlying the Origin of Human Monsters," *Journal of Morphology* XIX, no. 1, (1908): 1–367; Franklin P. Mall and Arthur W. Meyer, *Studies on Abortuses a Survey of Pathologic Ova in the Carnegie Embryological Collection,* Contributions to Embryology, vol. 12 (Washington: Carnegie Institution of Washington, 1921). Chapter 1 (13–24) describes the founding of the embryological collection at the Carnegie Institution.

[31] Charles R. Stockard, "The Origin of Certain Types of Monsters," *American Journal of Obstetrics and Diseases of Women and Children* 59 (January–June 1909): 582–93. Stockard is not as famous as his assistant, George Papanicolaou, who studied the estrus cycle of rabbits, resulting in the pap smear. Philip J. Pauly, *Biologists and the Promise of American Life: From Meriwether Lewis to Alfred Kinsey* (Princeton, NJ: Princeton University Press, 2000), 231.

Postwar Institutionalization of Academic Teratology

Teratology's Transformation: From Acquired Characteristics of Monsters to Environmental Factors Affecting Congenital Malformations

If external and internal origins of monsters had long fascinated researchers, what was novel about research on environmental causes of infant anomalies in the mid-twentieth-century? Was teratology really transformed? In the 1950s, philanthropists and pediatric, anatomical, and embryological researchers, most working in academic laboratory and clinical settings, tried to reframe teratology on modern terms during a period of economic and demographic expansion. Academic researchers such as pediatrician and professor of preventative medicine Theodore Ingalls argued forcefully that congenital malformations were not the product of chance, or fate or genetics, but most likely had their origins in environmental factors acting during the prenatal period, which could be addressed by collective preventative action.[32] The Teratology Society cofounders, likewise, argued that the environment had a particular role in the etiology of congenital malformations, that congenital malformations were not exclusively genetic. The academic institutionalization of these scientists occurred in tandem with the expansion of the philanthropic missions at the AACC and the National Foundation-March of Dimes from educational and rehabilitative approaches to childhood disability, to science-

[32] Theordore H. Ingalls, "Causes and Prevention of Developmental Defects," *Journal of the American Medical Association* 161, no. 11 (1956): 1047–51; Ingalls, "Congenital Malformations: Environmental Influences That Act to Cause Them."; Gordon and Ingalls, "Death, Defect, and Disability in Prenatal Life. An Epidemiologic Consideration."

based methods of preventing or ameliorating congenital disability. In addition, the HED formed in 1955 and helped fund and build these networks of researchers.[33] A number of conferences (at least eight) addressed the topic of environmental factors in mechanisms of abnormal developmental in the 1950s, among them three teratology symposiums initiated by Warkany and Wilson.

Table 1: Conferences on Environmental Factors and Mechanisms of Abnormal Development 1950–1960

Conference Name	Date	Location	Organizers	Sponsors/Funders
Prematurity, Congenital Malformations and Birth Injury[34]	June 1952	New York, NY	Emmett L. Holt, Theodore H. Ingalls, and Louis B. Hellman	AACC
Effects of Radiation and Other Deleterious Agents on Embryonic Development[35]	April 20–21, 1953	Oak Ridge National Laboratory, TN	Alexander Hollaender	Biology Division, Oak Ridge National Laboratory
Mechanisms of Congenital Malformations[36]	June 15–16, 1954	New York, NY	Samuel R. M. Reynolds (Ingalls presented a paper, "Mechanisms of Congenital Malformations")	AACC

[33] Robert W. Miller, "My Half-Life in Teratology," in *Issues and Reviews in Teratology, Vol 6*, ed. Harold Kalter (Boston: Springer, 1993), 19–20.
[34] Emmett L. Holt, ed. "Prematurity, Congenital Malformation and Birth Injury; Proceedings" (New York: Association for the Aid of Crippled Children (AACC), 1953).
[35] Alexander Hollaender, "Introduction: Effects of Radiation and Other Deleterious Agents on Embryonic Development," *Journal of Cellular and Comparative Physiology* 43, no. S1 (1954): 102.
[36] Harold G. Wolff, ed. "Mechanisms of Congenital Malformation: Proceedings of the Second Scientific Conference of the Association for the Aid of Crippled Children, June 15–16, 1954" (New York: AACC, 1954).

Teratology Conference (First)[37]	January 12–13, 1956	Cincinnati, OH	Josef Warkany, James G. Wilson	Human Embryology and Development Study Section, AACC
Environmental Influences on Prenatal Development[38]	August 2–4, 1956	Bar Harbor, ME	Paul Weiss, Beatrice Mintz	National Academy of Sciences, National Research Council
Second Teratology Conference	April 15–16, 1957	Bethesda, MD	James G. Wilson, Josef Warkany, Bradley Patten (78 people registered)	Human Embryology and Development Study Section, AACC
Third Teratology Conference	March 30–31, 1959	Portland, OR	David L. Gunberg	University of Oregon Medical School
National Foundation Medical Advisory Committees Meeting[39]	April 5, 1959	Palm Beach, FL	Thomas Rivers	National Foundation-March of Dimes

A particular medical vision of rehabilitation of infant anomaly and effort to define and ferret out, classify, prevent, and treat birth defects was born in midcentury America. Previously, charitable organizations directed at childhood disability, such as the AACC or the NFIP, had emphasized either epidemic diseases or rehabilitation or education of children with disabilities. This was a pivotal moment in philanthropic and medical approaches to childhood disability, as evolving

[37] Wilson and Warkany, "The History of Organized Teratology in North America."
[38] Beatrice Mintz, ed. *Environmental Influences on Prenatal Development, Conference held August 2–4, 1956 at the Roscoe B. Jackson Memorial Laboratory at Bar Harbor, Maine* (Chicago: University of Chicago Press, 1956).
[39] Warkany recorded this as occurring on April 5, 1959 in Palm Beach in Wilson and Warkany, "The History of Organized Teratology in North America," 287. Thomas Rivers, President-Medical Affairs at the NF, invited Warkany to a similar meeting of the Medical Advisory Committees in Hollywood Beach April 4-7, 1960, Thomas Rivers to J. Warkany, 28 January 1960, Box 6, Folder 2: "National Foundation," Series 1.4, Teratology Society Records.

research concerns of pediatric, genetic, and embryological physician scientists were linked to new funding practices and aims of philanthropic organizations directed at understanding and preventing childhood crippling. Animal and human developmental defects and conditions had been named, classified and researched by the emergent disciplines of biomedicine in the latter half of the nineteenth and early part of the twentieth century, contributing to a process of "medicalizing monsters." Yet amid postwar affluence and new funding sources for research science, fears about the developmental effects of radiation, and interest in medical intervention on chronic diseases of children, research on environmental prenatal factors affecting abnormal development blossomed, though not always in the ways intended by teratologists who joined the Teratology Society. If medical intervention to prevent prenatal or neonatal disability had often been the ideal of biological research on abnormal development, for teratologists at midcentury, it seemed within reach.

This medicalization of monsters should be understood in the context of the broad professional organizing within fields of pediatrics and biomedical research (embryology, anatomy, zoology, genetics) around the problem of infant anomalies, or congenital malformations. Teratology defined its professional terrain as basic research on prenatal environmental etiological factors leading to malformations, in a dialogue with genetics. Yet historians of genetics focus on evolving human genetics approaches to particular rare familial disorders. Influenced by the power of genetic explanations and tracing conditions particular to certain families, historians may downplay debates about environmental influences or broader trends in pediatric academic research that were organizing around infant disorders and

malformations.[40] At the time, human genetics was but one component of pediatric specialization on the problem of infant anatomical anomalies and other chronic disabling conditions.

Teratologists also tried to define localized prenatal causes of abnormality, but would reframe the field from study of "acquired characteristics" of monsters to "environmental causes" of congenital malformation—emphasizing a broader range of infant anatomical anomalies conceived in the increasingly hazardous environment of the womb. By the 1960s, the term "monsters" was rarely used to refer to children born with severe and obvious anatomical anomalies. It was replaced by the much more inclusive categories of congenital malformations or abnormalities, or even more broadly, birth defects. Reference to the birth or gestation of monsters could still be found in the 1950s, yet these were typically hyperbolic and referred to rare, exceptional, and severe cases of infant disability.[41]

Pediatric specialization and disability advocacy also helped bring a wider range of human anatomical and functional diversity within the purview of medicine, even as experimental teratologists sometimes clung to a narrower anatomical

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[40] Historian of genetics Susan Lindee traces genetic disorders such as Down syndrome, characterized and named Mongolism in 1866; osteogenesis described between 1935 and 1918; and xeroderma pigmentosum, named in 1874. Likewise, familial blood cell deficiency or deformity illnesses (such as thalassemia and sickle cell) and connective tissue disorders (such as Marfan syndrome or various types of short stature), and biochemical "inborn errors of metabolism" (such as Tay-Sachs and PKU) are considered some of the pioneering research arenas of medical genetics in the mid-twentieth century. Lindee, *Moments of Truth in Genetic Medicine*. The late-nineteenth-century work of Archibald Garrod on "chemical individuality," was retrospectively resurrected amid new enthusiasm for understanding biochemical mechanisms of disease. See Barton Child's analysis of the resurrection of Garrod's work: Barton Childs, "Sir Archibald Garrod's Conception of Chemical Individuality: A Modern Appreciation," *New England Journal of Medicine* 282, no. 2 (1970): 71–77.
[41] See Alan F. Guttmacher, *Pregnancy and Birth: A Book for Expectant Parents* (New York: Viking Press, 1957), 307–09; Abigail Lewis, *An Interesting Condition, the Diary of a Pregnant Woman* (Garden City, NY: Doubleday, 1950), 120.

definition of what constituted congenital malformation. By the 1960s, David Smith (a pediatric endocrinology researcher trained under Lawson Wilkins and known for characterizing fetal alcohol syndrome in 1973[42]) would argue that teratology should more aptly be called dysmorphology, because the characteristics being tracked were no longer astonishingly unusual anatomical cases but usually more subtle deviations from normal.[43] Yet teratologists had purposely defined their professional terrain as severe clinically relevant anatomical or functional disability evident shortly after birth and advocated for research funds to support clinical studies or mechanistic experimental studies in animals of diverse types of congenital malformations. Even as teratologists tried to restrict teratology's disciplinary territory to severe structural anomalies, advocates, media, and philanthropies often portrayed this research as a means to have more perfect children, expanding the boundaries of infant and childhood disability.

When the representatives of the National Foundation for Infantile Paralysis (NFIP) were considering the possibility of taking on congenital malformation as a new project in 1957, they listed as a potential negative the terminology of monsters and malformations, which might be unpleasant or repugnant to most people, but "the coin could be reversed, and the idea of assuring more nearly perfect children—children bearing no legacy of defect—could be made positive and attractive."[44] Paramount among their concerns as they selected a new project was finding a topic

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[42] Kenneth L. Jones, "From Recognition to Responsibility: Josef Warkany, David Smith, and the Fetal Alcohol Syndrome in the 21st Century," *Birth Defects Research Part A: Clinical and Molecular Teratology* 67, no. 1 (2003): 13–20.
[43] David W. Smith, "Dysmorphology (Teratology)," *The Journal of Pediatrics* 69, no. 6 (1966): 1150–69.
[44] Anonymous, "Proposed Program: Congenital Malformations, 1957," 32. Box 6, Folder "Proposed Programs: Congenital Malformations, 1957," Series 6, Medical Program Records, March of Dimes Archives, White Plains, NY.

which would inspire and mobilize their volunteers and maintain donations. Teratology research and the new mission of the NFIP combined popular interest in visual difference and the ascendant authority of biomedical science policing the boundaries of the pathological.

In addition to these doubts about the public appeal of severe childhood disability, other potential negatives the NFIP foresaw if they focused congenital malformations was the issue of evoking further anxieties and fears in parents (balanced by increased awareness that would raise donations) and the fact that there would be many children (particularly those with severe or multiple malformations or those that severely impaired intelligence) for whom they could offer little funds for patient care or hope for medical, at least in the short term. Such concerns would remain problematic as the NF-March of Dimes attempted different avenues of research and advocacy in birth defects prevention.

Foundations such as the AACC and the NF supported conferences and the academic institutionalization of teratologists, but diverse research scientists and philanthropists were not always in agreement about what constituted the most fruitful or important avenue of research. Indeed, teratologists maintained that their research would provide insight on the naturally occurring yet extremely severe anatomical disabilities, even as other scientists advising the NF in the 1960s emphasized biochemical and genetic arenas that appeared most fruitful for biomedical intervention (such as in-born errors of metabolism or chromosomal disorders) yet might do little for large numbers of the severely congenitally disabled.

McGill-based medical geneticist F. Clarke Fraser, pediatrician Josef Warkany, and embryologist James G. Wilson were instrumental in forming the

society in 1960, partially motivated by a sense that the NF was losing sight of common severe anatomical anomalies of children in favor of prioritizing research on rare biochemical and genetic anomalies.[45] Several accounts describe Warkany, Fraser, and Wilson walking on a beach in Florida after the 1959 National Foundation Medical Advisory Committees Meeting and deciding to fully incorporate the Teratology Society.[46]

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[45] Warkany describes this episode as follows: "committee members were not enthusiastic about accepting congenital malformations as one of the main areas of activity by the National Foundation. Several of the scientist members of the committee thought that the projected emphasis on structural malformations would be a mistake; inborn errors of metabolism, which had been gaining prominence, and other genetic problems were considered much more interesting and promising fields for future research." He also contrasted the funds spent to fund the society with the amount of money put into the Salk Institute. Josef Warkany, "Story of a Teratologist," *Issues and Reviews in Teratology* 4 (1988): 51.

[46] Secondary and primary sources point to Warkany's sense of being excluded from the direction that the National Foundation-March of Dimes was taking by 1960, despite their continued organizational and financial support for the Teratology Society. In particular, a National Foundation-March of Dimes Medical Advisory Committees meeting in Florida in 1959 gave additional impetus to incorporate the society. Although efforts to prepare a constitution were underway in 1959, several accounts report that the decision to incorporate the society was made while walking on a Florida beach subsequent to a meeting of a scientific advisors in April, many of them virologists, who advocated for biochemical, molecular and genetic methods as the most promising avenue of research. In her diary, Virginia Apgar described trying to prevent Warkany's resignation from one of the medical review committees and assuage his hurt feelings and sense of being left behind or out, particularly with respect to organization of a Los Angeles-based conference, probably the "The First Inter-American Conference on Congenital Defects," held in January 1962. Virginia Apgar, "Professional Diary, 1961," 33, Box 2, Folder 3, Virginia Apgar Papers, Mount Holyoke. Wladimir Wertelecki, "Of Dreaming on Solid Grounds and Silent Triumphs of One Man: A Story About Josef Warkany," *American Journal of Medical Genetics* 33, no. 4 (1989): 532. Wilson and Warkany, "The History of Organized Teratology in North America," 287.

The Teratology Society: Observable Abnormal Morphology in Animals and Environmental (Non-Genetic) Causes

Despite a desire for interdisciplinarity, the Teratology Society that officially formed at a meeting at Sloan Kettering Institute in New York City on April 10, 1960, after meeting yearly since 1956, was composed mostly of academics interested in studying animals in laboratory settings to understand questions of abnormal development. The founding meeting was planned to coincide with an annual meeting of the International Congress of Anatomy, demonstrating the anatomical research commitments of many of these scientists. The use of teratology in the name of the society is also a self-conscious reference to the long history of interest in severe infantile developmental anomalies (or "monsters"), although these researchers also used the newer rhetoric of applied research and the possibility of ameliorative or preventative action to justify their work.

The society organizers cast a broad net. In a 1959 letter to colleagues, Fraser recommended the society for the "discussion of teratological problems" to anatomists, embryologists, geneticists, obstetricians, pathologists, and pediatricians to have a "broad interdisciplinary liaison."[47] Josef Warkany's announcement describes attendees at the foundational meeting as "anatomists, biochemists, embryologists, geneticists, obstetricians, pathologists, pediatricians, plastic surgeons and others."[48] Members of the newly chartered society originated from diverse specialties and research fields, but often had particular expertise in experimental teratology, primarily laboratory-based studies on pregnant animals. Among the

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[47] F. Clarke Fraser to "Colleagues," 15 June 1959, Box 1, Folder 1: "Annual Meeting, First," Series 1.2, Teratology Society Records.
[48] Josef Warkany to Sidney Q. Cohlan, 3 June 1960, enclosed: "Teratology Society," Box 1, Folder 1, Series 1.2, Teratology Society Records.

founding members and officers of the Teratology Society were anatomists such as Ian Monie and Marjorie Nelson, who studied antimetabolites and pregnant rats at the University of California, San Francisco; the New York-Based experimental cancer chemotherapy specialists David A. Karnofsky and M. Lois Murphy (who organized the meeting in New York in 1960); pediatrician Sidney Q. Cohlan; and anatomist David B. Gunberg.[49] Although Wilson and Warkany seem to have courted well-known geneticists, such as Curt Stern and James V. Neel, they were minimally involved with the society. Despite close ties to anatomical investigation, members wanted to send announcements about the new society to diverse journals in medicine and biology, addressing fields as far-flung as nutrition, cancer, genetics, physiology, endocrinology, and pediatrics. Members sent lists of journals specific to their discipline, among them *The American Journal of Human Genetics, Journal of Heredity, Cancer, Endocrinology, Journal of Cellular and Comparative Physiology, Journal of Nutrition, AMA Journal of Diseases of Children, Journal of Pediatrics,* et cetera.[50]

Philanthropies concerned about childhood disability, like the Association for the Aid of Crippled Children (AACC) and the National Foundation (NF-March of Dimes) were fundamental to supporting the initial professional organizing of U.S. scientists studying environmental factors acting on anomalous development. Early meetings of the Society had been funded by philanthropic agencies concerned about

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[49] Josef Warkany sent an announcement out to colleagues for their review in mid-April and by June 3, 1960 sent Sydney Q. Cohlan a letter stating that he'd sent it to a long list of journals. David L. Gunberg to Josef Warkany, April 28, 1960, Box 1, Folder 1, Series 1.2, See also, announcement by Josef Warkany, "Teratology Society" in the same folder.

[50] See letters from F. Clarke Fraser, M. Lois Murphy, Marjorie Nelson and Sidney Cohlan, in May 1960, Box 1, Folder: 1 Series 1.2: "Annual Meeting, 1959–1960," Teratology Society Records.

childhood disability, such as the AACC, and starting in 1958, the NF-March of Dimes. Warkany and Wilson had also solicited funds for the first meeting from government sources, such as the HED of the NIH.[51] The National Foundation-March of Dimes underwrote expenses involved in incorporating the Society, sent a representative (Thomas M. Rivers) to give a speech on the topic of congenital malformation at the founding meeting, and helped to draw up their constitution and by-laws.[52] In April 1960, Warkany wrote a letter of gratitude to the NFIP cofounder and president, Basil O'Connor, describing the formation of the Society during a larger meeting of the International Congress of Anatomists in New York City.[53] The society was relatively small, growing from 62 charter members in 1960, to 161 members by 1964.[54]

When it was founded, the society was composed mostly of academic scientists, and efforts to attract more "clinical people" would remain difficult.[55] This professional society functioned as much to exclude those with conflicting

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[51] Warkany and Wilson to Elsa Orent Keiles, Executive Secretary of the Metabolism and Nutritional Study Section, NIH, 7 June 1955**,** Box 1, Folder 1,"Correspondence," Series 1.1, "Teratology Conference (1954–Aug 1955)," Teratology Society Records. In a reply, Elsa Orent Keiles indicated agreement to fund travel expenses on behalf of the Human Embryology and Development Study Section. Elsa Orent Keiles to Josef Warkany, 27 June 1955, Box 1, Folder 1, Teratology Society Records. Warkany and Wilson also sent a similar letter to Mr. Leonard W. Mayo of the AACC, suggesting that they jointly fund a conference on normal and abnormal prenatal development. The AACC and Human Embryology and Development Study Section jointly funded the first conference.

[52] Josef Warkany to Thomas Rivers, March 10, 1960, Box 1, Folder 4, Section 1.1, Teratology Society Records. Melvin Glasser to Josef Warkany, March 21, 1960, Box 1, Folder 4, Series 1.1. Teratology Society Records.

[53] He also reassured Virginia Apgar that he had sent a thank you letter. Josef Warkany to Basil O'Connor, 14 April 1960, Box 1, Folder 1, Annual Meeting (1st) 1959–1960, Series 1.2, Teratology Society Records.

[54] Wilson and Warkany, "The History of Organized Teratology in North America," 287–91.

[55] Dr. James G. Wilson to Josef Warkany, 20 December 1956, Box 2, Folder 7: 1956–1957, Series 1.1, Teratology Conference (2nd), Teratology Society Records.

perspectives or inadequate professional credentials as much as to include like-minded researchers. New applications for membership had to have recommendations from existing members, excluding at least one dental researcher who criticized the research of one of the society's members. Hannelore Loevy complained to Virginia Apgar that she felt like she was not accepted in the society because of her critical assessment of Fraser's work on cleft palate.[56]

Many members of the Teratology Society studied experimental teratology, similar to Warkany and Wilson's research on nutritional deprivation and radiation exposure on pregnant animals. Experimental teratologists typically wanted to use animal models to examine undesired morphological outcomes and to define abnormal embryological developmental pathways that these pathologies demonstrated. Toxicological approaches to investigate obscure chemical or pharmaceutical causes of congenital malformation were not their initial concern, though some members would take on questions of reproductive toxicology of pharmaceuticals in the early 1960s. They grouped and defined possible non-genetic causes of malformation under the overarching category of "environmental causes," which was defined broadly, including microbial, mechanical, physical, chemical and other non-genetic causes of fetal abnormalities.[57]

A range of experimental studies had previously demonstrated external ("environmental") causes of fetal abnormality in the early twentieth century. Among

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[56] Virginia Apgar, Professional Diary 1964, Box 2, Folder 6, Series 1: "Diaries 1959-1967," Virginia Apgar Papers, Mount Holyoke.

[57] The influence of lead and other heavy metals known to be neurotoxins is conspicuously absent from many of these early research efforts, perhaps because they were unlikely to produce obvious anatomical malformation and remained within different professional dominions, of acute heavy metal poisoning, the responsibility of neurologists and toxicologists.

them were zoologist Charles Stockard's eugenic work on amphibian maldevelopment at Columbia in the early 1900s,[58] agricultural scientist Fred Hale's reports of ocular effects of vitamin A deficiency in pigs in 1933, [59] and obstetrician Douglas P. Murphy's clinical surveys of radiation exposure during pregnancy in the 1920s and 1930s.[60] Industrial hygienists in the U.S. had identified lead as a concern for healthy reproduction among women workers since the beginning of the twentieth century and cited older European studies.[61] By the mid-twentieth century, many research scientists were very interested in the relationship between environmental factors acting during the prenatal period and infant maldevelopment, often inspired by Australian Norman McAlister Gregg's linking rubella infection and ocular anomalies in 1940.[62] Boston-based pediatrician, Theodore Ingalls played a role in publicizing teratology research and advocated for the use of both experimental and epidemiological methods to examine environmental causes of developmental disability, but he didn't join the Teratology Society.

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[58] Stockard, "The Origin of Certain Types of Monsters." Though Charles Stockard is best known for his assistant George Papanicalaou, who developed the pap smear, the Rockefeller Foundation gave Stockard a grant in 1925 to create an eugenic dog farm. See Pauly, *Biologists and the Promise of American Life: From Meriwether Lewis to Alfred Kinsey*, 231.

[59] Fred Hale, "Pigs Born without Eye Balls," *Journal of Heredity* 24, no. 3 (1933): 105–6.

[60] Douglas P. Murphy, *Congenital Malformations; a Study of Parental Characteristics with Special Reference to the Reproductive Process*; Douglas P. Murphy and Leopold Goldstein, "Etiology of the Ill-Health of Children Born after Maternal Pelvic Irradiation," *American Journal of Roentgenology* 22 (1929): 207–19; Leopold Goldstein and Douglas P Murphy, "Microcephalic Idiocy Following Radium Therapy for Uterine Cancer During Pregnancy," *American Journal of Obstetrics & Gynecology* 18, no. 2 (1929): 189–95.

[61] Alice Hamilton, *Women in the Lead Industries. February, 1919*, vol. 253 (U.S. Government Printing Office, 1919), 12.

[62] Norman Gregg, "Congenital Cataract following German Measles in Mother," *Transactions of the Tropical Ophthalmology Society of Australia* 3 (1941): 35–46; Reagan, *Dangerous Pregnancies: Mothers, Disabilities, and Abortion in America*.

Outside the formal purview of teratogenic studies, a Scottish multiple sclerosis expert, Douglas McAlpine, published an article in the *Lancet* in 1958 on an outbreak of neurological symptoms seen among families after eating contaminated marine life from Minamata Bay, probably due to methyl mercury poisoning from the nearby Chisso factory, for which congenital cases were identified in the early 1960s (See Chapter 4).[63] The cancer chemotherapeutic and folate analog aminopterin was linked to fetal birth defects in 1952.[64] By the late 1950s, endocrinologist Lawson Wilkins reported that progestin might cause masculine features in female fetuses, providing one justification for FDA scientist Francis Kelsey's caution with respect to approving thalidomide in the U.S. [65] Quinine was thought to cause deafness or abortion and cortisone cleft palates.[66] From that point forward, the list of suspicious substances began to literally fill volumes and indexes.[67] In the 1960s, teratologists became particularly engaged in carefully examining the myriad pharmaceuticals implicated as potential teratogens, informing approaches to reproductive toxicology.

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[63] Douglas McAlpine and Sukuro Araki, "Minamata Disease: An Unusual Neurological Disorder Caused by Contaminated Fish," *Lancet* 2, no. 7047 (1958): 629–31.
[64] John B. Thiersch, "Therapeutic Abortions with a Folic Acid Antagonist, 4-Aminopteroylglutamic Acid (4-Amino PGA) Administered by the Oral Route," *American journal of obstetrics and gynecology* 63, no. 6 (1952): 1302.
[65] Daniel P. Carpenter, *Reputation and Power: Organizational Image and Pharmaceutical Regulation at the FDA* (Princeton: Princeton University Press, 2010), 218. Lawson Wilkins, "Masculinization of Female Fetus Due to Use of Orally Given Progestins," *Journal of the American Medical Association* 172, no. 10 (1960): 1028–32.
[66] F. Clarke Fraser did research on cortisone and cleft palates and Warkany identified quinine as a problem in the 1950 Nelson-Mitchell textbook of pediatrics. F. Clarke Fraser, interview by Andrea Maestrejuan, 2004. Waldo E. Nelson and Albert G. Mitchell, *Mitchell-Nelson Textbook of Pediatrics*, 5th ed. (Philadelphia: Saunders, 1950).
[67] Thomas H. Shepard, *Catalog of Teratogenic Agents* (Baltimore: Johns Hopkins University Press, 1973). Heinonen, Slone, and Shapiro, *Birth Defects and Drugs in Pregnancy*.

Teratologists were also well aware of the controversial implications of their research and the ways that, in their view, it was sensationalized by media reports and some alarmist researchers and caused increased anxiety among prospective parents. Likewise, the National Foundation also acknowledged internally that it could be problematic if they were seen as increasing the fears of abnormalities that parents might experience, which they weighed against the number of donations that could be derived from widespread interest in infant anomalies. In a 1957 proposal for their new mission, the anxieties of mothers were addressed: "[T]he 'fear' angle would certainly require careful handling. It obviously would be a questionable public service if every potential mother were made to fear that she might have a deformed child. Nevertheless, public awareness of the problem and its scope would contribute to motivations for giving."[68] The National Foundation's goals to raise awareness of congenital malformations and raise donations were often aligned, but they never satisfactorily resolved the question of whether they were unduly alarming mothers with their public relations efforts. For their part, many teratologists argued for a skeptical and cautious approach to identifying myriad potential environmental chemical hazards, so as to avoid unnecessarily frightening parents. Warkany, in particular, urged cautious interpretations of experimental data and emphasized innate environmental deficiency rather than a poisoned environment.

[68] National Foundation, "Proposed Program: Congenital Malformations" 1957, 32, Box 6, In Folder of same name, Series 6, Medical Program Records, March of Dimes.

Experimental Teratology and Explanatory Insecurity in Inference Using Animal Models

Josef Warkany, Nutritional Deficiency, and Experimental Teratology

One of the founders of the Teratology Society was the pediatrician and mammalian experimental teratologist, Josef Warkany. He was overtly grappling with eugenics and the atrocities of the World War II in his work, even as he also saw great promise in biomedicine for preventing or alleviating disabling conditions of children. Warkany influenced mid-century approaches and interpretations of experimental mammalian teratology, arguing for the importance of environmental factors in developmental disability at a time when most congenital malformations were attributed to chance or inheritance. He had a specific vision of what constituted a harmful environment that emphasized nutritional deficiency and the usefulness of improved nutrition or dietary micronutrient additives during pregnancy to improve pregnancy outcomes. This section highlights his motivation and preferred case study, illustrating his both his vision of a potentially disabling environment and his effort to counter eugenic assumptions that congenital malformations were the sole product of genetic factors. His depiction of a deficient environment and hope from ameliorative solutions from basic research also justified some of his reservations about visions of prenatal toxicity derived from a poisoned industrial environment that arose with the environmental movement in the late 1960s. Warkany's cautious assessment of the small role that chemical prenatal exposures played in overarching (non-genetic) environmental causes of developmental disability and emphasis on

anatomical and functional deficit evident shortly after birth was shared by many of his peers in the Teratology Society.

Born in Vienna in the early part of the twentieth century into a modestly comfortable Hungarian Jewish family (his father was the owner of a dry goods store), Warkany immigrated to the U.S. with a short-term scholarship from well-known pediatrician Albert Graeme Mitchell to work at the Cincinnati Children's Hospital Research Foundation (CCRF) in 1932. At the time of his arrival, CCRF was a brand new pediatric research center funded by one of the heirs to Proctor & Gamble, William Cooper Proctor. The foundation provided space for the expanding research specialties of pediatrics and considerable resources and intellectual freedom to enthusiastic pediatric investigators.[69] Albert Graeme Mitchell and his colleague Waldo E. Nelson published an influential textbook of pediatrics in 1927, known as the *Mitchell-Nelson Textbook of Pediatrics,* with at least twenty subsequent editions.[70]

The research foundation was also a fertile ground for Albert Sabin's work on the oral polio vaccine in the mid-1950s. Through these contacts, Warkany was recommended to Basil O'Connor as a potential advisor on the new direction of the National Foundation for Infantile Paralysis, and met with his assistant, Melvin Glasser in January 1957.[71] For Warkany, Cincinnati proved a favorable environment for clinical work in pediatrics and independent research, and he declined a position

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[69] Cronin and Lyon, *Albert Graeme Mitchell*.
[70] In 1927, the second edition of *The Diseases of Children* was published by John Prize Crozer Griffith and Mitchell (Griffith independently published the textbook starting in 1919); the *Nelson Textbook of Pediatrics* was on its twentieth edition in 2015.
[71] Wertelecki, "Of Dreaming on Solid Grounds and Silent Triumphs of One Man: A Story About Josef Warkany," 532. Warkany, "Story of a Teratologist," 50–52.

at the National Foundation in order to maintain his academic post in Cincinnati. His accounts of research in Vienna emphasized constrained resources in contrast to ample access to research material in America (apparently in Austria research resources, such as rabbits, were in short supply).[72]

Warkany began his research on mammalian nutritional deprivation in the 1930s, publishing an initial paper in 1941 on abnormalities induced feeding a pregnant rat a deficient diet. Despite his effort to counter biological ideas of genetic inferiority and advocate for environmental origins of developmental disability, Warkany's personal recollections of his early research on nutrition tended to emphasis happenstance and serendipity over premeditation. Following immigration to Cincinnati in the 1930s, he worked on nutritional deficiency conditions of children, such as rickets and scurvy. When improved nutrition and the availability of Vitamin D and Vitamin C made rickets and scurvy less common disorders, Dr. Warkany was at a loss for a research project. For a time, he had worked in an endocrinology clinic seeing patients with impaired growth or other endocrine disorders.[73]

Attempting to take up endocrinology and induce thyroid problems associated with iodine deficiency (cretinism), he and a colleague fed pregnant rats inadequate diets, creating goiters, to see the effects on their offspring.[74] They were able to induce skeletal deformities, but to their surprise, adding iodized salt back in to the maternal diet cured the maternal goiter but didn't prevent the malformations

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[72] "Story of a Teratologist."
[73] Ibid., 15.
[74] Josef Warkany interviewed by Benjamin Felson and William Schubert, December 8, 1980, Cincinnati Center for the History of the Health Professions, accessed May 13, 2015, http://hdl.handle.net/2374.UC/733173.

(though dried liver did).[75] In 1940, he and Rose Cohen Nelson published a short report in *Science* noting that they had produced structural deformations of the mandible and other extremities among rats born to mothers fed a deficient diet, consisting mostly of cornmeal and wheat gluten.[76] Later, he and his colleagues identified riboflavin as the missing ingredient and experimented further to identify the effects of vitamin A deficiency. To his dismay, they were never able to create a mouse model of cretinism to understand the mechanisms of iodine deficiency. Other researchers who became part of the Teratology Society in the 1950s, such as Marjorie Nelson at the University of California, San Francisco, pursued similar lines of nutritional inquiry in pregnant rats, but used antimetabolites that mimicked deficiency states by interfering with utilization of micronutrients. Such studies shifted experimental teratology research on nutritionally deficient diets to one interrogating the harmful developmental effects of particular chemicals, such as aminopterin.

Josef Warkany and Environmental Factors as a Counter to Eugenic Interpretations of Congenital Disability

Warkany's advocacy in the 1940s and 1950s for the role of environment factors affecting development can be interpreted as a reaction to the excesses of eugenics, particularly sterilization or extermination policies directed at the disabled. In several publications he mentions the German "Law for the Prevention of Heritable Disorders" of July 14, 1933 as his inspiration for insisting on the

[75] James G. Wilson et al., *Teratology: Principles and Techniques* (Chicago: University of Chicago Press, 1965), 3.
[76] Josef Warkany and Rose C. Nelson, "Appearance of Skeletal Abnormalities in the Off Spring of Rats Reared on a Deficient Diet," *American Association for the Advancement of Science. Science* 92 (1940): 383–84.

importance of environmental factors.[77] If congenital malformation could be produced in animals by deficient diets and other environmental factors, then efforts to exterminate bad genes by sterilizing or euthanizing humans must be folly.

Warkany seems to be highlighting eugenics sterilization to support his investigations into environmental factors, but eugenics was a complex movement that has received considerable historical attention.[78] Historian of science Martin Pernick notes that the first American advocates for eugenics were "radical utopian socialist-communitarians." In his work on eugenic approaches to neonatal disability in the early twentieth century, he demonstrates some of the showmanship, controversies, and ethical dilemmas faced by parents and physicians when infants were born with extremely disfiguring and life-threatening disabilities.[79] His work particularly highlights considerable support for euthanasia of severely disabled infants in the early part of the twentieth-century. Paradoxically, medicine bent on

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[77] He refers to this law in a 1948 article, and in his autobiographical article in 1988. Warkany, "Story of a Teratologist," 2; Josef Warkany, Carolyn B. Roth, and James G. Wilson, "Multiple Congenital Malformations: A Consideration of Etiologic Factors," *Pediatrics* 1, no. 4 (1948): 462–71.

[78] Kevles, *In the Name of Eugenics: Genetics and the Uses of Human Heredity*; Reilly, *The Surgical Solution: A History of Involuntary Sterilization in the United States*; Dowbiggin, "'A Rational Coalition': Euthanasia, Eugenics, and Birth Control in America, 1940–1970."; Evans, "Parental Eugenics: Congenitally Anomalous Newborns and the Continuing Debate over Selective Non-Treatment and Neonatal Euthanasia in the United States," (PhD. Dissertation, University of California, Berkeley, 2008) ; Daniel J. Kevles, *In the Name of Eugenics: Genetics and the Uses of Human Hereditys*, 1st ed., Harvard University Press (Cambridge, MA: Harvard University Press, 1995); Cowan, *Heredity and Hope: The Case for Genetic Screening*; Paul, *Controlling Human Heredity, 1865 to the Present*; Wendy Kline, *Building a Better Race: Gender, Sexuality, and Eugenics from the Turn of the Century to the Baby Boom* (Berkeley: University of California Press, 2001); Pernick, *The Black Stork: Eugenics and the Death of "Defective" Babies in American Medicine and Motion Pictures since 1915*; David J. P. Barker, "The Biology of Stupidity: Genetics, Eugenics, and Mental Deficiency in the Inter-War Years," *British Journal for the History of Science* 22 (1989): 347–75.

[79] Pernick, *The Black Stork: Eugenics and the Death of "Defective" Babies in American Medicine and Motion Pictures since 1915*.

saving the lives of premature or severely disabled newborns might result in greater numbers of disabled. The question remained a difficult problem, as medicine was able to preserve the life of many infants born prematurely or with severe disabilities but was not always able to ameliorate the disabilities.

Though eugenics is often retrospectively associated with extreme policies of state-initiated forced sterilizations and racial extermination, eugenics was a complex and at times utopianist social movement, initially reflecting both popular and scientific views from diverse political arenas within society. The eugenics movement resulted in a range of public policies to control reproduction of those considered to be unfit, such as involuntary sterilization and immigration exclusion or pronatalist maternal and child health policies.

In the early twentieth century, notions of inheritance were malleable and did not rule out the possibility of neo-Lamarckian environmental influences on traits, which meant that some versions of eugenics emphasized controlling the environment in addition to or instead of selective control of reproduction (an argument for dietary supplementation and other forms of social support for mothers and children). At times, mass media in the 1920s and 1930s represented eugenics as simply good parenting.[80] In some respects, the founders of the Teratology Society can be seen as holdouts from this more social and environmental approach to eugenics. Their vision of the environment was of an inadequate environment that could be ameliorated through medicine or social factors, preventing at least some instances of disability and leading to healthy and robust children.

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[80] Ibid.

Nevertheless, some with monist or social Darwinist views, such as German biologists Ernst Haeckel or Sigmund Engel, made overt calls to euthanize impaired infants. This eugenic discourse considered children with developmental disabilities hopeless cases and referred to them as "cripples, high-grade cretins, idiots, and children with gross deformities."[81] Others in the twentieth century tended to emphasis the finality of inherited material and the possibility for eradicating "bad" genes (following German biologist August Weismann). Postwar teratologists saw themselves as working on environmental causes of childhood disability as a counter to the determinism of genetics and darker legacies of this approach to eugenics. In particular, sterilization of the congenitally disabled would be useless if most congenital disabilities were partially mediated by environmental factors. Even as eugenics is now associated with the worst excesses of state-initiated policies of extermination, there were often unacknowledged continuities with later conflicts over how to prevent and manage infant and fetal disability to produce robust, healthy, defect-free children.

But how should this be achieved? Who had a right to decide who could and could not exist in the world? By midcentury, birth defects were understood as the product of complex and multicausal events in the growth and development of an embryo, which resulted in a range of conditions of diverse degrees of severity, sometimes affecting multiple organ systems.[82] Given the complex and multicausal

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[81] Ibid., 23.

[82] By teratologists, James V. Neel is frequently cited to describe the relative influence of genetic and environmental factors) as etiological agents in developmental disability (an estimated 20–30% of congenital anomalies were thought to be genetic and 10% viral in 1963, with 60% unknown), but one might also cite theories of epigenetics to illustrate multicausal interpretations. The term epigenetics was coined in the 1940s by Conrad Waddington. Conrad H. Waddington,

nature of most developmental anomalies and their 'natural' background rates (2-3% or more, depending on what conditions were included), apparently irrespective of environmental exposures, it was difficult to draw conclusions about causality.[83]

Warkany didn't always distance himself from the term, seeing efforts to improve the conditions experienced by pregnant women as eugenic: "Eugenic measures and advice are not restricted to the genetic aspect of prenatal life ...the fetus should be assured so far as possible by protection of the expectant mother from adverse environmental influences."[84] Likewise, in a pediatrics textbook in 1950, he stated, "In many instances eugenic measures or eugenic advice may contribute to the well-being of children," though he emphasized that it was best to give "all the available facts" rather than advise parents on whether or not to have children, urging physicians to allow them to make their own decision.[85]

Warkany's depiction of chemical injury describes both the results of nutrient deficiency and substances implicated as teratogens. His version of the environment

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"Embryology, Epigenetics and Biogenetics," *Nature* 177, no. 4522 (1956): 29; James G. Wilson, *Environment and Birth Defects*, Environmental Sciences (New York: Academic Press, 1973); Morris Fishbein, *Birth Defects* (Philadelphia: Lippincott, 1963).

[83] An articulation of the relationship between genes and the environment can be seen in Warkany, Roth, and Wilson's 1948 article on multiple congenital malformations, or James G. Wilson's 1973 monograph on environment factors affecting development (even as they argued for the importance of studying environmental etiologies). In 1948, Warkany et al. stated "It has been repeatedly observed in both man and animals that an abnormal gene with pleiotropic effects, or several such genes in combination, can produce syndromes of multiple malformations. But it is the purpose of this paper to emphasize the fact that similar syndromes may also be caused by a variety of environmental influences and there is no evidence that such defects are hereditary." "Warkany, Roth, and Wilson, "Multiple Congenital Malformations: A Consideration of Etiologic Factors," 463; Wilson, *Environment and Birth Defects*.

[84] Wertelecki, "Of Dreaming on Solid Grounds and Silent Triumphs of One Man: A Story About Josef Warkany."

[85] Nelson and Mitchell, *Mitchell-Nelson Textbook of Pediatrics*.

highlighted that, "mechanical, actinic, chemical, nutritional and infectious agents must be considered as possible causes of prenatal injury," but that such deleterious factors should be interpreted with considerable caution.[86] This caution is related to the complexity of development and the difficulties in extrapolating from animals to humans. As he notes, "in animals, malformations can be produced by adding toxic substances to the environment. The evidence for similar effects on mammalian embryos is scant."[87] In 1950, he mentioned that alcohol, lead, nicotine, and mercury have been suspected as injurious agents, but experimental results were "contradictory."[88]

Warkany's specialization in pediatric and prenatal nutritional research combined noble aims with a need to build a meaningful career. He saw himself as focusing attention on children with disabling conditions who had been ignored or neglected or left to die by other physicians during the heady days of pediatric infectious disease and nutrition research when, those with severe anatomical disabilities were treated as hopeless cases by medicine.[89] An advocate and champion for the developmentally disabled, as the National Foundation-March of Dimes increasingly turned to molecular or genetic approaches, he decried overemphasis on what he saw as obscure inherited biochemical problems (such as phenylketonuria), while severe and challenging problems of anatomical defect and functional disability were neglected because they defied simple causal explanations or easily apparent preventative or therapeutic solutions.

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[86] Ibid., 271.
[87] Ibid.
[88] Ibid., 271.
[89] Warkany, "Story of a Teratologist."

Warkany and his contemporaries were involved in an old debate within medicine (part of the division that arose between the biological fields of embryology and genetics) about the relative importance of nature and nurture, or exogenous and endogenous etiologies on developmental disability. He and others sought to demonstrate that at least some aspects of human congenital disability was related to simple ameliorable conditions of the maternal environment and imagined that pregnant women should and could be protected, an approach that emphasized the need for expectant mothers to consult professionals who would manage women's exposure to prenatal harms.

In essence, he and other researchers of the 1940s and 1950s were defining their research agenda as a positivistic alternative to some of the most drastic ideas of negative eugenics, and the hopelessness and determinism they associated with genetic disorders at the time. As some of the preoccupations of eugenicists were reframed as the field of medical genetics, Warkany was claiming a role for the environment of the womb and physiological effects of *in utero* existence as affecting the child to be, a site for intervention of medical science. He wanted to bring within the purview of pediatrics other disabling conditions of infants occurring during development by probing etiological factors acting during the then relatively inaccessible prenatal period and emphasizing potentially ameliorable environmental harms to pregnant women and fetuses. Warkany and Wilson's research helped spark a range of studies that examined the mechanics of environmentally mediated developmental disability in animals that emphasized the uterus as a dangerous environment or substrate for deviant fetal growth resulting in severe anatomical anomalies.

His preferred case study, endemic cretinism, was a correction to older eugenics literature and studies of family inheritance of degeneracy (often in rural settings), described in the early twentieth century.[90] Warkany argued that childhood disability might in some cases be prevented by proper nutrition or by a micronutrient dietary supplement during or before pregnancy with substances such as iodine. In 1948, Warkany, Catherine Roth and James G. Wilson explicitly referenced German eugenic laws about sterilization of those thought to have hereditary defects in an article on nutritional environmental origins of congenital malformations in the journal *Pediatrics*.[91] Likewise, in his autobiographical article, Warkany references such policies explicitly: "Hitler and his scientists incorporated similar principles in the German Law for Prevention of Genetically Defective Offspring ... such radical and misguided conceptions can be enthusiastically accepted by millions of people and that they can approve of killing mentally and 'racially inferior' persons for improvement of the race."[92] In this perspective, social policies that were too reliant on deterministic genetic interpretations of disability could be perilous, which justified emphasis on the influences of the prenatal environment on development.

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[90] In *Inventing the Feeble Mind,* James W. Trent examines an impressive list of eugenics literature on families with inherited degeneracy or disabilities. Among the most famous were Richard Dugdale's publication from the late nineteenth-century, *The Jukes: A Study in Crime, Pauperism, Disease and Heredity* or Henry Herbert Goddard's, published starting in 1912, *The Kallikak Family: A Study in the Heredity of Feeble-Mindedness.* James W. Trent, *Inventing the Feeble Mind: A History of Mental Retardation in the United States, Medicine and Society* (Berkeley: University of California Press, 1994), 70–72, 163–64.
[91] Warkany, Roth, and Wilson, "Multiple Congenital Malformations: A Consideration of Etiologic Factors."
[92] Warkany, "Story of a Teratologist," 21.

This emphasis on the prenatal environment combined both a call for parental decision making and a protectionist instinct. In his 1971 monograph on congenital malformations, a section on "Protection of the Mother" urged,

> The normal development of the embryo and fetus should be assured so far as possible by protection of the expectant mother from adverse environmental influences… The mother should be protected from trauma, intoxication, and infection during her early pregnancy... Attention should be paid to the maternal diet before the pregnancy begins and also during the entire period of gestation. Roentgen ray treatment must be avoided whenever the possibility of a pregnancy exists.[93]

Warkany's vision was grounded in a protectionist approach to pregnancy, yet he opposed insufficiently nuanced interpretations of their experimental data for the purposes of public policy. Urging attention to the environment of the womb rather than genetics, Warkany nevertheless turned to biological conditions to explain prenatal origins of infant disability. In particular, he highlighted radiation and nutritional deprivation.

Josef Warkany and the Deficient Environment of Endemic Cretinism

Some of his assumptions about "doable problems,"[94] the simple ameliorative tools of biomedical science, and his neo-Hippocratic[95] views about the influence of a

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[93] Nelson and Mitchell, *Mitchell-Nelson Textbook of Pediatrics*, 279–82.
[94] This term is derived from Fujimura and Adele Clarke's work: "Before beginning the work, scientists must both pull together and articulate a wide array of requisite elements to make as sure as possible, given the circumstances, that results recognized as worthwhile will emerge downstream." Adele Clarke, *Disciplining Reproduction: Modernity, American Life Sciences, and "the Problems of Sex"* (Berkeley: University of California Press, 1998), 85.
[95] Hippocratic approaches to health are often depicted as a state of balanced flows (such as diet, evacuations, bile, etc.) in a salubrious environment. In this case, Warkany's emphasis on diet and other environmental factors affecting development recalls a more ancient approach to healing. See William Arthur Heidel, *Hippocratic*

local environment can be seen in the pediatric disorder he most emphasized. Warkany described viewing endemic cretinism (now called congenital hypothyroidism and rarely seen in places with iodine supplementation) in rural Alpine villages as his motivation for investigating the effects of dietary deficiency on rats.[96]

His encyclopedic tome on congenital malformations, published in 1971, *Congenital Malformations: Notes and Comments,* illustrated the breadth and complexity of the congenital conditions he and other physicians encountered. Yet he particularly emphasized endemic cretinism, along with disabilities associated with thalidomide and rubella, as environmentally determined conditions:

> There are huge areas on this planet where man can exist and subsist on the products of the land and where nutrition seemingly is adequate; yet, lack of iodine in the soil, water and vegetation results in hazards that threaten the health of the population from birth on—and even before... Endemic cretinism must never be forgotten, since it illustrates that even human embryos and fetuses can be endangered in their development by maternal nutritional deficiency.[97]

Warkany's description articulates an understanding of disability that takes into account socioeconomic conditions, the local landscape, and maternal malnourishment (in lieu of heredity) as important factors in the health and well-being of future children. He characterizes a social understanding of infant and childhood disability and poor nutrition that is inherently linked to the inadequacy of the local environment and to poverty. In his account, iodine is an effective prevention against a severe disabling condition of children and can be added to salt

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Medicine, Its Spirit and Method (New York: Columbia University Press, 1941); *Hippocratic Writings*, Pelican Classics (Harmondsworth; New York: Penguin, 1978).

[96] Kalter, *Issues and Reviews in Teratology*, vii–viii. Robert L. Brent, "Biography of Josef Warkany," *Teratology* 25, no. 2 (1982): 137–144.

[97] Josef Warkany, *Congenital Malformations; Notes and Comments* (Chicago: Year Book Medical Publishers, 1971), 102–03.

or food products to prevent congenital hypothyroidism. Thus the environment he imagined was inherently deficient rather than potentially poisoned.

> There was plenty of space and fresh air, but there apparently were some hidden adverse forces acting in this treacherously beautiful environment that condemned the people forced to live there permanently to mental and physical deterioration…if genetic and environmental factors are intertwined in the etiology of endemic cretinism…it proves how widespread such genetic weakness can be and how easily it can be overcome sometimes by regulation of the environment—addition of a few micrograms of an available nutritional element to a deficient diet, in the case of cretinism.[98]

The quote above illustrates that Warkany was grappling with both overly deterministic genetic interpretations and with populist interpretations of environmental damage that assumed there existed some pure and optimally healthy pre-industrial state of nature. Warkany chose to characterize the broader environment as dangerously chemically deficient rather than polluted by industrialization.

The famine experienced by European populations during the war (particularly in 1944–45) engaged researchers who wondered about the effects of periods of nutritional deprivation during pregnancy on the newborn.[99]

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[98] Ibid., 121.

[99] The severe famine experienced by Dutch populations in 1944–45 in particular was viewed as a 'natural experiment,' and it was influential in providing data for more contemporary theories about nutritional deprivation during pregnancy and the developmental origins of disease. As early as 1947, American pediatrics professor Clement A. Smith reported that babies born following the famine were likely to have low birth weight. In 1975, the influential South African-born and New York-based epidemiologist pair Vena Stein and Mervyn Susser wrote a monograph about the effects of prenatal nutritional deprivation during this period. In James G. Wilson's monograph from 1973 he summarized nutritional deprivation research as affecting birth outcomes such as birth weight and stillbirth but as having little impact on malformations or prematurity. Zena Stein, *Famine and Human Development: The Dutch Hunger Winter of 1944–1945* (New York: Oxford University Press, 1975). Wilson, *Environment and Birth Defects*. Clement A Smith, "Effects of Maternal

Retrospectively, Warkany claimed that one researcher (Mount Sinai pediatrician, Bela Schick) lost interest in his research once it became clear that starvation in Holland during the war did not cause congenital malformations.[100] Subsequently, in his massive 1971 book on congenital malformations Warkany also links research on nutritional deficit during pregnancy with conditions of warfare: "Long-lasting peace, which made possible safe conduct and communications, permitted introduction of foods that contained more iodine than the products grown in the homeland – and the incidence of goiter decreased. But the war brought back the endemic with regularity."[101] Several times, he emphasized roads and commerce as ameliorating nutrition-related disabilities: "When they [isolated rural areas] are opened up to commerce and traffic goiter disappears! It has been said that the best way to abolish cretinism and endemic goiter is to build a road in an endemic area."[102] In his view, an insalubrious deficient environment was a small but potentially important factor that influenced childhood physical and intellectual disability and could be resolved by peace, prosperity, and improved nutrition—or, barring that—nutritional supplementation.

Such a perspective at times conflicted with an environmentalist vision that arose in the 1960s and 1970s that conceptualized a poisoned environment and threat to future generations resulting from industrial products and the comforts of modern life. Warkany justified skepticism about rising environmentalist fears of pollution in

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Undernutrition Upon the Newborn Infant in Holland (1944–1945)," *The Journal of Pediatrics* 30, no. 3 (1947): 229–243.

[100] Warkany, "Story of a Teratologist," 9.

[101] *Congenital Malformations; Notes and Comments*.

[102] Gordon E. W. Wolstenholme and Cecilia M. O'Connor, eds., "Ciba Foundation Symposium on Congenital Malformations," (Boston: Little Brown & Company, 1960), 176.

the 1970s by aligning contemporary environmental politics with the curious ways in which Nazi ideology emphasized different types of "natural" purity:

> This form of mental retardation could be eradicated by preventing goiter in the female population through administration of iodine as iodized salt or consumption of foods containing this element….There was no need for sterilization of parents or euthanasia to eliminate this form of mental subnormality as advocated by Hitler, who was opposed to iodized salt and iodized food because as a naturopath he was against any contamination of natural food by addition of chemicals or other impurities.[103]

Warkany and other teratologists emphasized complex and apparently naturally occurring overlapping anatomical disorders of infants and children and multifactorial gene environment reactions that resulted in prenatal developmental anomalies. Warkany also focused on developmental disability rooted in malnutrition and micronutrient deficiency states, to be modified by better diets or vitamins, conditions of peace and prosperity, and high standards of living.

As Warkany and other teratologists argued for greater attention to congenital disabilities, at least two different methodological research constellations became especially prominent in the study of environmental causes of abnormal embryos: clinically focused approaches, which drew on statistical study of human populations, and laboratory-based scientists who emphasized the complex nature of teratogenic effects in animals. Many geneticists and obstetricians were interested in addressing the questions and concerns of families who had experience with infant anomalies, helping to give advice on the chance of reoccurrence. If the concerns of geneticists and obstetricians were directed at particular families who had experienced an adverse pregnancy outcome, experimental teratology was initially more concerned

[103] "Story of a Teratologist," 21.

with defining environmentally mediated mechanisms or ameliorative approaches to address more broadly distributed clinically relevant childhood impairment.

Teratology After Thalidomide: Public Involvement and Fruitless Effort

In 1961 and 1962, the congenital deformity of *phocomelia* (absent or shortened "seal-like" limbs) and other severe infant disabilities were traced to exposure to the sedative thalidomide in the early months of pregnancy, and the Teratology Society suddenly transformed from a small and little-known community of experts into a more influential organization whose expertise was enlisted by government and pharmaceutical representatives seeking to ensure the safety of future medications, or at least appear to be doing something about a problem of pharmaceuticals likely to cause human infant anomalies. Chemie Grünenthal had first marketed thalidomide in Germany as the sedative Contergan in 1957. Developed as an anti-anxiety medication and used in an over-the-counter respiratory remedy, the drug seemed extremely safe because it was difficult to overdose, in contrast to other sedatives such as barbiturates. It was also prescribed for nausea and sleeplessness. After exposure to thalidomide during a short period early in pregnancy, some women bore infants who had multiple malformations. Initially, the reasons for a slight increase in the birth of with such a rare physical anomalies was mysterious. A West German geneticist (Widukind Lenz) and an Australian physician (William G. McBride) independently reported such unusual cases linked to thalidomide in medical publications in 1961.[104] At least 4,000 infants

[104] Carpenter, *Reputation and Power: Organizational Image and Pharmaceutical Regulation at the FDA*, 240. The original articles are the following: Widukind Lenz,

were affected in Germany, and many others were affected in other parts of the world where thalidomide had been sold.[105] In the U.S., approval for William S. Merrell Co. to market the drug was delayed due to Francis Kelsey's lingering concerns about safety, particularly accounts by some adult patients of tingling extremities.[106] Even so, samples were passed out on an investigational basis to 1,200 physicians (much more than initially notified of teratogenic potential in December 1961), or women obtained them from abroad. These exposures produced at least seventeen cases in the U.S., though Francis Kelsey reported that the drug was withdrawn by November of 1961.[107] Widespread publicity, shock, and concern about other drug-induced birth defects followed the public exposé of the story by *Washington Post* reporter Morton Mintz on July 15, 1962.[108]

"Kindliche Missbildungen Nach Medikament-Einnahme Während Dergravidität?," *Deutsche Medizinische Wochenschrift* 86, no. 52 (1961): 2555–56; William G. McBride, "Thalidomide and Congenital Abnormalities," *The Lancet* 278, no. 7216 (1961): 1358. Arthur Daemmrich, "A Tale of Two Experts: Thalidomide and Political Engagement in the United States and West Germany," *Social History of Medicine* 15, no. 1 (2002): 137–58.

[105] Rock Brynner and Trent D. Stephens, *Dark Remedy: The Impact of Thalidomide and Its Revival as a Vital Medicine* (New York: Basic Books, 2001). Arthur A. Daemmrich, *Pharmacopolitics: Drug Regulation in the United States and Germany*, Studies in Social Medicine (Chapel Hill: University of North Carolina Press, 2004).

[106] This was widely perceived as validating the American system of pre-market pharmaceutical review, bolstering the reputation of the Food and Drug Administration (FDA) and increasing popular support for legislative reform of the Food and Drug Act in the form of the Kafauver-Harris Amendments, which increased FDA oversight over efficacy in addition to safety, among other reforms. Carpenter, *Reputation and Power: Organizational Image and Pharmaceutical Regulation at the FDA*.

[107] Frances O Kelsey, "Thalidomide Update: Regulatory Aspects," *Teratology* 38, no. 3 (1988): 221–26.

[108] Carpenter, *Reputation and Power: Organizational Image and Pharmaceutical Regulation at the FDA*, 242; Morton Mintz, *The Therapeutic Nightmare: A Report on the Roles of the United States Food and Drug Administration, the American Medical Association, Pharmaceutical Manufacturers, and Others in Connection with the Irrational and Massive Use of Prescription Drugs That May Be Worthless, Injurious*

By August of 1962, in the wake of the intense media coverage, teratology took on a new stature and became intimately linked to drug or chemical causes of birth defects, even though the interests of the Teratology Society and associated researchers were much broader and had previously the emphasized morphology and mechanisms of embryonic deviant development (such as cellular interactions, differentiation, molding of particular structures, growth, and expression of genetic traits[109]). As one account put it, the emphasis of teratology "shifted from the analytical to the severely practical."[110] Teratology researchers were called to weigh in on the risks of various drugs and asked how to prevent future tragedies. Questions of what external chemicals could cause birth defects overwhelmed more fundamental questions emphasized by experimental teratologists about the mechanisms of deviant morphological development.

Another effect of the publicity surrounding children disabled by thalidomide was a certain level of "therapeutic nihilism" with respect to drugs for pregnant women, or more aptly, any fertile woman (detection usually was not possible in the early stages of pregnancy during the period of greatest risk, organogenesis).[111]

(Boston: Houghton Mifflin, 1965). Kelsey, "Thalidomide Update: Regulatory Aspects," 223. Bale, "Women's Toxic Experience."

[109] David A. Karnofsky, "Drugs as Teratogens in Animals and Man," *Annual Review of Pharmacology* 10 (1965): 448.

[110]Anonymous, "Teratology," *The Lancet* 2, no. 7619 (1969): 530.

[111] It was a central dogma of teratology that the period of organogenesis (early in pregnancy, when organs and limbs were formed) was the period of greatest susceptibility to congenital malformations, though there had been considerable debate in the 1950s about theories of "critical periods," that posited that shocks or different types of drugs or interventions during particular periods of embryonic development might result in similar types of anomalies. Teratology Society member and chemotherapy expert, David Karnofsky, described such effects in the mid-1960s as follows: "There are critical embryonic periods, such as implantation and organogenesis during the first trimester; and the drug must be present in relation to these specific events to result in a significant effect, by causing either fetal

Chapter 2 addresses in more detail the advice that resulted from public health campaigns warning about pharmaceutical exposures for fertile women. Notably, thalidomide was a sedative used to help with sleep or nausea, not a medicine constructed as essential to health. Thalidomide affected women in a very specific stage of pregnancy, during organogenesis, often before they knew they were pregnant.

Teratology Society members were enlisted to advise on regulations and policies intended to protect pregnant women and fetuses from pharmaceutical products. Not surprisingly, stakeholders such as the Pharmaceutical Manufacturer's Association (PMA) were also interested in sponsoring, learning about, and weighing in on how the safety of various chemicals and pharmaceuticals were evaluated. Following publicity surrounding thalidomide exposure, the PMA created and funded a Commission on Drug Safety under the leadership of the infectious disease researcher and Vice President of the University of Chicago, Lowell T. Coggeshall. Composed of fourteen appointed members representing the PMA, AMA and academia (including cofounder of the Teratology Society, Joseph Warkany, who headed a committee focused on teratology), the commission met monthly between September 1962 and March 1964, planned conferences,[112] workshops, and supporting manuals on teratology, [113] and published a report in 1965. In October

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destruction or developmental defects if the embryo survives." Karnofsky, "Drugs as Teratogens in Animals and Man," 465. For more on David Karnofsky, see M. Lois Murphy and John A. Osmundsen, "David A. Karnofsky: A Biographical Sketch," *Teratology* 3, no. 1 (1970): 1–5.

[112] Commission on Drug Safety, *Report: Conference on Prenatal Effects of Drugs, Chicago March 29–30, 1963.*

[113] Commission on Drug Safety and University of Florida*, Teratology: Principles and Techniques*, James C. Wilson, Josef Warkany, eds., (Chicago: University of Chicago Press, 1965). Wilson and Warkany's edited book on teratology is based on these

1963, forty participants attended the first Workshop on Teratology organized by James G. Wilson and Executive Director of The Commission, Duke C. Trexler, in Gainesville, Florida.[114]

Additionally, James G. Wilson produced lesions from thalidomide on rhesus monkeys and served as an expert witness in the Grünenthal trial.[115] In 1964, Duke Trexler, Executive Director of the Commission of Drug Safety and part of the Drug Research Board at the National Academy of Sciences, wrote that the PMA would be happy to fund the next meeting of the Teratology Society, which would not "commit the Society in any way." [116] He would later forward a check for $2,000 from Eli Lilly to David Karnofsky for partial sponsorship of the fourth meeting of the Teratology Society.[117] Though relatively small sums, they helped maintain the professional meetings and organizing of the Teratology Society. In the early 1960s, amid regulatory reform intended to improve drug safety and efficacy, government representatives, industry scientists, toxicologists, and pharmacologists became much more involved with questions of prenatal exposure and teratogenesis.

The Commission on Drug Safety report recommended three phases of research: 1) small pharmacological studies to assess dose range, absorption, and safety, 2) testing against disease states or for prophylaxis, and 3) expansion of the

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workshops: "The Lectures and Demonstrations were given at the First Workshop in Teratology, University of Florida, February 2–8, 1964." and lists the Commission on Drug Safety as an author.

[114] Box 4, Folder 3: "Teratology Workshop (1st)," Teratology Society Records.

[115] Many teratologist provided expert testimony in trials, though apparently not Warkany. I have reports of testimony by James G. Wilson, Ernest Hook, and Robert L. Brent but likely many others provided testimony. Warkany, "Story of a Teratologist," 59.

[116] Duke C. Trexler to David A. Karnofsky, March 5, 1964, Box 2, Folder 4: "Annual Meeting, 1963–1964" Series 1.2, Teratology Society Records.

[117] Duke C. Trexler to David Karnofsky, April 20, 1964. Box 2, Folder 4, Series 1.2, Teratology Society Records.

trials to larger number of patients.[118] Pre-market teratogenic testing on two species of animals for teratogenic effect was recommended, followed later by recommendations for three-generation testing.[119] Beyond the moral imperative to protect innocents from harm, industry had an interest in mitigating the risks of negative publicity associated with pharmaceutical harm to fetuses, and physicians valued their professional prerogative of prescribing useful and safe drugs.

Subsequent to the thalidomide catastrophe, teratologists were often called upon to pass judgment on issues of reproductive toxicology and methods for testing the safety of drugs and chemicals. Initially, these efforts were focused on pharmaceuticals. The Senate Hearing on Drug Policies emphasized 1) stricter surveillance and monitoring of the pharmaceutical industry, 2) more elaborate pre-market pharmaceutical testing, particularly for teratogenic effects, 3) removal of drugs that were not efficacious from the market, and 4) careful clinical testing, in particular excluding fertile women from testing procedures and monitoring more long-term effects.[120] If the mobilization after thalidomide gave the Teratology Society status and a role in determining public policy with respect to potential teratogens, it also allied them with the pharmaceutical industry, despite difficulties inherent to extrapolating information about developmental defects gained from animals to humans. Experimental evidence of anatomical anomalies in animals was both touted as a solution to protect humans from teratogens and sometimes dismissed as too

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[118] Clinton H. Thienes, "Report of the Commision on Drug Safety," *California Medicine* 103, no. 2 (1965): 159–60.
[119] Robert L. Brent and David Karnofsky ascribe the three-generation testing recommendation to the FDA. Karnofsky, "Drugs as Teratogens in Animals and Man." Robert L. Brent, "Drug Testing in Animals for Teratogenic Effects. Thalidomide in the Pregnant Rat," *The Journal of Pediatrics* 64 (1964): 762–70.
[120] Brent "Drug Testing in Animals for Teratogenic Effects."

difficult to evaluate. If initial efforts in the early 1960s were optimistic and proactive, it increasingly seemed too difficult to detect effects in humans using small animal models. Experimental teratologists struggled with how to answer the questions raised by thalidomide about how to secure the safety of pharmaceuticals and other chemical substances before they were marketed to consumers.

Geneticist and Teratology Society cofounder F. Clarke Fraser, in an oral interview in 2004, recalled it as a period of, somewhat fruitless public involvement, "I spent a lot of time on committees and symposia and government commissions, trying to decide how to prove that a given drug would be safe for people by testing it in animals, which they still don't know how to do, of course."[121] Both Warkany and Fraser seemed exasperated by the public's newfound interest in teratology research.

For instance, common tests of teratogenesis hadn't, and couldn't have, detected thalidomide as a teratogen, unless the drug was tested on an appropriate species (rabbits). Warkany remarked defensively about thalidomide in 1969 "May I point out that the discoverers of this epidemic had been alerted by the often-denigrated science of mammalian experimental teratology. Unfortunately, nobody gave this drug to rabbits before 1961. Such a dull and uninspired experiment would have prevented malformations in many thousands of children."[122] This quote demonstrates Warkany's maneuvering to claim expertise based on a particular methodology. It also reflects his dismay that experimental teratology was unable to provide definitive answers to questions of human pharmaceutical safety and seemed to be being unexciting or left behind by genetic, biochemical, and epidemiological

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[121] Fraser, "F. Clarke Fraser Interview," 26.
[122] Josef Warkany, "Trends in Teratologic Research. Epilogue to the Third International Conference on Congenital Malformations," *Teratology* 3, no. 1 (1970): 89–91.

approaches (such as human epidemiological approaches or genetic toxicology). Yet there were different approaches to pharmaceuticals and environmental teratogens among Teratology Society members. For example, epidemiologist Robert W. Miller built a career at the Atomic Bomb Casualty Commission (ABCC) and the National Cancer Institute (NCI) studying pediatric effects of radiation and surveillance of health effects subsequent to industrial disasters.[123]

The public and press, drawing on from teratological experiments on animals, often framed concerns about chemical or radiation exposure in terms of the possibility of infant malformation.[124] However, there were some problems with relying on experimental teratologists, the "birth defect experts," for protocols to verify prenatal toxicological safety. They weren't necessarily prepared to assess

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[123] Robert W. Miller, "Cola-Colored Babies. Chlorobiphenyl Poisoning in Japan," *Teratology* 4, no. 2 (1971): 211–12; Robert W. Miller, "I'm from the Government and I'm Here to Help You: Field Work at Times Beach and Other Missouri Dioxin Sites," in *Annual Meeting of the Society for the Study of Social Problems, San Antonio Texas* (1984); Miller, "My Half-Life in Teratology"; Miller, "Pollutants in Breast Milk," *The Journal of Pediatrics* 90, no. 3 (1977): 510–511; Miller, "Susceptibility of the Fetus and Child to Chemical Pollutants," *Science* 184, no. 4138 (1974): 812–814; Miller, "Teratology in 1970: The National Scene," *Teratology* 3 (1970): 223–28; Ernest B. Hook, Dwight T. Janerich, and Ian H. Porter, eds., *Monitoring, Birth Defects and Environment: The Problem of Surveillance: Proceedings* (New York: Academic Press, 1971).

[124] This statement is based on perusal of popular literature between 1950 and 1980 (mainly based on examination of popular articles indexed in the *Reader's Guide to Periodical Literature* and by searching in newspapers). If geneticists like Haldane and Müller inspired dire articles about severe anomalies resulting from radiation-related mutations since the late 1940s, teratologists such as Theodore Ingalls tended to downplay the mutation-related impact of radiation and emphasize teratogenesis. Anonymous, "Atomic Bomb May Create 'Freak Crop'," *Los Angeles Times*, January 1, 1947; Theodore H. Ingalls., "No Race of Monsters: Excerpt from Address," *Science News Letter* 68 (1955): 371. By the late 1960s in response to a growing environmental movement, popular media linked drugs like LSD, food additives, and particular herbicides or pollution-related hazardous chemicals (such as NTA, Cyclamates, or 2,4,5-T/TCDD/Dioxin) with birth defects. "U.S. Report Linking NTA, Birth Defects in Rats Seen Killing Role in Detergents," *Wall Street Journal*, December 21, 1970; Morton Mintz, "Widely Used Herbicide Tied to Birth Defects," *Washington Post*, April 8, 1970.

impacts on humans nor interested in other outcomes of reproduction, such as miscarriage or subtle cognitive effects on children, as those weren't their primary area of expertise and were more difficult to study using animal models.[125]

Teratologists' enthusiasm for preventing environmentally-induced congenital malformations had been somewhat tempered by the mid-to-late 1960s. Most congenital malformations still seemed unexplained, and media, environmentalists, and consumer advocates were sounding alarms about chemical additives and low-level exposures to drugs and the pollution in the broader environment, which seemed unruly and uncontained. The author of a manual intended for parents in 1965 cited Theodore Ingalls as a major proponent of prenatal prevention of environmental exposures. Yet the same author provided little hope for individual or collective prenatal prevention:

> the idea that deformities…could be acquired by disturbance of embryonic development … might mean that these accidents could be avoided by individual and collective preventive measures… and that parents who have suffered such a fateful blow can safely beget further children without tragic repetition… [u]nfortunately, this notion does not correspond with reality… in each individual instance, the true cause can very seldom be determined with any degree of accuracy.[126]

Teratology researchers had described multicausal mechanistic complexity of unusual development even as they emphasized chemical, and uni-causal factors in

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[125] In 1965, chemotherapy expert David Karnofsky mentions several efforts to evaluate behavioral effects on animals, and Joan Spyker was particularly successful at efforts to design studies and promote behavioral teratology by 1971. Francis O. Kelsey, "Present Guidelines for Teratogenic Studies in Experimental Animals," in *Congenital Defects: New Directions in Research*, ed. Dwight T. Janerich, et al. (New York: Academic Press, 1974); Brent, "Drug Testing in Animals for Teratogenic Effects. Thalidomide in the Pregnant Rat."

[126] This book was originally published in 1959 in German. Rubella vaccination, prenatal diagnostics, and folic acid supplementation were arenas where collective preventative action to address environmentally-mediated congenital anomalies was relatively successful, but expectations for panaceas were often unrealized. Eric Weiser, *Pregnancy; Conception and Heredity* (New York: Blaisdell, 1965), 117–18.

their experimental studies of developmental mechanisms and the production of obvious anatomical anomaly. Nevertheless, they were frustrated by public interest and appropriation of their research to attribute causality and blame in what they saw as un-nuanced ways.

Likewise, in a retrospective article about thalidomide, Warkany made what was likely an oblique reference to Theodore Ingalls' postwar enthusiasm for prenatal prevention, noting that he was initially inclined to dismiss the possibility that thalidomide caused birth defects because "[t]he role of environmental teratogenic factors had been exaggerated by some investigators in the field who asserted in popular magazines that heredity played no role in the origin of birth defects and that protection of pregnant women would prevent all malformations within a short time."[127] Warkany and other teratologists describe his approach as "moderate," "cautious," and "critical" in the face of overly assertive claims being made about causation: "Another reason for my cautious and critical attitude was that some fellow teratologists had become too assertive about exogenous factors as causes of malformation and mental retardation; I thought it was time to tell parents and lay persons to be careful in their judgment about causation."[128] However, a the time personal testimony from a German mother in the presence of her disabled fraternal twin children quickly changed his mind. Indeed, Warkany's reaction to the public paranoia and anxieties that arose in relation to substances such as radioactive fallout in the 1950s, thalidomide in the 1960s, and pesticides or herbicides as part of the environmental movement in the late 1960s tended to emphasize sound evidence

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[127] Josef Warkany, "Why I Doubted That Thalidomide Was the Cause of the Epidemic of Limb Defects of 1959 to 1961," *Teratology* 38, no. 3 (1988): 217.
[128] "Story of a Teratologist," 55.

and expert interpretations of complex data in the face of claims he saw as exaggerated or alarmist.

Experimental Teratology and Explanatory Insecurity of Inference

In the 1960s and 1970s, Warkany expressed dismay and skepticism about both research on adverse prenatal effects of pharmaceuticals and some genetic interpretations of disability. In the case of pharmaceuticals, he was concerned that relatively harmless products such as aspirin might be inappropriately banned for pregnant women based on inadequate research or immoderate interpretations of animal experiments.[129] This was sometimes characterized as a healthy counterweight to alarmist interpretations of experimental teratology.[130] Even as research on genetically linked anomalies seemed to be gaining new ground in the 1960s and 1970s, he also resisted assumptions that developmental disability was primarily genetic in origin: "We must be aware that we can create new superstitions

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[129] Warkany wrote: "[I]f we are not careful, we may hear very soon that aspirin, "causes malformations." This should not happen since our animal experiments are usually different from therapeutic attempts in man." Gordon E. W. Wolstenholme and Cecilia M. O'Connor, eds., "Ciba Foundation Symposium on Congenital Malformations," 155.

[130] As Brent described it, "During these years and afterward, Warkany exerted a healthy constraining influence. Various therapeutic substances and even the common analgesic aspirin were discovered to be teratogenic in laboratory animals during the 1950s and some were even found capable of deforming human embryos. But it was appreciated that it is difficult to understand the meaning of such phenomena for most human pregnancy; and although it was felt that indiscriminate use of drugs was undesirable the prevailing attitude among teratologists was not alarmist. Part of this attitude was engendered by Warkany...by his example of conservative interpretation of experimental work, and by his knowledge of and respect for the past, which inculcate skepticism and moderation." Brent, "Biography of Josef Warkany," 138. See also, Kalter, *Issues and Reviews in Teratology*.

in place of the old… to blame, without proof, congenital malformations on faulty DNA, RNA, mutant genes."[131]

Experimental teratology depended on chemicals in laboratory studies on animal models. Sometime in the 1940s, various other scientists started to use nitrogen mustard and trypan blue as research tools to induce malformations in rats and other mammals.[132] In describing their use of nitrogen mustards, they emphasized impaired morphology and the close relationships between x-rays and nitrogen mustards, turning the tools of physical or chemical warfare into useful laboratory tools. As one article described: "The sulfur and nitrogen mustards have proven useful in the study of certain developmental processes. Their characteristic effects simulate in many respects those produced by x-rays and other penetrating radiation…innumerable experiments have demonstrated that deviation of normal morphogenesis may he induced by alteration of the fetal environment."[133] In this quote, the researcher highlighted how useful radiomimetic chemicals were in the study of developmental processes. Such substances produced deviation from normal anatomy in laboratory animals to examine "critical periods" of development or create "phenocopies" that mirrored conditions that were presumed to be genetic (and spontaneous and natural) in humans. Initially, teratology researchers emphasized outputs of their experiments and the mechanisms they revealed and viewed trypan blue or antimetabolites simply as useful research tools. Indeed, they often viewed chemicals as either potential therapeutics or tools for experiment, which allowed

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[131] Warkany, "Story of a Teratologist."
[132] Wilson et al., *Teratology: Principles and Techniques*, 6–7.
[133] David Haskin, "Some Effects of Nitrogen Mustard on the Development of External Body Form in the Fetal Rat," *The Anatomical Record* 102, no. 4 (1948): 493–511.

them to tinkering with the mechanics of biological systems: “With the use of these compounds it became possible to determine the point at which teratogenic agents interfere in the molecular machinery of the embryonic cell.”[134]

Research animals were also central to these investigations. The modern science of experimental teratology owes much to the development of institutional resources for maintaining animals, particularly mammals, used for research. As with reproductive health sciences, agricultural research also helped to foster early efforts in teratology.[135] Early researchers on reproductive health and endocrinology, such as George Corner, had developed working relationships with the local abattoir as a means of obtaining research material.[136] In another case, Fred Hale worked at the Texas Agricultural Experiment Station in the 1930s. He was often cited by teratologists as an early example of research on non-genetic causes of malformation, having fed a pregnant sow a diet deficient in vitamin A and produced a litter of blind piglets.[137]

Extrapolating From Animal Studies to Humans

Some clinical researchers hoped to find applications for the apparent abortive effect of drugs on the fetus. John B. Thiersch, while working at the Sloan-Kettering Institute in New York, was interested in the toxicity of folic acid antagonists and

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[134] Association for the Aid of Crippled, Conference Scientific, and L. Emmett Holt, "Prematurity, Congenital Malformation and Birth Injury; Proceedings" (New York, 1953), 151.
[135] Clarke, *Disciplining Reproduction: Modernity, American Life Sciences, and "the Problems of Sex"*.
[136] George Washington Corner, *The Seven Ages of a Medical Scientist: An Autobiography* (Philadelphia: University of Pennsylvania Press, 1981).
[137] Hale, "Pigs Born without Eye Balls."

noticed that 4-aminopteroylglutamic acid (aminopterin) caused abortion in some of his experimental animals. Thinking this might be a means of inducing therapeutic abortion, he tried it out on twelve pregnant women who were eligible for medical abortions.[138] The drug had rather disastrous results in three cases, leading to spontaneous abortion of a fetus that appeared to have myelomeningocele (a neural tube disorder) and other malformations.[139] In a meeting sponsored by the Ciba Foundation in London in 1960, Thiersch described these and other cases of malformations associated with women taking aminopterin as an abortifacient, sardonically observing, "We have thus demonstrated that human beings also belong to the mammalian species and the things which we can produce experimentally in the laboratory can find their application in man."[140] His statement provides a wry commentary on the longstanding debates about the relevance of mammalian research to prenatal environmental causes of disability in humans.

The use of animals as research subjects to study environmental etiologies raised many questions about the relevance of such study findings to humans. The

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[138] It's difficult to judge to what extent admonitions about protection of pregnant women from harmful drugs were really warnings about use of pharmaceuticals and other substances as abortifacients. As Londa Schiebinger has demonstrated in the 18th century, the uses of various botanical substances as abortifacients was often illicit and occult, sometimes confined to oral traditions among women, and infrequently recorded in the official records of botanists and physicians. In at least one article, there was explicit reference to the possibility of abortifacient causing birth defects (which was probably also an argument for legalization of safer medical abortion). Timothy J. David, "Nature and Etiology of the Poland Anomaly," *New England Journal of Medicine* 287, no. 10 (1972): 487–9.

[139] Thiersch, "Therapeutic Abortions with a Folic Acid Antagonist, 4-Aminopteroylglutamic Acid (4-Amino PGA) Administered by the Oral Route."

[140] The meeting brought together 30 experts in anatomy, obstetrics, genetics, biochemistry, epidemiology and pediatrics. It was chaired by W. J. Hamilton and published as an edited volume by Cecilia M. O'Connor and G. E. W. Wolstenholme. Theodore Ingalls and Lionel Penrose also attended. "Ciba Foundation Symposium on Congenital Malformations," 154–55.

same scientists who would argue that their research was intended to provide clinical breakthroughs in pediatric disease or disability, would in other contexts emphasize that their results obtained from animal models could not be extrapolated to humans, particularly with respect to reproductive toxicology. Their hesitancy to apply animal results to humans stems from the high doses of teratogens required to produce anomalies in animals, and the complexity of responses they saw in the laboratory. Different animal species and different strains of the same species responded to chemical assaults and nutritional deficiencies in very different ways. In his 1971 monograph, Warkany recited a two-page litany of reasons why the complexity of animal systems made extrapolation to humans based on animal studies nearly impossible:

> The reaction to a teratogen may vary greatly according to the route of administration. Oral administration to the mother may be harmless, whereas intravenous injection may reach the embryo and damage it. There exist differential susceptibilities to drugs at different ages. The effects of a drug differ greatly before, during and after organogenesis. A drug often adversely affects the embryo before organogenesis and leads to its death; in late pregnancy, it may cause disease or death. Even within the periods of organogenesis, different malformations are produced by administration of a drug on different days of gestation, since the effects depend to a great extent on the developmental stage of the embryo. Experiments in animals that carry more than one young demonstrate that a teratogen applied to the mother may produce different types of malformations in different members of a litter.[141]

The laboratory is often imagined as a clean and controlled environment in contrast to the messiness and unpredictability of field research. For instance, philosopher and sociologist Bruno Latour reminded us of the elaborate staging and performance Louis Pasteur had to put together on a farm in order to demonstrate

[141] Warkany, *Congenital Malformations; Notes and Comments*, 101.

that his vaccine worked outside the confines of his laboratory.[142] Yet teratological accounts of animal experiments in the laboratory often portray nature as complex, unruly, and resistant to easy conclusions—very high dosages of pharmaceuticals or other potential teratogens were required to induce anomalies in animals, sometimes enough to kill the pregnant animal, and different species or strains of the same species showed different results. There were considerable challenges to making causal inferences based on laboratory-based animal models. Any conclusions to be drawn from such studies need to be interpreted cautiously.

At the root of experimental teratologists' reticence to identify substances as teratogens based on animal tests were concerns about inappropriately linking a particularly familiar and useful drug to birth defects, based on animal experiments. At a Ciba Foundation *Symposium on Congenital Malformations* convened in London in 1960, Warkany warned,

> [W]e know now that sulpha drugs, penicillin, streptomycin and even salicylates can be teratogenic as shown in experiments. On this occasion I should like to plead that we should be very cautious in making general statements about these drugs. One could easily make a mistake and accuse a drug wrongly. The cases in which a drug has been proven to be teratogenic in humans are very few. Dose and time play a role, and probably also the genetic constitution. But if we are not careful, we may hear very soon that aspirin, 'causes malformations.' This should not happen since our animal experiments are usually different from therapeutic attempts in man.[143]

This description shows that, at least for Warkany, the knowledge produced by animal experiment could easily be misinterpreted by those with insufficient

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[142] Bruno Latour, "Give Me a Laboratory and I Will Raise the World," in *The Science Studies Reader*, ed. Mario Biagioli (New York: Routledge, 1999): 258–275.
[143] Among the attendees at this symposium in London January 19–21, 1960 were Josef Warkany and Theodore Ingalls, as well as John B. Thiersch and Thomas McKeown. Other Teratology Society members presented, such as Marjorie Nelson and M. Lois Murphy. "Ciba Foundation Symposium on Congenital Malformations," 155.

expertise, and experimental teratologists feared that useful (and presumably relatively harmless) pharmaceuticals might be wrongly implicated as a result of their experiments. Media sources and environmental scientists might emphasize the reproductive toxicity of particular substances, particularly after the late 1960s, but teratologists struggled with challenges of causal inference and extrapolation to humans inherent to experimental teratology and urged careful and cautious interpretations of data obtained from animals to answer questions of human reproductive toxicity.

Statistical Calculation of Risks and Prenatal Environmental Influences

Social Medicine, Risk-Factor Epidemiology, and Theodore Ingalls

Postwar, a new enthusiasm for tracking chronic disease patterns using population studies also arose, associated with British academics at departments of social medicine, typified by John A. Ryle, Thomas McKeown, and Austin Bradford Hill.[144] McKeown began a registry of congenital malformation in Birmingham, starting in 1947.[145] McKeown's work has been described as the first population-based register of congenital malformations, and he and his colleagues published some of their work in the journal *Teratology* (published starting in 1968; previously, compilations of articles presented at symposia were published in journals such as *Pediatrics* or *Genetics).*[146]

Some clues to the motivations of those interested in applying epidemiology to the prevention of congenital malformations are evident in the articles of Theodore H. Ingalls. Ingalls was present at the first teratology meeting of in 1956 and he practiced both epidemiological and experimental research on teratology. Ingalls was an enthusiastic public promoter of prenatal prevention, at times too much so for more laboratory-inclined teratologists such as Warkany, Harold Kalter, and Wilson.

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[144] Mervyn Susser, "Epidemiology in the United States after World War II: The Evolution of Technique," *Epidemiologic Reviews* 7, no. 1 (1985): 147–77; Dorothy Porter, ed., *Social Medicine and Medical Sociology in the Twentieth Century*, vol. 43 (Amsterdam: Rodopi, 1997).
[145] Leck, "Mckeown, Record, and the Epidemiology of Malformations."
[146] Ian Leck et al., "The Incidence of Malformations in Birmingham, England, 1950–1959," *Teratology* 1, no. 3 (1968): 263–280; Al-Gailani, "Making Birth Defects 'Preventable': Pre-Conceptional Vitamin Supplements and the Politics of Risk Reduction."

Teratology Society members often alluded to Ingalls as an example of overemphasis on "critical periods" and excessive publicity about unsubstantiated environmental factors affecting anomalous development. Trained as a pediatrician, Ingalls wrote prolifically and with rhetorical flourish on the topic of congenital malformations from various positions in preventative medicine and public health at academic institutions in the Northeast. As an inspiration for his work, he describes his own wife's miscarriage that he attributed to German measles.[147] He was an early proponent of using both experimental teratology and the epidemiological tools of the time to investigate preventable environmental etiologies of human malformation. He initially started as a pediatrics instructor at Harvard Medical School, and after the war he took a position in preventative medicine and epidemiology at Harvard, then other academic placements in the Northeast—the University of Pennsylvania and Boston University.

In a 1948 paper titled "Death, Disability and Prenatal Life," Ingalls argued that developmental defects should be considered as a medical problem of collectivities, of public health, rather than "unavoidable accidents of nature."[148] Bemoaning the anachronistically clinical nature of research on congenital malformations at the time, as opposed to the earlier application of biology to infectious disease, he argued that "agents" cause developmental arrests and that epidemiology should be used to investigate developmental disability. His approach was a rather expansive interpretation of environmental agents acting during "critical periods" during development that didn't appeal to the more cautious and

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[147]Gladys Denny Shultz, "The Uninsulated Child," *Ladies' Home Journal* (June 1956), 60–63, 133–136.
[148] Gordon and Ingalls, "Death, Defect, and Disability in Prenatal Life. An Epidemiologic Consideration."

skeptical laboratory-based scientists and clinicians who later formed the Teratology Society. He used analogies to infectious disease epidemiology to explain the study of human disease, even when speaking of chronic conditions: "The task of epidemiology is to quantitate the movement of disease through various populations and define specific causative factors as they relate to the host and the environment quite as thoroughly as those related to the agent."[149] Ingalls wanted to use the tools of the laboratory and epidemiology to probe the environment of the womb, with an eye to preventing infant anomalies.

The identification of rubella as a teratogenic agent during pregnancy in 1940 motivated researchers to more carefully consider environmental causes of congenital malformation.[150] Ingalls and other medical practitioners working in the 1950s and 1960s cited 1940 as a turning point for thinking about environmental causes of congenital malformations in humans, related to new interpretations of the role of inheritance and changing methodological approaches.[151] Accounts from such researchers often attribute the changing attention to environmental causes of birth defects to the rising discipline of epidemiology and previous overemphasis on research on hereditary conditions.

Efforts to define environmental risk factors for congenital malformations using epidemiology or clinical observation were in dynamic tension with laboratory-based science of experimental teratology. Each methodology provided information

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[149] Ingalls, "The Study of Congenital Anomalies by the Epidemiologic Method: With a Consideration of Retrolental Fibroplasia as an Acquired Anomaly of the Fetus," 67.
[150] Reagan, *Dangerous Pregnancies: Mothers, Disabilities, and Abortion in America.*
[151] Ingalls, "The Study of Congenital Anomalies by the Epidemiologic Method: With a Consideration of Retrolental Fibroplasia as an Acquired Anomaly of the Fetus," 67–74.

about potential human teratogens but nevertheless struggled with diverse issues of causal inference.

Methodological Differences and Legal Responsibility: Clinician Epidemiologists, Geneticists, and Laboratory Scientists

It was the specific aim of the organizers of the Teratology Society in 1955 to bring together scientists with expertise in many different aspects of abnormal animal and human development. However, in many respects, this interdisciplinary project of addressing environmental causes of infant disability was unfulfilled. Epidemiologist Theodore Ingalls never joined the Teratology Society, and the concerns of clinician epidemiologists interested in developmental disorders were a minority voice in a society that was primary preoccupied with laboratory-based studies of malformations using a range of animal models. Experimental teratologists focused on animal studies sometimes looked with skepticism on epidemiological methods and statistics tracking human congenital malformation, a growing source of evidence about potential risk factors affecting human health. Warkany remarked in his memoir that if one needed statistics to assess one's experiment, one had done the wrong experiment.[152] The members who came to teratology with expertise in epidemiology of human malformations had different training and research interests from animal experimentalists. Underlying these differences was the experimentalists' perspective that the clinician epidemiologists lacked scientifically rigorous understanding of developmental biology and the epidemiologists' sense that teratological animal experiments were uninspired or weren't very useful to problems of human health or the impact of drugs or chemical substances on humans. The

[152] Warkany, "Story of a Teratologist," 35.

Teratology Society attracted many laboratory scientists and fewer clinicians or clinician epidemiologists. As epidemiologist Robert W. Miller noted, "There were plenary sessions only, so the clinicians had to sit through what seemed like dozens of papers on methylene blue, and the experimentalists sat through clinical papers they must have regarded with equal dismay."[153]

Clinician epidemiologists, interested in broad programs of prevention and public health, like public health and pediatrics professor Theodore Ingalls and later Godfrey Oakley at the Centers for Disease Control and Prevention and Robert W. Miller at the National Cancer Institute, remained a minority voice in the Teratology Society. In the late 1950s philanthropic research agenda, laboratory studies of congenital malformation were emphasized over epidemiology, which was confined to state-funded projects. At the time, funders like The National Foundation-March of Dimes discouraged sponsoring epidemiological projects. Virginia Apgar noted in her diary in 1962, "It was recommended that the applicant for large, widespread projects be advised that our funds in the future will be spent on definite areas in basic research. Epidemiological grants belong in the province of government."[154] By 1969, however, Apgar raised questions about the effects of environmental factors in a speech, concluding that, "until we know what we're talking about on the basis of

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[153] Robert W. Miller, "My Half-Life in Teratology," in *Issues and Reviews, Vol 6,* ed. Harold Kalter (Boston: Springer, 1993), 25.
[154] Virginia Apgar, *Professional Diary*, 1962, 30, Box 2, Folder 4, Series 1: "Diaries 1959–1967," Virginia Apgar Papers, Archives and Special Collections, Mount Holyoke College, South Hadley, MA. See also, *Professional Diary, 1961*, 89, Box 4, Folder 3, Virginia Apgar Papers, Mount Holyoke.

sound prospective data from pregnant women, instead of pregnant mice or rabbits, we won't have the answers we want."[155]

Proponents of using epidemiological investigation to examine environmental factors affecting prenatal development in humans in the 1950s included Theodore Ingalls, and UK-based researchers with a social medicine orientation, such as Thomas McKeown, and Brian MacMahon.[156] At least some of this research was funded by the AACC. Later, in the 1960s and 1970s, Columbia University-based epidemiologists such as Mervyn Susser, Jenny Kline, and Vena Stein would take up the mantle of epidemiological assessment of reproductive hazards.[157] Epidemiology of environmental factors acting during the prenatal period is notoriously difficult, and in the face of uncertainty, many epidemiologists counseled precaution about

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[155] Virginia Apgar, "Priorities for Progress," 10, April 1969, Box 1, Folder: "March of Dimes Memos, Press Releases, and Copies of Articles, 1960–1970," Series 1, Virginia Apgar Papers, March of Dimes Archives, White Plains, NY.

[156] By 1947, Thomas Mckoewn and his colleagues had set up a large cohort study of congenital malformations from the Department of Social Medicine in Birmingham. MacMahon and McKeown published several articles in the early 1950s about pyloric stenosis. McKeown's PhD student in social medicine, Brian MacMahon, took a master's degree in public health at Harvard, where he became chair of the Department of Environmental Medicine and Community Health in 1958, and later head of the Department of Public Health. Brian MacMahon, R. G. Record, and Thomas McKeown, "Congenital Pyloric Stenosis; an Investigation of 578 Cases," *British Journal of Social Medicine* 5, no. 3 (1951): 185–92; Thomas McKeown, Brian MacMahon, and R. G. Record, "The Incidence of Congenital Pyloric Stenosis Related to Birth Rank and Maternal Age," *Annals of Eugenics* 16, no. 3 (1951): 249–59; Brian MacMahon, R. G. Record, and Thomas McKeown, "Secular Changes in the Incidence of Malformations of the Central Nervous System," *British Journal of Social Medicine* 5, no. 4 (1951) 254–8; Thomas McKeown, Brian MacMahon, and R. G. Record, "Size of Tumour in Infantile Pyloric Stenosis Related to Age at Operation," *Lancet* 2, no. 6683 (1951): 556–8. Walter Willett, "A Conversation with Brian Macmahon," *Epidemiology* 15, no. 4 (2004): 504–8.

[157] Stein, *Famine and Human Development: The Dutch Hunger Winter of 1944–1945*; Zena Stein, Jennie Kline, and Martin Kharrazi, "What Is a Teratogen? Epidemiological Criteria," in *Issues and Reviews in Teratology, Vol 2*, ed. Harold Kalter (New York: Plenum Press, 1984).

possible risk factors.[158] Risk factor epidemiology grappled with how to make causal inferences linking environmental determinates and congenital malformations. Problems arose when defining control groups and questioning parents about their exposures. Conclusions reached from epidemiological studies were often *post hoc* and remained tentative and subject to criticism that they merely indicated a correlation rather than a true relationship of causality.[159] Large expensive epidemiological studies, intended to create generalizable medical knowledge, favored research on behavioral factors for which dosage was quantifiable (prescription drug exposure, smoking, vitamins, alcohol, and fish consumption) and provided limited information about diffuse, low-level, overlapping or chronic exposures from pollution for which control groups were difficult to identify, problems specific to small numbers of women working in highly toxic industrial settings, or efforts to understand the complex and multifaceted experiences of people often living under conditions of structural stress, who were inclined to drink excessively or use illicit drugs.[160]

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[158] Richard Doll, "Hazards of the First Nine Months: An Epidemiologist's Nightmare," *Journal of the Irish Medical Association* 66, no. 5 (1973): 117–26.
[159] Criticism of epidemiology as *post hoc* can be seen in many environmentalist accounts, particularly advocacy by Samuel Epstein, who was a professor of pediatrics and environmental science, an advocate for reform of chemical regulatory policy, and an early member of the Environmental Mutagen Society. See National Academy of Sciences, "How Safe Is Safe? The Design of Policy on Drugs and Food Additives," (1974). Rosner and Markowitz paraphrase Joseph Wagoner's criticism of epidemiology's ability to detect potential carcinogenic hazards, "[e]pidemiology was weak and inadequate, *post hoc* in nature, and was likely to underestimate risk by studying death from cancer not induction of cancer." Markowitz and Rosner, *Deceit and Denial: The Deadly Politics of Industrial Pollution*, 202.
[160] This statement is based on a range of literature examining epidemiology as a methodology to study environmental factors affecting human health outcomes or prenatal development, some sources from the 1970s–1990s derived from critiques within epidemiology and environmental health science, and some secondary. For instance, Samuel Epstein was a leading advocate to reform regulatory policy addressing chemical hazards and food additives in the 1970s and articulated the commonly discussed problem of how to define a control group in the case of widely

In addition, the long history of popular and medical interest in unusual morphology at birth initially shaped the outcomes considered, rather than more occult experiences of women, such as spontaneous abortion or impaired fertility or more long-term or sub-clinical impacts of prenatal exposures. By the late 1970s, epidemiologists were calling for studies with more power and consideration of a broader range of reproductive outcomes to understand the impacts of parental chemical exposures.[161]

However, both experimental teratologists and epidemiologists interested in non-genetic etiologies of birth defects had directed scrutiny to the womb as the fetal environment, porous to the outside world, which could negatively impact fetal growth and development. In the early 1950s, philanthropic leaders, such as Leonard Mayo, Director of the AACC, had emphasized the localized environment of the womb

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dispersed potential chemical hazards like waste products, food additives and pesticides. Other authors and environmental advocates, such as medical editor Joseph Mori at the March of Dimes, or Joseph Wagoner at the NIH bemoaned the delayed information obtained from epidemiological studies of teratogens on human populations. David Smith and Kenneth Jones, who coined the term fetal alcohol syndrome based on eight children of alcoholic mothers in Seattle, acknowledged the complex social circumstances and conditions of poverty associated with the condition. In the 1990s, voices within epidemiology interrogated the problem of "black box" epidemiology and the difficulties in mathematical models of human experience and populations. Samuel S. Epstein, "Chemicals in the Environment [Sound Recording] " in *Man and Molecule*, ed. American Chemical Society (Washington, DC: American Chemical Society, 1974). Sellers, *Hazards of the Job: From Industrial Disease to Environmental Health Science*; Sellers, "Discovering Environmental Cancer: Wilhelm Hueper, Post-World War II Epidemiology, and the Vanishing Clinician's Eye"; Mervyn Susser and Ezra Susser, "Choosing a Future for Epidemiology: II. From Black Box to Chinese Boxes and Eco-Epidemiology," *American Journal of Public Health* 86, no. 5 (1996): 674–77; Douglas L. Weed, "Beyond Black Box Epidemiology," *American Journal of Public Health* 88, no. 1 (1998): 12–14. Gerald M. Oppenheimer, "Becoming the Framingham Study 1947–1950" *American Journal of Public Health* 95, no. 4 (2005): 602–10; Golden, *Message in a Bottle: The Making of Fetal Alcohol Syndrome*.

[161] Barbara Reiber Strobino, Jennie Kline, and Zena Stein, "Chemical and Physical Exposures of Parents: Effects on Human Reproduction and Offspring," *Early Human Development* 1, no. 4 (1978): 371–99.

as the site of fetal harm: "The reaction of the trophoblast to a wide variety of metabolic and physical insults offered by the maternal environment, seems of fundamental importance."[162] Attribution of markings to maternal impressions emphasized disciplining the emotional state of the pregnant woman and avoidance of shock or excitement in order to protect the unborn, reflecting nineteenth-century ideals of passive womanhood.[163] It could also be argued that if monsters were portents, maternal impressions invested considerable power in the wandering minds of pregnant women to affect the fate of the future humanity.[164] For much of the early part of the twentieth century, authors of medical manuals for expectant parents rejected maternal impressions and aspired to reassure parents, mostly mothers, about the rare possibility of fetal abnormality. They offered platitudes about the safety of the pregnancy provided that women were under medical supervision.[165] By the late 1950s, under the auspices of finding techno-scientific methods for preventing birth defects, these researchers emphasized viral, chemical, physical, and mechanical insults that could occur in the maternal environment.[166] These findings

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[162] Leonard Mayo to Mr. Melvin Glasser, 5 February 1957, Box 7, Folder: "Public Relations: Association for the Aid of Crippled Children, 1955–1958," Series 6, Medical Program Records, March of Dimes.
[163] Rosi Braidotti has argued that warnings about maternal impressions were part of efforts in the 18th century to discipline and pathologize women's bodies. Braidotti, "Signs of Wonder and Traces of Doubt: On Teratology and Embodied Differences."
[164] Philip K. Wilson quotes Roy Porter to argue that if monsters were portents, then maternal impressions vested considerable power in of the wandering minds of pregnant women. Wilson, "Eighteenth-Century 'Monsters' and Nineteenth-Century 'Freaks': Reading the Maternally Marked Child," 9.
[165] Rima Apple, among others, has demonstrated how networks of family members guiding new mothers were partially replaced by manuals and other prescriptive literature elaborating scientific norms of motherhood, redefining what it meant to be a good mother. Apple, *Perfect Motherhood: Science and Childrearing in America.*
[166] James G. Wilson's publication in 1973 summarized some of the ways environmental (non-genetic) factors were categorized. Published after the rise of the popular environmental movement, it nevertheless took an expansive definition of

were often both initiated and helped reinforce a protectionist impulse towards pregnant women and mothers, even as they were accompanied by new responsibilities and the apparent need to be informed and proactive citizens managing potential exposures for the good of future humans.

In the 1960s and 1970s, there were differences between how the two methodologies approached the problem of assessing pharmaceutical or chemical safety. First, the methodologies were used in an effort to answer different questions, one to identify products likely to be safe (pre-market reproductive toxicology testing) and the other to identify what might be harmful (in post-market epidemiological studies, often retrospectively). With respect to assessing the teratogenic potential, the use of animals to test substances for reproductive effects of pharmaceuticals designed in the 1960s was intended to assess which pharmaceuticals were not harmful for human use before they were extensively tested on humans and sold. Whether pre-marketing mammalian screening tests could actually prevent the sale of teratogens was a matter of much debate. Epidemiological studies were typically oriented towards determining substances that might have harmed pregnant women and fetuses, most frequently pharmaceuticals, but with the rise of environmentalist concerns about pollution in the broader environment in the 1960s, also other industrial synthetic chemicals. The practitioners of the relatively new science of risk factor epidemiology aspired to a more "persuasively generalizable approach to extrinsic causes."[167] Both animal experiment and epidemiology seemed to have limitations for making causal inferences about environmental factors affecting

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environmental etiologies of which toxins and chemical exposures play a relatively small role. Wilson, *Environment and Birth Defects*.

[167] Sellers, "Discovering Environmental Cancer: Wilhelm Hueper, Post-World War II Epidemiology, and the Vanishing Clinician's Eye," 1829.

developmental outcomes. Arguably, effects seen on animals were too sensitive an indicator of human harm (yet highly dependent on dosages, and the animal used). In the mid-1960s, it was posited that human epidemiology and birth defects registries might provide better information, and birth defects registries were started in New York in 1962 and in Atlanta by 1967.[168] Yet even with more comprehensive surveillance, epidemiological efforts to ascribe causal relationships to identify and explain birth defects clusters proved difficult.[169] Epidemiology of birth defects was seen alternatively as an overly sensitive or insensitive tool for interrogating potentially harmful effects, depending on the perspective of the beholder.

Much of the contention centered on how information obtained from the laboratory studies of animals or statistical study of human populations should be vetted and communicated to media and parents. In 1956, professor of preventative medicine Theodore Ingalls lamented the millions of dollars spent on human genetic studies of the effects of the atomic bomb, noting, "All the tragic evidence is that the malformations were acquired and not inherited. The practical demonstration is the direct effect of high dosage of ionizing radiation upon the mammalian conceptus and

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[168] Karnofsky, "Drugs as Teratogens in Animals and Man." Samuel Milham reported starting a birth defects registry and surveillance system in upstate New York as early as May 1962. The Metropolitan Atlanta Congenital Defects Program started collecting data in October 1967. Ernest B. Hook, Dwight T. Janerich, and Ian H. Porter, eds., *Monitoring, Birth Defects and Environment: The Problem of Surveillance; Proceedings*, 101, 37.

[169]Godfrey P. Oakley and Clark W. Heath, "Cancer, Environmental Health, and Birth Defects—Examples of New Directions in Public Health Practice," *American Journal of Epidemiology* 144, no. S8 (1996): S58–S64; Godfrey Oakley, "Birth Defect Surveillance in the Search of and Evaluation of Possible Human Teratogens," 1–6, in *Cytogenetics, Environment, and Malformation Syndromes*, ed. Daniel Bergsma and Neil Shimke, Birth Defects Original Article Series (National Foundation-March of Dimes, 1976).

not a confirmation of dire speculations about mammalian mutations."[170] In this quote he challenges large-scale human genetics studies as very expensive and existing mammalian radiation safety research directed at genetic outcomes as unhelpful for assessing mutation risks to humans. Several of Ingalls's articles offer a strong polemic that acquired disabilities of the prenatal period could be prevented, unlike those caused by genetic mutations. Ingalls wrote an article, "Causes and Prevention of Developmental Defects" in the *Journal of the American Medical Association (JAMA)* in 1956. In the article he advocates for attention to the epidemiology of environmental factors affecting development over genetic approaches and that "maternal illnesses are more easily controlled in human populations than are marriages."[171] Ingalls studied the effects oxygen lack (anoxia) or excess on development. As evidence of maternally determined conditions, he cited German measles, Rh factors, and toxoplasmosis. He also attributed the birth of a set of "Mongoloid twins" to a car accident and another case to an operation requiring gas oxygen anesthesia. Ingalls is particularly optimistic about medicine's ability to control environmental factors: "[A]ll that is known of maternal rubella, syphilis, toxoplasmosis, and influenza; of the effect of thiouracil, lead, carbon monoxide poisoning during pregnancy... is that many, if not most, congenital anomalies will eventually be brought under the control as appropriate scientific studies clarify causes."[172]

Geneticist James Neel, who was responsible for the expensive studies of radiation effects on genetic material in Japan, wrote to Josef Warkany about this

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[170] Ingalls, "Causes and Prevention of Developmental Defects," 1050.
[171] Ibid., 1048.
[172] Ibid., 1051.

article printed in *JAMA*: "It is so shot with misconceptions… that I was tempted to write a rejoinder."[173] Warkany and Fraser's protégée, Harold Kalter, did write a rejoinder, criticizing the article on the grounds of inaccuracies, scientific and historical. In addition to a dispute over priority, his criticisms were that the idea of stress acting during critical periods of pregnancy was an oversimplification, that Ingalls argued too enthusiastically and uncritically for the role of environmental exposures as causative factors for developmental disabilities (Kalter names thirteen "genetically-determined" conditions), and that one could not easily draw conclusions about humans based on animal experiments. Additionally, he notes that claiming that "such routine measures can prevent congenital malformations places a heavy responsibility on the physician caring for the woman before pregnancy," who might be blamed for causing congenital malformations.[174]

Fraser later noted that Ingalls provided expert testimony to support the case of a woman who was in an automobile accident while pregnant; which she saw as the cause of her infant's Down syndrome. Fraser used this anecdote to illustrate how erroneous testimony could be used and abused.[175] The story of the automobile accident attributed as a cause of disability acted as a trope recited by scientists in effort to illustrate how the concept of assaults acting during critical periods of development (a version of maternal impressions) could be misinterpreted when used incorrectly or out of context, and how commonly disabilities or abortions were incorrectly attributed to emotional shock or fright, or other events during critical

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[173] James Neel to Josef Warkany, November 19, 1956, Box 1, Folder 3, "Correspondence: publication of proceedings," Series 1.1, Teratology Society Records.
[174] Harold Kalter, "Developmental Defects," *Journal of the American Medical Association* 163, no. 4 (1957): 303.
[175] Fraser, "F. Clarke Fraser Interview."

periods of development that might cause developmental damage. Embryologist Arthur Hertig describes an abortion attributed to an automobile accident.[176] Warkany cites a similar case when describing some problems with the idea of a critical period of teratogenesis:

> If the simplified idea of 'critical periods' should reach the lay public we must expect serious consequences. If, for instance, a woman who had an automobile accident in a taxicab during the seventh week of pregnancy gives birth to a mongol child, she could sue the taxi company. This will happen when we let this erroneous idea of critical periods become too widespread.[177]

One of the issues that members of the Teratology Society had with Theodore Ingalls was his advocacy and public statements about environmental causes of malformations, which they saw as likely to fan the fears of expectant parents and erroneously cast blame upon physicians or others for disabled children. Theodore Ingalls was profiled in the *Ladies' Home Journal* in 1956 in an article called "The Uninsulated Child."[178] The article described an apparently new theory of 'epigenetics' attributed to Ingalls, in which,

> the fertilized human ovum, normal to begin with, becomes defective only if a 'catastrophe' overtakes it in the womb after conception. This 'catastrophe' might result from disease carried by the mother, or it might come from an outside source. This shock to the unborn baby doctors call an 'insult.' If it is sufficient to damage, the 'insult' will affect that portion of the baby's body which happens to be in a developing growth-stage at that particular time.[179]

In addition the article argued that though many pregnant women feared infant death or disability, now there were means of prevention. Two cases of infant disability associated with anesthesia (gas-oxygen-ether) during an operation are

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[176] Association for the Aid of Crippled, Scientific, and Holt, "Prematurity, Congenital Malformation and Birth Injury; Proceedings," 175.
[177] Josef Warkany, "Disturbance of Embryonic Development by Maternal Vitamin Deficiencies," *Journal of Cellular and Comparative Physiology* 43, no. S1 (1954).
[178] Shultz, "The Uninsulated Child."
[179] Ibid., 61.

recounted. Ingalls seems particularly interested in pointing out instances where medical care might prove detrimental to pregnant women, fetal development, or newborns.[180]

Writing to the eminent perinatal pathologist Edith Potter about the article, Warkany lamented,

> "I was rather disturbed about the article… It is a mixture of true and false statements. In regard to the proportion of true and false, it reminds me of the sausage advertised by the butcher as 'half chicken and half horse.' It was made from the meat of one chicken and one horse. I have already experienced the confusion aroused by this article in mothers of abnormal children. I fear it is only a matter of time until law suits will be started against doctors recommending chest films on pregnant women, or taxi drivers who shake expectant mothers in the 7th week of pregnancy.[181]

In other words, the cautiousness and resistance to uncritical claims about etiology or extrapolation from animals to humans that characterized the science of experimental teratology was justified on the grounds that 1) the science of mammalian teratology was complex and resisted simple causal inference, 2) they didn't want to alarm parents with improperly vetted claims, and 3) if parents were aware of the possibility of environmental causes of malformation, they might blame the physicians or others for accidental events experienced in the event of childhood disability, resulting in increased medical liability and excessive lawsuits.

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[180] Ingalls also described cases of infantile blindness associated with premature birth and exposure to oxygen in early incubators, known as retrolental fibroplasia. In his articles about oxygen deprivation and excessive exposure, Ingalls wanted to reform medical interventions and approaches to pregnancy and prematurity. Ingalls, "The Study of Congenital Anomalies by the Epidemiologic Method: With a Consideration of Retrolental Fibroplasia as an Acquired Anomaly of the Fetus"; "The Strange Case of the Blind Babies."

[181] Edith Potter to Josef Warkany 22 June 1956. Folder 6: July 1956–1958, Series 1.1, 1. "Teratology Conference Publications" (3 of 3), Teratology Society Records.

Retrospectively, Theodore Ingalls appears misguided and wrong about his approach to explaining the origins of developmental disability and some of his investigations into the effects of anoxia. Certainly, his attempt to make an overarching thesis about the predominant impact of stresses during critical periods of fetal development reflects a minimally modified interpretation of maternal impressions. His statements are often expansive philosophical arguments, less absorbed by biochemistry, micro-mechanics of development in the laboratory, and human genetics. His publications also reflect the unknown disciplinary territory of infant disability in the early 1950s, when human genetics was a barely respectable field associated with what was then seen as the shoddy and questionable scientific basis of eugenics, determinism, and the worst atrocities of the war. Ingalls's research predated many concerted efforts to define and classify various rare (and not so rare) genetic disorders, such as the various blood disorders, chromosomal non-disjunction, and in-born errors of metabolism.[182] By the 1960s, medical genetics became well-established and Mongolism was classified as a chromosomal disorder, a trisomy of a chromosome designated as 21, and would soon be renamed Down syndrome (though some had previously suspected that it had genetic etiology because there were cases of identical twins who both had the disorder). Indeed, the

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[182] Archibald Garrod is credited with coining the term to describe inheritable biochemical errors in the production of metabolic enzymes around 1902. Phenylketonuria (PKU) was one of the early examples, and children could be fed diets without phenylalanine to prevent severe brain damage and seizures. Pearl S. Buck wrote about her daughter with PKU in 1950. Archibald E. Garrod, *Inborn Errors of Metabolism*, 2nd ed. (London: H. Frowde and Hodder & Stoughton, 1923); Alexander G. Bearn, *Archibald Garrod and the Individuality of Man* (Oxford, New York: Clarendon Press; Oxford University Press, 1993); Pearl S. Buck, *The Child Who Never Grew* (New York: J. Day Co., 1950). Pernick, *The Black Stork: Eugenics and the Death of 'Defective' Babies in American Medicine and Motion Pictures since 1915*. Lindee, *Moments of Truth in Genetic Medicine*.

Teratology Society incorporated in April 1960 partially in response to such trends and the National Foundation's scientific advisor's enthusiasm for biochemical and molecular approaches to studies of inborn errors of metabolism and genetic etiologies of congenital malformation.[183]

This episode can also be viewed as a turf battle of sorts. Theodore Ingalls, with training in embryology and pediatrics, had interest in epidemiology and had a strong clinical and public health focus (though he also performed animal experiments). Animal experimentalists and geneticists more linked to the laboratory were subject to the critique that their investigation of high doses of radiation and radiomimetic chemicals on animal models in the laboratory might inappropriately alarm the public about the risks of 'monsters' resulting from radiation, and later chemical exposure during pregnancy. These genetically-inclined experimental teratologists were most interested in mechanisms of abnormal development and thought they were best qualified to examine the complex interactions between genes and the maternal environment that caused abnormal animal development and drawing conclusions about how it related to humans. Such experimentalists also thought the lay public was often misguided in their understanding of the causes of malformation (which, in many cases, is hard to dispute).

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[183] Various sources indicate that the decision to incorporate the Teratology Society was made following a Scientific Advisory Board at a National Foundation-March of Dimes meeting in Florida in April 4–7, 1959, at which biochemical and genetic approaches were seen as the most promising line of scientific and philanthropic investment. See Wertelecki, "Of Dreaming on Solid Grounds and Silent Triumphs of One Man: A Story About Josef Warkany," 532; Wilson and Warkany, "The History of Organized Teratology in North America," 287. Also see the letter sent to colleagues in 1959: F. Clarke Fraser, Josef Warkany, and James G. Wilson to "Colleagues," 15 June 1959, Box 1, Folder 1: 1st Annual Meeting, Series 1.2, Teratology Society Records.

Teratology research owes much to government investment in examining the health effects of radiation, but teratologists interested in what they considered fundamental questions of development were somewhat ambivalent about using animal experiments to identifying reproductive hazards. Even as they used chemicals on animals to induce various defects, their emphasis was on morphology and mechanisms rather than chemical inputs. For these researchers, chemicals in high doses on pregnant animals were used to produce sufficient numbers of visible malformations for study. Their research emphasized that 1) doses needed to be high to produce malformation, and 2) vast differences existed between animal species and even different strains of the same species. They feared that if their research was taken out of context or examined without proper scientific training, it would be misinterpreted.

Obstetricians, Teratologists, and Epidemiologists Debate X-Rays, Low-Level Radiation From Fallout, and Chemical Pollution

"What are the Risks of Recurrence?" Obstetrics, Biological Statistics, and X-Rays During Pregnancy

Between 1929 and 1933, medical students visited the home of 546 families in Philadelphia to inquire about the birth of and death of a child malformed at birth. When they launched the study in 1929, Douglas P. Murphy and a colleague Leopold Goldstein had recently identified therapeutic x-rays as harmful during pregnancy.[184] Murphy, based at the Gynecean Hospital Institute of Gynecologic Research at the University of Pennsylvania, noted that he often fielded questions from parents who had experienced adverse birth outcomes, such as "What caused the maldevelopment? And what are the chances that any subsequent child will suffer a similar fate?"[185]

Many obstetricians and medical geneticists were particularly interested in how to answer questions from concerned parents who already had a child with a developmental disability. Murphy described inspiration for the study as derived from a colleague "who delivered a patient of two monsters in successive pregnancies, having informed her after the birth of the first that she was no more likely to give birth to a second one than was any woman who had never had such an

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[184] Goldstein and Murphy, "Microcephalic Idiocy Following Radium Therapy for Uterine Cancer During Pregnancy."; Murphy and Goldstein, "Etiology of the Ill-Health of Children Born after Maternal Pelvic Irradiation."
[185] Murphy, *Congenital Malformations: a Study of Parental Characteristics with Special Reference to the Reproductive Process,* 2nd Edition, 3.

experience."[186] Medical geneticists describe similar difficulties in counseling parents with a family history of disability about their pregnancies, and the need to use biological statistics to know the chances or risk of recurrence. F. Clarke Fraser, a McGill-based geneticist and co-founder of the Teratology Society, emphasized how counseling parents about genetics around midcentury required knowing the risks of repetition: "[I]n those days the counseling was fairly simple. You had to decide whether the risk of recurrence was big enough that you didn't want to take it, or that you wanted children enough so you would take it. There was no question of prenatal diagnosis, and abortion was illegal, and contraception was illegal in Quebec. So getting the recurrence risks was important."[187]

Murphy's assistants interviewed mothers about their diet and health, reproductive history, the income and occupation of the father, marriages between relatives, relatives with birth marks or underdevelopment, x-ray treatment, bleeding or unusual symptoms during pregnancy, etc. In addition, the students would judge the families' economic status as "very poor, poor, moderate, well-to-do," on the basis of the income, appearance of the house and furnishings or presence of consumer goods like radios, and the education of residents.[188]

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[186] Ibid.
[187] Fraser, "F. Clarke Fraser Interview," 19–20. Part of the UCLA Oral History of Human Genetics Project.
[188] This research has a eugenic overtone, though eugenics as a movement was already in decline (Kevles and Pernick argue that many geneticists were distancing themselves from the eugenics movement in the 1920s, even as it achieved legislative and judicial success in ethnic immigration exclusion and compulsory sterilization laws). The question remains whether Murphy was proposing eugenic solutions. He does classify "efficient matings" and "inefficient matings" in a eugenic way, but the problem of infant disability is approached mainly as individual decision of prospective parents, based on a statistical calculation of "chances," evocative of contemporary genetic counseling. Kevles, *In the Name of Eugenics: Genetics and the*

Code sheets and punch cards for Murphy's study were designed with the advice of the Bureau of Vital Statistics. The conditions cataloged as malformations included nervous system disorders such as hydrocephalus, spina bifida, anencephalus, meningocele, encephalocele; gastrointestinal disorders such as pyloric stenosis; musculoskeletal effects such as harelip, cleft palate; Mongolism; intestinal obstructions; biliary obstructions; and malformations of the lung or kidney. Murphy's research study was an effort to use biological statistics to track the "frequency of defects among siblings" and ascribe causes in order to answer the questions about recurrence that parents asked obstetricians when a child with a malformation was born.[189]

Murphy was particularly interested in defining environmental and genetic causes of malformations informed by the writings of embryologist Franklin P. Mall. The first results that he published in 1940 were generally dismissive of the possibility of environmental causes of infant anomalies, despite reference to Mall's attributing pathological ova to impaired nutrition and improper implantation. Murphy concluded that "The observations dealing with environmental factors offer no proof that environment plays a role in etiology" and "The evidence does not appear to entirely convincing, however, that spontaneous occurring abnormalities can be due to environmental factors."[190] In the second edition of his study findings, published in 1947, he revised his thinking considerably, reflecting a widespread

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Uses of Human Heredity; Pernick, *The Black Stork: Eugenics and the Death of "Defective" Babies in American Medicine and Motion Pictures since 1915*.

[189] No mention was made of the families' reactions to having a survey conducted subsequent to an upsetting event.

[190] Douglas P. Murphy, *Congenital Malformations: A Study of Parental Characteristics with Special Reference to the Reproductive Process*, (Pennsylvania: University of Pennsylvania Press, 1940), accessed December 6, 2013, http://catalog.hathitrust.org/api/volumes/oclc/5656162.html.

postwar enthusiasm for environmental causes of infant disability.[191] He categorized pelvic x-rays and rubella virus infection as environmental factors leading to infant disability.

When Murphy wrote about unusual morphology, he used the terminology of congenital malformation, or "defect, anomaly, deformity or abnormality" interchangeably with "monsters."[192] Possibly a semantic shift, it indicated a substantive change in research on unusual infant morphology. From objects of wonder and natural curiosity, human "monsters" had been transformed by at least the 1940s into a carefully cataloged and named example of congenital medical disorders of environmental or genetic origin with a given probability of recurrence. This provides an example of physicians' efforts to bring both severe and subtle variability in infant form and function under medical care, part of a process of medicalizing what would now be called developmental disability. It also demonstrates the efforts to calculate probabilities of occurrence that later became so integral to genetic counseling and epidemiological investigation of birth defects. From the clinical arena of obstetrics, statistical methods were deployed in the interest of identifying the origins and recurrence of neonatal disability within families, an early form of genetic counseling, yet the implications would be much more widespread.[193] If high levels of radiation or x-rays were acknowledged as

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[191]Typically, professional accounts attribute interest in environmental causes of infantile disability to Greg's work linking rubella to a pattern of disability and ocular anomalies. For example, see Ian W. Monie, "Influence of the Environment on the Unborn," *California Medicine* 99 (1963): 323–7.

[192] Murphy, "Congenital Malformations a Study of Parental Characteristics with Special Reference to the Reproductive Process".

[193] Notably, this effort to help families with one disabled child or a history of familial illness, a variation on modern genetic counseling, was very different than the more

problematic for exposed fetuses or neonates by 1930s, the debate about lower-level exposures during pregnancy would become a major point of conflict in the 1950s and beyond.

Radiation Biology, Elusive Evidence, and Public Anxieties

Public environmental concerns related to the harmful effects of radiation from nuclear testing fallout on reproduction undergirded the research of teratologists in the 1950s. The Teratology Society began meeting in an era where nuclear destruction seemed an imminent possibility. Amid a postwar boom in the American economy, expanding consumer markets in the 1950s welcomed a broad range of synthetic chemicals for household or industrial use and products manufactured from such new, durable, and cheaply produced materials. Despite this prevailing climate of optimism with respect to the potential of the American chemical industry and a general expansion in quality of life and access to consumer products amid economic prosperity, there were also some signs of concern about the proliferation of radiation, with its ability to pass through or accumulate in human tissues, and growing awareness of small amounts of undesired materials and potential carcinogens added to or leaching into food.[194] However, there was tension

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population-based prevention efforts attempted by organizations such as the National Foundation/March of Dimes in the late 1950s and 1960s.

[194]Other than fears about fallout, this is most evident in debate over regulation of carcinogenic food additives, resulting in an amendment that came to be known as the Delaney Clause, also known as the Food Additive Amendment of 1958. Samuel P. Hays, *A History of Environmental Politics since 1945* (Pittsburgh: University of Pittsburgh Press, 2000); Samuel P. Hays and Barbara D. Hays, *Beauty, Health, and Permanence: Environmental Politics in the United States, 1955-1985* (Cambridge; New York: Cambridge University Press, 1987); Langston, *Toxic Bodies: Hormone Disruptors and the Legacy of DES*; Marcus, *Cancer from Beef: DES, Federal Food Regulation, and Consumer Confidence*.

over uses of radiation as a therapy, an energy source, weapon, and a tool for interrogating the nature of inheritance and visions of radiation as a possible health risk to humans. One of the first large-scale epidemiological studies of prenatal exposures concerned the germ cell mutagenic effects of exposure to atomic radiation, conducted by Neel and William Schull on behalf of the ABCC in Japan after the Second World War.[195] At the same time, physicians and researchers were debating the risks of therapeutic and diagnostic x-rays used during pregnancy amid an evolving science and tolerance of low-level exposures. It was clear by 1929 that therapeutic x-rays during pregnancy were problematic, but lower dosages used in diagnostic x-rays seemed below a threshold of effect necessary to cause health effects, and medical practices changed slowly.[196] While adverse effects of prenatal

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[195] In addition to interviews or autobiographical accounts from Miller, Neel, and Schull, there are comprehensive reports and summaries from the ABCC, and historians Susan Lindee and John Beatty have written on the genetic studies conducted by the ABCC. See also, William J. Schull, *Song among the Ruins* (Cambridge, MA: Harvard University Press, 1990); James V. Neel, *Physician to the Gene Pool: Genetic Lessons and Other Stories* (New York: J. Wiley, 1994). Miller, "My Half-Life in Teratology."; Hiroo Kato et al., *Survival in Children of Parents Exposed to the Atomic Bomb: A Cohort-Type Study* (Hiroshima: Atomic Bomb Casualty Commission, 1965); Seymour Jablon, Hiroo Kato, and Commission Atomic Bomb Casualty, *Sex Ratio in Offspring of Survivors Exposed Prenatally to the Atomic Bombs, Hiroshima-Nagasaki* (Hiroshima: Atomic Bomb Casualty Commission, 1970); J. W. Wood et al., *Mental Retardation in Children Exposed in Utero to the Atomic Bomb—Hiroshima and Nagasaki* (Japan, 1966); Atomic Bomb Casualty Commission, *The Atomic Bomb Casualty Commission, 1947–1975: A General Report on the ABCC-JNIH Joint Research Program* (Hiroshima: The Atomic Bomb Casualty Commission, 1978); Lindee, *Suffering Made Real: American Science and the Survivors at Hiroshima*; John Beatty, "Genetics in the Atomic Age: The Atomic Bomb Casualty Commission, 1947–1956," in *The Expansion of American Biology*, eds. Keith Rodney Benson, Jane Maienschein, and Ronald Rainger (New Brunswick: Rutgers University Press, 1991); Frank W Putnam, "The Atomic Bomb Casualty Commission in Retrospect," *Proceedings of the National Academy of Sciences* 95, no. 10 (1998): 5426–31.

[196] Goldstein and Murphy, "Microcephalic Idiocy Following Radium Therapy for Uterine Cancer During Pregnancy."; Murphy and Goldstein, "Etiology of the Ill-Health of Children Born after Maternal Pelvic Irradiation."

exposures above a certain threshold of effect were relatively clear-cut and uncontroversial, reproductive outcomes from more low-level exposures became increasingly controversial.

During World War II, research projects at the University of Rochester Medical Center were sponsored by the Manhattan Engineering District to assess the human health effects of radiation (mainly aimed at determining acute effects and possible therapeutic approaches to acute exposures).[197] Several researchers who would later become involved in the Teratology Society, including Robert W. Miller, Thomas Shepard, and Robert L. Brent, were trained at the University of Rochester during and immediately postwar in defense-funded projects intended to assess "acute radiation effects through animal experimentation."[198] In addition, James G. Wilson began research on embryological effects of radiation at the University of Rochester, where he was an instructor of anatomy.[199] The geneticist James V. Neel was also trained at University of Rochester (he started his PhD there in 1935, earned an MD in 1944 and stayed on for his internship and residency) and used contacts to inquire about future work assessing the impact of the atomic bombs.[200] At the same time, the effect of what was typically called "trace" radiation exposure

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[197] Neel, *Physician to the Gene Pool: Genetic Lessons and Other Stories*, 26–27.
[198] Miller, "My Half-Life in Teratology," 7. Aser Rothstein described the origins and objectives of the department in a Foreward to an edited volume in 1969, "Part of our job, very secret at the time, was to determine as rapidly as possible the toxicity of uranium compounds and of other heavy elements such as polonium and plutonium. We were to become 'instant experts': in toxicology" Morton W. Miller, George G. Berg, and University of Rochester. Department of Radiation Biology and Biophysics, "Chemical Fallout: Current Research on Persistent Pesticides" (Springfield, Il: Charles C. Thomas, 1969).
[199] Miller, "My Half-Life in Teratology," 7; Robert L. Brent, "In Memoriam: Robert Warwick Miller," *Birth Defects Research Part A: Clinical and Molecular Teratology* 79 (2007); "James G. Wilson (1915–1987)," *Teratology* 39, no. 4 (1989): 317.
[200] Neel, *Physician to the Gene Pool: Genetic Lessons and Other Stories*.

on unwitting human patients was conducted at the University of Rochester and other sites around the country, which was largely kept secret until the 1970s, when questions were raised about bioethics and informed consent, even if study policies on research participation and consent were not unusual for the time period. Journalists and the 1990s investigation on wartime human experimentation on behalf of Clinton's Advisory Committee did not implicate teratology researchers as participants.[201] Genetics historian Daniel Kevles characterizes this relationship as human genetics' link to funding from national security concerns,[202] but it was equally an effort to identify potential adverse human health outcomes and potential therapeutic approaches from such exposures, mostly aimed at acute exposures during preparation, testing, or deployment of atomic bombs.

Subsequent to explosion of the atomic bombs in Japan in 1945, there was continued desire to marshal evidence to allay pubic concerns about insidious and pervasive effects of atomic radiation—among them concerns that monsters or malformations would result from ionizing radiation from the bombs or nuclear testing.[203] As military teams entered the destroyed cities of Hiroshima and Nagasaki, physicians and scientists documented the severe impacts of radiation poisoning—burns, nausea, infections, bleeding, necrosis, and other types of acute radiation sickness apparently unanticipated by American authorities—who called for continued assessment of the human health effects of the atomic bomb on

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[201] Ruth R. Faden, "The Human Radiation Experiments: Final Report of the President's Advisory Committee," (New York: Oxford University Press, 1996).
[202] Kevles, *In the Name of Eugenics: Genetics and the Uses of Human Hereditys*, 223–24.
[203] Ibid., 223.; Lindee, *Suffering Made Real: American Science and the Survivors at Hiroshima.*

Japanese citizens.[204] At the time of the atomic bombing in Japan, there was speculation about two possible reproductive outcomes, 1) teratogenesis related to exposed pregnant women, and 2) a germ cell mutation with implications for malformations or other impacts on future offspring.[205]

Further testing of nuclear weaponry and the hydrogen bomb raised public opposition and fears about radioactive fallout's effects on prenatal development. Well-known geneticists such as John Burdon Sanderson Haldane, and Nobel Laureates such as Josef Müller and Alfred Sturtevant, used their positions of influence to make predictions of dire mutation-related effects of radiation on human populations based on their experiences with fruit flies and genetic studies of mice.[206] British geneticist Haldane was one source of publicity about dramatic effects of the atomic bomb on the unborn, as he predicted a "crop of freaks" would be born as a result of the mutations caused by radiation.[207] In an article in *Science* in 1954,

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[204] William J. Schull, "The Somatic Effects of Exposure to Atomic Radiation: The Japanese Experience, 1947–1997," *Proceedings of the National Academy of Sciences* 95, no. 10 (1998): 5437–41. A short overview of the origins of the ABCC is available here: Frank W. Putnam, "The Atomic Bomb Casualty Commission in Retrospect."
[205] Gordon and Ingalls, "Death, Defect, and Disability in Prenatal Life. An Epidemiologic Consideration."; Ingalls, "No Race of Monsters: Excerpt from Address."
[206] Muller, incidentally, had leftist and eugenicist leanings, though without an emphasis on race, class, or state coercion to control reproduction. He advocated for a voluntary program of reproductive control, germinal choice, which would include using the sperm of highly worthy individuals – mostly noble-prize-winning scientists. According to Kevles, the sperm bank housing sperm from superior specimens that was started by one of his collaborators was still in operation in 1995 in Escondido, California. See Kevles, *In the Name of Eugenics: Genetics and the Uses of Human Hereditys*. 259–263 and Tino T. Balio, "The Public," *Bulletin of Atomic Scientists* 23, no. 9 (November 1967): 8–12. Herman J Müller, "Human Evolution by Voluntary Choice of Germ Plasm," *Science* 134 (1961): 643–9.
[207] Haldane, "Atomic Bomb May Create 'Freak Crop'." Haldane was a polymath and popularizer of science, also known for coining the term ecotogenesis to describe 'artificial wombs,' in his science fiction fantasy, *Daedelus*. See Hanson, *A Cultural History of Pregnancy: Pregnancy, Medicine, and Culture, 1750–2000*, 122–28. Some

Sturtevant stated that, "There is no possible escape from the conclusion that the bombs already exploded will ultimately result in the production of numerous defective individuals—if the human species itself survives for many generations."[208]

There was continued alarming publicity in the mid-1950s about the adverse effects of nuclear weapons testing and radioactive fallout on infants. It was in this context of alarm about teratogenic and mutagenic effects of nuclear radiation that new concerns about environmental causes of congenital malformation were framed. Considerable research demonstrated that the placental barrier was permeable to radiation and chemicals substances in the 1950s, as a conference held just before publication of the first results from the ABCC genetic mutation studies on congenital malformations (by Neel and Schull) demonstrated. In April 1953 at the Oak Ridge National Laboratory, scientists gathered for a "Symposium on effects on radiation and other deleterious agents on embryonic development."[209] James G. Wilson was among the presenters, noting that his research on the effects of radiation on the embryo originated from work funded by the Atomic Energy Commission at the University of Rochester Atomic Energy Project.

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radical second-wave feminists, such as Shulamith Firestone, saw utopianist potential in reproductive technology, advocating for artificial wombs. As Clare Hanson points out, artificial wombs were partially realized in the form of the test tube and incubator. For a graceful study of reproductive technologies and a short review of their recent history, see Charis Thompson, *Making Parents: The Ontological Choreography of Reproductive Technologies* (Cambridge, MA: M.I.T. Press, 2005).

[208] Alfred H. Sturtevant, "Social Implications of the Genetics of Man," *Science* 120, no. 3115 (1954): 407.

[209] The proceedings were published in a supplement to the *Journal of Cellular and Comparative Physiology,* Vol. 43, in May 1954. See Hollaender, "Introduction: Effects of Radiation and Other Deleterious Agents on Embryonic Development."

In this research, he attempted to isolate the effect on the embryo from the maternal effects, operating on rats to install internal lead plates before irradiation so as to assess the impact on specific embryos. Others presented papers on "radiomimetic drugs" such as nitrogen mustard. One commentator wanted the three papers on radiation to be abstracted and sent to every clinical radiologist in the country, noting that "last year 2,500,000 women in this country were exposed to X-rays from 5 to 80 r, in clinical diagnosis; and it's anyone's guess as to how many thousands of these women were pregnant within the first 3 or 4 weeks."[210]

Concern about radiation came from professionals working on more applied public health problems as well. One suggestion for the initial teratology meeting in 1955 came from physician Ethel Collins Dunham, formerly of the Children's Bureau, who expressed interest in the prenatal effects of radiation to Josef Warkany. She wrote, "one particular problem that gives me concern is the effect of radiation as a cause of fetal malformation… the extensiveness of exposure of pregnant women to all types of radiation, but particularly to atomic products – i.e. from their manufacture, their waste products and from fallout from the exploding atomic bombs."[211] Such concerns provoked new studies. One such study was initiated in 1958 and collected children's teeth and fetal or stillborn infant's bones in Saint

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[210] This comment is from Dr. Rugh on Dr. Hicks' paper, on page 177. Samuel P. Hicks, Regina C. O'Brien, and Alice A. Williams, "The Effects of Ionizing Radiation, Certain Hormones, and Radiomimetic Drugs on the Developing Nervous System," no. S1, 177; James G. Wilson, "Differentiation and the Reaction of Rat Embryos to Radiation."

[211] Ethel Dunham Letter to Josef Warkany, 14 November 1955. Box 1, Folder 1, Series 1.1. Teratology Society Records.

Louis, demonstrating that strontium-91 was deposited in children's teeth and bones.[212]

However, geneticists struggled with providing conclusive proof of human congenital malformations associated with radiation-related mutations. In 1947, when the ABCC studies on the reproductive effects of the atomic bomb were initiated, there was fairly limited information on radiation's effects on other types of animals besides drosophila and mice.[213] As one of the researchers studying the genetic effects of the atomic bomb, William Schull, framed the problem, "you were getting all this publicity, every other child would be a two-headed monster or a cyclops or something else."[214] Teratogenic effects—mental retardation and small head circumference and possibly other cognitive impairments—were evident in several infants exposed to the atomic bomb while *in utero,* but clear evidence that the atomic bomb's effects on genetic material could cause congenital malformations proved elusive.[215] James V. Neel and William Schull examined genetic effects on reproduction by tracking infants born to atomic bomb survivors (more than 75,000 infants were examined as part of this study) and concluded that major congenital malformations did not result from the effects of radiation from the atomic bombs on germ cells, though surely some mutations had occurred.[216]

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[212] Louise Z. Reiss, "Baby Tooth Survey—First Results," *Nuclear Information* (1961): 1–6. Reiss, "Strontium-90 Absorption by Deciduous Teeth," *Science* 134, no. 3491, 1669–1673.
[213] William J. Schull et al., "The Effect of Exposure to the Atomic Bombs on Pregnancy Termination in Hiroshima and Nagasaki: Preliminary Report," *Science* 118 (1953): 537–41.
[214] William J. Schull, interviewed by Andrea Maestrejuan, 2005.
[215] George Plummer, "Anomalies Occurring in Children Exposed in Utero to the Atomic Bomb in Hiroshima," *Pediatrics* 10, no. 6 (1952): 687–93.
[216] William J. Schull, James V. Neel, *The Effect of Exposure to the Atomic Bombs on Pregnancy Termination in Hiroshima and Nagasaki* (Washington: National

Tellingly, the study that James V. Neel and colleagues set up, one of the first large-scale human genetic epidemiology projects, was intended to assess 'major' congenital malformations and other adverse events (such as stillbirth) in infants born to parents who had been exposed to radiation. Even though it was unquestionable that these populations experienced some radiation-related genetic mutation in germ cells, the study results were largely interpreted as negative with respect to congenital malformations resulting from radiation exposure to genetic material. By November 1953, James Neel and his colleagues had published these essentially negative findings in *Science*, which provided little evidence of an increase in congenital malformations as a result of radiation exposure to parents before conception, except perhaps some trends towards differential sex ratios.[217] Final study results were published in 1956, and confirmed these preliminary results.[218] As historian of genetics John Beatty has noted, the study was expected to be inconclusive from inception and was used as evidence of the safety of atomic energy by the Atomic Energy Commission (AEC), though Neel and Schull preferred to emphasize the inconclusiveness of the results.[219]

There were numerous controversial technical problems involved with this study, such as estimating dosage received by survivors, negotiating with Japanese science and scientists who had conducted preliminary surveys, defining what

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Academy of Sciences, National Research Council, 1956); Kato et al., *Survival in Children of Parents Exposed to the Atomic Bomb: A Cohort-Type Study*. Plummer, "Anomalies Occurring in Children Exposed in Utero to the Atomic Bomb in Hiroshima."

[217] Schull et al., "The Effect of Exposure to the Atomic Bombs on Pregnancy Termination in Hiroshima and Nagasaki: Preliminary Report."

[218] Neel, *The Effect of Exposure to the Atomic Bombs on Pregnancy Termination in Hiroshima and Nagasaki*.

[219] Beatty, "Genetics in the Atomic Age: The Atomic Bomb Casualty Commission, 1947–1956."

reproductive effects would be counted as the possible result of mutation of germ cells, and defining suitable control groups. Historian of genetics Susan Lindee illustrates these points of tension that the researchers had to sort out in occupied Japan and during the many years of follow-up as researchers defined what would count as an exposed person and what evidence would count as a mutation.[220] To add to the controversy, the Atomic Bomb Casualty Commission (ABCC) didn't provide treatment and was sometimes accused of using Japanese citizens as guinea pigs. In later years, the AEC would face domestic criticism that it was inappropriate to have the same entity involved with both promoting and assessing the effects of nuclear power, seen as an example of the fox guarding the henhouse.

In the light of these issues, some researchers in the mid-1950s wanted to steer the discussion away from radiation and drugs into apparently less controversial territory. Embryologist Bradley Patten suggested anoxia (oxygen deprivation) as a topic for a future conference as a common ground in less controversial and divisive research territory. He wrote to James G. Wilson, "Not only is the field rich in itself, but the fact that the disturbances involve situations that are probably of frequent natural occurrence instead of the use of powerful drugs or intense radiation would give it a 'down-to-earth' atmosphere that should have broad appeal."[221] Patten implied that teratologists were studying prenatal exposures that

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[220]Lindee describes how the initial data collected on abortion was contrary to expectations and thus suggested that the use of maternal interviews for estimating paternal exposure was flawed, calling into question the value of all study data. Lindee, *Suffering Made Real: American Science and the Survivors at Hiroshima.*
[221] In at least two instances, Bradley Patten, an embryologist, argued for teratologists to consider questions of normal human embryology and wrote with dismay of the problems inherent to extrapolating from animal studies to humans. Bradley M. Patten to James G. Wilson, 28 November 1956. Folder 6: "July 1956-1958," Series 1.1, Teratology Society Records. See an example of Patten's dismay

were potentially inflammatory. Such accounts help explain teratologists' hesitancy to publicizing substances implicated as teratogens without adequate proof, including low-level exposures from pollution from industrial waste, herbicides, or pesticides, which were described as potential teratogens. Environmental etiologies and chemical hazards were controversial and prone to being hijacked by maverick physician-researchers, lawyers, social scientists, and lay citizens, casting blame on physicians, pharmaceutical companies, government defense projects, and polluting industries.

The sensationalism surrounding publicity about radioactive fallout and teratological research had a dampening effect on the information that philanthropy- and federally-funded scientists, who were seeking to avoid controversy, wanted to convey to the public. This also demonstrates what Robert Proctor has characterized with respect to environmental health and cancer as a tension between experts whose conservative commitment to veracity of their knowledge claims based on science were in conflict with advocates, often within environmental or public health, whose commitments to a conservative approach relied on ensuring a greater degree of safety and prevention to affected populations (the precautionary principle), even in the face of inconclusive results or uncertain claims that might also fan the flames of public anxiety.[222]

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about the neglect of human embryology in his letter about the program of the planned teratology workshops. Bradley Patten to Josef Warkany, 9 October 1963, Box 4, Folder 1: "1st Teratology Workshop, 3 of 5," Series 1.3, Teratology Society Records.

[222] Robert Proctor and Londa L. Schiebinger, *Agnotology: The Making and Unmaking of Ignorance* (Stanford, CA: Stanford University Press, 2008); Proctor, *Cancer Wars: How Politics Shapes What We Know and Don't Know About Cancer*.

So in the mid-1950s, stakes with respect to how one attributed causality of infant disability were high. Even amid widespread enthusiasm for addressing preventable environmental factors, most of the teratologists who joined the Teratology Society chose to emphasize genetics, move cautiously with respect to publically identifying potential hazards, carefully vet their claims among colleagues, and define congenital malformation narrowly, as obvious physical anomaly at birth. To do otherwise might have repercussions for practicing physicians responsible for pregnant women and alarm a press and public reputedly already too concerned with "monsters and malformations."

Though pediatric physician scientists such as Theodore Ingalls or Josef Warkany had argued for using knowledge about developmental disability acting during the prenatal period as a means of prevention (perhaps by biomedical tools or improved nutrition), Warkany and other teratologists took a cautious approach towards managing the way their findings were disseminated to general practitioners and patients. The overarching concern was that if prevention of birth defects was emphasized to the public in injudicious ways without proper vetting, parents would be overly alarmed and doctors or organizations would be blamed for the birth of malformed babies. By the late 1970s, children and infants proved compelling defendants in a courtrooms and they often won their suits or reached a monetary settlements, as court trials over substances such as Bendectin would confirm.

Expanding Definitions: From 'Fundamental Questions' of Experimental Teratology to Reproductive Toxicology Testing and more Subtle or Long-Term Prenatal Effects

Debates about animal testing for the purposes of determining teratogenicity often rested on the difficulty of extrapolating results obtained in animal experiments to humans. For experimental teratologists, chemicals had long been tools of laboratory research used to investigate mechanisms of unusual growth. It had been clear since at least the turn of the century that many different chemicals could induce similar effects depending on the time period of organogenesis in which they were administered. In addition, with further experimentation, it seemed that different species and even different strains of the same animal model would exhibit different reactions to the same chemical. Thalidomide, in fact, exemplified this because it appeared to have no effect on the progeny of many animals commonly used in the laboratory, though it was teratogenic in rabbits.

Nevertheless, teratologists remained part of the debate as the environmental movement and epidemiologists raised further questions about insidious exposures and subtle harms. James G. Wilson helped organize some of the workshops for industrial scientists and other interested parties about teratogenesis and remained supportive of animal tests for pre-market reproductive toxicology testing of pharmaceuticals. Yet even in the mid-1960s, some thought that epidemiological surveillance and testing might be a more productive way to approach the problem of identifying and protecting humans from teratogens.[223]Indeed, registries and efforts to monitor unusual birth defect clusters were set up in the late 1960s, such as the

[223] Karnofsky, "Drugs as Teratogens in Animals and Man."

Metropolitan Atlanta Congenital Defects Program started in 1967.[224] Nevertheless, the observations of astute specialist clinicians remained a primary way to identify unusual clusters of birth defects. At a conference on detecting environmental teratogens in the 1970s, epidemiologist Robert W. Miller challenged experimental teratologist James G. Wilson about the difficulties in assessing human risk of pharmaceutical exposures based on reproductive toxicology testing using animals:

> R.W. Miller: Since I cannot get a recommendation, can I see if this is a fair understanding of the role of animal testing, namely, that it is an imperfect predictor of teratogenesis in man and that as a result useful drugs may be erroneously deemed hazardous? Is that what the gist of this conversation is? Didn't you say in your presentation that aspirin, meclizine, cortisone and Dilantin among others would have been deemed hazardous if the animal experiments had been done before these drugs were used by man?
>
> J. G. Wilson: They would not have passed current tests used in rodents.
>
> R.W. Miller: Would they have been approved for human use or would they have been forbidden?
>
> J. G. Wilson: I meant to imply that they probably would not.
>
> R.W. Miller: But then animal tests are imperfect.
>
> J. G. Wilson: Indeed they are. If Dr. Miller is blaming the animal-test people for not having achieved perfection, or we might wait until we have a chance to question the epidemiologists to see what degree of perfection they have achieved. I think we have all got to do the best we can with currently available methods while at the same time searching for ways to develop better methodology.[225]

Once again, the epidemiologists and experimentalists grappled with causal inference based on different methodologies and uncertain knowledge of prenatal harm. Even as teratologists relied on experimental methods that looked at animal

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[224] Ernest B. Hook, Dwight T. Janerich, and Ian H. Porter, eds., *Monitoring, Birth Defects and Environment: The Problem of Surveillance: Proceedings*.
[225] L'Institut de la Vie, "Methods for Detection of Environmental Agents That Produce Congenital Defects: Proceedings of the Guadeloupe Conference," Shepard, Thomas H., James R. Miller, M. Marois, eds. (Amsterdam: North-Holland Publishing Co.; New York: American Elsevier Publishing Co., 1975), 57.

anomalies and short-term functional or anatomical defects in effort to resolve questions about safety, epidemiological methods also struggled with causal inference. Simultaneously, the definition of congenital malformation was expanding as both public-health-oriented epidemiologists and environmental scientists probed more subtle exposures and subclinical outcomes.

Warkany himself acknowledged changing definitions of congenital malformations, attributing the change to medical technologies of observation that identified hidden anatomical disorders: "Originally the word 'malformation' signified a gross structural anomaly. Only defects on the surface of the body were recognized at first, but with the progress of pathology and the practice of necropsy, internal structural defects were included in the term."[226] By 1967, the World Health Organization (WHO) chose to define congenital malformations broadly to include not only the anatomical but also the functional. They specify that their terminology includes both the macro and the micro, the anatomical and the functional: "use in this report of the word 'malformation' does not necessarily connote only structural maldevelopment but may also include functional and biochemical entities... For the present purpose teratology is considered to concern developmental deviations of structural, functional or biochemical nature that are initiated prenatally."[227] In 1983, epidemiologist Zena Stein and her colleagues defined a teratogen even more expansively: "A teratogen is a factor acting between conception and birth, on the pregnancy, blastocyst, embryo, or fetus, that adversely affects the progeny."[228] The

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[226] Warkany, *Congenital Malformations; Notes and Comments*, 3.
[227] World Health Organization, Scientific Group on Principles for the Testing of Drugs for Teratogenicity, *Principles for the Testing of Drugs for Teratogenicity. Report of a Who Scientific Group*, (Geneva: World Health Organization, 1967), 7.
[228] Stein, Kline, and Kharrazi, "What Is a Teratogen? Epidemiological Criteria," 24.

broad trajectory of research on prenatal harm shifted away from narrow definitions of anatomical defect to include a broader definition of developmental anomaly, which included functional deficit, inborn errors of metabolism, transplacental carcinogenesis, neurological impacts, or more long-term health effects. Through this framing, the WHO and other researchers effectively pushed the experimental teratologists to expand their previously limited scope of observable morphological malformations to include more subtle pediatric health outcomes. Starting in the 1970s, inspired by studies of prenatal mercury or lead exposure in children, there was a growing emphasis on the fetal brain and subclinical neurotoxicity induced by chemical exposures that might include behavioral effects (the Collaborative Perinatal Project had raised similar neurological questions in the late '50s and early '60s but was more oriented towards obvious cognitive impairment associated with excess anesthesia, adverse events, and oxygen deprivation occurring during labor and delivery). This was not without resistance from the teratologists, as exemplified by Harold Kalter's 1969 definition of congenital malformation as "gross structural abnormalities of prenatal origin present at birth or near birth and recognizable with unaided sense or detectable by conventional methods of examination… definitions have been suggested, especially with reference to human subjects, which would include histological, metabolic, and even molecular defect; but for various reasons these are considered by the author to be impractical or erroneous."[229]

Broader definitions of reproductive hazard, extending beyond unusual form and obvious functional deficit, such as effects on fertility or miscarriage or

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[229] Samuel S. Epstein, ed. *Drugs of Abuse: Their Genetic and Other Chronic Nonpsychiatric Hazards, Proceedings of a Conference in San Francisco, October 29–30, 1969* (Cambridge, London: M.I.T. Press, 1971), 93.

neurological or behavioral effects on children, increasingly preoccupied researchers seeking to demonstrate occupational or environmental hazard. In the late 1970s, epidemiologists Vena Stein, Jenny Klein, and Barbara Strobino argued that most studies looking at reproductive health outcomes associated with reproductive hazards were poorly powered and needed to move beyond gross structural anomaly to look at a broader range of reproductive issues in both males and females.[230] In other words, the historical medical fascination with unusual infant anatomy and mechanisms of development had been the primary focus of teratology researchers, ignoring paternal exposures or long-term and hidden outcomes that were harder to measure or part of the lived experience of women (such as neoplasms, intellectual deficit, growth disturbances, miscarriages, or impaired fertility). Yet such long-term and or subtle outcomes resulting from prenatal exposures were harder to verify except in a handful of cases, such as mercury and cerebral palsy and DES and adenocarcinoma.

Uncertain Fetal Environmental Exposures

In the 1970s, environmental concern about fetal exposures appeared to be linked to social justice concerns about heavy metal exposure in poor urban neighborhoods, issues of occupational exposure of pregnant women, and public concern about the ubiquity of industrial pollution. Representative of other concerned physicians of his generation; Boston-based pediatrician John Scanlon began tracking lead levels in fetal cord blood, attempting to correlate results to rural or urban

[230] Strobino, Kline, and Stein, "Chemical and Physical Exposures of Parents: Effects on Human Reproduction and Offspring."; Stein, Kline, and Kharrazi, "What Is a Teratogen? Epidemiological Criteria."

location. He argued, "It is probable that the traditional means of detecting fetal insults (i.e., stillbirth rate, neonatal deaths, patterns of gross congenital malformation, and so forth) are too crude for determining the results of insidious environmental pollution. The time has come to turn to the developmental biologist and fetal biochemist for clues to understand these more subtle, but potentially more ominous changes."[231] Such accounts from physicians, environmental scientists, or epidemiologists, particularly in the late 1960s, characterized the outcomes that had initially concerned teratologists and geneticists when considering environmental exposures as too "crude" or "gross."[232]

By the early 1970s, scientific researchers interested in demonstrating the effects of community-based industrial pollution or pesticides on the health of women and children often phrased their understanding of the situation as an uncertainty over whether the available tests were sufficient to identify potential fetal harm.

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[231]John Scanlon was Chairman of the Committee on Environmental Hazards of the Massachusetts Chapter of the American Academy of Pediatrics when he wrote this. Other members of the Committee included Alan H. Kaufman, Jonathon Fuerbinger, Donald C. Shukan, James King, Fred Mandel, and Herbert Needleman. John Scanlon, "Fetal Effects of Lead Exposure," *Pediatrics* 49, no. 1 (1972): 145–6; John Scanlon, "Umbilical Cord Blood Lead Concentration: Relationship to Urban or Suburban Residency During Gestation," *American Journal of Diseases of Children* 121, no. 4 (1971): 325–6; "Clinical Review: Human Fetal Hazards from Environmental Pollution with Certain Non-Essential Trace Elements," *Clinical Pediatrics* 11, no. 3 (1972): 135–41.

[232] In 1972, Scanlon used the term "too crude" to describe the effects previously studied in attempt to associate them with trace exposures. In 1977, Columbia-based epidemiologists Vena Stein, Jennie Kline and Barbara Strobino stressed that it was important to use a "broad definition of reproductive outcome" when studying reproductive hazards. In 1979, in *Work and the Health of Women* on page 113, Vilma Hunt referred to the methods as "too gross:" "Clinical and epidemiological methods could well be too gross to establish the presence of a risk, if one exists." Strobino, Kline, and Stein, "Chemical and Physical Exposures of Parents: Effects on Human Reproduction and Offspring," 389; Vilma R. Hunt, Kathleen Lucas-Wallace, and Jeanne M. Manson, *Work and the Health of Women* (Boca Raton, FL: CRC Press, 1979), 113; Scanlon, "Fetal Effects of Lead Exposure," 145.

John Scanlon wrote a letter to the editor of *Pediatrics* about the problem of leaded gasoline with Herbert Needleman, noting that fetuses in utero were particularly at risk.[233] These physician researchers expressed dismay that in cases such as black lung and asbestosis, epidemiological methods only identified health effects after many people had already been affected. They wrote "by the time epidemiological methods certify to the satisfaction of regulatory agencies that an agent is toxic, large numbers of people have paid the cost of avoidable exposure."[234]

The disabilities of thalidomide-exposed infants had been both rare and severe, raising questions about whether more subtle effects would have ever been detected, particularly amid the environmental activism of the late 1960s and early 1970s. In 1971, the advocate and pediatric environmental health researcher Samuel Epstein wanted to cast public attention towards the ubiquity of substances that could potentially cause more birth defects. He told a reporter, "There is no question in my mind that the severe birth defects caused by thalidomide would have gone undetected for years but for one factor: The types of birth defects thalidomide caused [stunting of the arms and legs] were as rare as a dodo."[235] Physicians, policymakers, journalists, and researchers wondered what other pharmaceuticals, or other prenatal toxins, might cause subtle effects on infants and children, initially unnoticed by physicians and patients. Teratologists who studied this question often grappled with how to respond to public fears. They often summarized a broader range of environmental factors influential in apparently naturally occurring

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[233] Herbert L. Needleman and John Scanlon, "Getting the Lead Out," *New England Journal of Medicine* 288, no. 9 (1973): 466–7.
[234] Ibid.
[235]Richard Lyons, "Rise in Chemicals Is Causing Alarm," *New York Times*, September 25, 1971, 92.

developmental disability, pointing out numerous cases of spurious accusations (such as aspirin, or potato blight) and seeing the possibility of a hidden effects of synthetic substances dispersed in the environment as anxiety-driven, overwrought, or unsubstantiated given the available evidence. They urged caution and skepticism about diverse claims from journalists, feminists, environmental scientists, and activist geneticists that birth defects might result from pesticides, food additives, and toxic waste (frequently expressed as uncertainty over whether testing was adequate to detect more obscure effects). Experimental teratologists such as Warkany and Robert L. Brent argued that sometimes epidemiological tests identified specious relationships, false allegations had been made in the past, and useful pharmaceuticals might be implicated erroneously (such as in the case of aspirin in the 1950s and Bendectin in the late 1970s).

Nevertheless, identifying unusual clusters of congenital malformation and linking them to a particular environmental factor also animated the work of some teratologists, particularly epidemiologists and government employees such as Robert W. Miller at the National Cancer Institute (NCI) or Godfrey Oakley at the Centers for Disease Control and Prevention (CDC). Teratology Society member Robert W. Miller helped to organize a pediatrics conference in Browns Lake Wisconsin in 1973 on "Susceptibility of the Fetus and Child to Chemical Pollutants," sponsored by the National Institute of Environmental Health Sciences (NIEHS), the National Institute of Child Health and Human Development (NICHD) and the Committee on Environmental Hazards of the American Academy of Pediatrics. As cancer researcher Joseph Fraumeni noted at this conference, "The chemicals so far identified as transplacental hazards to man have been primarily drugs. However, it

seems unlikely that Japan is the only country in the world where pollutants in the external environment are harmful to the fetus. The major problem is detection of risk."[236]

Yet other researchers at the conference expressed amazement at the apparent adaptive and resilient characteristics of human development. Frederick Robbins noted at the same conference, "One must be impressed that, in spite of the incredible number of hazards we have talked about, we have been able to name only a few chemical pollutants that do, to our knowledge, produce demonstrable disease, disability, or death. This circumstance may reflect the insensitivity of our test systems, or it may be that man has survival capacities far beyond our remotest dreams."[237] These viewpoints contrasted uncertain and subtle developmental outcomes (often long-term or neurological) with the apparent low number of chemicals decisively linked to obvious anatomical anomalies that spoke to the resilience of human development despite diverse and overlapping prenatal exposures to chemical hazards.

The epidemiologist Robert W. Miller's career, in particular, managed to span the shifting priorities of research on environmentally cased birth defects – from early research on mutagenic and teratogenic effects of radiation to surveillance of settings after industrial disaster.[238] His time as president of the Teratology Society in 1970 coincided with fraught public concern about pesticides and other more

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[236] Joseph F. Fraumeni, "Chemicals in Human Teratogenesis and Transplacental Carcinogenesis," *Pediatrics* 53, no. 5 (1974): 881.
[237] Frederick C. Robbins, "Overview: The Effects of Chemical Pollutants on the Fetus and Child," *Pediatrics* 53, no. 5 (1974): 860–2.
[238] Luigi Dardanoni and Robert W. Miller, "Plans for Clinical and Epidemiologic Follow-up after Area-Wide Chemical Contamination: Proceedings of an International Workshop, Washington, D.C., March 17–19, 1980" (Washington, DC, 1982).

insidious environmental pollution as possible causes of childhood impairment. Likewise, the University of Rochester Department of Radiation Biology and Biophysics, once involved in secret wartime research on the human health effects of uranium compounds and polonium and plutonium, by 1969 convened a conference of ecologists, toxicologists, and public health physicians to assess the dangers of persistent pesticides, focusing on organomercurial and organochlorine pesticides.[239]

Even though Miller spent his career researching pediatric and perinatal exposures, he nevertheless described how clinicians approaching the topic of perinatal chemical hazards felt the need for secrecy and discretion to prevent publicity about insufficiently vetted claims. While a member of the Committee on Environmental Hazards of the American Academy of Pediatrics in the 1970s, Miller describes pediatricians sidling up to him at coffee breaks to mention an association they thought they had observed, afraid that they would be accused of making unsubstantiated claims. He wrote, "members preferred to tell of their observations at coffee breaks when they would not risk the embarrassment of raising a false issue."[240] This quote illustrates how there was social pressure among physicians to avoid such controversial issues or imply speculative or spurious associations between prenatal exposures and birth defects. By the time journalist Chris Norwood interviewed him in the late 1970s about the effects of prenatal exposures, Robert Miller lent considerable time to her project and described developmental neurotoxicity as the area of greatest concern from prenatal exposures. Nevertheless,

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[239] Miller, Berg, eds, and University of Rochester, Department of Radiation Biology and Biophysics, "Chemical Fallout; Current Research on Persistent Pesticides."
[240] Miller, "My Half-Life in Teratology."

he argued that funds to study environmental hazards would be better spent in basic research rather than studies of occupational hazards in specific industries. [241]

Although teratologists concerned themselves with exogenous factors contributing towards congenital malformations, they remained ambivalent about the impacts of environmental pollutants on the development of the fetus and outcomes of other explicitly clinical concerns related to anatomical or functional deficits at birth. Since at least 1948, teratologists had been using radiation and radiomimetic substances, such as nitrogen mustard, to induce malformations in animals. Furthermore, their efforts to train government and pharmaceutical representatives on practices of experimental teratology for the purposes of reproductive toxicology testing of pharmaceuticals had brought them in dialogue and close association with representatives of the pharmaceutical industry.

Their empirical experiences in the laboratory and fears about sensationalistic or insufficiently nuanced descriptions of their research made them cautious about how animal data was interpreted, particularly as environmentalists and toxicologists made more expansive claims about prenatal exposures. In contrast to the scientific activism of pediatric cancer specialists like Samuel Epstein or geneticists' advocacy about chemical mutagenesis described by sociologist Scott Frickel, teratologists sometimes took a critical perspective with respect to the possibility of such low-level exposures as pesticides or food additives having an effect *in utero*.

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[241] Norwood, *At Highest Risk: Environmental Hazards to Young and Unborn Children*, 70–73.

Instead, they emphasized issues of complexity, dosage, and difficulty of interpreting teratological research on animals. In this respect, they became unlikely advocates to avoid unnecessarily alarming parents and pregnant women. While some teratologists were actively engaged in disseminating techniques in experimental teratology for the purposes of pre-market testing for pharmaceuticals and others became involved in post-industrial disaster surveillance, most were inclined to qualify, complicate, or rein in populist concerns about toxic chemicals and environmental harm. Rationales for their hesitancy and ambivalence include the following: 1) their networks of relationships with industrial and defense research, 2) their clinical experiences with multifaceted and severe childhood disability, 3) the complexity of results obtained from animal experiment and the difficultly extrapolating to humans, and 4) the fact that their field was founded on a longstanding medical and popular preoccupation with unusual infant anatomy, so their primary outcome of concern was obvious structural malformations at birth.

Those who were interested in the mechanics of development saw chemicals merely as research tools and were reluctant to take the controversial topic of reproductive toxicology amid fights between the burgeoning environmental movement and American industry. Teratologists' reservations about the effects of low-dose chronic effects of pollutants (such as pesticides or industrial chemicals in water or air) on human health evoked toxicology's long emphasis on Paracelsus's maxim about the dose making the poison.[242]

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[242] The actual aphorism as quoted by Frederick Davis is "the right dose differentiates a poison and a remedy." Frederick Rowe Davis, *Banned: A History of Pesticides and the Science of Toxicology* (New Haven: Yale University Press, 2014), xiii.

To express these reservations, some teratologists voiced concern about extrapolating from animal studies to humans or made references to the importance of dosage on the final outcome of a given chemical. They might remark that the dosages given during animal testing procedures far exceeded what humans were likely to encounter in real life or dismiss the effect of 'homeopathic' levels of chemicals or radiation. A common perspective juxtaposed economic costs against the uncertainty of harm. A congressional inquiry on behalf of the Committee on Government Operations, *Chemicals and the Future of Man,* was conducted in April 1971, chaired by Abraham Ribicoff. It raised many questions about teratogenic hazards and called one member of the Teratology Society, Robert L. Brent, to testify about prenatal hazards, along with pediatric environmental health scientist Samuel Epstein, Umberto Saffiotti of the National Cancer Institute, and scientists from the National Institute of Environmental Health Science. Brent expressed doubt or skepticism about the ability to avoid controversy and avoid public alarm while attempting to detect teratogenic environmental hazards. In congressional testimony, he told Abraham Ribicoff, "It you remember the cranberry incident, where the whole cranberry crop was destroyed because of trace amounts-that is ignoring the concept of dosage. If an agent is toxic at a certain dose level, you have to know what its presence is in the population, so you need the help and assistance of your fellow scientists in reflecting this information."[243]

Some of their ambivalence about researching the teratogenic effects of environmental pollutants can be traced to the controversial nature of the topic and the ways in which the media and consumer advocates magnified the implications of

[243] Hearings of the Committee on Government Operations, U.S. Senate, Washington, D.C., *Chemicals and the Future of Man*, 1971, 81–92.

research findings. In his congressional testimony, Brent railed against scientists who publicized research results prematurely, without giving time to reach a scientific consensus, leading, in his view, to misinformation and scientific controversy.[244] He argued for greater research funding for fundamental research to understand developmental disability and targeted clinical surveillance.

Those less sympathetic to the possibility of reproductive hazard derived from "trace" prenatal low-level chronic occupational or pollution-related chemical exposures from a broader environment, including some of the laboratory-focused members of the Teratology Society, tended to emphasize one or more of three issues: 1) high background 'natural' rates of spontaneous abortion and malformation and the proportionally small role that chemical toxicity played in developmental disability, 2) the relative minor impact of low dosages, and 3) the inherent differences between animals and humans that made it unlikely that malformations produced in animals would be seen in humans. As F. Clarke Fraser noted,

> I was bold enough to say that all these teratogens that we had already, like hypoxia and cortisone and, by that time, several other things that would work in animals – 6-amino-nicotinimide, a nicotinimide antagonist – that all these things were sledgehammer blows – that you had to suffocate the mouse till it was blue in the face or give it enough cortisone that it would kill it if it wasn't pregnant, and give it enough 6-amino-nicotinimide that it would be practically paralyzed. These were way above the sort of physiological thresholds that would [be reached and] cause malformations in people, so not to worry.[245]

At a lively conference about occupational hazards to fertile women prepared by Eula Bingham in 1976, *Women and the Workplace*, Josef Warkany gave a lecture on "Toxic Substances and Congenital Malformations," and noted that salt could

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[244] Ibid., 92.
[245] Fraser, "F. Clarke Fraser Interview."

cause birth defects in animals, "…sodium chloride which under certain experimental conditions can induce congenital malformations in mice. You can draw your own conclusions concerning regulatory procedures based on this animal experiment."[246] In these accounts, teratologists expressed the view that concerns about low-level dosages of certain synthetic chemical pollutants in the community or work place were overblown. More directly, Warkany stated, "I am opposed the uncritical application of results obtained in experimental animals to man. To show on television one deformed animal, or to publish in a newspaper results of teratogenic experiments with suggestions of stopping fabrication or consumption of the inducing substance, is not the way to proceed."[247] In his depiction, an overactive media seeking to sell newspapers fanned the anxieties of parents.

At the conference, an opposing perspective often brought up two concerns: 1) the possibility that legitimate reproductive risks were being dismissed due to inadequate testing and 2) ethical and legal issues about how the workplace and society should handle groups of people who were considered more susceptible to industrial toxicities (often making the point that it was both discriminatory and a

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[246] The conference occurred in June 17–19, 1976 and was sponsored by the Society for Occupational and Environmental Health, the National Institute for Occupational Safety and Health, and the National Foundation-March of Dimes, with addition sponsorship from Coalition of Labor Union Women, D.C. Lung Association, United Church Board for Homeland Ministries and the Industrial Union Department of the AFL-CIO. Among the topics addressed were the relationship between neonatal deformities and exposure to vinyl chloride (in particular, Peter Infante argued that birth defects were common among children in Ohio who lived near vinyl chloride plants) and susceptibility of pregnant women and fetuses to lead exposure. The conference occurred in the same year as the passage of the Toxic Substances Control Act of 1976, which aimed to test chemicals newly introduced into the market and control selected other toxins with particularly severe human health effects.
[247] Eula Bingham, ed., *Conference on Women and the Workplace, June 17–19, 1976, Washington, D.C.: Proceedings* (Washington: Society for Occupational and Environmental Health, 1977), 31.

folly to try to isolate and contain risks only for groups considered especially susceptible). At the same conference, a biology professor from the University of Texas acknowledged Warkany's point about salt even as he expressed doubt about testing procedures. He raised a common counterargument that it was difficult to prove safety, and testing may well have been inadequate. He argued, "The problem is, how do we know which [chemicals] are safe? I think that Dr. Warkany and I would certainly continue to eat table salt without any concern… [but] if you run a compound through a test and get negative results, that's by no means an indication that it's safe."[248]

Umberto Saffiotti, of the National Cancer Institute, cautiously addressed the topic of fertile (or potentially pregnant) women in hazardous workplace settings supporting a vision that science must be used carefully to identify precise information about susceptibility. He acknowledged a unique role for women:

> In considering carcinogenesis in women, one must take into account the specific role of women as mother, because of transplacental exposures. In addition we should not forget the role of the woman as a member of the population having certain special physiological characteristics and susceptibilities…the study of how environmental chemicals really react in the body to affect the target tissues… is very important in trying to identify exactly the levels of susceptibility of different members of a population to a given type of exposure.[249]

If Warkany and other experimental teratologists emphasized the reproductive toxicity of high dosages of many substances, the importance of sound data, and the sledgehammer blows frequently required to impair development in animals, the environmentalist perspective tended to emphasize the perils of inadequately assessing questions of low doses, particularly with respect to potential

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[248] Ibid., 84.
[249] Ibid., 85–86.

mutagens (one version of the precautionary principle). Peter Infante (from the National Institute of Occupational Safety and Health) stated, "There's concern about concluding from inadequate testing or assessments that there is no risk involved."[250] In another presentation, Joseph Wagoner, David Brown, and Peter Infante would enumerate the problem of mutagens in the workplace, asking,

> Will Society require the enumeration of fetal deaths and/or congenital anomalies in humans before regulatory control is implemented? Will society now exclude the male worker from the industrial setting of chloroprene and vinyl chloride as previously proposed for women following the findings of transplacental carcinogenesis in animals exposed to vinyl chloride? Or will the legacy of Society to future generations be the rapid reduction of human exposure to mutagens at their industrial source?[251]

In their statement, some of the debates about teratogenesis and mutagenesis were omnipresent. One of the reasons that company policies emphasized teratogenesis and protection of the fetus, beyond the obvious issues of legal liability in cases of childhood disability, was that emphasizing teratogenesis simplified the problem of protecting future generations, as the problem became one of preventing fertile women from working in hazardous conditions. Undoubtedly, companies were also very concerned about their own legal liability to the fetus and reticent to expend unnecessary resources, if they could avoid it, in the interests of workplace safety. Environmentalists and geneticists framed reproductive hazards more broadly and emphasized mutation because it was a more distributed risk. Simply trying to shield fertile women or exclude them from the workplace would be insufficient because mutation risks could potentially affect the germ cells of all workers.

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[250] Peter Infante is a pediatric dentist and epidemiologist who performed epidemiological studies of birth defects (neural tube defects) in communities exposed to vinyl chloride in Ohio while working for the local health department. Ibid., 89.
[251] Ibid., 103.

The heated politics that arose around workplace risks to women shifted into questions of pollution in the broader environment, as the problem of shielding or guarding pregnant women (or monitoring their health behaviors) seemed a much easier problem than eliminating the widespread exposure of all adults, children and fetuses, to potential mutagens. However, this is further complicated by the activism in some contexts of women who made maternalist arguments about teratogens, arguing for example, that toxic waste and spraying of herbicides had particularly unique risks for pregnant women and children, risks that should be controlled for everyone on the basis of the particular vulnerability of some members of society and the unborn.[252]

Industry representatives, mostly associated with manufacturing and chemical production, tended to emphasize the high 'natural' rates of miscarriage and congenital malformation (up to 40% of all pregnancies), teratogenesis over mutagenesis, and they relied on teratologists to identify and testify about chemical and biological agents of particular concern.[253] At the 1976 conference on *Women and the Workplace,* scientific debate about chemical risks to women in the workplace was challenged by some, such as the Women's Political Action-Occupational Health Caucus who descried the "narrow view… toward women" such that "Women have been seen as reproductive vessels," and protested the "trivialization of their personal experiences," calling for lay perspectives and involvement in science and broader

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[252] For example, Love Canal and Agent Orange and the activism of women like Lois Gibbs and Bonnie Hill. Bonnie Hill lived in coastal Oregon and became alarmed about the apparent excess of miscarriages in her community in the late 1970s following herbicide spraying. Sara Pacher, "Bonnie Hill: Oregon Environmental Activist," *Mother Earth News* December/November 1981.
[253] Bingham, ed., *Conference on Women and the Workplace, June 17–19, 1976, Washington, D.C.: Proceedings*, 120.

suggestions for reform beyond addressing chemical hazards (such as daycare, etc.). They rejected the assumptions that education about workplace hazards and free self-interested choices about employment were sufficient, given socio-structural conditions of high unemployment and discrimination against women.[254]

At this conference in 1976, labor organizations and other critics of workplace protection politics rejected discriminatory policies on the grounds that the workplace should be safe for everyone, challenging any policy that selectively excluded susceptible employees from workplaces. The Labor and Safety and Health Institute emphasized the reproductive hazards that women and men both faced and called for safe conditions for all workers, evoking occupational and environmental health heroines/martyrs such as Norma James and Karen Silkwood.[255] Other female labor representative emphasized that with "screening policies aimed at the fertile female, the position of women in the workplace becomes tenuous at best." They concluded that "[a]ny other policy than that of safety of health for all workers would logically culminate in a kind of labor Darwinism in which those workers considered 'unfit' for the job would be selectively weeded out."[256] Some depicted slow removal of different "susceptible" types of workers from the workplace, evoking the lecture about the Holocaust by Martin Niemoller ("First they came for the Socialists, and I did not speak out…").[257] As environmental health professor Bertram Carnow opined, with

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[254] Ibid.
[255] Bingham, ed., *Conference on Women and the Workplace, June 17–19, 1976, Washington, D.C.: Proceedings*, 359–63.
[256] Ibid., 126.
[257] "Otherwise what happens is that after the women, we eliminate the bronchitics, we eliminate the asthmatics, we limit everybody with G6PD deficiency, and we eliminate everybody with alpha one antitrypsin deficiency. I could go on and on because I have been looking at high-risk populations for the last 15 years, and I can

the removal of all those with potential reproductive risks from the workplace, "we'll either wind up with 60-year-old eunuchs in the workplace, or we'll have to eliminate the teratogens. I suggest that it would be easier to eliminate the teratogens."[258]

At an earlier conference in 1975 on detection of environment teratogens, Teratology Society co-founder James G. Wilson expressed both concern about the effects of industrial pollutants and additives and preoccupation with appropriate interpretation of conflicting data. Wilson is a bit more sympathetic to obscure low-level chemical risks than some teratologists, but nevertheless dismayed by insufficiently nuanced public interpretations of teratological research and "overwrought concern about environmental influences." He noted,

> It is variously estimated that 2,000 or more new chemicals are synthesized or otherwise produced each year and that as many as 200 of these may find their way into the environment in measurable amounts. The immediate as well as the long-term impact of these on the environment is a matter of increasing concern to most thoughtful people. Not the least among these concerns is the possibility of adverse effects of these compounds, many inadequately or not at all tested, on unborn and future generations of human beings. These effects seem especially insidious because not only are some chemical agents known to be capable of reaching the highly susceptible early embryo and of altering the normal course of its development, but are also thought to be able to change the genetic material so as to produce structural or functional abnormality one or more generations later. These possibilities, constituting teratogenesis on one hand and mutagenesis on the other, are made more alarming by the fact that current technology is not able to test the potential hazard of existing substances in the environment, much less properly evaluate the new ones constantly being added…What is the degree of risk to the unborn child of the environmental additives referred to above? ...it might be imagined that the early embryo, which is known to be susceptible to some such influences, is at the mercy of all factors in the environment…The actual situation is somewhere between these

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tell you that there are many of them" Ibid., 135–136. See also, James Bentley, Martin Niemoller: 1892–1984 (NY: Macmillan Free Press, 1984).

[258] Ibid., 134.

> extreme views, hopefully somewhat nearer that of protection than of vulnerability."[259]

This quote shows the ambivalence of teratologists as they grappled with the apparent inadequacy of methodologies intended to identify the effects of environmental teratogens. James G. Wilson was sympathetic to the desire to identify chemical hazards and wanted to identify legitimate environmental teratogens. He highlighted the deficiency of contemporary methodologies for assessing environmental teratogens. He acknowledged that fears about prenatal permeability and damage were understandable, but nevertheless emphasized protective qualities of the prenatal environment and maintained that public fears about fetal vulnerability to environmental chemicals were likely overwrought.

Conclusion

Teratology research and professional meetings in the 1950s seemed to herald a new era of elucidation and prevention of environmental causes of birth defects. Teratological research on congenital malformations in the 1940s and 1950s was imbued with both positivist enthusiasm about the possibility of preventing infant disability prenatally and dark visions of fetal harm from radiation. Infant disability was constructed as a product of the uterine environment, based on rational scientific laws explained by animal experiment and human epidemiology studies, rather than a fantastical or fate-driven occurrence, despite the consistent difficulty in explaining the cause of many malformations. Clinician scientists and epidemiologists interested in preventative health in the 1950s, such as Theodore Ingalls, tended to emphasize

[259] L'Institut de la Vie, "Methods for Detection of Environmental Agents That Produce Congenital Defects: Proceedings of the Guadeloupe Conference," 29–30.

environmental causes of fetal anomalies with broad claims about how these birth defects could be ameliorated by collective preventative measures that controlled environmental factors, sometimes questioning the practices of medicine. A countervailing perspective was espoused by many in the Teratology Society who were seeking to minimize controversy, ground their science in genetics and embryology, and base their claims on solid data obtained from laboratory animals. They emphasized the vast range of environmentally mediated infant disability, the complexity of development, and the difficulty in extrapolating from animal tests to humans.

Even before the 1960s, teratology research served to highlight and publicize the womb as a vulnerable site, porous to the broader environment, which required a protectionist approach to pregnancy. The public fervor over thalidomide-associated deformities of limbs and heart buoyed teratology research and gave status and funds to researchers interested in experimental teratology and epidemiological research as physicians, government, industry, media, and the public grappled with the implications of pharmaceutically induced deformity. Amid new legislation (the Kefauver-Harris Amendments) that bolstered the responsibilities of the FDA and increased pharmaceutical investment in questions of reproductive toxicology, experimental teratology researchers were consulted as experts, and their methodologies became part of regulatory science and practices of assessing environmental risks to pregnant women.

Though founded by those seeking to demonstrate non-genetic influences in human development, experimental teratology researchers were cautious and skeptical of the idea of low-level chemical exposure from industrial sources or

widespread industrial pollution affecting fetal growth and development. This was linked to their institutional commitments, status and affiliations as physician scientists who prioritized obvious clinical disease and anatomical malformation. Additionally, experimental teratologists emphasized the broad range of environmental factors affecting development, the complexity and difficulty in introducing birth defects in mammalian systems in the laboratory, numerous challenges to causal inference, and problem of cross-species comparison. Increasingly, in the late 1960s and early 1970s, amidst a robust public concern about environment problems, some members of the Teratology Society used epidemiology to define causal links between environmental hazards and prenatal developmental anomalies. However, they too struggled with causal inference and accusations that the registries and epidemiological test systems set up to identify subtle developmental effects of chemical pollution (radioactive fall-out, pesticides or herbicides, industrial effluent or waste) were inadequate and *post hoc*.

Chapter 2: "Is My Baby All Right?" Advocates and the Popular Press Define Birth Defects and Publicize Teratological Research (1950-1975)

In 1972, Virginia Apgar and Joan Beck published *Is My Baby All Right?,* a publication for a lay audience highlighting the causes and risks of birth defects. This book reflects a more pro-active approach to birth defects prevention evident in much of the advice literature of the period. By then, infant and childhood disabilities were no longer a hidden private experience of certain families and institutions, nor considered an unavoidable and ill-fated accident of nature. Instead, they were widely discussed in the context of science-based means of preventing congenital disability, broadly grouped under the category 'birth defects,' and championed by advocates and scientists. This effort originated in the perceived success of biomedical researchers' triumphant vanquishing of polio after development and trials of the polio vaccine 1952–1954 and professional organizing around pediatric research fields such as teratology and genetics.[1]

My intention is to highlight how teratological research originating in midcentury America was translated to the public by advocates and the popular press. While teratology researchers attempted to define and bracket the prenatal environmental factors and reproductive outcomes considered relevant, the fetus was constructed as a politicized, vulnerable, and public figure in the 1970s amid debates

[1] "In the autumn of 1952 when America was experiencing the worst infantile paralysis epidemic in its history, results from the laboratory of Dr. Jonas E. Salk at the University of Pittsburgh suggested a successful vaccine against paralytic polio might be achieved. The fight against paralytic polio, although still unfinished, soon became unmistakably a winning fight." 3, 20 March 1958, Box 6, Folder: "Approved Program [Booklet]" Series 6, Medical Program Records, March of Dimes.

about abortion. The rhetoric of advice manuals and popular articles combined faith and hopefulness about the potential of science to prevent disability with new metaphors of pregnancy and responsibilities for pregnant women. Apgar's advice characterizes the professional and epistemological enigma of studies of environmental causes of birth defects, which translated concerns of parents, often mothers, into "legitimate" and "illegitimate" risks and logics of causality to be communicated to other parents. This chapter addresses the epistemological negotiations between parents, advocates, physicians, and scientists which influenced the public framing of the science of birth defect risk and made parents look to prenatal chemical causes for infant congenital disability in the late twentieth century.

Using parental advice manuals, published magazine and newspaper articles, and archival material from the March of Dimes Archives and the Virginia Apgar Papers at Mount Holyoke College, this chapter explores the popularization of teratological research, in the form of advice and advocacy about birth defects intended for lay citizens from 1958–1973. If groups of scientists and physicians in the early-to-mid-twentieth century medicalized birth defects, removing them from the province of enchantment or "unavoidable accidents of nature,"[2] it was (often female) authors, parental advocates, and journalists writing for a lay audience who communicated science-based norms of birth defect avoidance. I demonstrate that while most general manuals intended for parents in the early 1950s sought to dispel parental fears of fetal or infant disability as improbable, advocates linked to philanthropic, clinical, and biomedical research communities studying teratogenesis

[2] Gordon and Ingalls, "Death, Defect, and Disability in Prenatal Life. An Epidemiologic Consideration."

began to publish materials from the late 1950s that served to highlight birth defects as a medical category with common and preventable prenatal risks. I show how the science of birth defects prevention research and advocacy contributed to the characterization of pregnancy as a risky state, pathologizing pregnancy.

This chapter describes the way that environmental causes of congenital malformation, the arena of research framed in the mid-twentieth century by teratologists and like-minded researchers in the late 1950s, was communicated to an increasingly skeptical public amidst the turbulent social movements of the 1960s and early 1970s. This chapter primarily portrays 1) the framing of birth defects and teratological research by the National Foundation-March of Dimes (NF-March of Dimes) and advice manuals and popular media between 1950–1975, 2) the shifting mission of the National Foundation for Infantile Paralysis (NFIP) in the late 1950s, and 3) the life and advocacy of Virginia Apgar. Experimental teratologists and perinatologists clung to explicitly clinical categories of anatomical anomaly as to what was relevant and traceable, despite choruses of voices that arose in the 1970s that pointed to other outcomes and more subtle, long-term, or insidious harms, as epidemiology became an increasingly powerful way of confirming or denying these claims about chemical harm.

The Popular Press and Advice Manuals About Birth Defects

Apgar and Beck's book is reflective of a 1970s desire to inform women about science and medicine that evokes the women's health movement, even as it is similar to older forms of prescriptive literature and maternalist advocacy about maternal and child health. In chapter after chapter, the book elaborates the many

types of disability fetuses and neonates might exhibit, including a section on prevention. In Chapter 31, "How to Prevent Birth Defects" the authors gave specific prescriptions for prevention, admonishing parents to consider genetics, age, pregnancy timing, intercourse frequency, prenatal care, prevention of contagious diseases, contact with raw meat or cats, and drug exposure when trying to conceive. Apgar and Beck recommended that good medical care was necessary to provide optimum conditions for having a healthy baby, not only for fertile women but perhaps also extending to include their mothers: "Ideally, the kind of good medical care that helps a woman to provide a healthy, nourishing environment for her unborn child begins long before pregnancy, even as early as the mother's own prenatal life."[3]

In this book, these two prominent women, a journalist and a physician at a philanthropic agency, championed increased awareness of potential hazards to pregnancy. Other publications by Virginia Apgar also warned that any woman who was married needed to be vigilant about preventing birth defects: "When do you begin taking care of your baby? It may sound strange, but the answer is: As soon as you're married."[4] Apgar, unmarried with no children, provided advice based on her professional credentials rather than her personal experiences. Her scientific and clinical expertise allowed her to make recommendations for all women, even though she had no lived experience of parenting.

Though *Is My Baby All Right?* was the most comprehensive book on birth defects intended for a lay audience, there were other publications with similar

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[3] Virginia Apgar and Joan Wagner Beck, *Is My Baby All Right? A Guide to Birth Defects* (New York: Trident Press, 1972), 478.
[4] Virginia Apgar, "New Ways to Save Your Unborn Child," *Ladies Home Journal* 83 (August 1966): 46.

themes. Examples of such manuals included the public affairs pamphlet *Will My Baby be Normal?,* published in 1958 by the New-York-based Public Affairs Committee with funding from the Association for the Aid of Crippled Children (AACC); British obstetrician Geoffrey Chamberlain's book, *The Safety of the Unborn Child,* published in 1969; or dysmorphologist Davis Smith's 1979 book, *Mothering Your Unborn Baby*. These publications were linked to professional and philanthropic organizations workings to study and prevent congenital malformations. Between the 1950s and 1970s, scientists and advocates turned attention to fetal and infant disability and advocated for science-based principles of "environmental" causes and prevention of birth defects. Their efforts coincided with debates about more widespread access to medical abortion, at times also justified as a means of "preventing" infant disability. Many authors justified such publications as a means to both provide simple steps to collective prevention of birth defects and allay parental fears about the possibility of having a disabled newborn.

Though these debates were implicitly linked to neo-eugenic debates about approaches to prenatal or neonatal disability and advocacy for and against medical abortion, I will instead emphasize debates about the prenatal environment and advice on environmental exposures. The popularization of teratological research portrayed childhood disability as both likely and avoidable, provided pregnant women followed certain habits of behavior and submitted to medical monitoring.

Throughout the late 1950s and 1960s publications in newspapers and popular magazines gave advice on how to have a normal baby, highlighted incidents of fetal deformity caused by drugs and new research on medical specialties and interventions, and emphasized both a calculative science of risk and the hazardous

potential of chemical substances, though mainly pharmaceuticals. With the publicity in 1962 surrounding Rachel Carson's *Silent Spring* and the dramatic 'seal limb' abnormalities associated with thalidomide exposure in the first months of pregnancy, lay citizens were widely exposed to the possibility of iatrogenic, and other chemical- or drug-related causes of birth defects. Thus, by 1962, some Americans (particularly those with existing concerns about overuse of pesticides, occupational hazards, or industrial pollution of air and water) were aware of the possibility of fetal harm during pregnancy due to viral, iatrogenic and possibly, unintentional exposure to toxic substances in the broader environment.

Apgar's book, *Is My Baby All Right?,* illustrates her effort on behalf of the March of Dimes and other midcentury researchers to create a coherent and intelligible scientific research and advocacy arena out of seemingly very different infant conditions and anomalies. The overarching category of 'birth defects' allowed relatively rare and diverse congenital anomalies to be constructed as a common concern. This grouping allowed for a statistical sleight of hand and made sometimes obscure infant conditions seem highly prevalent by advertising that "1 of every 16" infants were born with a birth defect.[5] From 1958, it was the explicit agenda of The National Foundation (originally founded in 1938 as the The National Foundation for Infantile Paralysis [NFIP], the name was changed in 1958 to simply the National Foundation [NF] and then the March of Dimes Birth Defect Foundation, abbreviated here as NF or NF-March of Dimes) to raise awareness of birth defects and eventually promote the neo-eugenic objective to "give every child the right to be well

[5] Virginia Apgar cites this statistic many times. See correspondence with Isobel Tan in 1969, Box 5, Folder 11, Series 2, Virginia Apgar Papers, Mount Holyoke, or in *My Baby is All Right* on page 4.

born." At times, however, biomedical prevention for many disabilities was not prove readily forthcoming and prenatal diagnosis and abortion played a larger role in this prevention. The NF tried to maintain neutrality and avoid involvement in such controversial issues, though their emphasis on parental decision making and support of clinics to counsel parents about birth defects allied them with those in favor of wider legal access to medical abortion.[6]

In the case of some diseases and conditions associated with the maternal environment, such as rubella-associated disabilities, congenital anatomical defects correctible with surgery, and erythroblastosis due to maternal-fetal Rh incompatibility, technological fixes seemed to have dramatic results on a population level. In the 1950s, it appeared that improved diets, vaccines, and intrauterine blood transfusions might easily vanquish congenital malformations as vitamins had largely vanquished childhood nutritional deficiencies such as rickets and antibiotics and vaccines had reduced childhood mortality from infectious disease.[7] This agenda

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[6] Virginia Apgar tended to portray the NF's position as neutral, simply responding to societies' resolution of a controversial issue. See her letter in 1967 in response to a newspaper article by James Conniff, "The World of the Unborn." In a letter to the editor, she acknowledges that the MoD approach did not preclude the termination of malformed fetuses. She states, "The March of Dimes position is simply that new advances in science and medicine are posing difficult moral and philosophical questions. We do not propose to supply the answers to the questions since they obviously can only be answered by public consensus." Virginia Apgar, "Letter to the Editor," *New York Times*, January 29, 1967. A memorandum on amniocentesis was circulated internally in 1972, stating that the "decision to terminate is a parental decision, not under March of Dimes purview." See "Memorandum" written by George Voss in Box 3, Folder: "Amniocentesis," Medical Program Records, March of Dimes Archives.

[7] See Virginia Apgar's summary of the field in "Congenital Anomalies, 1968," Box 11, Folder 11, Virginia Apgar Papers, Mount Holyoke. The speech was given in 1968 in San Francisco at the International Anesthesia Research Society and highlights genetics, rh, and rubella as key areas of progress in preventing congenital anomalies. She also notes thalidomide and progestins as teratogenic drugs and acknowledges the expanding definition of birth defects to include functional deficits

paralleled efforts to understand and address genetic causes of some conditions, such as PKU (phenylketonuria) and mongolism (now Down syndrome), though such conditions raised complex bioethical questions and seemingly simple biomedical solutions (such as restricted diets, vaccines or prenatal diagnosis) might face considerable barriers to implementation.[8] In addition, publicity about thalidomide (in 1962) and much later diethylstilbestrol (DES) exposure (in 1971) as teratogens (or transplacental carcinogens) when used during pregnancy, helped to publicize potentially lethal or damaging consequences of exposure to pharmaceuticals, raising the specter of birth defects caused by chemical exposure in the public imagination.

Staying Home From the Circus: Mothering Manuals and Maternal Impressions

In the early twentieth century, parenting manuals often tried to dispel maternal impressions or the idea that a shock, fright, or visage of something horrific might mark or damage the unborn child. A manual in 1924 described maternal impressions as the superstitious province of gossiping women, not part of physiological processes, underscoring that the causes were unknown and nothing that a pregnant woman could do or say could prevent anomalies. The lack of blood or nervous connection between the growing fetus and the pregnant woman was used to justify the falseness of maternal impressions. The author, an obstetrics instructor at Harvard University, wrote,

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diagnosed in early infancy. Apgar, "Human Congenital Anomalies," *Anesthesia and Analgesia* 47, no. 4 (1968): 325–9.

[8] Keith Wailoo, *Three Shots at Prevention: The HpV Vaccine and the Politics of Medicine's Simple Solutions* (Baltimore, MD: Johns Hopkins University Press, 2010).

> The superstition is this: if the patient hears of or sees some very unpleasant sight, she will receive such as shock that her baby will be marked... There is absolutely no physical connection between the mother's blood and the blood of the unborn child, nor is there any nervous connection between the mother and the baby. The pregnant woman must not be allowed to think that anything that she may do or say or think can in any way cause her baby to be marked or malformed. [9]

In 1938, in a manual called *Tiny Garments,* Cornelia Skinner remarked, "As for prenatal influence, the general attitude toward that theory is much the same as my own toward ghosts. I don't believe in ghosts, but I'm afraid of them. I bravely pooh-pooh the notion of Indian guides and ectoplasms, yet no one could pay me to sleep in a haunted house. And while prenatal influence has supposedly gone the way of mustache-cups and Rogers groups, not many of us would risk deliberately haunting the monstrosities of Huber's Dime Museum, or standing hours in meditation before a wart-hog."[10] Her account demonstrated that the theory was old-fashioned and out of favor, even as it articulates cautious avoidance of the supernatural despite general disbelief.

Yet even as most lay publications and physicians were dismissive of the potential impact of maternal impressions, even in the 1950s scientists sought to justify mechanistic biochemical relationships between emotional stress and unusual anatomy or behavior of offspring.[11] Theories about stress hormones such as cortisone

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[9] Robert L. DeNormandie, *The Expectant Mother, Care of Her Health*, The National Health Series, Ed by the National Health Council (New York, London: Funk & Wagnalls Company, 1924).
[10] Cornelia Otis Skinner, *Tiny Garments* (New York: Farrar and Rinehart, 1932).
[11] "Whether much less severe degrees of exposure would produce a cleft palate in a genetically susceptible human baby is an open question, but there is no proof that it will. It is also true that a number of claims have been made to this effect, and you will probably be able to find articles, even books, stating that malformations can be caused in man by hormones produced as a result of emotional stress, oxygen

causing cleft palate were relatively common in the 1950s and demonstrate how popular ideas about emotional shocks and environmental influences were translated into a particular vision of biochemically induced developmental defect.[12]

Eastman's Expectant Motherhood, written initially by Nicholson J. Eastman, an obstetrician at Johns Hopkins University, affords the opportunity to observe the same manual in different iterations (1940–1989). In 1942, Eastman noted that,

> No discussion of the growth and development of the baby would be complete without consideration of the old belief that the mental condition of the mother may modify the development of the unborn infant, or, as they used to say "mark" it. Many a young woman, with commendable determination, has set her facial muscles into a constant grin for nine long months because certain well-intentioned elders have told her that a cheerful attitude on her part ensured a cheerful disposition in her offspring...Others have stayed home from the circus, in the fear that some animal might frighten them and in this way cause the baby to be "marked" or distorted in the likeness of the ugly beast... The facts are these, there is not the slightest nervous connection between the mother and child; in other words, no possible pathways along which any such impulses, pleasant or otherwise, could travel. The blood of the mother is likewise separate and distinct from that of the child.[13]

Eastman uses clinical and anatomical expertise to refute the theory of maternal impressions. He does not use the terms birth defects, monsters, or anomalies, but instead gives examples of very minor skin conditions, primarily

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deficiencies resulting from airplane [sic] flights or anesthetics and so forth. Attractive as such hypotheses may be, they are not supported by valid evidence and should be discounted until the time when (if ever) such evidence is obtained." This quote is from a chapter written by F. Clarke Fraser, "Harelip and Cleft Palate" in the edited volume Virginia Apgar prepared: Fishbein, *Birth Defects*, 243.

[12] A number of popular articles linked stress hormones and cleft palates 1956–1958, probably based on the work of Lyon Peter Strean. See Lyon Peter Strean, *The Birth of Normal Babies* (New York: Twayne, 1958); Alton L. Blakeslee, "Stress and Abnormalities," *Today's Health* 34, November 1956, 14; Anonymous, "Old Wive's Tale Confirmed? Abnormalities in Newborn Children," *Time Magazine* 68, September 17, 1956, 65.

[13] Nicholson J. Eastman, *Expectant Motherhood* (Boston: Little, Brown and Co., 1942), 36–37.

blemishes or positive associations such as musicality or cheerfulness. He instead primarily attributes the future child's mental characteristics to its legacy due to intermarriage and inheritance, to genetics.

In 1940, the author of parenting manual *Getting Ready to Be a Mother*, Carolyn Van Barcom, stated: "Do not believe that anything you do, think, or see can 'mark' or deform your baby, for remember that after conception you give him nothing but nourishment. The only communication between you and the baby is through your and his blood and blood does not carry mental impressions. Accordingly, no effects of fear, horror or unpleasant memories which you may have can possibly reach him."[14] In 1944, William Carrington published *Safe Convoy; the Expectant Mother's Handbook*. In this this manual, he admonished, "Aside from those hereditary traits that are inherent in the germ plasm there is no such thing, let me repeat, as a maternal impression. The only connection between mother and child-to-be in her womb is through an interchange of gasses and fluids through a sponge-like membrane."[15]

The language of biology—nervous impulses, chemicals, blood, fluids, tissues, membranes, and gases—was represented as remote from the effects of emotional distress and used as a rational for why maternal impressions were false. As there was no nervous or blood connection between the fetus and the pregnant woman, then the old theory of maternal impressions must be wrong. These early twentieth-century efforts to banish maternal impressions nevertheless hint of the gradual process by which lay parental concerns about monsters or marking resulting from

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[14] Carolyn Conant Corbin Hazel Van Blarcom, *Getting Ready to Be a Mother* (New York: The Macmillan Company, 1940), 44–45.
[15] William John Carrington, *Safe Convoy: The Expectant Mother's Handbook* (Philadelphia: Lippincott, 1944), 110.

viewing something shocking became translated into chemically or biologically mediated birth defects.[16]

Popular Media and Childhood Disability in the 1950s

In 1953, journalist and parental advocate Leona S. Bruckner wrote an article for *Ladies' Home Journal* called "The Triumph of Love: An Unforgettable Story of the Power of Goodness… an Irresistible Little Boy Born without Arms." She describes her experience of childbirth in March of 1950. She was placed on the delivery table amid the pains of labor and an ether mask was slipped onto her head, as she breathed deeply, "waiting for sleep to end the throes of childbirth." The next morning, when she awoke to daylight, she had a healthy breakfast, saw her husband, and asked after her baby boy.

Her husband was exhausted and the nurses seemed brisk and evasive. Finally, one asks if this was her first child. When she described her lively three-year-old, the nurse wondered, "Is she abnormal too?" Later her doctor expressed considerable anguish about her newborn: "My dear, I am so sorry, but the child is a monstrosity. I have never seen child like it before in all my years of obstetrics…He is a monstrosity. He has no arms, just curious appendages. I once delivered a baby with its stomach on the outside, but a surgeon was called immediately and the child

[16] Here, I'm reminded of Fleck's analysis of the relationship between lay ideas and scientific facts and the way that scientific theories maintain a kernel of lay logics. Ludwik Fleck, *Genesis and Development of a Scientific Fact* (Chicago: University of Chicago Press, 1979).

lived and is healthy and strong... Nothing can be done for your son. I don't know what to say. I don't know what to do."[17]

From her account, the cultural assumptions made about disability by doctors and nurses helped to color her understanding of her child's disabilities before she was able to see him. As the condition did not seem correctable by surgery, the attending physician saw it as a failure or hopeless case. Likewise, her husband questioned whether they were able to care for a child with a disability, pinpointing concerns about the possibility of intellectual disability and the stigma or loss of anonymity of those who are visually different might experience. He argued, "Suppose there is something wrong with him organically; or even suppose he is not normal mentally? How would you live, having to raise a child like that, watching the curiosity of strangers? I do not believe that either of us is mentally or emotionally equipped to handle such a problem." The overarching purpose of the story was one of parental advocacy, to demonstrate "the triumph of love," and describe a family embracing a child with a disability and helping him thrive. Yet healthcare workers informed expectations about disability. In particular, they saw conditions uncorrectable with surgery as lost causes, and there was an implicit message that if the child in question were more disfigured or intellectually impaired, he would be far less lovable.

The author describes a disabled physician in a wheelchair who takes her into the hospital reserved for children with developmental defects, and she is shown a child with hydrocephalus and another with severe cranial deficit and intellectual impairment. She felt that she could accept her child because the impairment was

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[17] Leona Bruckner, "Triumph of Love," *Ladies Home Journal* January 18, 1953, 91.

relatively minimal and did not appear to affect his intelligence. Articles about children with disabilities in 1950s women's magazines tend to emphasize the physical beauty of disabled children they write about. The assumption is that a child with a beautiful face, normal intelligence, and a minor handicap is a child worthy of love and should not be rejected or institutionalized as a result of the disability. Such parental accounts can be seen as a form of advocacy on behalf of disabled children, but nevertheless made many assumptions about the kinds of disabled children that were acceptable and worthy of love and support, imagining disability as a bodily defect and medical prevention, surgery, or rehabilitation as the optimum goal. As other scholarship has demonstrated, parental interpretations of infant disability were framed by the expectations of physicians and other healthcare staff about their severity and potential for rehabilitation.[18]

From Infant Paralysis to "Crippling" Birth Defects: The National Foundation's Expanded Program of 1958

The promotional machinery of the NF-March of Dimes also influenced parental perceptions of childhood disability. The Teratology Society formed during a period of considerable philanthropic and government mobilization to fund research on the origins of congenital malformation. At the end of the 1950s, the administration of NFIP engaged in soul-searching about their mission. As they prepared to expand their focus from polio, they considered many options: geriatrics, mental health, viral diseases, muscular dystrophy, maternal and child health, arthritis, diseases of the central nervous system, the common cold, dental health,

[18] Longmore, *Why I Burned My Book and Other Essays on Disability*; "Uncovering the Hidden History of Disabled People."; Longmore and Umansky, *The New Disability History: American Perspectives*.

and juvenile delinquency. Any new program would have to be a compelling issue that would maintain the grassroots appeal and volunteerism associated with childhood polio.[19]

As part of this reassessment of their mission, the NFIP commissioned a study by Gallup and Columbia University, Bureau of Applied Social Research Study between 1953 and 1956, to consider their options.[20] Gallup and Columbia University specialists recommended an approach that built on NFIP's reservoir of public goodwill and emphasized helping children over approaches that were primarily oriented towards training professions or mobilizing volunteers. In addition, the social research experts recommended emphasis on the hopeful potential of science, "A future program might well be handicapped if it were concerned with a program in which hope and the possibilities of science did not play a part."[21] Eschewing medical language of congenital anomalies or malformations, the negative degeneration discourse of eugenics, or the mysticism of monsters or marked children, NF staff used the terminology 'birth defects' and the language of human rights to explain their mission of preventable birth defects.[22]

In defining the "Expanded Program," staff members considered many factors that would affect the success of the program. They chose a topic influenced by the

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[19] By the 1950s a vast network of volunteers at local chapters of the March of Dimes, helped to raise funds for polio treatment, research and professional scholarships. With the mission of addressing polio between 1938 and 1958, The Foundation for Infantile Paralysis had raised more than $489 million, spending $34.2 million on research, $316.2 million on patient care, $35.2 million on professional education, $39.3 million on medical assistance and other services, and $21.2 million on administration. Harold Hutchings, "Broadening Goals of Foundation to Fight Polio: Arthritis, Birth Defect Study Planned," *Chicago Tribune* July 23, 1958.
[20] David Sills, "Gallup-Columbia Study on the National Foundation 1953–1956," 2–3, Box 6, Folder of same name, Series 6, Medical Program Records, March of Dimes.
[21] Ibid.

potential for attracting and retaining volunteers and grassroots funding they had developed for polio research and rehabilitation. In addition, the magnitude of the problem was important. They considered that during polio epidemics, nearly everyone had known polio victims, but would citizens participate in activities associated with congenital malformation? They wondered whether congenital malformations would be too disturbing to engage their intended audience. In order to retain public interest, including volunteers and monetary contributions, they wanted to frame the topic of birth defects in a positive and proactive light.[23]

Yet they also expressed dismay that for years to come the NF would need to reject the claims of some of the most severely impaired. A strong argument against choosing congenital malformations as a mission was that they would need to "reject patient care for the largest number of children who have congenital malformations—namely those with mental deficiencies and with multiple malformations now beyond the knowledge and treatment skill of the medical profession."[24] The issue of how to prioritize research and medical funds for the vast expanse of childhood disability they defined as their new problem would long remain a concern.

Though inspired by "crippling" disorders of children, the NF's new expanded program announced in July 1958 was deliberately broad and not tied to any particular disease, encompassing the field of congenital malformations (over 600 different birth defects), as well as juvenile arthritis and their previous area of focus, polio. This could be interpreted to mean both therapeutic and basic science questions

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[23] Joseph Mori, "Essay on the Meaning of the National Foundation's New Program—Retrospective and Prospect," 4, Box 6, Folder of the same name, Series 6, Medical Program Records, March of Dimes Archives.
[24] National Foundation for Infantile Paralysis, "Proposed Program: Congenital Malformations, 1957" 32–33, Box 6, Folder of same name, Medical Program Records, March of Dimes Archives.

related to a diverse range of disorders, though they specifically excluded cardiac conditions (other foundations were dedicated to these disorders). Examples of the types of research they were interested in funding encompassed both basic processes of life and studies in rehabilitation, including viral and radiation research, genetics, pharmacology, and studies of causes and prevention.[25]

In this new project, the prenatal period was of particular concern, as science "was just entering the era where we are learning what causes damage to the embryo," and it was too early to say that "chemical means cannot be discovered for protecting the unborn child within its mother" (the phrasing implies that it was unlikely). *In utero* radiation is also listed as an area of research and a cause of birth defects: "Any radiation may damage human germ cells and result in the birth of children with defects."[26]

The Expanded Program was launched at a televised press conference at the Waldorf-Astoria in New York City in July 1958 with speeches by well-known scientists, among the NFIP's grantee and polio vaccine investigator, Jonas Salk. The director of the newly renamed NF, Basil O'Connor, was prepared to answer a range of probing questions about the breadth and objectives of the program: Was the prevention of birth defects effectively a matter of "birth control"? Was the program so broad that it was "a blank check to do whatever you choose?"[27]

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[25] "Approved Program," 20–21, 20 May 1958, Box 7, Folder: "Approved Program [booklet], May 20, 1958," Series 6, Medical Program Records, March of Dimes Archives.
[26] Ibid.
[27] "Probable Questions By Reporters and Suggested Answers By Mr. O'Connor at Press Conference, July 22, 1958," Box 7, Folder: "Televised Announcement," Series 6, Medical Program Records, March of Dimes Archives.

Most public reactions to the expanded program were laudatory, a testament to the widespread excitement about the potential of basic research and biomedicine in the 1950s and public support for the objectives of the NF. The *New York Times* gushed that: "The brilliant history and achievement of the National Foundation augur well for the future. The record of the past gives confidence that the same approaches that brought victory over one group of crippling diseases will bring similar victory in other fields as well."[28] A cartoon in the *Philadelphia Daily News* depicted a muscular, Teutonic March of Dimes boxer defeating polio in a fighting ring with boxing gloves labeled "Salk vaccine." Medical science is the referee and other menacing chronic disease opponents are lined up in the sidelines waiting for their due.

[28] "The National Foundation," *New York Times,* 27 July 1958, Box 7, Folder: "Publicity: News Articles, Editorials, Clippings" Series 6, Medical Program Records, March of Dimes Archives.

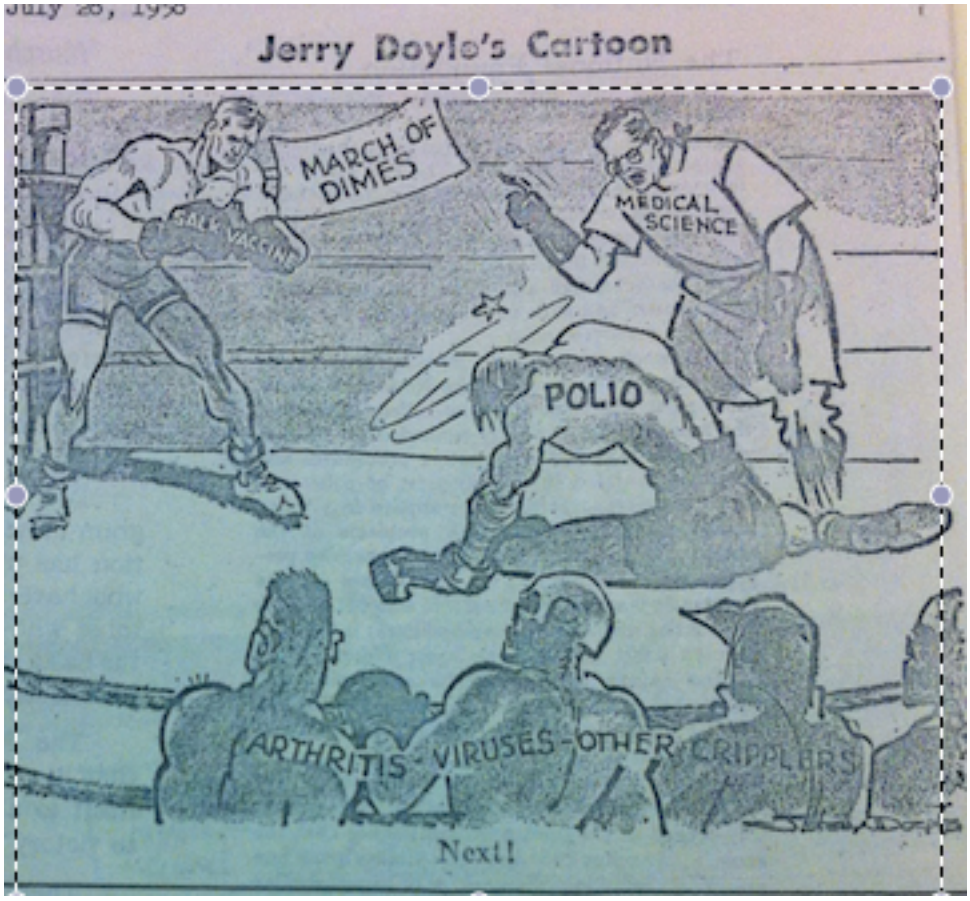

Figure 1: Cartoon on the National Foundation's Expanded Program in the Philadelphia Daily News, July 28, 1958.[29]

More critical perspectives emphasized lack of collaboration. One pointed out that the March of Dimes had refused to join the United Fund yet was essentially creating a large fund in the hands of private charity with a similarly broad program. Others noted the overlapping missions of various philanthropic organizations, suggesting rivalry over public fundraising with the Arthritis and Rheumatism Foundation and others.[30] One such article noted that the "voluntary non-profit

[29] Jerry Doyle's Cartoon, *Philadelphia Daily News*, 28 July 1958, Box 7, Folder: "Publicity: News Articles, Editorials, Clippings," Series 6, Medical Program Records, March of Dimes Archives.
[30] George P. Voss and Dorothy Ducas to State Representatives, "Memorandum" 8 August 1958, Box 7, Folder: "Publicity: News Articles, Editorials, Clippings," Series

health agency, has come of age… [or] at least to a stage of advanced adolescence…we now have a long, long list of foundations, associations, or societies all geared toward the conquest of some specific ailment and affliction."[31]

The expanded program was an explicit effort to bring congenital deformity more fully within medical science and move away from hereditarian ideas of physical handicap and mental deficiency (likely because of the association with eugenics, sterilization policies, and genocide). It contained kernels of a parental advocacy and a disability rights perspective even as it repackaged eugenics in the language of rights and progressive improvement, emphasizing the perfectibility of infants and their "right to be wellborn." The program was intended to be educative and destigmatizing, modifying community attitudes and shifting blame away from hereditary problems of parents: "A skilled and delicate interpretation would need to be done to overcome the prevalent belief that most birth defects are due to hereditary factors and therefore, by implication, to deficiencies in the parents."[32]

Poster Children: Neural Tube Defects and Visible Disabilities

Based on the poster children chosen in the first few years of the expanded program, neural defects were a major area of focus, particularly spina bifida. In 1959 the NF chose three children, one for each area of focus (polio, congenital malformation, and juvenile arthritis). One of them, Jeffrey Reil was "born with an

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6, Medical Program Records, March of Dimes Archives. Also, "Victory Through Dimes" *Washington Post* July 27, 1958 in same folder.

[31] "Editorials: The National Foundation," *New York Medicine*, 20 August 1958, 587–589. (Circulated to staff of the National Foundation by Raymond Barrows, September 8, 1958.) Box 7, Folder:" Publicity: news articles, editorials, clippings; 1958," Series 6, Medical Program Records, March of Dimes Archives.

[32] Ibid., 17.

open spine." The poster children of 1960 and 1961, sweet-faced toddler girls Mary Beth Pyron and Linda Gail Breese, were also born with spina bifida (in addition, Breese had hydrocephalus).[33] Indeed, NF financial aid was initially limited to infants, children, and adolescents through eighteen years of age with "progressive hydrocephalus, encephalocele or symptomatic spina bifida."[34] Despite the broad research program with emphasis on basic mechanisms of science, it became clear that some disease focus was necessary for rehabilitative support and effective action and advocacy (not to mention fundraising), and neural tube defects were a relatively common and obvious cause of handicapped children. Not surprisingly, these children were iconic poster children and combined aesthetically pleasing image and intellectual acuity with an obvious disabling condition equivalent to the paralysis of polio. In the late 1950s, the NF circulated medical information on meningocele, meningomyelocele, and hydrocephalus among their staff (these are defined by fluid in the brain and two different types of exposed spinal material, one associated with damaged meninges and the other with protruding portions of the spinal cord and impaired function of the lower portion of the body).[35] Even as they publicized images and stories about children with spina bifida, the NF research program was far

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[33] Publicity photos of the NF's poster children for the March of Dimes were broadly distributed to press services. For examples of publicity-related images of March of Dimes poster children, see photographs by Grey Villet of 1960 poster child Mary Beth Pyron with Cecil Rogers in *Life Magazine* in 1960.
[34] "Expanded Program of the National Foundation," 8, Box 7, Folder: "Development and Planning, 1952-1959," Series 6, Medical Program Records, March of Dimes Archives.
[35] I have "meningocoele" and "meningomyelocoele" written in my notes, but I have deferred to what I believe is contemporary usage. "Medical information, 1958" 4, Box 7, Folder of same name, Series 6, Medical Program Records, March of Dimes Archives.

broader and increasingly began to support genetic, biochemical, and other molecular methods to study or prevent developmental disability as these fields grew.

The expanded program reflects a pivotal moment in research on childhood disability, as charities founded with the objective of educating disabled children and supporting families and children living with disabilities or responding to epidemic disease turned to funding medical rehabilitation or biomedicine and expert medical authority to prevent infantile disability. This effort combined the rhetoric of amelioration and prevention with funding for laboratory methods to answer basic questions about the origins of such disability, emphasizing the utility of basic science and micro-mechanical techniques of chemicals and cells. Virginia Apgar's speech to the Bergen County March of Dimes chapter in 1959 outlines the objective of preventing severe disability through medical research and progress. She predicted, "Some day, when you read that 'the cause of cleft palate has been found', that 'club feet need not exist' or that 'protection against radiation has been found', you will be thrilled, because you know you voluntarily chose to put your efforts and money into the March of Dimes."[36] This rhetoric combines a plea for dispersed fundraising with explicit promises that scientific research would provide a return on the investment by vanquishing particular common types of infant disability and producing healthier and more physically perfect children.

[36] "Speech given to Bergen County March of Dimes," 1959, Box 11, Folder 2, Series 2: Correspondence, 1925–1974, Virginia Apgar Papers, Mount Holyoke.

Defining Birth Defects: Foundations, Experts, and Popular Media

The National Foundation helped popularize the use of the words "birth defect," even though they weren't the first to use the term. The use of the word "defect" or "defective" was common in eugenic discourse, though not always used with a reference to the words "congenital" or "birth." In 1931, a Los Angeles-based advice columnist and naturopathic doctor Philip M. Lovell (born Morris Saperstein in New York) used the word birth defects principally to decry the "high-pressure salesmanship of an enterprising surgeon." In his description, "freaks—an oddity utterly dissimilar to the source of origin" were unintelligible, baffling, and unexplainable by the laws of inheritance and little could be done for them except adjust them to the environment. In contrast, lesser oddities and slight peculiarities (birth marks, skin blemishes) might correct themselves or be fixed through surgery, though there was "no hard and set rule for the normalizing of birth defects."[37] In his account, birth defects represented minor and ameliorable skin conditions that were juxtaposed against more dramatic anatomical deviations in form. In contrast, the new framing of birth defects in the 1950s collapsed such distinctions, placing diverse types of childhood disability more fully within the purview of the medical profession.

Apgar and Beck's effort in the 1970s to detail myriad types of congenital disability and means of prevention in lay manuals was part of a larger organizing effort to create a cohesive field out of diverse conditions with wide-ranging etiologies and make the field intelligible for an audience of parents without expert training. Medical terminology typically referred to congenital malformations or congenital

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[37] Phillip M. Lovell, "Care of the Body: Birthmarks," *Los Angeles Times*, December 31, 1931. Gary Marmorstein, *Steel and Slurry: Dr. Philip M. Lovell, Architectural Patron*, *Southern California Quarterly*, 84 (2002): 241–270.

anomalies or abnormalities, two overlapping but slightly different definitions that sought to encompass both obvious abnormalities visible at birth and more subtle deviations from normal that became evident as an infant or young child grew. Though they primarily wanted to address severely anatomical anomalies and disabling conditions such as neural tube disorders, the cultural work of scientists and advocates of the era served to denaturalize infant anatomical diversity, defining clinical boundaries to the considerable diversity of human morphology and function.

Popular literature from the period demonstrates the sensational enthusiasm for surgically correcting disabling conditions of children, particular conjoined twins or cardiac defects. There were many popular articles from the 1950s that highlight the successful surgical division of conjoined twins.[38] Diverse infant malformations were grouped under the term "birth defect." The definition might include relatively minor anatomical issues, such as webbed toes and cleft palates, or vastly more severe and disabling conditions including "in-born errors of metabolism," like diabetes and phenylketonuria (PKU), as well as severe neural tube defects often incompatible with life, like anencephaly. Virginia Apgar and other representatives of the NF would portray birth defects as far more common and probable than most expected, grouping diverse conditions into one overarching statistic. In *My Baby is*

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[38] Since the separation and survival of conjoined twin girls who shared intestinal material, Catherine and Carolyn Moutin, in Louisiana on September 17, 1953 there was considerable attention from media sources to successful feats of surgical prowess required to separate conjoined twins. The story of the Brodie brothers in Chicago, Rodney Dee and Roger Lee, poised more challenging ethical questions as only one survived the surgery to separate their shared cranial material. Reports of twin separations were common in indexes of popular literature in the early 1950s. For examples, see: Anonymous, "Siamese Twins Ready to Mark First Birthday," *Chicago Tribune,* July 21, 1954, 9; Ronda V. Walker, "Siamese Twin Surgery Studied," *Deseret News*, August 14, 1954, B1, B3; Anonymous, "Happy Twin, Rodney Brodie," *Life*, May 31, 1954, 45–6; Anonymous, "Brodie Boy," *Newsweek,* May 2, 1955, 20.

All Right, she writes, "250,000 children with birth defects are born annually in this country—one out of every 16 babies."[39] The objective of the March of Dimes was to spread the gospel about the risks of infant disability to a wider audience, which combined a moral and medical mission and a fundraising effort. In a speech by Basil O'Connor given at a March of Dimes Pre-Campaign Meeting in Atlanta in 1966, birth defects were portrayed as something that could happen to any family, not the isolated concern of selected families with inheritable forms of disability. He described the mission of the NF as exposing something previously hidden or shameful and making it seem more common and relevant to a wider audience. In his vision, parents are likely to dismiss or deny risks of birth defects and they must be alerted so that they might avoid such a fate:

> Our appeal for public support begins by informing the public about birth defects. The information we give out is shocking. It consists of facts our society has never faced before because it hasn't wanted to. People are shocked to learn that more than a quarter of a million American babies each year are given a *bad* start in life, many of them a tragically bad one overshadowed by disease, handicap and early death. When we warn our fellow-Americans that it can happen in any family, with or without a known history of birth defects—that it can strike at their own children or grandchildren—they are concerned, and some are frightened, and some can't accept the possibility that such a shattering blow will ever fall on them.[40]

Groups such as the AACC and the NF wanted to make birth defects everyone's concern, to distribute knowledge about birth defects more broadly. As part of their advocacy, they emphasized the potential for parents to have more perfect children who had a better start in life. There was a concomitant evolution of

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[39] Apgar and Beck, *Is My Baby All Right? A Guide to Birth Defects*, 4.
[40] Basil O'Connor at the National March of Dimes Regional Pre-Campaign Meeting at the Marriott Hotel, Atlanta, Georgia, 10 October 1966, Box 6, Folder 2, Series 1.4 1965–1969, Teratology Society Records.

terminology, as the words 'monster,' 'freak,' 'crippled,' and 'feebleminded' became outdated in both elite and popular discourse in favor of newer and reputedly more specific, scientific, or kinder terms. In their place a new overarching terminology was used for congenital anomalies: birth defects. This term was difficult to parse, in that it could be a more or less inclusive definition depending on how, and by whom, it was wielded. Researchers studying teratology were often inclined to favor a pragmatic definition of gross physical abnormalities or functional deficit, visible at or shortly after birth, as the primary definition (congenital malformations), while competing voices in the late 1960s and early 1970s embraced an inclusive definition that might include more minor conditions, in-born errors of metabolism such as PKU or diabetes, intellectual or behavioral deviations from normal, or functional syndromes that manifest themselves later in childhood or life.[41] Considerable differences arose in the 1960s and 1970s between teratologists who emphasized visible anatomical or short-term functional deficit in infants and environmental scientists or epidemiologists who looked for more long-term effects or subtle reproductive or neurological outcomes from various types of chemical pollution.

In practice, investigating birth defects medically involved experimental teratology on pregnant animals as well as epidemiological methods or clinical surveillance interrogating the pregnant body and maternal experiences to identify associations between early exposures and infant death, abnormal development, or

[41] For discussion of how teratogenic effect was defined by different researchers see pages 68-70. The definition was under considerable pressure from different groups. See the article in *Science* that accused Dow chemists B. A. Schwetz, G. L. Sparschu,and P. J. Gehring of trying to redefine teratogenic effects. N.W., "Dow Redefines a Word It Doesn't Like," *Science* 176, no. 4032 (1972).

disability.[42] Attitudes gradually transformed from a relative sanguinity regarding the protections afforded the placenta and the womb (despite considerable evidence to the contrary) to concerns about pharmaceuticals and radiation tinged with foreboding about other exposures. As environmentalists represented the world as full of complex and interconnected ecological relationships, and pollution a likely scenario, the pregnant body was increasingly treated as contiguous and connected to this polluted landscape. Clinical scientists and advocates such as Apgar referenced these connections and deleterious effects of anesthesia or x-ray exposure during pregnancy, even as they pushed interventions such as blood transfusions, vaccines, or modified diets as simple effective solutions for environmental factors acting during pregnancy.

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[42] In this article, Brent provides perspectives on methods used to examine mutagenic and teratogenic effects in the early 1970s. He advocates for greater clinical surveillance and more funds for basic research, seeing greater funds for pesticide research as unnecessarily, biased, or politically motivated: "When the recent announcement about pesticide research contracts were made, I received a half dozen phone calls from around the country requesting that our laboratory perform teratogenic testing for their pesticide contract. What kind of information do you think will develop from laboratories where the motivation behind the project is the need to qualify for support?" Robert L. Brent, "Protecting the Public from Teratogenic and Mutagenic Hazards," *Journal of Clinical Pharmacology and New Drugs* 12, no. 2 (1972): 68. James G. Wilson's monograph from 1973 and an article by Robert L. Brent in the 1990s provide overviews of teratologists' perspectives on environmental teratogens. They tend to note the broad range and scope of spontaneous, genetic, or prenatal environmentally-induced infant disability and the overall small role that synthetic chemicals and toxins play in developmental defects: Wilson, *Environment and Birth Defects*. Brent and Beckman, "Environmental Teratogens." Contrast that with late 1970s publications that emphasize identifying reproductive hazards such as Sullivan et al., "Congenital Malformations and Other Reproductive Hazards from Environmental Chemicals [and Discussion]." or Strobino, Kline, and Stein, "Chemical and Physical Exposures of Parents: Effects on Human Reproduction and Offspring."

Virginia Apgar at the March of Dimes

Following more than twenty years in anesthesiology (1938–1958), some acclaim for creating an extremely influential method of assessing neonatal health and viability (known as the Apgar Score), and reportedly delivering more than 16,000 babies, Virginia Apgar shifted careers. This second career addressed advocacy about and research support for congenital malformations, after she accepted a position as the Director of the Division of Congenital Malformations at The National Foundation (now known as the March of Dimes) in 1959. A highly energetic, hardworking, and indefatigable individual, (she played and built violins in her spare time and took flying lessons in her 50s),[43] Apgar proved excellent at moving into new disciplinary territories in the face of obstacles associated with being a female physician in that era.[44]

Her undergraduate education was at Mount Holyoke in the 1920s followed by medical training at Columbia University College of Physicians and Surgeons, completed in 1933. Despite training in surgery and a position as House Staff in Surgical Service, she felt compelled to study anesthesiology as a means to make a living, when the ranks of surgery seemed too difficult for a female physician to penetrate. Anesthesiology at this time was a new professional field, and physicians

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[43] Several popular profiles of Virginia Apgar mention that she played and made fiddles and one mentioned that she started taking flying lessons in 1969. See Sally Bly, "Prenatal Data is Valuable to Doctor," *Courier-Journal, Louisville Kentucky* or Marjorie Farnsworth, "Dr. Virginia Apgar," *World Journal Tribune*, October 2, 1966. Box 1, Folder: "Correspondence: March of Dimes Memos, Press Releases, and Copies of Articles, 1960–1970," Series 1, Virginia Apgar Papers, March of Dimes Archives. The reference to flying is in Janice Gaston, "Birth Defects Expert is Helpful and Hopeful," *Winston Salem, North Carolina,* circa 1971, Box 1, Folder: "March of Dimes Memoranda, Press Releases, and Copies of Articles; 1971–1974," Series 1, Virginia Apgar Papers, March of Dimes.
[44] Ibid.

with specialist training in anesthesiology were increasingly taking responsibility for administering drugs during surgery (as opposed to surgeons or nurse anesthetists).[45] Indeed, Apgar founded the first division of medical anesthesia at Presbyterian Hospital in New York City and negotiated to allow anesthesiologists to charge for their services outside of the purview of surgeons performing surgeries.[46]

In 1958, Dr. Apgar took a sabbatical to get a master's degree at Johns Hopkins University in maternal and child health. She wanted to focus on perinatal mortality, a thesis topic on the fringes of obstetric, anesthesiology, and pediatric disciplines. Indeed, in her view there was a need for greater overlap and collaboration between these specialties, which had been impeded by the economic structures (initially, obstetricians were paid for labor and delivery and caring for both mother and infant, much the way surgeons had controlled compensation for surgeries until anesthesiology became established).[47] When casting around for a new project after years of working as an obstetric anesthesiologist, Apgar described perinatal medicine as a new frontier midway between three disciplines.

Inspired by Leonard Mayo of the AACC, Apgar wrote to the head of the Johns Hopkins School of Hygiene and Public Health about the need for postgraduate education on perinatal medicine:

> Three groups of physicians are directly concerned with the perinatal period; the obstetrician, the anesthesiologist and the pediatrician. In the past, there has been little communication among them. The

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[45] For references to Virginia Apgar's early experiences and negotiations in anesthesiology, see Box 5, Folder 2–4, Series 2, Virginia Apgar Papers, Mount Holyoke College.

[46] A letter in 1940 requested a raise and the ability to charge fees for private anesthesia. Virginia Apgar to Dr. Whipple, 28 October 1940. Box 5, Folder 4, Series 1, Virginia Apgar Papers, Mount Holyoke College.

> obstetrician perforce has had to manage pain relief and labor without assistance, and has fallen into certain rigid grooves of thought and practice. The pediatrician has not considered the newborn infant to be his responsibility until he or she reaches the nursery. Only recently have the anesthesiologists begun to accept responsibility for pain relief during labor, and resuscitation of the infant when indicated, and to learn enough obstetrics and pediatrics to make them useful members of the team… A splendid liaison challenge among these three specialties awaits solution.[48]

In this description she identified professional tensions that defined the new field of perinatology. Much historical research about pregnant women has focused on maneuverings between (female) midwives and (male) obstetricians over the care of pregnant women, particularly during labor and delivery, yet these accounts are increasingly complicated by interprofessional tensions in the growing field of perinatal and pediatric medicine preoccupied with the health of the fetus and newborn.

Subsequent to completing her master's degree, Apgar accepted a position overseeing the newly created Division of Congenital Malformation. She worked at the National Foundation-March of Dimes in various capacities from 1959 until her death in 1974. Among her responsibilities were communications with scientists, assessment of their research activities, and review of grant applications to the National Foundation-March of Dimes. Additionally, she maintained a public voice, creating publicity materials and writing about prenatal risks of birth defects for popular magazines such as *Good Housekeeping* and the *Ladies' Home Journal*.[49] Her

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[48] Virginia Apgar to Dr. Paul A. Harper 24 March 1958**,** Box 5, Folder 7: "1958–1962," Series 2: "Correspondence, 1925–1974," Virginia Apgar Papers, Mount Holyoke.

[49] Apgar, "New Ways to Save Your Unborn Child."; Apgar, "Medicine's Next Frontier," *PTA Magazine* 56, January 1962, 20–2; Apgar, "What Every Mother-to-Be Should Know," *Today's Health* 44*,* 1966, 35.

collaborator on her last book project, Joan Beck, was a journalist and columnist for the Chicago Tribune-New York News Syndicate, Inc.

Apgar's professional diaries provide a clue to the NF's relationship to teratology and the growing fields of molecular biology and genetics in the early 1960s. Starting July 1, 1959, she was Director of the Division of Congenital Malformations, and thus had a front-row seat and active role in the myriad directions of research on congenital malformation in the early 1960s. In this role, she reviewed funding requests and visited various scientists to discuss their grant applications or examine their research potential, and she maintained a network of contacts in biomedical sciences. Additionally, she attended meetings of the Teratology Society, American Association of Pediatrics, Human Genetics, and other conferences. The creator of a widely used clinical scoring system for neonatal vitality, she was a respected authority on obstetric anesthesiology and neonatal health. She lectured, interfaced with journalists, and facilitated the further adoption of the test for neonatal vitality that came to be called the Apgar Score. Her career beginning as an anesthesiologist provoked concerns about the effects of anesthesia on the newborn and required complex interprofessional interactions with surgeons and obstetricians.

Professional concern with the effects of anesthesia and other drugs during labor and delivery was one rationale for creating a standardized clinical quantification tool to assess neonatal viability. In addition to providing a guide to neonatal resuscitation efforts and making comparisons of obstetric and anesthesiology practice, Apgar's concern about iatrogenic exposure of pregnant

women to anesthetic drugs was at the heart of new efforts to quantify the health of young infants shortly after birth.[50]

Apgar's Working Life As Director of the Division of Congenital Malformations

Apgar's professional diaries from the 1960s had a dizzying array of appointments scheduled across the U.S., demonstrating the complex networks of the scientific enterprise associated with developmental biology, genetics, and pediatrics by the mid-twentieth century. They also demonstrated professional jockeying within biomedical research, such as referral and patronage among insiders and professional maneuvering for position and acclaim. Her primary activities included corresponding with scientists about their work and grant applications, writing for lay and professional audiences on the topic of congenital malformation, publicizing the NF's work to the general public and physicians, presenting at conferences, and corresponding with colleagues about her publications.

As part of her work she also attended training centers and institutions that housed disabled people, such as the Sunland Training Center in Florida and the Sonoma State Hospital in California, to assess possible research projects. In her view, medical geneticists and pediatric researchers were increasingly parsing rare biochemical, environment, and genetics diagnoses from the previously undifferentiated masses of institutionalized disabled children. By 1963, one researcher told her that a urine-based screening test for the rare genetic syndrome

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[50] Virginia Apgar and E. M. Papper, "Transmission of Drugs across the Placenta," *Current Research in Anesthetics and Analgesia* 31, no. 5 (1952): 309–20; Virginia Apgar, "A Proposal for a New Method of Evaluation of the Newborn Infant," *Current Research in Anesthetics and Analgesia* 32, no. 4 (1953): 260–7.

Wilson's disease had identified four positive cases at a mental institution in Tennessee.[51] After visiting the Sunland Training Center, she noted that the most common diagnoses were "hydrocephalus, craniasynostosis, PKU, kernicterus, and ABO incompatibilities, post rubella and mumps, [and] gargoylism [Hurler's syndrome]" and pronounced it "really a gold mine for human research."[52]

This quote likewise indicates Apgar's interest and involvement in the materials of research study—human or animal. Occasionally, she would become enamored with a particular experimental model for studying developmental disabilities, such as opossums with twin compartments in their uteruses or puppies with cleft palates, or she lamented problems that her affiliates encountered, such as the reputed shortage of human embryos for study. Of Rhesus monkeys at a Perinatal Research Laboratory in San Juan, Puerto Rico, she remarked, "These animals should do well for experimental teratology but for their litters of one, their gestational period of 164 days and their cost."[53] In these respects, their similarity to human gestations made them undesirable as research tools.

It's unclear how much she shaped the agenda of perinatal research while at the National Foundation-March of Dimes, since she was working closely with Dr. Thomas M. Rivers, Vice President of Medical Affairs, and Dr. Theodore Boyd, Assistant Director of Research, on allocating funds for research projects. She could,

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[51] Virginia Apgar, "Professional Diary 1963," 19, Box 2, Folder 5, Virginia Apgar Papers, Mount Holyoke.
[52] Virginia Apgar, "Professional Diary 1960," 94–95, Box 2, Folder 2, Virginia Apgar Papers, Mount Holyoke.
[53] Virginia Apgar made a trip in March 1963 to visit Dr. Stanley James, a colleague from Presbyterian Hospital, NYC, at a perinatal research lab based in Playa Humacao on Cayo Santiago. Apgar, "Professional Diary 1963," 17, Box 2, Folder 5, Virginia Apgar Papers, Mount Holyoke. For more on the research colony, purchased in 1956 by the NIH, see William F. Winkle, "The Cayo Santiago Primate Colony," *Science* 209, (1980): 1496–1489.

however, be scathing in her assessment of a scientist's capacity to complete projects and initially showed a clear inclination towards laboratory-based fundamental research, some types of clinical research on pediatric disabilities, and study of rare familial genetic disorders in the clinic or in socially isolated populations rather than applied epidemiological projects.[54] Overall, she tended to think that smaller and more detailed clinical studies or laboratory studies were more helpful than studies of large numbers. She was at times dismissive of applied research. In her diary, she pondered whether a given research project (such as a gene linkage study, mechanisms of salicylate poisoning in rats) was sufficiently "basic." Of another researcher she wrote that she was "not too encouraging, on the grounds that the study of mechanisms was not basic enough."[55] This results-oriented approach that nevertheless emphasized basic or fundamental experimental research infused the funding program of the NF.

In her role reviewing applications, she acted as a gatekeeper, judging the reputations and ability of scientists and defining the kind of work that would be useful to prevention or treatment of birth defects. Many applicants or scientists she visited she deemed insufficiently focused on basic research or unable to take up a specific clinical problem and make something useful of the research. Of a potential applicant involved in a study of "over 1,400 institutionalized at California State institutions," she wrote, "She deplores the lack of information about normal growth and development but seems to find it difficult to define one problem at a time and

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[54] References in her diary express reservations about funding research that was epidemiological or not "basic" enough. For examples, see Virginia Apgar Diary, 1962, 44, 52, Box 2, Folder 4, Virginia Apgar Papers, Mount Holyoke.
[55] Apgar, "Professional Diary 1962," 49, Box 2, Folder 4, Virginia Apgar Papers, Mount Holyoke.

get it done."[56] Of another group, ""I have grave doubts about the ability of this team to do the work they suggest."[57]

Of another aspirant, she noted that she knew his advisor from her days at the committee meetings of what she called the "Collaborative Study of Brain Deficiency of the NINDB" and that she had met up with him at the medical genetics course in Bar Harbor. He was "typical of the group of bright young men, with clinical background in pediatrics, who want to make human genetics their life work," who might have headed a department of medical genetics at Yale, if there had been one.[58] His potential was partially confirmed by mutual colleagues and multiple points of interaction such as at Bar Harbor.

In her position as director, she maintained contact with many now well-known and junior scientists involved in research on human genetics, teratology, and congenital malformation. Her professional diaries provide a glimpse of networks of scientific exchange, mentorship, and funding that supported such research. She was consulted about perinatal health in various instances. She met and consulted with Dr. Elving Anderson and Richard Masland to discuss the forms being prepared for the Collaborative Perinatal Project, a large epidemiology study set up by the National Institute of Neurological Disease and Blindness (NINDB) to assess the relationship between adverse events during pregnancy and "brain deficiency," reviewing the forms for family history, obstetrical and anesthesiological. The study

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[56] Apgar, "Professional Diary 1961," 39–40, Box 2, Folder 3, Virginia Apgar Papers, Mount Holyoke.
[57] Apgar, "Professional Diary 1962," 100, Box 2, Folder 4, Virginia Apgar Papers, Mount Holyoke.
[58] Ibid, 51.

had incorporated the Apgar Score as part of their pediatric assessment.[59] She maintained contact with various physicians involved with the Collaborative Perinatal Project, informally exchanging medical and scientific publications and reviewing protocols.

Apgar was also in contact with and funded projects in in the field of genetics, reproductive endocrinology, and embryology, such as George Pincus at the Worchester Foundation for Experimental Biology, the creator of the birth control pill. He felt "that experimental embryology holds many answers for the etiology of congenital malformation."[60] She maintained contact with female physicians involved with diagnosing or treating infant anomalies, such as perinatal pathologist Edith Potter and pediatric heart surgeon Helen Taussig and more public-health-oriented physicians such as Ethel Collins Dunham (at the Children's Bureau until 1952).

She provided accounts of lectures by Baltimore-based medical geneticists such as Barton Childs and Victor McKusick and the chronic disease epidemiologist Abraham Lilienfeld. She attended conferences for practicing physicians, such as the American Medical Association (AMA) and the American Academy of Pediatrics (AAP), setting up booths to publicize the work of the foundation, research opportunities, and new methods of birth defects treatment or prevention. In 1962, pedestrians at the AAP were exceptionally interested in an exhibit on chromosome

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[59] Apgar, "Professional Diary 1960," 93, Box 2, Folder 2, Virginia Apgar Papers, Mount Holyoke.
[60] Apgar, "Professional Diary 1959," 23, Box 2, Folder 1, Virginia Apgar Papers, Mount Holyoke.

21 (trisomy of chromosome 21 had been linked to Down syndrome in the 1960s), "standing two and three deep before it."[61]

In addition to her responsibilities reviewing research projects and professional interchanges, Virginia Apgar also acted as a public voice for the NF in many instances, fielding requests from journalists and preparing various lay materials on birth defects and genetics. Her role as an expert on resuscitation and quantification of neonatal vitality at birth overlapped with her agenda to publicize birth defect prevention as Director of the Division of Congenital Malformation. To advertise the work of the NF, she participated in various radio programs, press interviews, and TV programs. She was filmed resuscitating infants for public awareness films produced by the Foundation. In collaboration with human geneticist James V. Neel she worked on a lay publication, initially tentatively titled "Our Defective Children," (which eventually became a more academic publication in 1963, simply titled *Birth Defects* and edited with the help of former *JAMA* editor and *Medical World News* founder Morris Fishbein[62]) and others on DNA and genetics. She reviewed the content of books written by other authors, such as galley sheets of Ashley Montagu's synthetic monograph on environmental influences on development, *Prenatal Influences* and an advance copy of Carson's *Silent Spring*.[63]

Not infrequently, she would receive impassioned pleas from physicians or parents about individual cases. A woman from Singapore, Isobel Tan, wrote her about her child born with spina bifida, wondering if it was something she had done

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[61] Apgar "Professional Diary 1962," 83, Box 2, Folder 4, Virginia Apgar Papers, Mount Holyoke.
[62] Fishbein, *Birth Defects*.
[63] Apgar, "Professional Diary 1961," 57 and "Professional Diary 1962," 86, in Box 2, Folders 3,4, Virginia Apgar Papers, Mount Holyoke.

to have a child with such disabilities. She wondered, could it have been the iron pills she took during pregnancy? Was there likely to be a risk of repetition if she had a second child?[64] Apgar often served as a counselor and referral service for individual families who had access to her expertise. For a NF staff member's friend, she recommended a physician to consult on nasal speech related to an operation for cleft palate. Another mother called her "who gave birth 7 weeks ago to a mongol baby." Apgar had a long talk with her about the prognosis, and referred her to other physicians.

Virginia Apgar and the Teratology Society

Virginia Apgar's diaries demonstrate how embedded she was in pediatric and perinatal research networks. In addition, she visited and funded many members of the newly formed Teratology Society (in 1960), such as Robert L. Brent and Marjorie Nelson. Teratology Society cofounder Josef Warkany had been referred by Albert Sabin as a potential advisor to the NF as they embarked on their expanded program. By the early 1960s, however, many of their scientific advisors favored a more biochemical and genetic approach. Virginia Apgar tried to placate the hurt feelings of Josef Warkany, and discourage his resignation from an advisory committee in April of 1961, but was unsuccessful. He was dismayed by the biochemical and genetic turn taken by the NF, and felt that "his specialty [was] considered to be 'second-rate' by many of the committee members, that he 'flunked' his oral exam," and so his usefulness to the committee was at an end. Additionally, he felt disgruntled to be left out of planning for a Los Angeles-based conference he had

[64] Isobel Tan to Virginia Apgar, 1969, Box 5, Folder 11, Series 2: Correspondence, 1925–1974, Virginia Apgar Papers, Mount Holyoke.

suggested.[65] Indeed, this sense of rejection and being left behind by genetic and molecular interpretations of developmental disability may have inspired him to move forward with incorporating the Teratology Society aided by the NF, F. Clarke Fraser and James G. Wilson.[66]

Thus, Warkany showed his frustration and feelings of marginalization as it became increasingly clear that genetic and molecular methods were gaining a larger share of research funding and interest, sidelining more clinical perspectives and mammalian research on morphological anomalies. Physician scientists such as Warkany and TIngalls had helped shape (and had their research shaped by) the emphasis of philanthropic efforts focused on infant and childhood disability, such as the AACC and the NFIP, as the philanthropies moved towards funding research on congenital anomalies. However, they were somewhat left behind by transformations in research on congenital malformations moving away from clinical medicine and into apparently newer and more exciting fields in biochemistry and molecular biology—the molecular vision of life.[67]

In 1969, at the Third International Conference on Congenital Malformations in The Hague, Warkany advocated for mammalian research on major malformations

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[65] Apgar, "Professional Diary 1961," 33, Box 2, Folder 3, Virginia Apgar Papers, Mount Holyoke.

[66] "a review of a steering committee of scientists, appointed by the National Foundation—March of Dimes and composed mainly of virologists linked to studies of poliomyelitis, judged that the study of inborn errors of metabolism and other genetic problems were of greater interest than studies of structural malformations. A few days later, during a walk along the edge of a nearby beach, Drs Clarke Fraser and Jim Wilson and Don Jose decided that it was time to call for the creation of the first teratology society." Wertelecki, "Of Dreaming on Solid Grounds and Silent Triumphs of One Man: A Story About Josef Warkany," 532.

[67] The phrase comes from Lily Kay. Lily E. Kay, *The Molecular Vision of Life: Caltech, the Rockefeller Foundation, and the Rise of the New Biology*, (New York: Oxford University Press, 1993).

as he lamented the turn towards relatively rare molecular deformities and inborn errors of metabolism: "Congenital malformations are not among those vanishing disorders…here they are, these children; we have to face them and their parents. Compared to them, children with inborn errors of metabolism and molecular deformities are rare…we have turned from macroscopic to microscopic research, from which we expect more practical results…there is danger though in celebrating victories in *related fields* in which the harvest is nearer and easier."[68] Thus, Warkany was rueful at the increasingly molecular and genetic emphasis of research and argued that large numbers of unexplained and severe childhood congenital disability justified continued support for teratologists' work, characterizing many genetic or biochemically mediated conditions as exceptional or rare, confined to particular families.

Growing Advocacy, Shifting Research and Philanthropic Emphasis

By the late 1950s, popular articles and manuals emphasized the possibility of anomalous development, rather than minimizing the chances of marked children or malformations. This shift coincided with growing scientific professionalization of research fields studying congenital malformations (among them teratology) and reorganization of philanthropic organizations and government towards science-based prevention of birth defects. The NFIP changed their mission and name in 1958, making congenital malformations a major area for investment and publicity and the AACC started to emphasize research and advocacy activities related to the

[68] Warkany, "Trends in Teratologic Research. Epilogue to the Third International Conference on Congenital Malformations," 90–91.

prenatal period in the early 1950s.[69] In June 1952, the AACC had funded a scientific conference in New York that was chaired by L. Emmett Holt, Jr., Theodore Ingalls, and Louis Hellman addressing "'Prematurity, Congenital Malformation, and Birth Injury."[70] Joan Gould and Holt, later published a pamphlet (in 1958) for the Public Affairs Committee, partially funded by the AACC, which emphasized the question "Will My Baby be Normal?"[71] A key objective of the writers of this pamphlet was to make readers more aware of various risks that a pregnant woman might face that might harm the fetus. As such, the pamphlet broaches the issue of babies with different mental or physical characteristics from the norm, highlighting the opportunities for intervention and the responsibilities of pregnant women.

In particular, these publications expand the potential risk group from pregnant women to all women who might get pregnant, noting that women were rarely aware of the pregnancy during critical periods of development. A pro-active approach by pregnant women to avoiding potential harms would be useless if it wasn't applied to all women who might conceive, regardless of whether they knew they were pregnant:

> One secret is starting soon enough. A woman must safeguard her child from the very moment when the child is conceived, and especially during those crucial first months in the uterus, when she may not even be sure yet that a new life is there. In other words, she should know all that she can know about safeguarding her baby before she even becomes pregnant, and as soon as she suspects that she has

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[69] Association for the Aid of Crippled Children, University Committee on Research in Congenital Malformations, Prematurity and Birth Injuries, "Plan" January 1955. Box 1, Folder 1, Series 1.1, Teratology Society Records.
[70] Association for the Aid of Crippled Children, and Emmett L. Holt, ed., *"Prematurity, Congenital Malformation and Birth Injury; Proceedings of a Conference in New York June 5*–6, 1952.*"*
[71] Joan Gould, "Will My Baby Be Born Normal?" (New York: Public Affairs Committee, 1958).

> conceived, she should put herself in the hands of a good doctor whose advice she is prepared to follow.[72]

In effect, changing approaches to infant abnormality that emphasized prenatal prevention of environmentally mediated disability served to accentuate the risk of harm during the period a fetus spent *in utero* and expanded the risk pool to all women of childbearing age.

A *Time* article from 1960 also took the title "Will My Baby Be Normal?" While not initially presented as reportage on a conference, the author was essentially summarizing information obtained at the First International Conference on Congenital Malformations, held in London in July 18–22 in 1960, describing the 480 experts from 26 nations who gathered in London.[73] In this case, publicity about a teratology conference was directly translated to an open question for women about the normalcy of their future offspring. The article quoted from such notables as the geneticist F. Clarke Fraser and the endocrinologist George W. Corner, emphasizing that "The vast majority of the inborn defects are now recognized as due to something that goes wrong in the environment of the fetus – in the womb."[74] Among the environmental factors listed were syphilis and rubella infection (rubella is presented as a common and unavoidable factor and syphilis as something that the mother did wrong), deficiencies in diet, stress, and strain. The author also emphasized opportunities for medical intervention: protective vaccines, penicillin, and surgery. Description of teratological scientific organizing in the media raised questions for lay audiences not just about severe infant disability but about infant deviancy broadly

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[72] Ibid., 4.
[73] Anonymous, "Will the Baby Be Normal?," *Time* 1960, 40.
[74] Ibid.

defined, caused by environmental factors. Medical intervention was seen as means of preventing such diverse types of infant disability and ensuring that future children approached a normal ideal.

Articles written by NF representatives such as Virginia Apgar or journalists in the 1960s using interviews or their promotional materials tended to emphasize the following points: 1) the problem of birth defects was much greater than previously imagined, 2) many parents worried about having abnormal children, 3) previous ideas of maternal impressions or ideas of inheritance or "tainted blood" were fatalistic and wrongheaded and the new science of teratology showed environmental causes of birth defects which were preventable, 4) medical science was working towards preventing birth defects in the future, with some successes (examples of preventative and therapeutic successes included PKU, diabetes, Rh incompatibly, and rubella infection), and 5) in the meantime, there were actions that the expectant mother (effectively anyone who might become pregnant) could take to ensure she had a healthy baby, among them avoiding all drugs, x-rays, infections and excessive drinking and smoking.[75] The NF also circulated educational and press materials, such as an information leaflet for pregnant women printed starting in January 1961, called "Facts About Birth Defects: Do's and Don'ts for Expectant Mothers."[76] This document highlighted the following categories: early consultation with a medical professional, x-rays, diet, diseases, powerful drugs, and issues of incompatible Rh-factors.

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[75] Two good examples: Virginia Apgar, "Medicine's Next Frontier; Birth Defects," *PTA Magazine* 56 (January 1962): 20–2; " A. Q. Maisel,"Good News about Birth Defects" *Parents Magazine* 35 (February 1960): 52–3.
[76] Anonymous, "Facts About Birth Defects: Do's and Don'ts for Expectant Mothers" January 1961, Folder: "Birth Defects Education Program," Series 3, Medical Program Records, March of Dimes Archives.

These popular articles emphasized that perfect, robust, normal children were a goal to work towards rather than a hazard of fate. Writing in *Cosmopolitan* in 1959, E. M. D. Watson detailed how to "have a perfect baby," describing deliberately exposing young women to rubella in order to make sure they were immune before they married. For those mothers who did become infected with rubella while pregnant, half of U.S. states saw rubella infection during early pregnancy as legal indication for a therapeutic abortion. Her list of other entities that could pose problems for the fetus included Rh incompatibility, x-rays, oxygen deprivation, anesthesia, improper nutrition, recreational drugs and impaired genes. [77]

Perceived vices, in particular, were subject to scrutiny by the 1960s. Smoking was one factor in the health of pregnant women and fetuses that demonstrated rapidly changing advice and perceptions. In the case of smoking, journalist and first daughter Anna Roosevelt argued in *Your Pregnancy* in 1950 that smoking in moderation was not harmful. She wrote, "The use of tobacco during pregnancy has been accepted as being of little or no harm if used in moderation. Again, however, some doctors object to smoking, so it's best to ask your physician how he feels about it."[78] Likewise, obstetrician and physician-advocate Alan Guttmacher's book for parents remained moderate about risks of smoking: "Smoking during pregnancy is no more or less injurious than smoking when not pregnant. Nicotine passes across the placenta into the fetal circulation, but does not harm the infant. Its only effect is benign, a temporary increase in the fetal heart rate."[79] This mainstream attitude

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[77] E.M.D. Watson, "How to Have a Perfect Baby," *Cosmopolitan* 1959, 74–7.
[78] Anna Doyle Leo Roosevelt, *Your Pregnancy* (New York: Henry Holt & Co., 1950), 67.
[79] Guttmacher, *Pregnancy and Birth: A Book for Expectant Parents*, 103–04.

that smoking was harmless began to shift by 1958.[80] By the early 1960s, newspapers reported on research studies linking low birth weight and smoking.[81] Despite this evidence, the Children's Bureau publication, *Prenatal Care,* published in 1962, tentatively suggested that moderate smoking and alcohol usage might have little effect but deferred to individual physicians' advice. The same publication also reassured parents about the risks of fallout, again referring readers to consult with their physician.[82] Women were asked to be attentive to and consult with their physician about diverse types of environmental hazards.

The work of teratologists and philanthropic advocates led to widespread reportage on particular dangers to pregnancy. International conferences on teratology resulted in popular reports that interrogated whether future children would meet normative ideals. Flyers published by the National Foundation-March of Dimes, such as the "Do's and Don'ts for Expectant Mothers" pamphlet explicitly targeted pregnant women with the message that they needed to manage their behaviors and exposures to avoid birth defects. Birth defects were represented as common and preventable, the responsibility of pregnant women.

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[80] A. Usher, "Research Indicates That Mother's Smoking Can Harm an Unborn Baby," *Better Homes and Gardens* January 1958, 24.
[81] Frankie McCarty, "Smoking by Expectant Mother Can Decrease Child's Size at Birth, Perinatalist Says Here," *Albuquerque Journal* (1963), 24.
[82] "Under certain conditions, tobacco, smoke, alcohol, excessive fatigue...may bring about changes in your body chemistry. Little is positively known, as yet, about the effect of such changes on fetal development. A moderate amount of smoking or drinking may not harm either you or your child but this is something you should check with your doctor about. In the unlikely event that radiation exposure from fallout should reach a level that calls for any special precautions, your doctor will be fully informed and can advise you." Muriel W. Brown, Marian M. Crane, *Prenatal Care* (Washington, DC: U.S. Children's Bureau, 1962), 12.

Scientists Bemoan the Popular Press

Even as they harbored concerns about prenatal exposures, scientists and physicians in the 1950s viewed popular media's depiction of prenatal environmental risks with dismay, complaining that information presented in the articles was often alarmist, confused, unsubstantiated, or incomplete. In his lay guide for expectant couples, Guttmacher seemed concerned about the approach taken by public media, particularly with the risks of x-rays and air travel:

> The lay press has been flooded with a lot of sensational scare literature about the topic of congenital abnormalities. Much is largely conjecture and lacks proof. I have seen no proof that the minor amount of radiation to which a fetus is exposed while the mother undergoes diagnostic (not therapeutic) X-ray has ever done harm. Despite the fact that abnormal mice can be created by exposing the pregnant mother to an atmosphere as rarefied as Mt. Everest for five hours, there is no proof that an airplane trip in a pressurized cabin during early pregnancy has ever damaged a human fetus.[83]

Other scientists expressed irritation about the way that their own work was portrayed in the popular press. Josef Warkany noted,

> I was rather disturbed about the article in *The Ladies' Home Journal*. It is a mixture of true and false statements...I fear it is only a matter of time until lawsuits will be started against doctors recommending chest films on pregnant women, or taxi drivers who shake expectant mothers in the 7th week of pregnancy.[84]

In the early 1970s, several Dow scientists wanted to change how teratogens were defined in their studies, arguing that, "If you tell congressmen or laymen or housewives that a compound is teratogenic they would think that here is something

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[83] Guttmacher, *Pregnancy and Birth: A Book for Expectant Parents*, 307–09.
[84] Josef Warkany to Edith Potter, 5 July 1956, Box 1, Folder 6: July 1956–1958, Series 1.1, Teratology Society Records.

very serious that we should not be exposed to. Every compound labeled teratogenic, they assume, must be as bad as thalidomide."[85]

This discourse reflects the ongoing frustration of experts on teratology in the context of journalistic reportage about fallout and other environmental risks that deployed sensationalism of accounts about severe infant anomalies linked to environmental exposures. Health-related anxieties of potential parents reflected and refracted information obtained from research studies, manuals, and popular articles on scientific research, not always in the ways intended by physician scientists. These articles demonstrate the complexity of the interface between scientist-physicians, the media, and parents during growing postwar concerns about the risks of technologies such as radioactive fallout, x-rays, and air travel. By the 1970s and 1980s, teratologists, among them Robert L. Brent and British researcher Richard Smithells (known for the definitive epidemiological studies on folic acid supplementation), were particularly vocal about the problem of media reportage, legal repercussions, and the need for public education about the relatively low number of infant anomalies caused by drugs or chemicals.[86]

Indeed, journalists writing magazine articles did take on inflammatory topics and provided dramatic advice on how to improve offspring or avoid prenatal harms, both quoting and glamorizing research scientists and providing sensational and

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[85] N.W., "Dow Redefines a Word It Doesn't Like."

[86] Brent wrote in 1986, “There is a widespread belief that many congenital malformations and abortions are caused by drugs and chemicals in the environment. This belief has been popularized in the lay press and even by some physicians. The magnitude of the problem is represented in the United States by the exponential rise in negligence litigation involving malformed children.” John L. Sever and Robert L. Brent, *Teratogen Update: Environmentally Induced Birth Defect Risks* (New York: A.R. Liss, 1986); Richard W. Smithells, "The Challenges of Teratology," *Teratology* 22, no. 1 (1980): 77–85.

quasi-speculative information about the dangers that might face a fetus *in utero,* particularly in the context of the political movements and radical anti-government youth activism of the late 1960s. In this setting, birth defects prove a useful political trope for consumer advocates, environmentalists, anti-war activists and also those who feared the impact on society of such restless and politically mobilized youth. This is most evident in the news articles surrounding birth defects, chromosomal breakages, and LSD, or the claims that arose around birth defects and Agent Orange and mercury.[87] News articles provided hyperbolic sound bites from scientific conferences about environmental exposures such as, "Simply by breathing the air a pregnant woman can permanently cripple her unborn child for life."[88]

Responding to Thalidomide

Some of the reportage around birth defects is likely linked to the fears and publicity surrounding thalidomide. Virginia Apgar first heard of birth defects linked to a popular tranquilizer called Contergan in February 1962, as her friend and colleague Helen Taussig made a trip to Germany to consult on some of the heart-related infant conditions. By then, radio and television programs throughout Germany had publicized alerts about the drug, but American audiences were still largely ignorant of its effects. Taussig reported on her trip in April of 1962 to colleagues in Baltimore, estimating that between 3,000 and 5,000 children in West Germany and England were affected by 1962 and that in addition to phocomelia,

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[87] Anonymous, "U.S. Report Linking NTA, Birth Defects in Rats Seen Killing Role in Detergents."; Mintz, "Widely Used Herbicide Tied to Birth Defects."; Davis E. Rosenbaum, "Monsanto Plans to Curb Chemical: Sales Limited on Substance Linked to Birth Defects," *New York Times*, July 15, 1970.
[88] Sue Reilly, "Grim Findings: Spotlight on Birth Defects," *Los Angeles Times*, March 29, 1971, E1.

children had been born with malformations of the ear, hemangioma of the forehead and face, malrotation of the gut, rectal and anal atresia, and cardiac anomalies. She reassured physicians and pharmacists that use of the drug before pregnancy had not caused disability (indicating that there were no genetic effects) and the families of American service members in Germany had no children with phocomelia.[89]

Calls from journalists inquiring about teratologists to interview about the story followed shortly. By August 6, 1962, in response to widespread publicity about thalidomide,[90] the NF began to "plan for a broad public education program to discourage the use of drugs during pregnancy."[91] Furthermore, a consultant's meeting of "six invited guests" and seven NF staff members was planned in September 1962. Participants decided, after much discussion, to initiate a "public education program for women of reproductive age and even adolescents, aimed at better health for better babies."[92] As part of this program, "premarital, pre-pregnancy examinations, care with radiation and drugs ingestion, and change of

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[89] Virginia Apgar, "Professional Diary 1962," 34, Box 2, Folder 4, Virginia Apgar Papers, Mount Holyoke.

[90] Morton Mintz is often credited with breaking the story on July 15, 1962, initiating an avalanche of media attention. See Carpenter, *Reputation and Power: Organizational Image and Pharmaceutical Regulation at the FDA*, 242 or Bale, "Women's Toxic Experience." For the differential role of experts in Germany and the U.S. see Daemmrich, *Pharmacopolitics: Drug Regulation in the United States and Germany*. For an examination of the lasting legacy of thalidomide see Brynner and Stephens, *Dark Remedy: The Impact of Thalidomide and Its Revival as a Vital Medicine*.

[91] Doctors Clarke, Boyd, Markham, Voss, and Schuman met to discuss the thalidomide story. Virginia Apgar, "Professional Diary 1962," 66, Box 2, Folder 4, Virginia Apgar Papers, Mount Holyoke.

[92] The meeting seems to be a type of focus group that occurred at Hotel Pierre on September 20, 1962, and was attended by Dr. Lowry, Dr. Mudge, Dr. Pfeiffer, Dr. Barnes, Dr. Noyes, and Dr. Robertson in addition to NF staff members: Dr. Boyd, Dr. Bergsma, Mr. Charles Bennett, Mrs. Ethel Brown, Mrs. Virginia Allison and Virginia Apgar. Virginia Apgar, "Professional Diary 1962" Box 2, Folder 4, Virginia Apgar Papers, Mount Holyoke.

habits for the better should be urged. Smoking was high on the list of undesirable habits." However, "It was noted that there was no scientific proof in human beings for any of the above advice."[93] All the physicians were pessimistic about teaching medical students "pharmaceutical nihilism." Dr. Pfeiffer thought that common drugs such as aspirin and nasal sprays might be related to birth defects. Another attendee, Dr. Noyes, emphasized that "responsibilities of pregnancy, not its privileges alone, should be stressed" in the National Foundation program.[94] This provides an example of how staff at the philanthropy felt the need to publicize the risks of pharmaceuticals and encourage medical surveillance to prevent birth defects and encourage healthful living during pregnancy, even as NF staff acknowledged that at the time there was very little scientific evidence to support this position. In the 1960s and early 1970s, considerable work would be expended by researchers studying perinatal exposures to illustrate the ill effects on the fetus of behaviors such as smoking or drinking during pregnancy.

The complex, multifactorial, and diverse processes of unusual fetal growth and disability were simplified in this model, characterized as caused by the misguided behavior of individual errant women with bad habits who were insufficiently compliant with medical supervision. This was occurring at the same time that thousands of women at high risk for miscarriage were still being given the synthetic estrogen diethylstilbestrol (DES) and progestin to prevent abortion, despite evidence that they were not effective. Likewise, Japanese pregnant women and their fetuses were poisoned by methyl-mercury contaminated sea life, causing higher incidences of cerebral palsy (see Chapter 4). It's unreasonable to expect

[93] Ibid., 75–76
[94] Ibid.

foresight about these calamities, revealed in the 1960s and 1970s. One cannot judge the past based on the values of the present. However, the NF framing of the problem immediately post-thalidomide sometimes highlighted the profligate use of pharmaceuticals and cigarettes by individual pregnant women, rather than larger socio-structural concern about poor health outcomes associated with inequity, the prescribing practices of physicians, or the waste disposal processes of industrial societies.[95]

The publicity campaign resulted in many public relations pamphlets. Apgar and other NF staff prepared "Swiss cheese stories" about infant disabilities that were sent to local chapters of the March of Dimes to be filled in with local details, gave interviews to journalists about research on congenital malformations, and wrote popular articles. Other news articles quoted Apgar, such as the article published in May 1963 in the *Omaha World Herald*, "Expert Suspects Even Aspirin in Pregnancy."[96] Many more were to follow, emphasizing that women should avoid drugs. The advice that Apgar published was at times contradictory, as it emphasized having faith in the prescriptions written by physicians and in the advice given by doctors, while at the same time recommending that pregnant women "avoid taking

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[95] This point about how particular types of behaviors of pregnant women were targeted for public health campaigns or criminalized has been underscored by scholars, though not specifically with respect to campaigns of the March of Dimes. For examples see, Oaks, *Smoking and Pregnancy: The Politics of Fetal Protection*. Golden, *Message in a Bottle: The Making of Fetal Alcohol Syndrome*; Stephen R. Kandall, *Substance and Shadow: Women and Addiction in the United States* (Cambridge, MA: Harvard University Press, 1996).
[96] "Expert Suspects Even Aspirin in Pregnancy," *Omaha World Herald* May 23, 1963. Clipping in Folder 8, Box 5, Series 2: Correspondence, Virginia Apgar Papers, Mount Holyoke.

anything that is not food."[97] The thalidomide tragedy pointed to the perils one might encounter in having complete faith in one's physician and demonstrated that the evidence to support (or reject) behavioral reform for pregnant women was scanty. Yet this public education campaign often emphasized the influence and advice of a medical profession.

Post thalidomide, in addition to new legislative efforts to regulate drug safety and efficacy (such as the Kefauver-Harris Amendments) and organizing on behalf of industry to train government and industrial scientists on the techniques of teratology, there was also considerable interest in collecting better data on infant anomalies. For instance, the Brookings Institute called a meeting of forty-five experts in early 1963 to discuss a resolution introduced in the August 1962 Sanitary Conference to discover the "relation of exogenous agents to birth defects." This resolution was primary directed at collecting data on infant anomalies via registries.[98]

Researchers at this Sanitary Conference, among them Apgar, F. Clarke Fraser and Chester Swinyard, agreed that a system to record birth defects would have to be instituted, measuring "fetal deaths and live births, as well as from death certificates… Once incidence figures had been obtained for specific malformations, a change in incidence could be noted and investigated."[99] Yet such a program was difficult to implement, given the difficulties in diagnosing and recording malformations. In at least one instance, Apgar noted considerable differences

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[97] Virginia Apgar, "Be Good to Your Baby Before it is Born," 5, 17, November 1963, Folder: "Baby Post, 1963" Box 1, Series 1, Virginia Apgar Papers, March of Dimes.
[98] Virginia Apgar, "Professional Diary, 1963," 1–2, Box 2, Folder 5, Virginia Apgar Papers, Mount Holyoke.
[99] Ibid.

("clashes") between clinicians and statisticians over how to record such information. For clinicians, "diagnosis is not a hard and fast decision," and they allowed for error, while statisticians "deal only with numbers."[100] The messy complexity of childhood disease and disability didn't lend itself to simple tabulation, especially in diverse cultural contexts. Likewise, clinicians wanted to solicit more information and resisted categorical simplicity, which the more statistically minded sought to winnow, "omitting complications of pregnancy, route of delivery, ethnic origin of parents, consanguinity and the like."[101] Ease of data collection and the clinical usefulness of the data were sometimes, if not always, at odds.

Women Advocate for New Responsibilities for Childbearing Women

A vision of individual pregnant women engaged in bad habits was not developed by an exclusively male decision-making body intent on abetting professional privileges and medical authority to exert control of women. A respected anesthesiologist and physician, Apgar helped to make decisions about NF policy. Yet, Apgar perpetuated a model common to many early women physicians, claiming particular clinical expertise on childbirth and infant health as a means to build a career in medicine[102] When queried about life as a female physician, she tended to emphasis that she worked harder than most male physicians. Her claims to expertise came primarily from her clinical experience and the large number of

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[100] Ibid.
[101] Ibid.
[102] Regina Markell Morantz-Sanchez, *Sympathy and Science: Women Physicians in American Medicine* (New York: Oxford University Press, 1985).

deliveries she had overseen.[103] She found both a personal cause and professional opportunity as an obstetric anesthesiologist and an expert on neonatal vitality, partially to highlight and remedy errors she observed in standard obstetric practice.

Other women were advocates and active participants in the volunteer efforts of the March of Dimes (in the early 1950s, there were already at least 3,100 local chapters of the March of Dimes). During the polio epidemics of the 1950s, most families had contact with polio and many middle-class women who worked at home were active in volunteer charitable activities, a form of community building and a marker of social status. These "mothers marches" would often involve women walking from door to door with mason jars, ringing the doorbells of their neighbors and asking for dimes to support the NFIP. By the 1970s, these door-to-door mothers' marches of the 1950s to raise money for research, treatment centers and scholarships to address polio became walk-a-thons to raise money for treatment and prevention of birth defects.[104] Early female health professionals gained legitimacy and a professional niche by focusing on problems of women and children, and at the time often assumed that the interests of women and potential children were entirely

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[103] Apgar herself rarely emphasizes her gender as a motivating factor for taking on obstetric anesthesiology; rather she emphasizes professional barriers to entering surgery and her own clinical expertise. Apgar wrote, "Since 1949, I have had the rare opportunity of spending as much time as possible on the obstetric service. Over 16,000 deliveries have been observed personally," Virginia Apgar to Dr. Paul A. Harper, 24 March 1958 3–4, Box 5, Folder 6, Series 2: Correspondence, 1925–1974 Virginia Apgar Papers, Mount Holyoke.

[104] Janice E. Nichols, *Twin Voices: A Memoir of Polio, the Forgotten Killer* (Bloomington: iUniverse, 2007), 99; Jane S. Smith, *Patenting the Sun: Polio and the Salk Vaccine* (New York: W. Morrow, 1990); Anonymous, "Hope to Make Birth Defects Stop on a Dime: Mothers Will March to Garner Funds" *Chicago Tribune*, January 24, 1965*; Anonymous,* "March against Birth Defects Slated Jan. 16" *Los Angeles Times*, Jan 9, 1977 SF, A2.

aligned.[105] Indeed, many pregnant women were concerned about protecting the health of their potential infant, especially as childbearing and childrearing seemed a more exceptional part of some women's lives.[106]

Thus the March of Dimes provided a venue for considerable health activism by women on behalf of children. Apgar carved a niche in medicine by addressing the particular needs of women and infants and sometimes acted as a voice of criticism of the uses of anesthesia by obstetricians. Apgar also saw herself as an advocate for the fetus and for children, even when she supported the abortion of possibly impaired fetuses. Of the NF meeting convened to discuss thalidomide, she wrote of the need to reach the FDA, "Since they finally agreed that a child is not a little man, it is possible that they will proclaim that a pregnant woman is not the same as a non-pregnant woman. They must recognize the fetus."[107]

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[105] Morantz-Sanchez, *Sympathy and Science: Women Physicians in American Medicine*.

[106] Rima Apple cites the statistic that the average number of children per family was 3.56 in the beginning of the twentieth century and 1.86 at the end (compared to 7 in the beginning of the nineteenth century). Apple, *Perfect Motherhood: Science and Childrearing in America*, 6. Despite a demographic hump in the family-loving 1950s, the women's movement and entry of more women into wage-earning professions substantively changed expectations about motherhood. Seigel, *The Rhetoric of Pregnancy*; Ruth Rosen, *The World Split Open: How the Modern Women's Movement Changed America* (New York: Viking, 2000); Plant, *Mom: The Transformation of Motherhood in Modern America*. Contemporaneous to the movement of more women into paid employment came increasing fears about the safety and well-being of children. Philip Jenkins, *Decade of Nightmares: The End of the Sixties and the Making of Eighties America* (New York: Oxford University Press, 2006). Elena Conis, *Vaccine Nation: America's Changing Relationship with Immunization* (Chicago; London: University of Chicago Press, 2015).

[107] Ibid.

Popular Magazines and Manuals on Birth Defects (1950-1975)

As Marika Seigel has noted, a booming trade in pregnancy manuals accompanied the baby boom.[108] Journalists writing in popular magazines also helped track the changes in the way that the prenatal period and the risks of fetal abnormality were observed. In the 1950s, many articles in popular magazines, particularly those intended for women such as *The Ladies Home Journal, Good Housekeeping,* and *Better Homes and Gardens,* consisted of advice columns and articles detailing the practices that women should consider and substances they should avoid while pregnant in order to protect the unborn child. The titles alone are very telling, ruminating on the healthy, natural, normal, and perfect: "We're Winning the Battle against Birth Defects,"[109] "How to Have a Perfect Baby,[110] "New Hope for Perfect Babies,"[111] and "Old Maternity Myths That Should Fade Away."[112] Popular science articles focused on the role of x-rays, vitamin A, and German measles as potential sources of harm, but they also relayed information on psychosocial dangers. There was also considerable attention paid to proper nutrition, along with rest and exercise. Information gleaned from national epidemiological research projects, such as the National Institute of Neurological Disease and Blindness's huge study of neurological outcomes, the Collaborative Perinatal Project, was used to buttress the authority of advice on how to "have a perfect baby." [113]

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[108] Seigel, *The Rhetoric of Pregnancy*.
[109] Albert Q. Maisel, "We're Winning the Battle against Birth Defects " *Reader's Digest* January 1961, 89–93.
[110] Watson, "How to Have a Perfect Baby," 74–77.
[111] Bernard Seeman, "New Hope for Perfect Babies," *Coronet* August 1961, 30–35.
[112] "Old Maternity Myths That Should Fade Away," *Good Housekeeping*1963, 150.
[113] Watson, "How to Have a Perfect Baby," 74–7. For more on the Collaborative Perinatal Project, see Kenneth Niswander and Myron Gordon, *The Women and Their Pregnancies* or Mark Klebanoff, "The Collaborative Perinatal Project: A 50-Year Retrospective."

Prior to thalidomide, medical practitioners and scientists were mainly concerned about the prenatal effects of therapeutic x-rays, if they discussed exposures at all. Medical concern about radiation exposure informed popular articles. In medical texts at the time, a deliberate distinction was made between "therapeutic radiation" and other common "diagnostic" uses of x-rays during pregnancy, such as to determine the orientation and size of the fetus.[114] This distinction was based on different dosages of radiation and served to rationalize and normalize obstetricians' use of x-rays for diagnostics and visualization, as opposed to higher doses of radiation used as a cancer therapeutic. However, the use of x-rays in obstetric practice declined gradually, related to concerns about safety and the increasing reliance on ultrasound as a tool for visualizing the fetus.[115]

A vast quantity of prescriptive literature was published in the twentieth century intended to counsel pregnant women and sometimes their partners.[116] Manuals intended for parents and articles from media and popular magazines approached the topic of birth defects differently, depending on their authors,

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[114] William Snow, *Roentgenology in Obstetrics and Gynecology*, 1st ed. (Springfield, IL: Thomas, 1952).
Gayle Greene, *The Woman Who Knew Too Much: Alice Stewart and the Secrets of Radiation* (Ann Arbor, MI: University of Michigan Press, 1999). Malcolm Nicolson and John E. Fleming, *Imaging and Imagining the Fetus: The Development of Obstetric Ultrasound* (Baltimore: Johns Hopkins University Press, 2013). ACOG published practice guidelines from 1959, which demonstrate the waxing and waning concern about x ray exposures during pregnancy as use of x-rays during pregnancy were slowly phased out.

[116] A search on World Catalog labeled as popular works during pregnancy between 1930 and 1985 turned up 372 entries in English, and that is a fraction of published materials. For more on prescriptive literature aimed at women, some of it on maternity or pregnancy, is Duke University Library's annotated bibliography, *Glory of Woman: An Introduction to Prescriptive Literature*. Rima Apple, in particular, has discussed the proliferation of scientific advice on motherhood, mostly with reference to the care of infants. Rima D. Apple, *Perfect Motherhood: Science and Childrearing in America*; Rima D. Apple, *Mothers and Medicine: A Social History of Infant Feeding, 1890-1950* (Madison, WI: University of Wisconsin Press, 1987).

audience, and stated purpose. Journalists writing magazine or newspaper stories typically identified new and interesting stories about scientific discoveries, while health educators and physicians were cautious and didactic in tone. For example, while most manuals on parenthood and pregnancy in the 1950s sought to dismiss maternal 'impressions,' popular articles covered new research on stress chemicals as a harmful factor that might affect the fetus.[117]

If popular magazines in the mid-1950s and after often discussed what to do to have a normal baby, took a precautionary tone, and heralded the most recent scientific finding on causes of defects, parents' manuals in the early 1950s were largely dismissive of fears of fetal deformity or mental impairment, when they mentioned them at all. Their messages tended to emphasis that birth defects were natural, unavoidable, and rare. They represented a standard of medical practice and widespread public acceptance in the 1940s and 1950s that attempted to dismiss or offer reassurance to patients about risks of congenital malformation. This might also reflect widespread reticence to talk about childhood disabilities or developmental defect, as advocates for research on congenital malformations claimed.[118]

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[117] New Jersey researchers Dr. Lyon P. Strean and Lyndon A. Peer studied 228 cases of cleft palate at Newark's Hospital of St. Barnabas. 68% recalled emotional experiences. "Drs. Strean and Peer reason that severe emotional disturbance of whatever kind, stimulates the adrenal glands to pump extra hydrocortisone; this checks the formation of connective tissue between the two sides of the palate or may actually dissolve tissue already formed." "Old Wive's Tale Confirmed: Abnormalities in Newborn Children," *Time* 68 (September 17, 1956): 65.

[118] Virginia Apgar and Josef Warkany tend to represent their work as breaking a code of silence to advocate for previously ignored and neglected children with disabilities. A 1970s profile of Virginia Apgar and her new book stated, "Years ago, people didn't mention such abnormalities out loud, she said. There were a number of parents who couldn't admit that their children had birth defects. And some of the damaged children were never allowed to leave their homes." Janice Gaston, "Birth Defects Expert is Helpful and Hopeful," *Winston Salem, North Carolina,* circa 1971,

Eve Stanton Featheringill's *Primer for Pregnancy, an Informal and Practical Guide for the Expectant Mother* (1951) stated that the risks of physical or mental deficiency in newborns was very low, as unlikely as a meteorite landing on a home.[119] In any case, medical science was presenting new explanations and rehabilitative opportunities for those born with disabilities every day. In response to the question "What if the baby isn't all right?" she replied, "Do you mean, what if he's born with some major deformity? Such babies seldom are born mature. The few that are, are likely to be stillborn or not to live long. The chance that your baby will not be perfect is infinitesimal, believe me. Do you lie awake nights worrying that an airplane will crash through the roof, that your family will be wiped out by a tornado, that gangsters will shoot their way through your house? Of course not."[120] Parental manuals in the early 1950s were concerned with reassurance and minimization of risk or chances of infant disability, in contrast to later literature that tended to emphasize birth defects as a probable scenario to be managed, extending beyond families with inheritable illnesses to the population at large. In particular,

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Box 1, Folder: "March of Dimes Memoranda, Press Releases, and Copies of Articles; 1971–1974," Series 1, Virginia Apgar Papers, March of Dimes.

[119]A contemporary review faulted the book for elitism, making clinics seem "unpleasant and undesirable although medically adequate in some cases." Another medical reviewer lauded the author for discouraging excessive use of obstetric analgesia and anesthesia. Featheringill was the mother of three children and also wrote a manual on teaching math to children and a 1965 advice manual for mothers, called *How to Be a Successful Mother*. Eve Stanton Featheringill, *Primer for Pregnancy; an Informal and Practical Guide for the Expectant Mother* (New York: Simon and Schuster, 1951); Justin Callahan, "Review: Primer for Pregnancy," Obstetrics & Gynecology 2, no. 3 (1953): 334. Anonymous, "Review: Primer for Pregnancy: An Informal and Practical Guide for the Expectant Mother," *Journal of the American Medical Association* 149, no. 1 (1952): 95.

[120] Eve Featheringill, "Chapter 19," *Primer for Pregnancy*.

Featheringill absolved parents from responsibility: "Do bare in mind, too, that nothing you do, or neglect to do, produces or prevents these defects."[121]

Beyond minimizing the risks of fetal harm, Featheringill emphasized that changing medical knowledge and practice provided rehabilitative solutions for disabled children (journalists often emphasized this as well). As an example, she cited "spastic children" who were once treated as mentally deficient but now were treated with "muscular and speech training and a lot of special exercises and help, even as children may who have had severe polio" as an example of the ways in which medical knowledge and practice had improved the circumstances of children born with disabilities. In addition, surgery and the treatment provided for those with in-born errors of metabolism showed that new techniques could minimize the impact of fetal abnormality from biochemical deficiencies: "Several glandular deficiencies that formerly doomed children to homes for the 'feebleminded' have now been found to be treatable in the same manner as diabetes… with doses of the missing substance maintaining the balance that should have been normal at birth."[122] Likewise, she minimized the risks of drugs, stating that barbiturates were fine to take during pregnancy.

Better Homes Baby Book from 1951 makes no mention of birth defects or anomalies. It does provide a section that advised, "Take precautions but live normally," that highlighted avoiding colds and other infections such as German measles, rest, proper diet (which also had its own dedicated section), avoidance of violent exercise or standing for long periods, fresh air and sunshine, avoiding a chill, refraining from intercourse during certain periods, visits to the doctor and avoiding

[121] Ibid.
[122] Ibid.

comparing notes with friends or relatives. The book provided a short description of diverse types of analgesics and anesthesia medication (including analgesia, amnesia, saddle block, caudal anesthesia, anesthetics, and twilight sleep) along with a brief overview of natural childbirth recommended by Dr. Grantly Dick Read. The book detailed diverse approaches to the pain of childbirth, but urged the patient that the doctor acted in the best interests of patient and baby, so the mother-to-be should "just relax and do what he tells you."[123]

Pregnancy manuals written before the late 1950s seemed intent on dispelling the exaggerated fears of nervous expectant parents while highlighting the ways in which medicine could improve the lives of the occasional unfortunate exception. When they mentioned infant anomalies at all, they often tended to convey the risks of infant disability as remote, subscribed to a non-interventionist approach during pregnancy, and tried to portray risks to the fetus as minimal. After birth, medical science was given great credit for healing, rehabilitating, or surgically repairing disabled infants.

If teratologists in the 1950s highlighted the utility of scientific knowledge for birth defects prevention, many parenting manuals in the early to mid-1950s emphasized that parents were blameless, maternal impressions were a fallacy, abnormalities were not preventable, and most imperfect fetuses were not viable. In 1955, Marion Goodwin Phillips, author of *More than Pregnancy,* relayed a perspective that normalized miscarriage as a means of disposing of embryos with imperfections. As historian of reproductive health Leslie Reagan has demonstrated, perspectives on the experience and meaning of spontaneous abortion shifted

[123] Philip Jeans, ed., *Better Homes and Gardens Baby Book* (Des Moines, IA: Meredith Publishing Company, 1951).

throughout the twentieth century, reflecting differing notions of fetal personhood. From her account, by mid-1950s, miscarriage was largely seen as a healthy biological mechanism, or blessing, that happened not infrequently (as many as 20% of all pregnancies) as a result of common physiological mechanisms when an embryo developed abnormally.[124] Phillips demonstrated this trend, stating, "for the average woman a miscarriage means that an accident *beyond her prevention* has produced an imperfection," and she advises parents to "try again."[125] Such accounts emphasized the rare and erratic nature of developmental disability or miscarriage, linking it to fetal abnormalities and taking the responsibility out of the hands of physicians and parents.

Teratological research and advocacy about birth defects changed the way that parenting manuals portrayed the probability of infant anomaly. The edition of *Eastman's Expectant Motherhood* published in 1977, describes miscarriages as blessings and most aborted fetuses as abnormal. Otherwise, it maintains some of the same text from the 1942 edition. However, the language about the likelihood of abnormalities was significantly changed between the 1942 and 1977 editions, from "the likelihood of a full-term child's being defective is very remote" to "there is much less likelihood of a full-term child's being defective." In 1942, the book had portrayed the odds of even a minor mark as improbable. Eastman wrote, "One baby in every two hundred approximately, is born with some kind of blemish. (If this worries you in the slightest, remember that one hundred and ninety-nine babies out of every two hundred are formed perfectly.) In the event that such a blemish is present...[such as]

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[124] Reagan, Leslie J. "From Hazard to Blessing to Tragedy: Representations of Miscarriage in Twentieth-Century America." *Feminist Studies* 29, no. 2 (2003): 357–78.
[125] Marion G. Phillips, *More Than Pregnancy* (New York: Coward-McCann, 1955), 28.

a reddish blotch..."[126] In the 1977 edition, mention of blemish did not appear in that section and maternal impressions are not mentioned except as "an old legend."[127] Tellingly, the word "parents" was substituted for "mother" in the 1977 edition.[128]

Marion Phillips's advice manual repeated the common trope that the mother or father inquired immediately after birth about whether the child was normal. She described the scene as follows: "The familiar sigh of a tired husband receiving news of his firstborn and his anxious voice inquiring as to its normality could be lessened by his understanding these simple facts."[129] Was medical staff responding to latent concerns expressed by parents or shaping those fears? This commonly repeated account of the mother or father inquiring about the normalcy of the newborn at birth could be taken at face value as a frequent concern among expectant parents that was expressed to medical staff, demonstrating that neonatal well-being was a concern of many new parents. The often-repeated parental inquiry also reflects a standard of childbirth practice where, depending on anesthetics used or hospital practices, mothers might not be immediately conscious nor immediately able to see the newborn at birth.[130]

The description serves the purposes not only perinatologists and teratologists but also authors of medical advice manuals on prenatal prevention, justifying their efforts to educate and inform parents about proper care during pregnancy and the risks of infant abnormality. Vague parental queries or anxieties about infant well-

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[126] Eastman, *Expectant Motherhood,* 1942.
[127] Nicholson J. Eastman and Keith P. Russell, *Eastman's Expectant Motherhood*, 6th ed. (Boston: Little, Brown and Co., 1977).
[128] Ibid., 118. Eastman, *Expectant Motherhood*, 90.
[129] Ibid, 37. See also, "many a brand-new mother has lifted up her head, turtle fashion when she first heard a lusty howl from the foot of the delivery bed and asked, 'Is the baby marked?'" in Carrington, *Safe Convoy: The Expectant Mother's Handbook*, 111.
[130] Leavitt, *Brought to Bed: Childbearing in America, 1750 to 1950.*

being were interpreted by the medical profession as a specific concern about anatomical anomaly or immediate and obvious intellectual impairment.

In 1959, Adele Davis stated in her manual, *Let's Have Healthy Children,* "If your nutrition has been adequate throughout pregnancy and your general health is good, what can we expect of this new baby of yours? We can, of course, expect him to be perfectly formed and free from physical defects."[131] However, she later noted that pregnant women often fear infant deformity and "Evidence is accumulating which indicates that it may be possible to prevention malformations rather than merely worry about them."[132] This was the prevailing attitude of advice manuals from the late 1950s, hinting that break-through research was presenting new opportunities for preventing birth defects, so parents shouldn't worry.

Physician and reproductive rights advocate Alan Guttmacher's *Pregnancy and Birth Book for Expectant Parents* addresses the topic of congenital anomalies cautiously, emphasizing the high rates of perfectly normal children. In 1957, he wrote, "This is difficult subject to discuss with lay readers, for each prospective parent has a secret dread that his or her child may not be normal...yet...97 per cent of human progeny are perfect at birth."[133] He further argued that many birth defects are extremely minor (hammer toe, extra digits, small appendages to the ear, birthmark, pilonidal sinus as the base of the spine) and surgery could do much to ameliorate some of the more severe anomalies (club foot, tracheal obstruction, congenital abnormalities of the heart). His manual explained medical approaches to severe anomalies such as anencephaly or hydrocephalus at the time. They were

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[131] Adelle Davis, *Let's Have Healthy Children* (New York: Harcourt, 1959), 4.
[132] Ibid., 17.
[133] Guttmacher, *Pregnancy and Birth: A Book for Expectant Parents*, 307–09.

identified based on palpating the uterus, visualized with x-rays, and optionally followed with premature induction of labor.[134]

Though it falls outside the specific genre of advice literature, there were other popular books on pregnancy that advocated for greater maternal responsibility for environmental hazards. The Boaz-trained anthropologist Ashley Montagu, motivated by social and environmentalist concerns, was an avid proponent of informing pregnant women about harmful environmental influences acting during the prenatal period. He lectured and published comprehensive popular books on the subject, *Prenatal Influences* (1962) and *Life Before Birth* (1964).[135] Montagu is best known for his work on race as a social construct. His interest in the topic seems to stem from an antipathy to a biologically deterministic perspectives and a desire to emphasize ameliorable social determinates of childhood well-being or disability. As early as 1950, in professional meetings, he had lectured on the need to better inform parents about prenatal hazards. He lectured: "to parents it should suggest something of the nature of the care and caution they need to exercise even before the baby is born."[136] At this meeting in 1950, others questioned whether such cautions were differentially directed at mothers rather than fathers.

In the early 1960s, Montagu summarized a huge volume of nature and nurture research in his popular books and particularly emphasized the permeability of the womb, "Until recently there has been a widespread belief that the fetus is so

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[134] Ibid.
[135] Ashley Montagu, *Prenatal Influences* (Springfield, IL: C. C. Thomas, 1962); *Life before Birth* (New York: New American Library, 1964).
[136] "Constitutional and Prenatal Factors in Infant and Child Health," in *Symposium on the Healthy Personality: Transactions of Special Meetings of Conference on Infancy and Childhood*, ed. Milton J. E. Senn (New York: The Josiah Macy Jr. Foundation, 1950).

well insulated in the womb and so well protected by the placental barrier that it lives a nirvana of life existence completely sufficient unto itself. Some have described this condition as a state of uterine bliss."[137] Social scientists such as Montagu promoted this perspective on the permeable uterine environment and the lost state of uterine bliss as an argument for ameliorative social solutions to developmental disability that carried a particularly heavy weight for women. He also described fears of environmental pollution, even as he iterated primarily behavioral responsibilities for women:

> I shall have little to say about the effects of automobile gases, the poisons belched by our factory chimneys which, among other things, contribute so exacerbatingly to the smog of our large cities, the effects of misused central heating, and the like, but I shall have a great deal to say about the effects of those gases which the mother voluntarily introduces into her own baby's system by smoking during pregnancy, by having various drugs administered to her by her well-meaning but insufficiently informed physicians, the food she eats, the illnesses from which she suffers and even her emotional states.

This quote illustrates how fears about the effects of pollution in the broader environment were often intermingled with specific prescriptive advice for pregnant women about maternal vices.

Metaphors of Parasitism and Attack in Advice Literature (1950-1975)

When describing pregnancy, advice manuals in midcentury deployed evocative metaphors, often derived from the science of ecology, to describe the reproductive organs and the interrelationships between a pregnant woman and the embryo or fetus. Obstetrician and teratologist John Ballantyne used ecological metaphors in the early part of the twentieth century to describe pregnant women.

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[137] Ibid., 149–150.

Similar depictions of the fetus and pregnancy as parasitic or symbiotic were ubiquitous. In 1956, Samuel Meaker described the fetus as a "baby" who was "like a parasite: he takes what he wants from the organism to which he is attached. For example, he may rob his mother of iron in order to build his own blood corpuscles."[138] Anthropologist Ashley Montagu described a pregnant woman as follows: "she is an organism in symbiotic relationship with another organism within her, indeed the avenue of all approaches to that organism."[139] In a manual on prenatal pediatrics, Alastair W. Blair and Jack M. Slater describe the fetus as "a complex organism, which is well adapted to its particular environment. This environment changes enormously throughout gestation and the products of conception are vastly different by the time term is reached."[140] These authors principally conceptualize pregnancy as a biological and ecological relationship, with the maternal body as an environment for rapid, and possibly deviant, growth.

Descriptions of the mother and fetus as organisms in dynamic relationship with each other tended to emphasize either harmonious and mutually beneficial interactions or antagonism. The depiction of mother and child as organisms fighting over resources reflected the rising tension over maternal rights or responsibilities and fetal rights and an understanding of the relationships between individuals in a group as essentially competitive instead of cooperative.[141]

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[138] Samuel Raynor Meaker, *Preparing for Motherhood: A Manual for Expectant Parents* (Chicago: Year Book Publishers, 1956), 81.
[139] Montagu, *Life before Birth*, 327–42.
[140] Gifford F. Batstone, Alastair W. Blair, and Jack M. Slater, *A Handbook of Pre-Natal Paediatrics for Obstetricians and Paediatricians* (Aylesbury: Medical and Technical Publishing Co. Ltd., 1971), 21.
[141] This interpretation is loosely based on Greg Mitman's historical analysis of shifting trends within ecology, informed by changing interpretations of relations between human groups, particularly a postwar vision that imagined difference,

Others authors writing for a popular audience used metaphors to characterize the placenta as either a shelter, guard, or nurse, or alternatively, a leaky and faulty barrier, depending on whether they intended to emphasize protection or permeability. Sociologists Aryn Martin and Kelly Holloway argue that the infallibility of the placental barrier was in some respects a historical reconstruction intended to emphasize the responsibility of pregnant women to protect the fetus.[142] Nevertheless, many references from the 1950s do emphasize the protective qualities of the placenta and the uterus, describing it alternatively as a buffer, a cushion, or a nurse. For Theodore Ingalls the relationship was protective, "It is evident that the mother and placenta together constitute a protective, buffering environment interposed between the embryonic host and injurious agents of the true external environment."[143]

Joan Gould, in a pamphlet called *Will My Baby be Born Normal*? published in 1958, thought it a blessing how the fetus was:

> protected from all that we swallow and inject into ourselves. Every child has a silent nurse, constantly on duty, protecting him from almost every kind of poison, and much better prepared than his mother to see to it that he receives precisely the right amount of food and oxygen. This nurse screens out almost everything in the mother's bloodstream that could harm the child, before it reaches him, and even manufactures the extra chemicals that he needs. That nurse is the

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diversity, and conflict as the grounding forces for American democracy. Even as metaphors of biology would inform depictions of the maternal-fetal relationship, these metaphors were influenced by assumptions about human society. Gregg Mitman, *The State of Nature: Ecology, Community, and American Social Thought, 1900–1950*, (Chicago: University of Chicago Press, 1992), 205–11.

[142] Martin and Holloway, "'Something There Is That Doesn't Love a Wall': Histories of the Placental Barrier."

[143] Ingalls, "The Study of Congenital Anomalies by the Epidemiologic Method: With a Consideration of Retrolental Fibroplasia as an Acquired Anomaly of the Fetus," 67.

> placenta, the spongy mass, like a round cushion, which is attached to the wall of the uterus and to the baby's umbilical cord.[144]

This nursemaid and cushion would shield and protect the baby in the womb, part of a medical narrative of reassurance directed at parents about possibility of prenatal harms.

However, this depiction of the uterus as the safest human habitat was increasingly challenged in the 1950s and virtually shattered by the avalanche of publicity about the harmful effects of thalidomide in 1962 and subsequent revelations about other risks to infant and fetal well-being. Some of this changing perception is derived from popular interpretations of teratology research. An article, published in 1956 by Gladys Denny Shultz, interviewed Theodore Ingalls and described Warkany's work. The journalist links Warkany's research to various hazards to pregnancy:

> Dr. Josef Warkany...first announced in 1943 that he could produce malformed rats by depriving the mothers of vitamin A. Since then experimenters have caused defects in animals by depriving the mother of other essential vitamins, such as riboflavin, folic acid, pantothenic acid. They have also caused defects by giving the mothers huge overdoses of these same vitamins. Malformations in animals, fish and chickens have been produced by alcohol and other intoxicants; by massive doses of cortisone and insulin; by heat; by cold; by lead poisoning and selenium poisoning; by drugs and by injecting a dye called trypan blue.[145]

As mentioned previously, reportage on the First International Conference on Congenital Malformations in London was printed under the title, "Will My Baby Be Normal?"[146]

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[144] Gould, "Will My Baby Be Born Normal?" 11.
[145] Shultz, "The Uninsulated Child."
[146] Anonymous, "Will the Baby Be Normal?"

Another journalist interviewed Virginia Apgar and published an article in the popular magazine *Coronet* in 1961, "New Hope for Perfect Babies." He noted that experimental teratology had alerted mothers to the dangers that lurked in the womb: "Fortunately, because of such laboratory research, the average mother can now be protected against many of the known stresses that might damage her baby. But all possible dangers are still far from known…Dr. Josef Warkany of the University of Cincinnati reports more than fifty such substances that can produce defective mammals if taken in large doses during early pregnancy. Among them are overdoses of vitamin A, antibiotics, aspirin, and certain anesthetics."[147] These quotes demonstrate how popular articles about teratology research might publicize hazards to pregnancy and encourage greater disciplining of pregnant women, even as teratologists decried the exaggerations of media reports.

In the early part of the twentieth century, the permeability of the placenta was described very positively, a delicate and essential process of nourishment and waste disposal. "The placenta is attached to the inside wall of the uterus. The baby is nourished, given oxygen, and his waste disposed of through this placenta by a delicate process into his mother's blood."[148] By the 1960s, this delicate exchange was seen less as an exchange and increasingly like an avalanche of harmful substances flooding the uterine environment, shattering faith in a lost paradise.

Similarly, after thalidomide, journalists tended to mark a contrast between previous depictions as a barrier or guard to emphasize the porousness of the barrier. One author, Geraldine Lux Flanagan, uses the unfortunate metaphor of a mother as

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[147] Seeman, "New Hope for Perfect Babies."
[148] Ellen D. Nicely, and the Cleveland Child Health Association, *Manual for the Conduct of Classes for Expectant Parents* (Cleveland, OH: Cleveland Child Health Association, 1942), 17.

a farm in 1965, describing the uterus and placenta as a leaky barnyard fence through which certain infectious agents and pharmaceuticals could pass and others could not:

> But the walls are like a barnyard fence, that is, impermeable to the horses but permeable to mice. Thus the smaller particles, the components of the large ones and also all gases pass through easily. This is why the anesthetics used in childbirth anesthetize the baby also; and why the agents of infections can be transferred from mother to baby. By the same token, drugs like penicillin or sulfa that may be used to treat the mother treat the baby as well, and all the immunities, which the mother acquires, are also transferred to the baby.[149]

Concerns about the harmful effects of environmental pollution on a newly visible fetal patient in the late 1960s are evident in the language used to describe the placenta. Not only is the expectant child constructed as a person, it's a person under toxic assault. Increasingly, the fetus was depicted as being bombarded or subject to atomic and chemical warfare, as language of "assault," "attack," and "hitting targets" were used to describe the interaction between the fetus and the outside world.

In 1968, Norman Berrill*'s The Person in the Womb* described this beleaguered entity: "The egg developing in the womb during the whole gestation period from conception to birth is vulnerable to both radiative and chemical attack."[150] Alix Kerr stated in *McCall's* magazine in July 1967, in the article "Protecting the Unborn Baby", "The old idea that the womb is the safest human habitat has been sharply disproved in recent years. Doctors used to think that the placenta prevented harmful

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[149] Geraldine Lux Flanagan was married to journalist Dennis Flanagan, who edited *Scientific American*. Geraldine Lux Flanagan, *The First Nine Months of Life* (New York: Pocket Books, 1965), 67–65.
[150] Norman J. Berrill, *The Person in the Womb* (New York: Dodd, 1968), 102.

agents from reaching a developing baby. But now it's known that antibodies from an Rh-negative mother, drugs like thalidomide and viruses such as the one that causes German measles can pass through the placenta and directly attack infants in the womb."[151]

Public fervor that characterized the environmental movement in the late 1960s and early 1970s is manifest in language used to describe the pregnant body with terms of warfare. A British manual on prenatal pediatrics published in 1971 described this assault as follows: "Chemicals of many kinds circulating in the blood, some simple, some of great complexity, may pass the barriers and reach the developing individual. Radiation, from cosmos rays to X-rays, may pass through the body tissues of the mother as though they did not exist and hit targets in either ovary or embryo."[152]

By the late 1970s, pregnant women were depicted as sponges soaking up a polluted environment. In *Caring for Your Unborn Child*, Barbara and Ronald Gots argued, "Despite a common misconception, the fetus is not safely sheltered from external assaults. The belief that the mother's womb and placenta magically extract only those good and necessary nutrients the mother has to offer, carefully extracting harmful agents is absolutely wrong! On the contrary, most of the things mother takes in through her lungs, her digestive tract and her skin are captured by the cells

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[151] Alix Kerr, "Protecting the Unborn Baby," *McCall's* July 1967, 48–50.
[152] Batstone, Blair, and Slater, *A Handbook of Pre-Natal Paediatrics for Obstetricians and Paediatricians*.

and tissues of the growing baby like a sponge absorbed in a puddle of water. They bathe these newly forming cells and become the environment in which they grow."[153]

By 1981, Gail Sforza Brewer and Janice Presser Greene recite a litany of substances to avoid while pregnant: "Generally, it is advisable to avoid all chemical substances possible during pregnancy, including food additives, aerosol sprays, aromatic cleaning compounds, alcohol, marijuana and other street drugs, exceedingly high doses of vitamins and minerals, purging preparations (whether administered by mouth or rectum), insecticide/pesticide sprays, immunizations (your own shots should be up-to-date before you conceive), hormones and *most important,* drugs prescribed by physicians."[154]

It's difficult to disentangle the effects of the conflicts over reproductive autonomy and abortion and fears of environmental degradation and pollution during a period of societal turbulence. Complex historical events made the fetus seem increasingly beleaguered or under attack. One could view this as the language of a country at war in a state of socio-political turmoil amid battles over topics as diverse as military involvement in Vietnam, women's economic and social equality, and the moral and legal parameters of medical abortion. Likewise, *in utero* visualization and medical intervention during the prenatal period was much more possible in the 1960s than previously. However, this language is partially derived from perceptions that the human race was in a state of jeopardy as a result of the damaged

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[153] Barbara A. Gots, Ronald E. Gots, *Caring for Your Unborn Child* (New York: Stein and Day, 1977).
[154] Gail Sforza Brewer and Janice Presser Greene, *Right from the Start: Meeting the Challenges of Mothering Your Unborn and Newborn Baby* (Emmaus, PA: Rodale Press, 1981).

environment. This threat to future humans was often evoked with references to a toxic attack or assault on fetuses and the next generation.

Pioneers of the Womb: Popular Depictions of Fetology and Fetal Surgery and the Womb (Mid-1960s and Beyond)

Popular media often reported on scientific research and new medical specialties in glowing terms. As described in Chapter 1, although the influence of the environment on the developing fetus had long been a preoccupation of embryologists, after the 1940s, researchers became particularly interested in examining the fetal environment as an important factor in the etiology of congenital abnormalities. During this period, as in earlier efforts, there was an effort to make a clear distinction between genetic and environmental factors in development (or inherited and acquired, as they were often characterized) though clear etiological cause was satisfactorily defined for only a small subset of disorders.

Research on congenital malformations, particularly teratology, helped raise the visibility of the womb as a site of harm to the fetus. Reportage on the 1960 International Conference on Congenital Malformations shows popular interpretations of professional organizing around teratology and environmental factors acting during the prenatal period: "The vast majority of inborn defects are now recognized as due to something that goes wrong in the environment of the fetus—in the womb. In most cases the underlying cause is unknown. In a few cases the direct cause is now clear."[155]

[155] Anonymous, "Will the Baby Be Normal?" 40.

Yet compared to teratologists, fetal surgeons were more dramatic and popular figures. Popular articles in the late 1960s described heroic attempts by fetal surgeons to explore the unknown territory of the womb, 'saving unborn babies' and deploying metaphors of space travel, exploration, and colonization. Alice Lake discussed how "'doctors heal the unborn" as follows: "Traditionally, the womb has been pictured as a cozy, warm nest in which the baby lies, unknowing, unknown and safe from the outside world. It is now known that the watery home sometimes proves a trap instead of haven. The unborn child may starve or be overfed. He may thrive until birth, and then die of asphyxiation during his passage through the birth canal." [156]

This viewpoint was particularly evident in publications heralding the beginnings of a new field—fetology. Fetology was begun by obstetricians willing to perform blood transfusions or amniocentesis in high-risk cases in the mid-1960s, such as that of Rh incompatibility, which eventually resulted in attempts at full-scale fetal surgery in the 1980s.[157] Medical sociologists Monica Casper and Sarah Franklin show how a new specialty concerned with fetal surgery arose out of these efforts and defined the fetal patient.[158] In cases where the possibility for a healthy birth was very unlikely without medical intervention, physician surgeons claimed triumphant successes in saving fetal lives. When describing fetology, journalists used metaphors of pioneers and space to emphasize that they charted unknown territory. One article in *McCall's* quoted a fetologist, Dr. Gerald Lucey as follows:

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[156] Alice Lake, "Medicine's Newest Patients," *Saturday Evening Post*, February 12, 1966, 40.
[157] Kolata, *The Baby Doctors: Probing the Limits of Fetal Medicine*; "Behavioral Teratology: Birth Defects of the Mind," *American Association for the Advancement of Science. Science* 202 (1978): 732–34.
[158] Casper, *The Making of the Unborn Patient: A Social Anatomy of Fetal Surgery.;* Sarah Franklin, "Fetal Fascinations: New Dimensions to the Medical-Scientific Construction of Fetal Personhood," in *Off-Centre: Feminism and Cultural Studies*, ed. Sarah Franklin, Celia Lury, and Jackie Stacey (London; New York: HarperCollins Academic, 1991).

> In the three years since the first baby was saved by a fetal blood transfusion, the pace of medical discovery about the unborn child has quickened enormously. In the future… we will no longer assume that there is nothing we have to offer the diseased fetus. It's like outer space. The environment of the fetus is still unknown country, but the time is coming when we will know more about it. Eventually we will probably even be able to *change the environment to make it safer for the unborn* child. [italics mine][159]

Reportage on the new pioneers of the womb tended to express awe and a sense of the new frontier evoked by the metaphors of space travel and entry into uncharted territory. Language on the valiant efforts of womb pioneers was used in tandem with visions of the womb as an environment that was uncharted and potentially hazardous, with a residence of nine uncertain months culminating in the perilous journey of childbirth. Ideas of pregnancy as routine, natural, or safe were in flux, as physicians and sometimes the public pathologized pregnancy and conceptualized the fetus as an isolated and at-risk traveler, even as the risks of maternal or infant mortality were decreasing in wealthy countries.

Though the exploits of fetal surgeons received the most press and attention, they were part of a broader shift in genetic and pediatric research and the growth of perinatal medicine.[160] By 1972, the NF would trumpet in their annual report, "The Foundation has been leading the fight against birth defects for about 15 years. During that very period, a new specialty has developed in medicine: the specialty called perinatal medicine, or perinatology, the study of the fetus and the newborn."[161] This report heralded an even more expansive emphasis—rather than simply birth defects, the Foundation would address infant prematurity and low birth

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[159] Lake, "Medicine's Newest Patients," 39. See also, J.R. Hixson "Forecasts from the Womb: Specialty Called Fetology Being Created,"*McCalls* 94 (February 1967): 60.
[160] Casper, *The Making of the Unborn Patient: A Social Anatomy of Fetal Surgery*.
[161] "The National Foundation/March of Dimes Annual Report 1972"
March of Dimes Archives Box 1, Folder: "Annual Reports, 1939–1994," Series 1: Administration, Medical Program Records, March of Dimes.

weight. In doing so, they hoped to help a greater numbers of infants, as low-birth weight and prematurity were associated with various poor health outcomes. This reflects medicine's growing emphasis on more subtle deviations from normality in the latter half of the twentieth century and effectively expanded the territory within the NF's stated mission.

Conclusion

This chapter traced the rise of advocacy on the topic of birth defects prevention, emphasizing the role of the National Foundation-March of Dimes and Virginia Apgar in publicizing a particular modernist medico-scientific vision of infant disability. It also seeks to trace the changing advice and language afforded pregnant women in the 1960s and 1970s, with an eye towards how a particular vision of pharmaceutical and environmental risk to a fetal patient arose and evolved. For the most part, parenting manuals in the 1950s and before took a reassuring or dismissive approach to infant disability. Many emphasized nutrition, exercise, and prenatal care as a way to have a healthy baby and minimized the likelihood of infant anomaly. Often, they would reject the idea of maternal impressions and offer placating language about the low risks of birth defects or highlight achievements in medical sciences that could ameliorate the effects of birth defects when they did occur.

Journal articles in magazines and newspapers tended to be more sensational and discuss groundbreaking medical research. They served as a voice to publicize scientific progress and innovation, though not always in the ways intended by teratologists and perinatologists. Often, popular articles in magazines consisted of

advice columns highlighting what substances pregnant women should avoid combined with report on the latest scientific discovery of harmful effects *in utero*. With the rise of the environmental movement (contemporaneous with a heated battle over abortion about a more public and baby-like fetus), metaphors of attack and bombardment were used to describe the relationship between the fetus and the polluted outside world. This illustrates the paradoxical tendencies of pregnancy and infant disability in the later half of the twentieth century. Even as the statistics on maternal and neonatal mortality declined, perceived risks during the perinatal period appeared to escalate.

The National Foundation-March of Dimes lent considerable promotional weight to the topic of birth defects. A specialized advocacy and advice literature grew from 1958, by Virginia Apgar among other authors, which emphasized the potential harms that pregnant women must avoid to prevent infant anomalies. Often written by and for women, this literature gave cultural weight to the medicalization of birth defects, which had aided the gradual transformation from "unavoidable accidents of nature" to "birth defects" with specific environmental or genetic causes, bringing them further under the purview of scientific medicine. This literature maintained particular responsibility for pregnant women to preserve the well-being of children and the fitness of future generations.

Pamphlets from as early as 1958 warned pregnant women, or women who might become pregnant, of the risks that the fetus might face *in utero*. In addition to the mobilization of scientific expertise, the timing of these materials suggests that concerns about the effects of nuclear fallout provoked some of this publicity. The American College of Obstetrics and Gynecology standards of practice provide a

robust section on radiation hazards, noting in 1959 that "Fallout radiation following nuclear denotations has focused attention upon the risk of somatic and genetic injury following exposure to all types of radiation."[162]

A tidal wave of public concern about birth defects is evident subsequent to 1962, when cases of *phocomelia*, heart defects, and other neonatal disabilities linked to thalidomide were widely publicized in Germany and worldwide. Along with growing environmental advocacy, publicity surrounding thalidomide served to place greater emphasis on drugs as 'environmental' causes of fetal abnormalities. Journalists, at least, became more attuned to chemical teratogens of all kinds as a danger to fetuses, though largely emphasizing pharmaceuticals. By 1965, there were also many articles about the new specialty of fetology, primarily glowing accounts of womb pioneers saving unborn babies. This literature demonstrates changing notions of embryos, fetuses, the placenta and the womb, as the embryo or fetus was increasingly portrayed as a precarious traveler in the hostile environment of the womb, subject to exogenous chemical assaults from a chaotic, polluted and out-of-controlled broader environment. Expectant mothers, pregnant or otherwise, were admonished to monitor their behavior in an effort to mitigate these risks, while they waited for the future rewards of scientific progress.

The rise of the birth defects advocacy and medical specialties directed at preventing birth defects, such as perinatology, fetology, and teratology, helped to illuminate the womb as much as their technological tools of observation or debates about abortion had, casting the embryo or fetus as a malleable and vulnerable organism, and highlighting interactions between this newly vulnerable developing

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[162] ACOG, "Manual of Standards in Obstetric-Gynecologic Practice," 1959, 44.

child, a permeable placenta, and the dangerous exogenous environment in the name of preventing infant defect or anomaly. Though this was a complex and interdisciplinary field, this transformation of the womb into the fetal environment owed much to teratologists, perinatal advocates, and, as described in Chapters 3 and 4, a burgeoning environmental movement that raised neo-eugenic concerns about more subtle infant defect or deviancy resulting from industrial pollution and the profligacy of modern life.

Chapter 3: Vilma Hunt: From Occupational Teratogens and Pregnant Women to a Broader Framing of Environmental Reproductive Hazards (1960–1980)

This chapter examines the rise of an expert perspective concerned about the reproductive effects of environmental pollution and the risks of occupational exposures to pregnant women. As women entered the workforce in greater numbers in the 1970s, moving into jobs previously closed to them on the factory floor despite a struggling economy, their right to work in hazardous settings became a politically volatile issue. The Equal Opportunity Commission put pressure on companies to hire women to comply with the Civil Rights Act of 1964, and in response, companies prepared policies intended to reduce liability associated with fetal or infant harm. However, these policies came under fire from labor and women's rights activists along with environmental health academics such as Vilma Hunt.

What on the surface seemed a simple question about what and whether industrial and other toxic chemical pollutants were likely to harm fetuses and infants became a fraught and contentious field, given the complexity of the chemical landscape and open questions about understudied occupational risks and more subtle effects of hazardous occupational exposures. Such controversial questions about prenatal harm from relatively low-level exposures were not easily resolved using standard methods of constructing scientific knowledge (epidemiological studies of humans, biomonitoring, and laboratory-based studies on pregnant animals). To some extent this remains a debate about the precautionary principle

and how public policy and regulations should be formulated amid uncertain data.[1] While severe acute poisoning with substances such as radiation or lead was understood as unquestionably problematic and likely teratogenic to pregnant women and fetuses, what impact did low-level chronic exposures to radiation and hazardous industrial chemicals to both sexes have in offspring exposed *in utero,* including effects on future generations? Could fertile women be restricted from hazardous work on the grounds that they might be pregnant?

The conflict over fetal protection pitted environmentalist perspectives about mitigating the risks of prenatal toxic harm with a women's rights perspective that emphasized equal opportunity for women.[2] The case of fetal protection policies has a unique twist, in that corporations appeared to act with extra precaution with respect to chemical reproductive hazards, and many women workers felt they were being discriminated against and excluded from jobs unfairly and erroneously. Critiques of fetal protection policies highlighted known reproductive risks to both males and females from occupational hazards, the fact that many women seeking to work in hazardous settings had no intention to get pregnant, and the imperative to make the workplace safe for all workers. Indeed, the bar for precaution about exposures seemed very low for fetuses relative to occupational exposures for adults—fetuses

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[1] Perspectives on the precautionary principle can be seen in Barbara Ley and Nancy Langston's work. Langston, "The Retreat from Precaution: Regulating Diethylstilbestrol (DES), Endocrine Disruptors, and Environmental Health." Barbara L. Ley, *From Pink to Green: Disease Prevention and the Environmental Breast Cancer Movement*, Critical Issues in Health and Medicine (New Brunswick, NJ: Rutgers University Press, 2009), 81–105. See also, Timothy O'Riordan and James Cameron, *Interpreting the Precautionary Principle* (London: Earthscan Publications Ltd., 1994).

[2] A contemporary commentary described health and safety legislation and the women's rights movement as on "a collision course." Sullivan et al., "Congenital Malformations and Other Reproductive Hazards from Environmental Chemicals," 94.

were assumed to be innocent parties, not rational actors making informed risk-benefit decisions about their health and economic opportunity.[3]

Ironically perhaps, corporations and some environmentalists were aligned in representing the fetus and pregnant woman as particularly susceptible to chemical hazards, with different aims—industry wanted to exclude fertile women from the workplace to reduce their liability, and feminist environmental scientists wanted to draw attention to the need for better workplace conditions for women, and all workers.

Vilma Hunt's writings and professional trajectory in environmental health science provide an entry point into evolving debates about occupational and more widespread environmental hazards to the fetus, standing in for many researchers who raised questions about subtle effects of prenatal exposures, originating from the allied health and environmental health sciences perspectives. Hunt's interest in biomonitoring of radiation and heavy metals in human tissues was part of environmental health science's growing emphasis on low-level and subclinical effects, as opposed to more acute poisonings that had concerned industrial hygienists in the first half of the twentieth century. Indeed, Vilma Hunt's career tracks the evolution of environmental health sciences from initial mobilization around issues of occupational hazards and radioactive fallout to more dispersed and community-based chemical concerns.

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[3] Robert Proctor analyzes risk vs. benefit logics in Proctor, *Cancer Wars: How Politics Shapes What We Know and Don't Know About Cancer*, 127. Cori Hayden and other anthropological accounts of contemporary biomedicine can be particularly incisive about the flaws in economic theories of rational actors in an idealized neo-liberal free market framework. Cori Hayden, *When Nature Goes Public: The Making and Unmaking of Bioprospecting in Mexico* (Princeton: Princeton University Press, 2003).

By the late 1970s, the pediatric psychiatrist Herbert Needleman was alternately lauded and attacked for linking lead exposures measured using the teeth of schoolchildren to more subtle subclinical cognitive and behavioral effects, adding convincing evidence to the long-standing debate about whether there was a relationship between low-level lead exposure and childhood cognitive impairment.[4] Thus by the 1970s, environmental health sciences tended to emphasize childhood neurological or behavioral effects due to toxic prenatal exposure to heavy metals and possibly other substances, but in making claims about fetus susceptibility and birth defects resulting from environmental exposures, they moved into the disciplinary territory of teratologists.

Historians of occupational health, Gerald Markowitz and David Rosner, have argued that conflict over fetal protection policies and the occupational lead standard marks, "an important transitional moment when the issues of workers' health, and the impact of industrial toxins on the broader environment became more intertwined and complex. Women, the fetus, the economic life of the family, and work within the factory all became issues of debate."[5] I concur with this assessment and argue that widely publicized conflicts over fetal protection influenced the way that pregnancy was characterized and brought questions of teratogenic hazards to pregnancy that

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[4] David Rosner and Gerald Markowitz, "Standing up to the Lead Industry: An Interview with Herbert Needleman," *Public Health Reports* (2005): 330–7; Herbert L. Needleman et al., "Deficits in Psychologic and Classroom Performance of Children with Elevated Dentine Lead Levels," *New England Journal of Medicine* 300, no. 13 (1979): 689–95; Philip J. Landrigan and Edward L. Baker, "Child Health and Environmental Lead," *British Medical Journal* 1, no. 6064 (1977): 836; Markowitz and Rosner, *Deceit and Denial: The Deadly Politics of Industrial Pollution*, 122–23.; Needleman and Scanlon, "Getting the Lead Out."

[5] Markowitz and Rosner, *Deceit and Denial: The Deadly Politics of Industrial Pollution*, 134; Proctor, *Cancer Wars: How Politics Shapes What We Know and Don't Know About Cancer*; Langston, *Toxic Bodies: Hormone Disruptors and the Legacy of DES*.

had been rooted in the workplace and pharmaceutical sciences into debates about subtle risks to reproduction from insidious exposures in the home and community. In 1950s, teratologists had also raised questions of congenital malformation resulting from environmental factors acting during the prenatal period. This chapter juxtaposes Vilma Hunt's career and institutional and political commitments forged in the 1960s and 1970s with those of teratologists.

Pediatric Clinical Perspectives on Fetal Deformity and Disability Juxtaposed Against Activist Geneticists and Environmental Scientists

Vilma Hunt was outside of mainstream pediatrics and maternal-fetal medicine. A dentist educated in Australia, Hunt made a professional career in environmental health via radiation research and contentious policies related to protection policies and working women in the 1970s. She wrote a widely consulted report with Clara Schiffer from the Department of Health, Education and Welfare (DHEW) in 1975 on the health of working pregnant women, *Occupational Health Problems of Pregnant Women*. Examination of Hunt's professional trajectory and research provides a unique window into the evolving concerns of environmental scientists as they used the fetus to highlight industrial damage, unsafe working conditions, diverse risks of chemical products, and unchecked environmental degradation.

Health scientists with training in dentistry, such as Vilma Hunt and Peter Infante, seemed to have had an outsiders' status in the field of human health effects of low-level chemical or radiation exposures that provided different professional trajectories than pediatric clinical or laboratory-based research. This relieved some

of the influential social and cultural pressures to avoid controversy experienced by those trained in medicine and laboratory science, particularly among those who had found professional opportunity amid wartime government funding for national defense. Also, several of the substances thought to cause birth defects in the early 1960s, such as therapeutic x-rays, hormones, anesthesia, and other pharmaceuticals, were in frequent use by the medical profession as diagnostic tools or treatments, and physicians valued the professional prerogative to prescribe safe pharmaceuticals. Medical practices often changed slowly. Teratologists seemed afraid of too vocal criticism of insufficiently vetted chemical exposures, since it might be interpreted as an indictment of the practices of colleagues, lead to unnecessary abortions, and risk inciting lay outcry or medical liability suits around issues of fetal harm.[6] Additionally, pediatric clinicians and obstetricians who confronted severe developmental disability daily or addressed parental anxieties about the uncertain outcomes of reproduction wanted to approach the matter carefully and avoid alarmist interpretations. This, in part, explains many physicians' caution about publicizing potential hazards, often justified by the desire to avoid frightening potential parents.

[6] See Warkany's mention of judicious and nuanced interpretations of "critical periods" at Samuel Hick's presentation in 1953 or Robert Miller's comment about pediatricians sidling up to him at meetings of the Committee on Environment Hazards of the American Academy of Pediatrics to discuss an unsubstantiated claim. Hicks, O'Brien, and Williams, "The Effects of Ionizing Radiation, Certain Hormones, and Radiomimetic Drugs on the Developing Nervous System."; Miller, "My Half-Life in Teratology," 30.

Activist Voices From Environmental Health Sciences and Genetics

Scientists and allied health activists removed from clinical experience were influential in raising questions about undetected prenatal mutagenic effects of environmental pollution. Alexander Hollaender, a biophysicist who became interested in mutagenesis and birth defects, founded the Environmental Mutagen Society in the late 1960s.[7] At a conference intended to assess detection of environmental contaminants that might cause birth defects, he described his early concern about the effects of teratogens in Appalachian communities:

> As biophysicists we have wondered what we might do to help alleviate this grave problem [of Appalachian families affected by birth defects]. We questioned whether our experience in promoting biological methods for the detection of radiation might not also be applicable in the field of teratology, even though we are not specifically trained in this area…We propose that at least part of the teratological effects is produced by chemicals in our environment—if not as direct effects, then through their breakdown of metabolic products in the body. When I first advanced this theory I was informed by teratologists and toxicologists that it did not seem reasonable that chemicals could have such serious effects.[8]

Thus, biophysicists and geneticists, such as Josef Müller, Albert Sturtevant, James Crow, and Joshua Lederberg, proved some of the most vocal scientific activists concerned about the mutagenic effects of chronic low-level exposures on

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[7] Alexander Hollaendar worked at Oak Ridge National Laboratory and published *Radiation Biology* in 1954. He also helped organize a symposium on developmental effects of radiation and other deleterious agents in 1953 and helped form the Environmental Mutagen Society in the late 1960s. Alexander Hollaender and National Research Council (U.S.), *Radiation Biology*, 3 vols. (New York: McGraw-Hill, 1954). Hollaender, "Introduction: Effects of Radiation and Other Deleterious Agents on Embryonic Development." See Scott Frickel's work for more on the Environmental Mutagen Society: Frickel, *Chemical Consequences: Environmental Mutagens, Scientist Activism, and the Rise of Genetic Toxicology*.

[8] L'Institut de la Vie, "Methods for Detection of Environmental Agents That Produce Congenital Defects: Proceedings of the Guadeloupe Conference."

genetic material and future generations.[9] In part, this emphasis echoes eugenic concerns about preserving the "quality" of the population, though without explicitly racist or coercive agendas.[10]

Vilma Hunt's training was far more clinical than these scientific activists, in dentistry and physical anthropology. I have used personal archives and published literature to examine Hunt's involvement in fetal protection policies and the contentious issues surrounding the workplace exposure of fetuses and other reproductive hazards in the 1970s. Hunt was part of a generation of researchers who emphasized issues of environmental pollution and widely distributed occupational or industrial hazards using tools of biomonitoring and epidemiology, raising the politically contentious yet popularly salient issue of fetal or infant defect or disability resulting from susceptibility to toxic exposures.

In some respects, Vilma Hunt's efforts to bring attention to the unique vulnerabilities of pregnant women reflects a maternalist effort to improve workplace conditions for women and children inspired by progressive industrial hygienists from the early twentieth century. If the fetus appeared increasingly discrete, vulnerable, and baby-like in the 1970s (fetal personhood), it was not exclusively as a result of anti-abortion politics. Elite professionals interested in inequality and gendered labor conditions, like Hunt, used the threat of fetal vulnerability to bring attention to conditions of working women, though she also sought to define the issue of hazardous chemical exposure to pregnant women as a broader issue of diverse reproductive outcomes experienced by both men and women.

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[9] Epstein, *Drugs of Abuse: Their Genetic and Other Chronic Nonpsychiatric Hazards*.
[10] Frickel, *Chemical Consequences: Environmental Mutagens, Scientist Activism, and the Rise of Genetic Toxicology*.

This contrasted with the more narrow concerns of employers, teratologists, and other pediatric specialists who had defined the study of environmental (non-genetic) causes of congenital malformation in the 1950s. Teratological research was rooted in the historical study of unusual anatomy that emphasized obvious physical anomaly or functional deficit shortly after birth as the outcome of primary concern. Also, teratologists who would form part of the Teratology Society (such as James G. Wilson and Robert L. Brent) were from a an older generation who had worked or were trained in the context of secretive Manhattan District projects studying human health hazards of radiation at the University of Rochester, coloring their work with concern for making truthful knowledge claims based on rigorous scientific practice, obvious clinically relevant disease, and pragmatic minimum worker safety standards, rather than industrial illness, social injustice, and exploitation.

At the heart of this debate was the question of how the environment of reproductive hazard should by defined: was the polluted workplace affecting all workers (typically, mutagenic risks) or exclusively the permeable body of a potentially pregnant woman (teratogenic risks)? Employers interested in reducing their liability and teratologists concerned with rooting out the "environmental" causes of severe developmental disability were unified in defining the environment as the permeable microenvironment of the uterus and emphasizing harm to the fetus or newborn as the outcome of concern (although teratologists often tried to de-emphasizing toxins as a source of childhood disability), while labor and women's rights activists framed the workplace and broader environment as the sites of reproductive toxicity for all. Some labor activists wanted to de-emphasize the technical issue of chemical toxicity in favor of other considerations, such as the fact

that most women excluded from hazardous work had no intention of getting pregnant or the importance of social programs intended to support working women. The work of Vilma R. Hunt and Jeanne M. Stellman, among others, served to expand research on reproductive health effects of industrial exposures on men and women and argued for making the workplace (and broader environment) safe for all. As part of this effort, they considered a broader range of reproductive hazards and outcomes than did teratologists, nevertheless helping to bring attention to pregnant women's bodies as the site in which occupational and other environmental risks should be mediated.

Vilma Hunt: Examining Conflicts Over Prenatal Chemical Effects Through the Career of an Environmental Scientist

Inspired by the legacy of female physicians, industrial hygienists, and toxicologists such as Alice Hamilton and Harriet Hardy, Vilma Hunt initially wanted to document radiation's accumulation in bone, teeth, and lung tissues, starting in the early 1960s. From her master's degree in physical anthropology and early research efforts at Harvard, she was involved with examination of human difference using anatomical measurements, particularly of teeth and skeletal material.[11] Thus to some extent, her early interests aligned with the anatomical engagements of teratologists.

[11] Vilma Hunt received her M.A. degree in physical anthropology in 1958 and started working at Harvard in 1961. A letter to Hunt from a scientists at the Fels Research Institute in 1963 discusses the finer points of how to grind teeth and variability in percent calcium among siblings. Stanley M. Garn to Vilma Hunt, 6 September 1963, Box 3, Folder 115, Vilma Hunt Papers. See also the autobiographical information from Box 1, Folders 1–2, Vilma Hunt Papers, particularly a Harvard University press release from 17 January 1964.

In a 1963 public relations piece on the Radcliffe Institute, Hunt is described as "a dental surgeon… studying measurement of radiation in bones and teeth."[12] She had come to the U.S. in 1951 to work at the Harvard-affiliated Forsyth Dental Infirmary, where she met a patrician physical anthropologist, Edward Eyre Hunt, Jr., whom she married after an abbreviated courtship (six weeks).[13] For a time, she devoted herself to teaching general anatomy and biology and raising four children. After taking an M.A. in physical anthropology at Radcliffe in the 1950s, she became a fellow at the Radcliffe Institute for Independent Study, an inaugural program intended to offer career growth opportunities for homemakers.[14] In her work, the overarching changes in environmental health research in the latter half of the twentieth century are also evident, as she started her research by documenting the body burden of low-level and chronic exposures to occupational toxins, cigarette smoke, or radioactive fallout, linking them to long-term effects of chemical pollutants, such as cancer, or subclinical effects—what environmental historian Christopher Sellers calls "a borderland of shadowy abnormalities and possible pathologies."[15]

Environmental health science is rooted in the history of industrial hygiene, yet allied health professions also played a role, such as scientists trained in

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[12] Deane Lord, "The Radcliffe Institute for Advanced Study," *Harvard Today*, August 1963. In Box 3, Folder 109, Vilma R. Hunt Papers, The Arthur and Elizabeth Schlesinger Library on the History of Women in America, Radcliffe Institute at Harvard University, Boston, MA.
[13] She married on April 13, 1952. Invitation, Box 39, Folder 5, Series III, Vilma R. Hunt Additional Papers (MC807), The Arthur and Elizabeth Schlesinger Library on the History of Women in America, Radcliffe Institute at Harvard University, Boston, MA.
[14] "Radcliffe Names 24 for Institute," *New York Times* June 5, 1961, 16.
[15] Sellers, *Hazards of the Job: From Industrial Disease to Environmental Health Science*, 11.

dentistry. Dentists had a curious role in occupational medicine and environmental health, linked to the early health effects of acute industrial heavy metal, phosphorus, and radium poisoning and the retention of these substances in bone and teeth. In the 1920s, occupational radium exposure had particularly devastating effects on the teeth and jaws of young female watch dial painters and proved an early arena for contested industrial science, public controversy over legal cases, and organizing around occupational health safety (and worker's compensation) for women, by organizations such as the National Consumers' League, as historian Claudia Clark has demonstrated.[16] The first deaths from radium poisoning in the 1920s involved anemia and infection of the bones, teeth, and tissues of the jaw (necrosis). Dentists seeking to alleviate the pain of oral deterioration would pull teeth, drain pus, and cut away the decaying bone, often to no avail.[17] Many of these women died quickly of acute disease, and few reproductive effects were recorded. Partially as a result of the publicity surrounding such industrial illness, workplace standards for radiation were implemented starting in the 1930s.

Nevertheless, with the creation of new radioactive isotopes, there was considerable uncertainty about how chronic exposures would affect workers such as uranium miners and physicists developing weaponry. Amelioration of some of the most egregious and obvious occupational poisoning and acute illness raised yet more

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[16] Claudia Clark, *Radium Girls, Women and Industrial Health Reform: 1910–1935* (Chapel Hill, NC: University of North Carolina Press, 1997).
[17] Ibid., 33–36. For a particularly compelling account of radium poisoning of the dailpainters, see Katherine Schaub's article in *Survey Graphics* on May 1, 1931 or William Sharpe's case study, "Radium Osteitus with Osteogenic Sarcoma: The Chronology and Natural History of a Fatal Case," *Bulletin of the New York Academy of Medicine* 47 (September 1971): 1059–82.

questions about less obvious effects and turned attention to teratogens and other reproductive hazards.[18]

In the 1950s, teeth would again play a role in efforts to monitor the effects of radioactivity, this time with respect to community-based exposures, to radioactive fallout or lead from paint, gasoline, or industrial sources, sponsored by early grassroots environmental groups (such The Greater St. Louis Citizen's Committee for Nuclear Information) seeking to document exposures to strontium-90 and lead.[19] As environmental health scientists grappled with the long-term effects of low-level radiation or other exposures, they tried to document the presence, or body burden, of radiation and heavy metals. Baby teeth were easy to collect and seemed likely to document population-level trends of radiation in teeth and bone that resulted from nuclear testing.

Hunt credits the Atomic Energy Commission with providing her first research funding, working with Edward P. Radford at the Harvard School of Public Health in 1961 on biomonitoring of alpha-emitting particles in teeth and bone and later on, polonium-210 in cigarette smoke[20] (in one case, she solicited teeth from

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[18] For instance, in the case of the radium watch dial painters, acute disease and death was sufficiently rapid that reproductive effects were not a major area of concern. However, by the early 1950s, there was funding for investigation of embryonic effects of radiation.

[19] The tooth survey was proposed by Danish biochemist Herman M. Kalckar in 1958. Reiss, "Baby Tooth Survey—First Results." Lillis F. Altshuller et al., "Deciduous Teeth as an Index of Body Burden of Lead," *The Journal of Pediatrics* 60, no. 2 (1962): 224–9; Herbert L Needleman, Orhan C. Tuncay, and Irving M. Shapiro, "Lead Levels in Deciduous Teeth of Urban and Suburban American Children," *Nature* 235, no. 5333 (1972): 111–2.

[20] For more on the debate about polonium and tobacco, see Brianna Rego, "The Polonium Brief: A Hidden History of Cancer, Radiation, and the Tobacco Industry," in *Science and the American Century: Readings from Isis*, eds., Sally Gregory Kohlstedt and David Kaiser (Chicago; London: The University of Chicago Press, 2013).

uranium miners, which required delicate interchanges with public officials indicative of government employees' desire for discretion about occupational radiation exposure in effort to avoid legal cases and public controversy).[21] By 1964, she was casting around for jobs but was offered the opportunity to extend her contract at Harvard, with hopes to take on new lines of inquiry such as tumors and radiation concentrations in the eyes of animals and polonium in sperm.[22]

Radford and Hunt's efforts to link lung cancer and polonium-210 in cigarettes were somewhat controversial. An unfavorable article about their work was published in *Medical World News* in 1966, "Theory Linking Lung Cancer to Polonium Goes up in Smoke," which provoked soul-searching and a relatively heated letter to the editor from co-authors Vilma Hunt, John B. Little and Edward P. Radford.[23] In a private exchange with Hunt, Radford remarked that this article made him paranoid that "the more tenable the hypothesis in lung cancer becomes, the more assiduously the devious minions of the tobacco industry try to discredit it."[24] These researchers present the problem as one of academic scientists diligently trying to expose man-made health risks despite the insidious efforts of researchers allied with industry to muddy scientific truth, a not uncommon narrative in the

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[21] A letter to Vilma Hunt from W. Clark Cooper, Chief of the Division of Occupational Health at the DHEW on August 9, 1962 notes that asking miners about their occupational history could be politically sensitive: "care would have to be taken to avoid explanation which might stir up public opinion. Such opinion might be stirred up by relating the tooth collection to the jaw necrosis of radium dial painters or by relating it to lung cancer." Box 3, Folder 115, Vilma R. Hunt Papers.
[22] Vilma Hunt to Mary [Polly] Bunting, 2 December 1964, Box 3, Folder 109: "HU/RI: Corres. 1963–72," Vilma R. Hunt Papers.
[23] Vilma Hunt, John Little, and Edward Radford to William H. White, circa August 1966, Box 41, Folder 201, Vilma R. Hunt Additional Papers.
[24] Edward Radford to Vilma Hunt, 4 December 1968, Box 41, Folder 201, Vilma R. Hunt Additional Papers.

history of environmental health sciences. Such interchanges expose how environmental health scientists saw their research as antagonistic to industrial investigators and their science, in contrast to teratologists who saw their role as advisors and consultants arbitrating questions of basic science and training representatives of pharmaceutical industry and government in teratological methodologies.

A more favorable article about Hunt's polonium research from the 1960s, "Will Your Cigarette Smoking Bring Harm to Generations of Children Yet Unborn," had been published in the *Boston Sunday Herald* in 1965, trumpeting the risks of smoking on unborn children.[25] The issue raised in this article concerned the germ-line effects of polonium. Radiation exposure and germ cell mutations had been constructed as a problem for prenatal development since at least the explosion of the atomic bombs in Japan, which summoned dark visions of monstrous children resulting from radiation exposure.

The journalist posed a question, noting the longstanding controversy over the effects of chronic low-level exposures to radiation: "[C]ould even a fractional increase in radiation, particularly from an intensely active element which this one is, be enough to alter these cells so as to cause birth defects or permanent damage through many generations?" These concerns were derived from the researchers, who wanted to demonstrate a link between plutonium exposure to lung cancer, rejected interpretations that there was a threshold under which radiation had no effect, and made allusions to genetic damage and impaired reproduction as an outcome of radiation exposure. Radford is quoted as follows: "The integrity of the reproductive

[25] Loretta Mclaughlin, "Will Your Cigarette Smoking Bring Harm to Generations of Children yet Unborn?," *Boston Sunday Herald* 1965.

tissue is one of our most precious possessions… [s]o it certainly behooves us to investigate what the genetic effect of polonium irradiation in humans may be."[26]

As was often the case, potential genetic mutations and damage to future generations were evoked as an uncertain concern, while teratogenic harm from high levels of radiation exposure, at least, was known and demonstrable. Geneticists such as William Schull and James V. Neel assumed that at least some mutations from acute radiation exposure *during* pregnancy had occurred in humans, in Japan after the atomic bombings and possibly from everyday use of therapeutic x-rays. However, teratology researchers were less certain about teratogenic effects. They were disinclined to extrapolate from animals to people; initially dismissed trace exposures as likely insignificant; and called for a careful and cautious interpretation of low-level chronic radiation, pharmaceutical, or low-dose chemical effects on the embryo or fetus.[27] For teratologists, this was related to the way they defined their disciplinary territory and their practical experience examining severe developmental disabilities in children and animals.

The threshold at which teratogenic effects from radiation was thought likely gradually lowered and physicians' uses of therapeutic and diagnostic x-rays during pregnancy declined slowly. Examination of the American College of Gynecology and Obstetrics guidelines show the phasing out of x-ray examination during pregnancy

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[26] Ibid.

[27] See Warkany's and Wilson's commentary at the 1953 symposium organized by Alexander Hollaender. Hollaender, "Introduction: Effects of Radiation and Other Deleterious Agents on Embryonic Development." Samuel P. Hicks, Regina C. O'Brien, and Alice A. Williams, "The Effects of Ionizing Radiation, Certain Hormones, and Radiomimetic Drugs on the Developing Nervous System," *Journal of Cellular and Comparative Physiology* 43, no. S1 (1954): 151–178; Regina C. O'Brien, E. C. Newcomb, Samual P. Hicks, "Developmental Malformations Produced by Radiation; a Timetable of Their Development," *The American Journal of Roentgenology, Radium Therapy, and Nuclear Medicine* 69, no. 2 (1953): 272–93.

in the 1960s, reflected in waxing and waning sections on radiation "precautions" and "hazards."[28] In the 1959 edition, an entire section was devoted to "Radiation Hazards" that detailed various sources of radiation exposure (natural background, man-made), tolerance doses, and precautions in radiation therapy. By the second edition, in 1965, a section on "Radiation Precautions" was curtailed to a half-page outline.

From the onset, environmental scientists evoked different research questions than teratologists. In general, teratologists were interested in questions of basic mechanisms of naturally occurring human and animal developmental defect and in developing vaccine, pharmaceutical, or vitamin therapies in the context of a growing genetic, biochemical, and molecular vision of human disease. Also, the empirical experience derived from the daily clinical work of pediatric physicians and mammalian laboratory experiments emphasized the vast range of severe structural and intellectual congenital disabilities of children, high doses necessary to produce anatomical malformations, and the messy biological complexity of human and animal malformation. Teratologists, versed in pediatric clinics and in animal experiment, called for greater attention to basic research or obvious clinical childhood disability in an effort to prevent or relieve such suffering. Environmental

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[28] ACOG guidelines demonstrate how use of x-rays moved out of mainstream practice and thus physicians' concern. The first 1959 *Manual of Standards in Obstetric-Gynecologic Practice* addresses radiation in some detail: Section X is on radiation hazards and evokes popular fears about fallout: "Fallout radiation following nuclear detonation has focused attention upon the risk of somatic and genetic injury following exposure to all types of radiation," (see 44–48). By 1974, the section was called radiation precautions (see 68–71). By 1982, the section on radiation precautions was much curtailed, consisting of less than one page (79). Practice guidelines were obtained from the American College of Obstetrics and Gynecology Library in D.C. The first edition is American College of Obstetrics and Gynecology, "Manual of Standards in Obstetric-Gynecologic Practice," (Chicago: ACOG 1959), 44–48.

scientists, after much of the most egregious acute workplace poisonings had been curtailed, wanted to root out the most sensitive humans and the underreported, understudied, or long-term effects of toxic industrial substances. To do so, they turned to the fetus.

Community-Based Lead Screening and Placental Permeability to Heavy Metals

During her brief tenure at Yale in their new department of environmental health from 1967–1969, Hunt taught radiation biology and a course on air pollution, while she researched respiratory physiology.[29] Inspired by work on childhood effects of lead by Baltimore- and Boston-based researchers J. Julian Chisholm and John Scanlon, after attending a New York conference on the topic in March 1969, she proposed a community-based program to identify lead poisoning in children.[30] As Christian Warren and other environmental historians have demonstrated, lead exposure in urban slums provided a venue for social-justice-oriented activism from some physicians and technical experts.[31]

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[29] Charles H. Taylor to Vilma R. Hunt, 25 January 1967, Folder 10, Box 23, Vilma R. Hunt Additional Papers.
[30] Vilma Hunt to Adrian M. Ostfeld, 7 April 1969, Box 63, Folder 10, Vilma Hunt Additional Papers, Schlesinger Library. See also, Scanlon, "Fetal Effects of Lead Exposure."; J. Julian Chisolm, Jr. and Harold E. Harrison, "The Exposure of Children to Lead," *Pediatrics* 18, no. 6 (1956): 943–58. J. Julian Chisolm, Jr., "Increased Lead Absorption: Toxicological Considerations," *Pediatrics* 48, no. 3 (1971): 349–52. Christopher Warren discusses this conference in New York, organized by the Scientists' Committee for Public Information (SCPI) and the New York Department of Health and chaired by the microbiologist-cum-environmentalist René Dubos, who made an impassioned plea for addressing lead poisoning, "if we don't eliminate this social crime, our society deserves all the disasters that have been forecast." Warren, *Brush with Death: A Social History of Lead Poisoning*, 193.
[31] *Brush with Death: A Social History of Lead Poisoning*.

Nevertheless collaborations between representatives of elite academic institutions and community programs for lead screening and treatment could be problematic. Shortly after the New York-based conference on lead poisoning, the director of a New Haven-based citizen's group called the Hill Action Group sent a charged letter to Paul Dubrai of the Scientists' Committee for Public Information challenging the "sacred and paternalistic domain of professionals" and calling for greater citizen participation, demonstrating both the compelling arguments made at the time about genocidal effects of industrial lead on children living in poverty and the challenge that anti-authoritarian radical movements of the New Left presented to elite institutions and structures of authority during the 1970s.[32]

Vilma Hunt's proposal for a collaborative community-based screening program for lead mentions the passage of heavy metals into fetal tissues. However, tensions between the university and the community members, particularly a group called Freedom Now, quickly became evident during politically turbulent times in a city with deep racial, class, and social divisions. In addition to conflict over professional authority, the main point of tension was a dispute about distribution of university funds promised to local activist groups involved in the screening program. Several years after her appointment at Yale, Hunt found a new position with her husband at the University of Pennsylvania, which would be her academic base for years to come.

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[32] For instance, "It is obvious that slow genocide is being perpetuated against our children. Genocide not only from lead poisoning, but emotional and social genocide." Margaret Leslie [of Hill Action Group] to Paul Dubrul, 29 March 1969, Box 63, Folder 10, Vilma R. Hunt Papers.

Pregnancy and Women in the Workplace During and After World War II

Hunt was not the only toxicologist or epidemiologist who had examined questions of occupational hazards to women in the workplace. As women had moved into war-related employment in the 1940s, employment in hazardous settings interested government and health professionals, though the imperatives of wartime did not favor protective legislation. A Department of Labor report from 1942 warned of certain toxic substances during pregnancy.[33] The Johns Hopkins University toxicologist Anna Baetjer was contracted to write a report for the Army Industrial Hygiene Laboratory on working women in the mid-1940s, as at least one third of women were engaged in paid employment outside the home, some of them in hazardous wartime manufacturing jobs. The report would inform government policy on working women during and after the war. [34]

Beatjer was preoccupied with comparative studies of working and non-working women; looking at stillbirth, abortion, infant mortality, prematurity and birth weight, an epidemiological project fraught with difficulties as the groups could hardly be considered equivalent. The resulting report was published in 1946. Like other reform-minded women industrial hygienists, Beatjer was skeptical of claims about women's inherent weakness or inferiority. Later, in 1955, British

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[33] The report warned of certain toxic substances to be avoided when pregnant, among them radioactive substances, phosphorus, benzene, nitrobenzene and its homologues, toluene, carbon disulphide, carbon monoxide, and chlorinated hydrocarbons. Women's Bureau Children's Bureau, "Standards for Maternity Care and Employment of Mothers in Industry," *Journal of the American Medical Association* 120, no. 1 (1942): 55–6. This report is referenced by Sullivan et al. in 1979. Sullivan et al., "Congenital Malformations and Other Reproductive Hazards from Environmental Chemicals."

[34] Anna M Baetjer, *Women in Industry: Their Health and Efficiency* (Philadelphia; London: W. B. Saunders Company, 1946).

epidemiologist and professor of social medicine Alice Stewart likewise tried to use epidemiology to compare pregnancy outcomes of mothers employed inside and outside the home, concluding that "occupations of mothers with dead babies did not appear to be either exceptionally dangerous or unusually exacting, even when compared with housework."[35]

Baetjer also wrote scathingly of the medical profession and the science of comparative studies between working men and women: "For the most part, the theory that women are more susceptible than men to occupational diseases has arisen by the repeated quoting in the literature of statements to this effect made by one or two industrial health authorities. In many cases, the statements represent only a personal opinion."[36] In general, she argued that women should be treated equivalently to men except when pregnant: "Since there is no very definite proof that women are more susceptible than men to the harmful chemical substances encountered in industry, there no reason why normal women should be restricted from working at jobs which involve the use of harmful chemical substances any more than men." Yet nevertheless, her overriding conclusion was that "[p]regnant women should not be allowed to work at occupations involving exposure to harmful chemical substances."[37] Lead, in particular, was known to be toxic to the fetus even when there was no demonstrable sign of toxicity in the mother, and some researchers (among them well-known lead toxicologist Robert Kehoe) thought that lead stored in blood, tissue, and bone could affect the health of a later pregnancy.

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[35] Alice Stewart, "A Note on the Obstetric Effects of Work During Pregnancy," *British Journal of Preventive and Social Medicine* 9, no. 3 (1955): 159–61.
[36] Baetjer, *Women in Industry: Their Health and Efficiency*, 146–47.
[37] Ibid.,155.

Baetjer acknowledged the difficulty of assessing the extent of occupational disease, attributing this to lack of attention that most physicians gave to it: "Many occupational diseases are chronic in nature and the employees may change their occupation before the symptoms appear. In many instances, the private physician does not ask about the industrial exposure and, for the most part, the medical profession is not familiar with many of the etiological agents encountered in the industrial environment."[38] In her view, workplace policies on employment of pregnant women should encourage disclosure rather than efforts to hide pregnancy, with the invisibility and vulnerability of the first trimester cited as the rationale.

Baetjer had many recommendations for improvement of working conditions for women, among them avoidance of certain toxic substances during pregnancy (lead, TNT, benzol, carbon monoxide, chloroform, phosphorus and mercury) because they might lead to abortion. In wartime America, "spontaneous" abortion, stillbirth, and infant mortality were still the major reproductive concerns of industrial hygienists.[39] This would change, however, as medicine, the state, and philanthropies turned to the problem of congenital malformation of children as a new arena for applied scientific medicine and epidemiological study after the war, highlighting preventable childhood disability and the prenatal period as a period of particular vulnerability and opportunity for medical intervention (see Chapter 1). With increasing workplace safeguards, acute maternal toxicity and associated miscarriages, stillbirth, or infant mortality were less likely, making questions about malformations or more subtle, long-term, or hard-to-trace harms possible.

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[38] Ibid., 144.
[39] "In addition to the effects of toxic chemicals on the mother, there are certain chemical substances which have a special effect on the uterus or on the fetus and thus lead to abortion." Ibid.

Increasingly, the effects of industrial exposures during pregnancy seemed insidious and likely to cause subtle fetal functional disability or cognitive impairment, rather than abortion, severe anatomical anomaly, or infant death.

Growing Sense of Fetal Vulnerability to Industrial Pollution and other Environmental Hazards

By the late 1960s, the issue of prenatal chemical exposures from industrial sources or herbicides/pesticides, or in community settings was proving inflammatory. In 1967, considerable medical and media speculation arose around whether LSD was causing chromosomal damage and birth defects.[40] Amid the politically volatile climate of the late 1960s, outrage about war in Vietnam incited claims that use of herbicides such as Agent Orange was causing birth defects in Vietnamese children and that the Army and U.S. government were seeking to hide or cover up reports of the teratogenic effect of 2,4,5-T or TCDD (a type of dioxin, 2,3,7,8-tetrachlorodibenzodioxin), components of the herbicide.[41] While information about congenital methylmercury poisoning causing cerebral-palsy-like symptoms Japan in the 1950s and early 1960s was relatively slow to trickle across borders, incidents of congenital poisoning with seed grain treated with organic mercury-

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[40] Robert Auerbach, "LSD: Teratogenicity in Mice," *Science* 170, no. 3957 (1970): 558; Lauretta Bender et al., "Chromosome Damage Not Found in Leukocytes of Children Treated with LSD-25," *Science* 159, no. 3816 (1968): 749; Maimon M. Cohen, Kurt Hirschhorn, and William A. Frosch, "In Vivo and in Vitro Chromosomal Damage Induced by LSD-25," *New England Journal of Medicine* 277, no. 20 (1967): 1043–9; J. A. DiPaolo and George J. Alexander, "LSD: Effects on Offspring," *Science* 158, no. 3800 (1967): 522; George J. Alexander et al., "LSD: Injection Early in Pregnancy Produces Abnormalities in Offspring of Rats," *Science* 157, no. 3787: 459–60; S. Irwin and J. Egozcue, "Chromosomal Abnormalities in Leukocytes from LSD-25 Users," *Science* 157, no. 3786 (1967): 313–14.

[41] Thomas Whiteside, "A Reporter at Large. Defoliation," *New Yorker* (1970), 32–69; *Defoliation* (New York: Ballantine Books, 1970); *The Withering Rain: America's Herbicidal Folly*, 1st ed. (New York: Dutton, 1971).

based fungicides were reported worldwide, and there was growing alarm, starting in the late 1960s and early 1970s, about the widespread mercury pollution of North American wildlife, lakes, and waterways which brought new attention to the Japanese experience (see Chapter 4).[42]

Though concerns about radiation had long permeated teratological research, members of the Teratology Society were principally involved in questions of pharmaceutical teratogenicity in the 1960s, but became increasingly engaged towards the end of the decade with questions about the effects of broader environmental chemical hazards on developmental disability. In the 1950s, Robert W. Miller had a fellowship in radiobiology at the University of Rochester (at which time Teratology Society members Thomas Shepard and Robert Brent were in medical training) and went to Japan in 1954 to serve as Chief of Pediatrics for the Atomic Bomb Casualty Commission (ABCC).[43] He subsequently completed a PhD in epidemiology and found work at the National Cancer Institute, and by the 1970s

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[42] H. Matsumoto, G. Koya, and T. Takeuchi, "Fetal Minamata Disease. A Neuropathological Study of Two Cases of Intrauterine Intoxication by a Methyl Mercury Compound," *Journal of Neuropathology and Experimental Neurology* 24, no. 4 (1965): 563–74; U. Murakami, "Embryo-Fetotoxic Effect of Some Organic Mercury Compounds," *Annual Reports of Research from the Institute for Environmental Medicine Nagoya University* 18 (1970): 33–43; Joan M. Spyker, " Methymercury, Mice and Men" (PhD Diss., University of Minnesota, 1971); Study Group on Mercury Hazards,"Hazards of Mercury: Special Report to the Secretary's Pesticide Advisory Committee, Department of Health, Education, and Welfare, November 1970," *Environmental Research* 4, no. 1 (1971): 1–69; Katherine Montague and Peter Montague, *Mercury*, (San Francisco: Sierra Club, 1971); Joan M. Spyker and M. Smithberg, "Effects of Methylmercury on Prenatal Development in Mice," *Teratology* 5, no. 2 (1972): 181–90; Frank D'Itri, "Sources of Mercury in the Environment," in *Environmental Mercury Contamination*, eds. Rolf Hartlung and Bertram D. Dinman (Ann Arbor: Ann Arbor Science Publishers, Inc., 1972); Patricia Ward D'Itri and Frank M. D'Itri, *Mercury Contamination: A Human Tragedy*, Environmental Science and Technology (New York: Wiley, 1977); Lars Friberg and Jaroslav J. Vostal, *Mercury in the Environment, an Epidemiological and Toxicological Appraisal*, (Cleveland: CRC Press, 1972).
[43] Brent, "In Memoriam: Robert Warwick Miller."

was consulting on post-disaster surveillance and follow-up such as the 1976 dioxin leak in Seveso, Italy.[44]

As President of the Teratology Society in 1970, Robert W. Miller wrote an address drawing attention to several controversial media reports about chemical safety that arose that year regarding cyclamates, MSG, oral contraceptives, and herbicides such as picloram and Agent Orange (the active components of the herbicide were 2,4,5,-T and 2,4-D, and it was sometimes contaminated with TCDD[45]). In 1969, a publication by the Mrak Committee on pesticide research outlined how pesticides could induce cancer, mutations, and congenital malformations and urged further efforts to monitor such effects. Robert W. Miller's address, published in *Teratology,* emphasized the propagation of unreliable media reports about chemical safety that demonstrated national interest in teratogenic effects and the accompanying epidemiological efforts to thoroughly examine unusual clusters of birth defects that might be linked to specific chemicals.[46]

By 1973, Robert W. Miller organized a conference on behalf of The Committee on Environmental Hazards of the American Academy of Pediatrics and the National Cancer Institute. The symposium was titled the *Susceptibility of the Fetus and Child to Chemical Pollutants.*[47] If some teratologists had sought to confine their field and

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[44] See the edited volume Robert W. Miller helped publish, *Plans for Clinical and Epidemiological Follow-up after Area-Wide Chemical Contamination: Proceedings of an International Workshop*, Washington D.C., March 17–19, 1980.
[45] Herbicide mixes were used as a defoliant in Vietnam between 1961 and 1971. 2.4.5-T was banned for most domestic uses in the U.S. by April 1970 due to concerns about teratogenicity that remained controversial. Jeanne M. Stellman et al., "The Extent and Patterns of Usage of Agent Orange and Other Herbicides in Vietnam," *Nature* 422, no. 6933 (2003): 681–87.
[46] Miller, "Teratology in 1970: The National Scene."
[47] Miller, "Susceptibility of the Fetus and Child to Chemical Pollutants." See also the articles in May 1974 *Pediatrics* supplement, volume 53.

disciplinary territory to physical malformations evident at birth, scientists from various disciplines called for consideration of more diverse and subtle outcomes when investigating questions of prenatal exposures and reproductive hazards.[48] As one participant commented, surely Japan was not the only country where industrial pollution had adversely affected the fetus.[49]

Robert W. Miller was a public health epidemiologist whose work was more oriented towards teratogenic substances in the broader environment than that of many members of the Teratology Society who practiced experimental teratology. Nevertheless, environmental health researcher Peter Infante described him as cautious and skeptical about the claims of the next generation of environmental scientists about teratogenic or carcinogenic effects, such as his mentee, Joseph Wagoner.[50] Miller was also critical of publications written by consumer advocates concerned about food additives, such as James S. Turner's *The Chemical Feast*. Turner argued that all chemicals demonstrated to be teratogenic in animals should be removed from the market, which struck Miller as folly and not grounded in experimental teratological knowledge of dose effects or species variability. In his review of the book, Miller remarked that there was room for a review of FDA policies that was dispassionate and more balanced, systematic, organized, thorough, and

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[48] Scanlon, "Fetal Effects of Lead Exposure." Joseph F Fraumeni, "Chemicals in Human Teratogenesis and Transplacental Carcinogenesis," *Pediatrics* 53, no. 5 (1974): 807–12; Strobino, Kline, and Stein, "Chemical and Physical Exposures of Parents: Effects on Human Reproduction and Offspring."
[49] "it seems unlikely that Japan is the only country in the world where pollutants in the external environment are harmful to the fetus." Fraumeni, "Chemicals in Human Teratogenesis and Transplacental Carcinogenesis," 811.
[50] Interview with Peter Infante, June 18, 2015.

grounded in biochemical and embryological knowledge—Turner's account being none of these.[51]

"The Strength and Vigor of the Race:" Eugenic Rhetoric and Workplace Protection Policies

In the 1970s, Vilma Hunt participated in legal and political debates about occupational health and private policies restricting fertile women from working in certain hazardous settings. Of course, protective labor policies limiting hours or excluding women from particularly hazardous work environments were long standing since at least the Progressive Era, and upheld by the courts in cases such as *Muller vs. Oregon* (in 1908), which supported reducing working hours for women on the basis of the preserving "the strength and the vigor of the race."[52] Childbearing and rearing had long been used as justifications for tacit practices excluding women from paid employment, early labor legislation was often directed at limiting hours and dangers to women and children, and working women often faced (and still face) the issue of "double duty," taking on both paid employment and a greater share of childcare and housework.[53]

In a speech about protective policies given at Smith College, "Protection of Workers Health," Hunt cited lead, benzene, and radiation as case studies of occupational exposures hazardous to pregnant women. She estimated that eighteen

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[51] Robert W. Miller, "Review: The Chemical Feast," *Teratology* 4, no. 3 (1970): 381–2.
[52] This Supreme Court case dealt with an Oregon statute that limited working hours for women to 10 hours a day. Dubow, *Ourselves Unborn: A History of the Fetus in Modern America*. 121. See also, Mary E. Becker, "From Muller V. Oregon to Fetal Vulnerability Policies," *The University of Chicago Law Review* (1986): 1219–1273.
[53] Hepler, *Women in Labor: Mothers, Medicine, and Occupational Health in the United States, 1890–1980*.

countries had protective labor legislation in effect for lead, mercury, phosphorus and arsenic by the early part of the twentieth century. She also noted that at the International Association for Labor Legislation, held in 1910, Italy and Austria among other countries, argued, "For the good of the race women must be forbidden to work in the printing trades, since the danger of lead poisoning is too great and not only are women susceptible, but the results are transmitted to their offspring," while others (Britain) resisted excluding women from such employment.[54]

This quote illustrates how in the early part of the twentieth century eugenic rhetoric was used to justify exclusion of women from certain jobs and improving workplace conditions for some women in industrial settings. In contrast to these eugenic interpretations of occupational hazards, which conceptualized workplace hazards to pregnant women as a "race poison"—a problem for the well-being of the collectivity and the quality of the population—after midcentury, concerns about the effects of pollution or occupational hazard on pregnant women were more often directed at liability associated with malformation of individual (innocent) fetal bodies. This reflected the particular socio-political climate of postwar American emphasis on liberal individualism, characterized by medical attention to the pathology of individual bodies, an active legal and tort trial landscape, and an

[54] Lecture on occupational hazards during pregnancy given at Smith College, "Protection of Workers Health," at *A Conference on Protective Legislation and Women's Jobs: Reevaluating the Past and Planning for the Future* on November 3–5, 1977. Box 7, Folder 325, Series IV, Vilma R. Hunt Papers. See also Alice Hamilton and Charles H. Verrill, "Hygiene of the Printing Trades," (Washington, DC: U.S. Department of Labor, Bureau of Labor Statistics, 1917), 59.

emphasis on individual choices and rights (seen as the democratic free-market alternative to the communitarian values of communism and fascism).[55]

Hunt points out that by the mid-1950s, "radioactive fall-out contaminated the whole world with the deposition of strontium-90 in the skeletons of every living person and there were demands for more detailed understanding of the biological effects of internally deposited radioactive material."[56] Animated by latent concerns about radiation and widespread industrial contamination, occupational settings proved a site of considerable debate about prenatal exposures, which eventually shifted concerns about occupational risks to families and communities to issues of industrial pollution in the broader environment. By the 1970s, corporate exclusionary practices targeting fertile women were often aimed at limiting legal liability associated with fetal harm, as more women (at least 43%[57]) joined the paid workforce. In her 1977 speech at Smith College, Hunt noted that "discussion surrounding the proposed lead standard during the past year would seem to indicate that there will be acceptance of a risk of biological damage to some people as well as efforts to exclude some 'susceptible' groups, and that economic considerations are more likely to prevail."[58] She provided an overview of effects on the reproductive system, emphasizing that information on male reproduction was sparse. Among the

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[55] James T. Patterson, *Grand Expectations: The United States, 1945–1974* (New York: Oxford University Press, 1996).
[56] Lecture on occupational hazards during pregnancy given at Smith College, "Protection of Workers Health," at *A Conference on Protective Legislation and Women's Jobs: Reevaluating the Past and Planning for the Future* on November 3–5, 1977. 38–39, Box 7, Folder 325, Series IV, Vilma R. Hunt Papers.
[57] The estimated rate of women (age 16 years or older) participating in the labor force was 34% in 1950, 38% in 1960, and 43% in 1970 and 51% in 1980. Mitra Toossi, "Century of Change: The U.S. Labor Force, 1950–2050, A," *Monthly Labor Review* 125 (2002): 22.
[58] Ibid,, 7.

conditions she cited as related to occupational lead exposure were irregular menstruation, sterility, reproductive loss, and mutagenic effects on male and female germ cells.

Hunt also provided a detailed examination of placental characteristics, including its permeability and maternal and fetal transfer of toxic substances based mainly on acute poisonings, concluding "we have no adequate quantitative information on human exposures to develop a dose response relationship for these conditions during pregnancy, so that choice of 'safe' maternal blood lead level is currently impossible."[59] Furthermore, she stated, "Lead is a toxic substance, which adversely affects biological systems. No human being is immune to its toxic effects."[60] If teratologists wanted to emphasize *in utero* environmental causes of severe anatomical developmental disability, Hunt wanted to broaden these risks and outcomes, despite her own apparent expertise on occupational reproductive risks particular to pregnancy.

Protecting Fetuses in the Workplace, an Old or New Problem?

One of the enigmas about the growing tensions over susceptibility of the fetus to a range of teratogens was that the knowledge that substances could pass through the placental barrier and affect the fetus wasn't particularly new, but it wasn't controversial until at least the 1960s. In a textbook of pediatrics published in 1950, Josef Warkany remarked, "It is true that in mammals the prenatal development protected to great extent, since it takes place in the uterus of the mother. The

[59] Ibid, 17.
[60] Ibid, 19.

protection, however, is not complete. Mechanical, actinic, chemical, nutritional and infectious agents must be considered as possible causes of prenatal injury."[61] Given the widespread awareness of occupational and other environmental hazards to the fetus detailed and described in professional literature in the 1950s and 1960s, why did corporate fetal protection policies become so contentious only in the early 1970s?

Legislative protection policies had been cast aside in 1964 with the Civil Rights Act, women had been entering paid employment in greater numbers for decades, and private fetal protection policies had been around since at least the 1950s.[62] Conflict over fetal protection in occupational settings could be interpreted as resulting from the women's rights movement, rising public concerns about industrial pollution, and negotiation over the implications of the Occupational Health and Safety Act of 1970. This legislation was intended to create a workplace free from hazards and established government regulatory and research agencies concerned with occupational health, among them the Occupational Safety and Health Administration (OSHA) and the National Institute of Occupational Safety and Health (NIOSH). Provisions in this legislation and the Toxic Substance Control Act of 1976 stated a worker or consumer's right to know about hazardous substances to which they were exposed.[63]

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[61] Nelson and Mitchell, *Mitchell-Nelson Textbook of Pediatrics*, 271.
[62] Hepler, *Women in Labor: Mothers, Medicine, and Occupational Health in the United States, 1890–1980*, 124; Vilma R Hunt, "The Emergence of the Workers' Right to Know of Health Risks," in *Strategies for Public Health: Promoting Health and Preventing Disease*, eds., Lorenz K. Y. Ng and Devra L. Davis (New York: Van Nostrand Reinhold, 1981); "A Brief History of Women Workers and Hazards in the Workplace," *Feminist Studies* (1979). Dubow, *Ourselves Unborn: A History of the Fetus in Modern America*; Warren, *Brush with Death: A Social History of Lead Poisoning*.
[63] Hunt, "The Emergence of the Workers' Right to Know of Health Risks."

Ultimately, concerns about fetal susceptibility were also linked to debates about abortion and the rise of reformist voices critical of existing social structures in a rapidly changing society, taking aim at medical authority, patriarchy, and industrial damage to the environment, workers, and surrounding communities. The anti-authoritarian social justice youth movements of the civil rights era spawned a number of diverse, polemical, and vocal perspectives by the late 1960s. Environmentalists decried environmental degradation and posited that subtle health effects could result from low-level imperceptible exposures, despite considerable faith sometimes in techno scientific solutions. Consumer advocates such as Ralph Nadar and Sidney M. Wolfe, and organizations such as Center for Science in the Public Interest and the Public Citizen's Health Research Group called for safer consumer products and more democratic policies towards scientific research. Women's "liberation" groups advocated for educational opportunity, economic empowerment, greater control over their medical care, and the banishment of certain ideals of femininity.[64] Within a couple of decades, common expectations that childbearing and childrearing would be the primary responsibility of most women were challenged, leading to a range of negotiated approaches to caring for children and paid employment for women.[65] Inextricably linked to ideas of fetal vulnerability and women's control over their reproductive capacity and working life, debates over the legality and morality of abortion brought the fetus into the public

[64] Ruzek, *The Women's Health Movement: Feminist Alternatives to Medical Control*.
[65] Plant, *Mom: The Transformation of Motherhood in Modern America*.

arena.[66] This public and baby-like fetus also proved a useful political tool for environmentalists and geneticists.

In addition to growing environmental concerns and conceptualizations of industrio-chemical pollution, the contention over fetal protection policies was implicitly linked to growing fetal patient and personhood. Several events of the early 1970s raised issues about the morals and ethics of science, appropriate medical care for women, the threat of damaged children and future generations, and the health and well-being of a public, vulnerable, and baby-like fetus. First, in 1971, physicians in Boston noticed an exceptionally rare form of vaginal cancer in several young women and linked it to a synthetic estrogen, diethylstilbestrol (DES), prescribed to their mothers from the 1950s in effort to prevent spontaneous miscarriage.[67] The inappropriate administration of hormonal substances during pregnancy in misguided efforts to prevent miscarriage and the possibility for transplacental cancer and other related reproductive health effects would galvanize women's health advocates outraged by the apparent negligence of the (then mostly male) medical profession and raise many questions about subtle or long-term reproductive harms.[68]

Second, there was ongoing tension over access to medical abortion, only partially resolved by the Supreme Court's decision legalizing medical abortions on the grounds of the private relationship between a woman and her doctor in *Roe vs.*

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[66] A hint of debates about prenatal diagnosis and abortion can be seen in articles such as Walter Sullivan's *New York Times* article on June 13, 1970. Walter Sullivan, "Wider Detection of Prenatal Flaws Expected to Spur Abortions," *New York Times* June 13, 1970.
[67] Arthur L. Herbst, Howard Ulfelder, and David C. Poskanzer, "Adenocarcinoma of the Vagina: Association of Maternal Stilbestrol Therapy with Tumor Appearance in Young Women," *New England Journal of Medicine* 284, no. 16 (1971): 878–81.
[68] Bell, *DES Daughters: Embodied Knowledge and the Transformation of Women's Health Politics*; Langston, *Toxic Bodies: Hormone Disruptors and the Legacy of DES*.

Wade in 1973.[69] The conflict over abortion is often credited with raising imagery and the status of a baby-like fetus as a politically contentious person and patient.[70] The NIH banned federal support for research using fetal material shortly afterwards.[71] Third, in 1973 Kenneth Jones and David Smith reported a particular constellation of dysmorphology and intellectual disability in children born to severely alcoholic (and socially disenfranchised) women in Seattle.[72]

Highly sensational accounts of iatro-chemical harm to fetuses raised the prospect that pregnancy was an uncertain and potentially dangerous period for a child-to-be (often painting pregnant women as untrustworthy or feckless), even as prenatal diagnosis and medical abortion within families with high possibility for genetic illness such as hemophilia or Tay-Sachs were increasingly practiced to avoid the birth of children with severe disabilities.[73] These medical and legal events occurred in a backdrop of pessimism about the future and growing economic uncertainty characterized by the rising inflation and unemployment, and the oil

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[69] Reagan, *Dangerous Pregnancies: Mothers, Disabilities, and Abortion in America*; *When Abortion Was a Crime: Women, Medicine, and Law in the United States, 1867–1973* (Berkeley: University of California Press, 1997).
[70] Petchesky, "Fetal Images: The Power of Visual Culture in the Politics of Reproduction."; Petchesky, *Abortion and Woman's Choice: The State, Sexuality, and Reproductive Freedom*.
[71] Teratologist Thomas Shepard and colleague Stephen Hauschka wrote to *Science* in 1973 in dismay at the prospect that fetal research would be curtailed. Stephen D. Hauschka and Thomas H. Shepard, "Human Fetal Research," *Science* 182, no. 4119 (1973): 263–85. See also, "Row over Fetal Research," *Newsweek* 1974, 74. For more on the ethics of fetal research see Emily K Wilson, "Ex Utero: Live Human Fetal Research and the Films of Davenport Hooker," *Bulletin of the History of Medicine* 88, no. 1 (2014): 132–60; Paul Ramsey, *The Ethics of Fetal Research* (New Haven: Yale University Press, 1975).
[72] Kenneth L. Jones and David W. Smith, "Recognition of the Fetal Alcohol Syndrome in Early Infancy," *The Lancet* 302, no. 7836 (1973): 999–1001.
[73] Reagan, *Dangerous Pregnancies: Mothers, Disabilities, and Abortion in America*. Cowan, *Heredity and Hope: The Case for Genetic Screening*; Lindee, *Moments of Truth in Genetic Medicine*.

embargo and energy crisis of 1973-1974. Despite this economic downturn, the Equal Employment Opportunity Commission (EEOC) was actively encouraging companies to increase employment of women workers to comply with the Civil Rights Act of 1964.

Since 1972, the National Institute for Occupational Safety and Health (NIOSH) had been publishing criteria documents, technical publications on workplace hazards, starting with asbestos and beryllium and later heavy metals, such as inorganic lead and mercury. Several feminist occupational health researchers reviewed these documents and noted the deficiency of information on prenatal and pregnancy-related risks. Jeanne M. Stellman reviewed the mercury document in 1972, noting that chromosomal effects and symptoms in pregnant women were lacking in the review documents and criticizing the omission, "The standard does not mention exposure in women and the possibility of fetal damage, even in asymptomatic women... Concentration of mercury in the blood of the fetus is 20% higher than that of the mother... Pregnant women should probably not be exposed to mercury at all. At the very least, the standard should mention the special condition of pregnant women."[74] According to labor scholar Andrea Hricko in 1975,

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[74] Jeanne Stellman to Herbert H. Christensen, Deputy Assistant Institute Director of Research and Standards Development, 8 November 1972, 2, Box 14, Folder 1, "Mercury Survey, 1972," Jean Mager Stellman Papers, 1970–1990, Arthur and Elizabeth Schlesinger Library on the History of Women in America, Radcliffe Institute for Advanced Study, Harvard University, Boston, MA. The same folder contains her annotated comments on the review questions provided by NIOSH, with questions such as: "Are there any other toxic effects, such as sensitization, carcinogenic, mutagenic, teratogenic, or psychogenic effects, for which mercury may have been implicated as a cause and which should be considered as a basis for the environmental standard?" (she annotated mutagenic and teratogenic with "low level chromosomal damage – non-symptom[atic] mothers") National Institute for Occupational Safety and Health, "Review Questions for the Criteria Document for a Recommended Standard for Occupational Exposure to Mercury and Mercury

the lead document did not mention prenatal or chromosomal effects. Other criteria documents did cover this area, albeit briefly.[75] In essence, Stellman, Hricko, Hunt, and their colleagues wanted to use the highly political threat of harm to fetuses to make the invisible visible, both toxins, fetuses, and women workers: "The shadow workforce in the U.S. is the woman worker, whose presence has been scarcely acknowledged in any of the criteria documents so far published… the pregnant worker appears to be completely invisible although they frequently work to term in hospitals, on assembly lines, and many other work settings."[76]

Thus it was sometimes feminists who asked for greater scrutiny and attention to potential occupational and other risks to pregnancy and the fetus. Hunt was concerned with women's economic opportunity amid a burgeoning second-wave feminist movement ('women's liberation') in the 1960s that emphasized education and employment for women and rejected expectations about feminine behavior and ideals imposed by a society that seemed sexist and patriarchal.[77] Common in many

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Compounds," October 21, 1972. Box 14, Folder 1, Jean Mager Stellman Papers, Schlesinger Library.

[75] Andrea Hricko to Vilma Hunt, 11 February 1975, Box 7, Folder 306, Vilma R. Hunt Papers.

[76] Vilma Hunt, Hand-written untitled notes from a speech draft, Box 68, Folder 11, MC807, Vilma R. Hunt Additional Papers.

[77] Second-Wave feminism was a diverse movement with wide-ranging perspectives and considerable internal disagreements about how women's empowerment should proceed. Betty Friedan's *Feminine Mystique* (1963) voiced the frustrations of millions of disgruntled homemakers with words such as I "thought there was something wrong with me because I didn't have an orgasm waxing the kitchen floor." Quote from article in Folder 43, Barbara Seaman Papers, Schlesinger Library. *Ms*, published from 1970, provided a venue for discussing women's rights, equitable employment, and reproductive autonomy. There were also more radical feminist voices which rejected institutions such as marriage. For instance, Shulamith Firestone's *Dialectic of Sex* (1970) argued for emancipation of women from childbirth "and the tyranny of the biological family" via artificial wombs, what J.B.S. Haldane had called 'ecotogenesis.' Rosen, *The World Split Open: How the Modern Women's*

of these critiques was a left-leaning skepticism about consumerism and a rejection of popular culture and corporate advertising that portrayed women as housewives fulfilled by shopping, fashion, cooking and nurturing children. Hunt's involvement in debating fetal protection policies was implicitly linked to this sense of the injustice of excluding fertile women from economic opportunity yet also raised many questions about the dangers that workplaces might pose to fetuses.

Many feminists, particularly more radical voices, called for a more participatory approach to science and medicine. Self-help-oriented clinics and collectives which had opened in various cities advocated for women to have more involvement and control over their medical care, seeking to vernacularize technoscientific tools and politicizing medical assumptions about women's healthcare and reproduction. Espousing a particular type of identity politics, one argument from members of the women's health movement was that the lived experiences of women had a particular value as knowledge claims that patriarchal science and male-dominated medical professions typically denied or overlooked (sociologists call the women's health movement an "embodied health movement"). One result of this movement was that some women patients (such as DES daughters) were more interactive, knowledgeable, and involved in medical decision making even as they were skeptical of medicine. Indeed, medical practices changed considerably in the 1970s as a result of these critics, as activist voices created new negotiated approaches to women's healthcare.[78]

Movement Changed America; Hanson, *A Cultural History of Pregnancy: Pregnancy, Medicine, and Culture, 1750–2000*.

[78] Bell, *DES Daughters: Embodied Knowledge and the Transformation of Women's Health Politics*.

In contrast to these lay health movements, Hunt remained an elite and highly trained technical expert with training and funding from institutions such as Harvard School of Public Health, Argonne National Laboratory, and the Atomic Energy Commission, but she was interested in expanding women's job prospects in science, increasing their economic opportunities, and improving labor conditions. She was a member of Women's Equity Action League (WEAL), a splinter group of the National Organization of Women founded by women professionals in Cleveland in 1968, which emphasized women's education and economic empowerment (with less of a focus on reproductive rights).[79] Hunt was also sensitive to community concerns about environmental health. As a feminist health scientist she bridged the concerns and knowledge claims of experts and lay health activists.

Hunt described public fears about occupational exposures at the mid-year meeting of health physicists in 1974 as follows: "Whether we like it or not, we are having to respond to the rational and irrational fears of the public concerning radiation. It is no different, really, when we have the most sophisticated laboratory technician who knows it all, but she still has a mother and a mother-in-law, a husband, etc., so we are having to respond to their fears as well."[80] In her depiction, female workers might be informed and inclined to dismiss small risks, but family members, public fears, and other kin would attempt to constrain her behavior, even if it was well within the limits then understood to be harmless.

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[79] WEAL's records and audio recordings are also at the Schlesinger Library, though they were not consulted extensively for this work.
[80]"Transcript from the Mid-Year Health Physics Meeting: Occupational Exposure of Women to Radiation, Biological and Legal Parameters" 10, Box 7, Folder 304, Vilma R. Hunt Papers.

She shared these concerns with Clara Schiffer, who was a health analyst for the Department of Health, Education and Welfare (DHEW), and also a member of WEAL. Schiffer was raised in Massachusetts by Eastern European Jewish parents and attend Radcliffe during the depression era, working odd jobs in factories to help with expenses. She graduated in 1932 and found work in the Farm Security Administration. She had an acute interest in working women, compiling a collection of historical photographs of women working that she later donated to the Schlesinger library.[81]

Schiffer and Hunt met some time in the beginning of 1974, and together prepared a document on the occupational health problems of pregnant women that alerted many to the potentially volatile social issues related to occupational health hazards for pregnant women.[82] In Vilma Hunt's account, Clara Schiffer hunted her down at WEAL and scraped together funds to publish a report on pregnant women and occupational settings.[83] Initially, it seemed that their work to document the health hazards that pregnant women could encounter in occupational settings provided fodder for workplace practices excluding fertile women from certain highly paid jobs.

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[81]Clara Goldberg Schiffer photography and print collection documenting working women, 1839–1994, Schlesinger Library, Radcliffe Institute, Boston, MA.
[82]Vilma R. Hunt, *Occupational Health Problems of Pregnant Women: A Report and Recommendations for the Office of the Secretary, Department of Health, Education and Welfare, April 30, 1975* (University Park: Pennsylvania State University, 1975).
[83] Untitled draft of a retrospective speech given by Vilma Hunt at Schlesinger Library, circa 1996–7. Box 60, Folder 125, MC807, Vilma Hunt Additional Papers.

Drawing Attention to Occupational Hazards of Pregnant Women

The first evidence of Vilma Hunt's involvement with fetal protection policies was at a heated session at a meeting of the Health Physics Society (founded in 1956) on "Occupational Exposure of Women to Radiation: Biological and Legal Parameters" at a conference in Knoxville Tennessee in 1974. This was a lively discussion of workplace standards and the risks of occupational exposures to pregnant women. The National Council on Radiation Protection had issued guidelines in 1971 limiting occupational exposure of expectant mothers to 0.5 rem, effectively treating the unborn as a member of the public involuntarily brought into the workplace. In addition to long-standing tacit exclusion practices, private exclusionary policies explicitly aimed at restricting the employment of potentially pregnant women in hazardous settings had been in existence at least since General Motors implemented such a policy in 1952.[84] However, Title VII of the Civil Rights Act of 1964 excluded discriminatory practices based on gender, policed by the EEOC. Among Vilma's papers was a 1973 legal brief by Eve Cary, "Pregnancy without Penalty," addressing legal protections of working pregnant women.[85] If Hunt and Schiffer seemed to be acting independently to raise awareness of occupational hazards to pregnant women, they were part of a broader feminist preoccupation of the era with gender equity in employment and maintaining both employment and safety working conditions for pregnant women.

By 1974, the Lead Industries Association issued a recommendation similar to the one on radiation protections that advised that fertile women be excluded from

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[84] Hepler, *Women in Labor: Mothers, Medicine, and Occupational Health in the United States, 1890–1980*.
[85] Eve Cary, "Pregnancy without Penalty," *Civil Liberties Review* 1 (1973): 31. In Box 8, Folder 370, Vilma R. Hunt Papers.

jobs where they would be exposed to lead.[86] However, amid contested science of fetal risks, the thorny issue of workplace protection policies was not easily resolved. In general, these perspectives either framed the problem narrowly as one of pregnancy and teratogenesis or emphasized mutagenesis, long-term transplacental carcinogenesis, and a broader framing of reproductive susceptibility and hazards that implicated male reproduction and embraced uncertain or understudied questions about industrial impacts on development and human health. Anonymous participants in this meeting sometimes thought protection policies were reasonable, highlighting teratogens and transplacental carcinogens during pregnancy as the primary area of concern. Some perceived that a women's-rights perspective ignored the biological realities of fetal susceptibility. Alternatively, some emphasized the uncertainty of understudied reproductive effects, the apparent inadequacy of test systems to identify hazards, and a broader view of human susceptibility and reproductive risk (particularly mutagenesis) in diverse professional settings.

For example, one unidentified participant at that mid-year health physics meeting in 1974 portrayed the issue as a problem of new women's rights perspectives that were challenging long-standing practices that had protected the fetus: "During the 35 years I was at Oak Ridge we became aware that we had to deal with this problem; we didn't have the women's rights issue so strong at the time so our decision was—at least in the Health Physics Division (which influenced other sectors) not to allow women to work in jobs where there was a potential for high exposure, e.g., in the old reactor pushing fuel out of the channels, where a person would get a high exposure which was difficult to measure…perhaps I am still old-

[86] Dubow, *Ourselves Unborn: A History of the Fetus in Modern America*, 120-21.

fashioned enough to believe in the rights of the fetus. I think the practice should continue."[87] The same speaker argued that the issue of concern was not genetic risk, thought to be more of a concern for male workers, or teratogenesis, but rather transplacental carcinogenesis based on the work of Alice Stewart, and as such, the radiation exposure should be kept as low as possible.

In contrast, another participant replied as follows, highlighting various occupational risks and contradictory workplace policies: "Radiation is not the only problem. The natural rate of congenital abnormalities is about 3%. Operating room nurses and anesthesiologists are now shown to have higher prevalence of congenital abnormalities possibly due to anesthetic gases in their working environment. There are numerous studies on smoking and alcohol during pregnancy. There are so many everyday risks for the fetus on its long journey that I just do not understand the propriety and wisdom of worrying about this small consequence – which is only a small part of the total risk to the infant."[88] This perspective emphasized the diverse risks associated with human development, in an effort to minimize the possibility of harm from fetal exposures in the workplace. Such arguments drew on the science of risk factor epidemiology, mutagenesis and genetic toxicology, and laboratory studies in animals, debating the relative effects of various risks to the fetus.

Another participant noted the widespread perception among women workers that such practices were illogical and discriminatory in nature, intended to exclude fertile women from some of the more highly-paid jobs: "A lot of women, especially militant ones, make the assumption that discrimination is a factor in our decision,

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[87] Transcript of the Mid-Year Health Physics Meeting, 1974, 4. Box 7, Folder 304, Vilma Hunt Papers, Schlesinger Library.
[88] Ibid, 5.

so that those of us who are trying to take care of workers must also defend ourselves against the people we are trying to protect."[89] In this framing, the conflicts over fetal protection came from more informed and vocal women workers. Voices critical of science and medicine called for more citizen input in public policy decision making, even on highly technical topics. Yet these debates raised questions of the extent to which lay citizens, patients, and workers were capable of weighing in on matters that were highly technical in nature. To what extent did fertile women and fetuses need to be protected?

Environmental feminists called into question many of these assumptions about pregnant workers and shifted the terms of the debate about teratogenic effects.[90] Employers and many health scientists conceived of fertile working women and their potential children as vulnerable and in need of protection from chemical hazards, which was in conflict with vocal advocacy from many women who either rejected such a narrow focus on chemical hazards or called for approaches to reproductive hazards that considered effects on male reproduction, made the workplace safe for all workers, and provided information and a range of choices for potentially fertile women rather than exclusion for highly paid employment.

Vilma Hunt, Andrea Hricko, and Jeanne Stellman, among other feminist voices, argued that many occupational settings could be unhealthy for pregnant

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[89] Ibid., 13.

[90] For feminist perspectives on fetal protection policies, see *Feminist Studies,* Vol. 5. For instance, Hunt, "A Brief History of Women Workers and Hazards in the Workplace," *Feminist Studies* 5 (1979): 274–85 or Wendy Chavkin, "Occupational Hazards to Reproduction: A Review Essay and Annotated Bibliography," *Feminist Studies* 5 (1979): 310–325. The San Francisco-Based Coalition for the Medical Rights of Women also formed a Committee against Reproductive Hazards and published on fetal protection policies in their newsletter *Second Opinion*, July 1981. See Box 12, Folder 6, Jeanne Mager Stellman Papers.

women. They further pointed out that occupational hazards could affect the reproductive potential of both sexes, not strictly poisonous places in factories but also settings where the employment of women was more socially sanctioned, such as healthcare and hair salons.[91] Studies of miscarriages and birth defects among anesthesiologists and nurse anesthetists conducted initially the U.S.S.R. in the 1960s seemed to suggest that there were harmful effects on pregnant women and their fetuses from these occupational settings, such as miscarriages or birth defects, though follow-up studies provided conflicting results.[92]

Schiffer and Hunt considered carefully the issues raised by portraying pregnant women and fetuses as particularly vulnerable to occupational toxins in order to draw attention to hazardous conditions encountered by working women. In November 1974, Hunt wrote to Schiffer, "Substances that are harmful to the fetus are probably harmful to everyone and one solution is using congenital

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[91] In her 1977 Smith address, Vilma Hunt noted: "It is very difficult to explain the low level of concern for the reproductive experience of those in the health professions, other than in terms of consistent disregard for the health and safety of hospital employees in all areas. Diagnostic and therapeutic radiation procedures involving technicians, nurses, and radiologists have provided a probable risk for adverse pregnancy outcome at least comparable with that for lead exposure over the past twenty years." Vilma Hunt, ""Protection of Workers Health," at *A Conference on Protective Legislation and Women's Jobs: Reevaluating the Past and Planning for the Future* on November 3–5, 1977, 39–40, Box 7, Folder 325, Vilma Hunt Additional Papers.

[92] Sullivan et al., "Congenital Malformations and Other Reproductive Hazards from Environmental Chemicals." Sullivan et al. trace the finding about anesthesiologists to "a Russian survey." AI Vaisman, "Working Conditions in Surgery and Their Effect on the Health of Anesthesiologists," *Eksp khir anesteziol* 3 (1967). Vilma Hunt quotes Alice Hamilton in a 1974 letter, indicating that Hamilton wrote in 1919 "It is very possible that under the guise of 'protection' women may be shut out from the occupations which are really less harmful to them than much of the tedious heavy work both in the home and in the factory which has long been considered their special province." Vilma Hunt to Peter J. Nord. 27 August 1974, Box 7, Folder 305: "conf: AAAS 1975," Series IV, Vilma R. Hunt Papers. Epidemiological research in the 1970s demonstrated higher prevalence of birth defects in occupations long considered safe and appropriate for women.

malformations, etc. as a signal that there is a dangerous situation for all."[93] In other words, for Hunt, the malformed fetus would initially serve as the canary in the coalmine, alerting people to the possibility of broader health concerns from subtle poisoning in workplaces and possibly the broader environment.

Schiffer had similar views. She wrote to Hunt in December 1974, "P.S. I'm beginning to resolve the legal problem in my mind: 1) If it's dangerous to the fetus, it s probably dangerous to everyone and something needs to be done for all; 2) there will always be special groups to be protected, e.g. a man with a heart condition, small people who can't lift weights, etc. So protecting pregnant women, when necessary, does not violate the principle."[94]

Schiffer was instrumental in raising issues about hazardous conditions and the employment of pregnant women, as she sponsoredHunt's writing on pregnant women. Schiffer and Hunt's report, *Occupation Health Problems of Pregnant Women* was published in 1975. Their publication drew attention to the issue of working pregnant women. After the report was published, Dr. John Finklea, then the director of NIOSH, told *The New York Times*, "Vilma's report for me was a bit like when St. Paul was on the road to Damascus and the scales fell from his eyes."[95]

Chemist, Columbia Professor, and labor advocate Jeanne Stellman shared Vilma Hunt and Schiffer's sympathies about the health of working women and maintained a friendship and written correspondence with Hunt starting in the mid-

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[93] Vilma Hunt to Clara Schiffer, 7 November 1974, Box 5, Folder 200, Series II, Vilma R. Hunt Papers.
[94] Clara Schiffer to Vilma Hunt, 20 December 1974, Box 5, Folder 200, Vilma R. Hunt Papers.
[95] David Burnham, "Rise in Birth Defects Laid to Job Hazard; Studies Attribute Increases in Birth Defects to Hazards in Work," *New York Times* March 14, 1976, 1, 42.

1970s.[96] Stellman's book *Women's Work, Women's Health,* published in 1977, suggests that "the combination of extreme sensitivity of the embryo early in pregnancy and growing worldwide environmental pollution both on and off the job may be taking its toll in birth defects, which, because of the scientific problems we have discussed, may not be discernible for many decades to come."[97] The threat of damaged fetuses was not simply the province of the anti-abortion movement, but amid controversy over abortion politics, the threat was wielded by industrial employers seeking to restrict liability and feminist environmental health scientists to draw attention to the plight of working women. Those affiliated with occupational health and environmental movements emphasized fetal vulnerability as a means of increasing public attention to issues of unhealthy working environments or environmental pollution and the potential for uncertain, long-term, and irreversible consequences of chemical exposures. There was suspicion that harmful effects on the fetus, like transplacental carcinogenesis, had been inadequately studied and would only be manifested much later. In this debate, teratologists were often called upon to frankly acknowledge that they saw little convincing evidence linking birth defects to particular chemical hazards.

By May 1974, Hunt was selected by the The American Association for the Advancement of Science (AAAS) to coordinate a symposium at their annual meeting on the "Occupational Health Status of Women." This symposium brought together a number of women (and a few men) who were involved with workplace hazards and women workers, such as Andrea Hricko and Jeanne Stellman. This opportunity to

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[96] See Box 43, Folder 2, Vilma R. Hunt Additional Papers.
[97] Jeanne Mager Stellman, *Women's Work, Women's Health: Myths and Realities*, 1st ed. (New York: Pantheon Books, 1977), 154.

foster an academic opportunity for debate would be followed by many others. In 1976, Hunt and Schiffer would participate in a lively symposium sponsored by the Society for Occupational and Environmental Health (SOEH), NIOSH, and the National Foundation-March of Dimes, among others. The proceedings were prepared and edited by Eula Bingham, head of OSHA.[98] Hunt also participated in a series of conferences at the Banbury Center at Cold Spring Harbor in May 1978 and 1980, intended to assess the impact of chemical mutagens. In this context, she presents the problems of the prenatal period as relatively neglected, in comparison to health effects on the neonate or adult. The published proceedings are organized by organ system and route of exposure, illustrating the complexity of the mechanisms and the research specialties involved in studying prenatal exposures.[99]

Many women concerned with labor issues and women's rights were angry at the apparent ulterior motives and flawed logic and rhetoric of those who portrayed employment for possibly fertile women in hazardous settings as undesirable, just as they saw the paradoxes and difficulties of women having and maintaining families and employment in the context of hazardous conditions and unequal gendered distribution of high-paying employment and household work.[100]

Professional women in occupational health sciences, such as Stellman and Hunt, portrayed themselves as fighting against networks of conservative male scientists unwilling to accept (and fund) female authority in science. Despite her various successes in academia, Hunt felt that science was at times exclusionary to

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[98] Bingham, ed., *Conference on Women and the Workplace, June 17–19, 1976, Washington, D.C.: Proceedings*.
[99] Vilma R. Hunt et al., *Environmental Factors in Human Growth and Development*, Banbury Report (Cold Spring Harbor, NY: Cold Spring Harbor Laboratory, 1982).
[100] Stellman, *Women's Work, Women's Health: Myths and Realities*.

women and was "an old boys club." When Stellman and Vilma proposed a study to NIOSH examining menstrual fluid collected from women workers, a review committee dismissed it as impossible because it would be too difficult to routinely collect such samples, calling it a "bloody mess."[101]

Vilma Hunt would continue to play a role in debating fetal protection policies and women's occupational and reproductive hazards in various academic venues throughout the 1970s and early 1980s, building a career by synthesizing scientific information, researching, and participating in debates about pregnant women's unique occupational risks and fertile women worker's exclusion from hazardous settings. Yet she moved away from specific problems of pregnant women. She published more general monographs and reports on working women in the late 1970s, *The Health of Working Women* and *Work and the Health of Women.*[102] Unlike her previous report, these were intended for a broader audience and emphasized a wide range of occupational hazards encountered by working women, among them those they encountered during pregnancy.

In her work as synthesizer and popularizer of scientific information on occupational hazards of women, Hunt often consulted teratological studies. The curious element of her work is how she both relied on teratological studies for information about risks to pregnant women and also began to call into question teratologists' framing of the problem. In 1979, Vilma Hunt noted in *Work and the Health of Women,* "It is difficult to establish a balance between the view that the number of established teratogens is small, or that the dispersed occurrence of

[101] It was also considered improbable that women would voluntarily and consistently donate menstrual fluid for six months. Stellman recounts this anecdote in a list of contents, dated April 15, 1989. Box/Folder 1.2, Jeanne Mager Stellman Papers.
[102] Hunt, Lucas-Wallace, and Manson, *Work and the Health of Women*.

congenital abnormalities defies epidemiological surveillance… Clinical and epidemiological methods could well be too gross to establish the presence of a risk, if one exists."[103] As the issue of the effect of environmental pollution on the health of the fetus *in utero* was raised as a concern, it became clear that the methods of detection were problematic at best. Critiques from environmental science often raised difficult-to-resolve-questions about fetal susceptibility that were difficult to resolve. Were the numbers of teratogens small or were they simply not easily detected by epidemiological surveillance or reproductive toxicology tests in the laboratory? Were teratologists, epidemiologists, and geneticists who examined environmental factors and congenital malformations simply looking at outcomes that were too obvious (in other words, "gross" or "crude"), emphasizing counting fingers and toes rather than studying miscarriages, infertility, or more subtle or long-term neurological or anatomical outcomes correlated with the diverse chemical or radiation-related exposures in the risky environments of both parents? By the early 1970s, laboratory scientists such as Joan Spkyer had demonstrated behavioral effects of rodents when prenatally exposed to methylmercury, opening up a field that was called behavioral teratology.[104] In the late 1970s, in part due to the efforts of Hunt and her colleagues, reproductive hazards to both males and females from exposure to toxic chemicals were more broadly framed than simply teratogenic risks.[105]

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[103] Ibid., 113–19.
Spyker, "Methymercury, Mice and Men."
[105] Peter Infante argued in 1976, "My second point is this: to look only at birth defects is, I think, an insensitive monitor of fetal development and child growth because what concerns us about agents that are mutagenic is that their effects are passed to future generations. Some fetuses are being aborted through a self-selection process, but what we are most concerned about is the genetic load for future

Grappling With the Implications of Scientific Uncertainty

Vilma Hunt also gave considerable thought to differing interpretations of uncertainty, as have other environmental health scientists and historians.[106] Pediatric physicians and obstetricians often expressed reticence about "frightening" parents about reproductive health outcomes, even as their research, advice, and medical monitoring informed maternal expectations about what constituted a healthy normal child. In a piece of undated and unpublished writing (though almost certainly written in the mid-1980s based on the historical reference points) called "Thoughts on Uncertainty or the Search for Certainty," Hunt grappled with the disparate ways in which scientists, engineers, bureaucrats, and the public interpreted elusive evidence and statements about birth defects, attempting to construct a model to explain how scientist-engineers, physicians or public health professions, and lay citizens approached uncertainty, resulting in differing interpretations of the same data. She highlights two definitions of uncertainty, contrasting the experiences of the potentially exposed with expert scientific interpretations committed to the integrity of their knowledge claims, "different interpretations of uncertainty become most dramatic when we hear public or worker perceptions voiced (e.g. Love Canal) as uncertainties being for them, possibilities

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generations." Bingham, ed., *Conference on Women and the Workplace, June 17–19, 1976, Washington, D.C.: Proceedings,* 101–103. In the 1990s Vilma recapped her experiences, saying. "We have to acknowledge that there are some end points of reproduction that don't allow for complex interpretation. Infant and neonatal mortality do not provide the answers, and there are other factors that may have to be considered." Vilma Hunt, Draft of a speech at Schlesinger Library, 16, circa 1996, Box 60, Folder 125, Vilma R. Hunt Additional Papers.

[106] Mitman, Murphy, and Sellers, *Landscapes of Exposure: Knowledge and Illness in Modern Environments*. J. Stephen Kroll-Smith, Phil Brown, and Valerie J. Gunter, *Illness and the Environment: A Reader in Contested Medicine* (New York: New York University Press, 2000). Proctor, *Cancer Wars: How Politics Shapes What We Know and Don't Know About Cancer*.

(e.g. cancer sometime in the future, perhaps), whereas scientists… state that there is insufficient evidence (uncertainty) to be certain that dangerous conditions exist."[107]

Essentially, Hunt was trying to reconcile philosophical and epistemological differences between citizens, various laboratory scientists, engineers, and public health professionals. She argued, "[t]he scientist dependent on conclusions from research process and progress in the laboratory might be miles apart philosophically from the public health professional, for example, who conjectures concerning the toxicological possibilities in the workplace and for whom action may or should be necessary because of the uncertainty."[108] Hunt's effort to reconcile these differing perspectives on uncertainty and the precautionary principle evokes many who have gone before and since. Should uncertainty be a galvanizing force for action or a cause for more meticulous research attention to the problem to ensure sound knowledge claims? She defines a triad of "separate enclaves" (engineers, scientists, and physicians) and remarks on social sanctioning of those who appeared to challenge the scientific method. Or as she described it, there existed "a feedback system which makes known the strong social sanctions controlling the actions of those who might undermine the purity of the scientific method."[109]

Differing interpretations of how to face uncertain harms was an aspect of the environmental science in which thoughtful people with the best of intentions might disagree. Scientists may have had particular incentives to favor delay or regulatory

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[107] This undated document (probably from the 1980s or after), "Thoughts on Uncertainty or the Search for Certainty," is in the folder Box 65, Folder 7, "Writings, 1967–2002," Vilma R. Hunt Additional Papers.
[108] Ibid., 3.
[109] Ibid., 5.

inaction, particularly if they had close associations to industry, yet in the case of teratologists and many other scientists it was commitment to truthful knowledge claims and to "good" science that was the justification they gave for rejecting citizen claims that seemed shoddily constructed, false, or overly emotional.

The contradictions are rife, however. When it came to pregnant women, even in the face of inconclusive, contradictory, or improbable evidence that a particular substance had a harmful effect on the fetus, precaution was advised. How strange, that a precarious scrap of cells still unviable outside of the mother's body, which could legally be aborted at any time, should hold such sway. The possibility of life with disability or impairment, and associated legal claims, then, by many accounts would be far worse than medical abortion or miscarriage.

Hunt's Later Efforts: EPA, The Citizen's Clearinghouse for Hazardous Waste, Re-Analysis of Data from the Collaborative Perinatal Project

By the latter half of the 1970s, the effort to document prenatal risks of occupational and community-based chemical exposure was continued apace. Researchers such as Peter Infante published studies that linked community-based exposures to industrial substances such as vinyl chloride to neural tube birth defects, even as scientists at the Centers for Disease Control and Prevention (CDC) protested his conclusions as spurious or premature.[110] Widespread publicity about waste-related exposures at Love Canal and industrial accidents involving dioxin at Seveso Italy, raised the prospect of community-based exposures as a danger to

[110] Peter F. Infante, "Oncogenic and Mutagenic Risks in Communities with Polyvinyl Chloride Production Facilities," *Annals of the New York Academy of Sciences* 271, no. 1 (1976): 49–57. Telephone interview with Peter Infante, June 18, 2015.

pregnant women and their children, providing a venue for maternalist environmental activism and citizen science.[111] By 1977, Andrea Hricko, Jeanne Stellman, and Vilma Hunt testified about teratogenic harm from lead at OSHA hearings, criticizing the scientific rationale for exclusionary policies and portraying the issue was one of social responsibility to future generations.[112] Various journalists published exposés on the environmental risks posed to unborn children from a range of sources in the late 1970s and early 1980s, particularly related to neurological damage, cognitive impairment, or behavioral effects that were hard to diagnose.[113]

Hunt, working as Deputy Assistant Administrator for Health Research at the EPA in the late 1970s, connected Love Canal activist Lois Gibbs to the expertise of scientists such as Beverly Paigen (who wrote a scathing review of design flaws of the New York State research study on reproductive outcomes at Love Canal[114]) and served on the board of the non-profit organization that Gibbs founded in the early 1980s, the Citizen's Clearinghouse for Hazardous Waste. Hunt maintained a correspondence with Gibbs, and provided feedback on research guides and survey questionnaires intended to aid community members in documenting local

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[111] Amy Hay, M., "Recipe for Disaster: Motherhood and Citizenship at Love Canal," *Journal of Women's History* 21, no. 1 (2009): 111–34. Lois Marie Gibbs and Murray Levine, *Love Canal: My Story* (Albany: State University of New York Press, 1982).
[112] Markowitz and Rosner, *Deceit and Denial: The Deadly Politics of Industrial Pollution*, 123–25.
[113] Norwood, *At Highest Risk: Environmental Hazards to Young and Unborn Children*. Elkington, *The Poisoned Womb: Human Reproduction in a Polluted World*; Kolata, "Behavioral Teratology: Birth Defects of the Mind."
[114] See materials and correspondence with Beverly Paigen in Box 4, Folder 153, Vilma R. Hunt Papers. Beverly Paigen raised some of the same questions about whether the existing methodologies were sufficient to evaluate the risks. In a December 8–10, 1980, presentation, "Methods for Assessing Health Risks in Populations Living Near Hazardous Waste Sites," Beverly Paigen and Joseph Highland of the Environmental Defense Fund stated that, "It is not clear that we have developed the appropriate methodologies to assess the potential health risks and to answer the legitimate questions being raised."

environmental hazards, an example of what has been called "citizen science."[115] In her own description of this work, written in the 1990s, she proudly notes that there were more than 5,000 groups across the United States concerned with inappropriate disposal of hazardous waste, nearly 80% led by women.[116]

Amidst debates about fetal protection policies, Vilma Hunt examined infant mortality in one county in Pennsylvania, trying to investigate more closely the causes of infant mortality and link them to the environment.[117] Later, under the auspices of the EPA, Vilma Hunt would try to re-analyze data from the Collaborative Perinatal Project in order to assess the effect of occupational pesticide exposures. Originally named the "The Collaborative Investigation on the Clinico-Pathologic Correlation in Cerebral Palsy, Mental Retardation, and other Neurological Disorders having their Origin in the Perinatal Period," the project was an early example of a large federally funded epidemiological project seeking to assess preventable prenatal neurological outcomes. It received congressional funds in 1953 and interviewed nearly 60,000 pregnant women and tracked birth outcomes in at least twelve regional centers, after enrolling the first participant in 1958.[118] From 1960–1973, the study was under the leadership of Heinz Berendes.[119] The data set was imperfect, as the researchers at the National Institute for Neurological Disease and Blindness (NINDB) initially set out to track intellectual deficiencies,

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[115] Lois Gibbs to Vilma Hunt, 13 August 1982, Box 1, Folder 14, Vilma R. Hunt Papers.
[116] Vilma Hunt, "Love Canal," December 1990, Box 1, Folder 2: "VRH Explanations, Descriptions, 1990," Series 1, Vilma R. Hunt Papers.
[117] Vilma R. Hunt and William L. Cross, "Infant Mortality and the Environment of a Lesser Metropolitan County: A Study Based on Births in One Calendar Year," *Environmental Research* 9, no. 2 (1975): 135–51.
[118] Klebanoff, "The Collaborative Perinatal Project: A 50-Year Retrospective."
[119] James L. Mills, "Heinz Berendes, 1925–1999," *American Journal of Public Health* 89, no. 8 (1999): 1156–7.

assuming a relationship between adverse events during pregnancy, fetal oxygen deprivation, and what chronic disease epidemiologists Abraham Lilienfeld and Benjamin Pasamanick termed a "continuum of reproductive wastage." This was understood as a range of intellectual impairment and clinical conditions associated with adverse events during pregnancy, labor and delivery, from severe mental deficit and cerebral palsy to behavioral problems in childhood.[120] However, that didn't prevent various entities from combing through the data retrospectively as the question of links between birth defects and chemical exposures, particularly pharmaceuticals, became politically salient.[121]

In a speech given in 1978 on reproductive toxicity of pesticides, Hunt reported that she was able to identify 23,961 cases with occupational health information reported, and 652 women with possible exposure to pesticides. Despite her efforts, she found it difficult to link chemical exposures and the complex life experiences of two parents to infant disability using the study, although she noted higher incidences of first and second trimester bleeding, low placental and birth weight, polyhdramnios, fetal deaths, low Apgar scores and poor neurological outcomes among those exposed to pesticides (Presumably, those exposed to high doses of pesticides might also be of lower socioeconomic status, a potential confounding factor). Quoting the Mrak report, Hunt noted that even ten years after the report was published in 1969, their commentary about teratogenic hazards of pesticides still held true: "Prospective studies on the subject are difficult to design

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[120] Martha E. Rogers and Abraham M. Lilienfeld, *Prenatal and Paranatal Factors in the Development of Childhood Behavior Disorders* (Copenhagen: Munksgaard, 1955); Benjamin Pasamanick, "Association of Maternal and Fetal Factors with Development of Mental Deficiency: Abnormalities in the Prenatal and Paranatal Periods," *The Journal of the American Medical Association* 159, no. 3 (1955): 155.
[121] Heinonen, Slone, and Shapiro, *Birth Defects and Drugs in Pregnancy*.

and almost nonexistent."[122] Though she suspected pesticides might have deleterious effects on human reproduction, such linkages could be hard to confirm.

Conclusion

Why investigate the professional trajectory of Vilma R. Hunt? Her career provides compelling clues to the role of a feminist environmental health scientist in drawing attention to occupational and other environmental health hazards to pregnant women. In doing so, it explodes the assumption that the increasing surveillance of pregnant women in the later half of the twentieth century, as the world was increasingly portrayed as a polluted and hazardous place, was the sole result of patriarchal medicine. Indeed, it shows how professional women continued to claim a unique role for themselves as reformers on the margins of the medical profession, addressing issues of caring for the family that had long been considered the purview of women, as had pioneering women physicians in other eras. It demonstrates how one environmental health scientist attempted to marshal evidence to support a particular view of the working life of women ain politically rancorous times.

It also demonstrates the differing perspectives and institutional commitments of environmental scientists from teratological science. Teratology had benefited from public concern about infant disability but nevertheless often attempted to be hopeful about ameliorating naturally occurring infant disability and tried to be objective, neutral, and uncontroversial. Mostly male pediatricians,

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[122] Vilma Hunt, "Reproductive Toxicology," presented at *Conference on Pesticides and Human Health*, December 1978, Box 7, Folder 363, Vilma R. Hunt Papers.

embryologists and scientists of mid-century America had sought to define a research field unified in its focus on mechanisms and prevention of unusual infant form derived from environmental factors acting during development, using animal models and epidemiology. By the 1970s there was considerable concern about subclinical neurological toxicity from prenatal exposures and other more subtle effects of industrial hazards. Scientists (leftist geneticists, lapsed dentists, and feminist environmental scientists) illuminated industrial hazards that threatened the reproductive fitness of a broad swath of the population, at times emphasizing mutagenesis and at times teratogenesis. Environmental scientists raised many questions about long-term effects of dispersion of hazardous chemical products that scientific methodologies seemed inadequate to answer.

Ironically, in the 1970s, corporations and feminist experts were at times allied in calling public attention to the vulnerability of the fetus during arguments for and against workplace restrictions on fertile women in hazardous. Environmental scientists' efforts to use the vulnerability of the fetus as a political tool to galvanize political will to improve workplace conditions and curb industrial emissions nevertheless contributed to a vision of pregnant women as a porous vessels susceptible to a hostile environment and at times they promulgated dark visions of the viability of the human race.

Despite alarmist reports in the media about birth defects resulting from herbicides, food additives, and toxic waste starting in the late 1960s, it's inaccurate to overstate the perception of many pregnant women to potential chemical risks that surrounded them. Nevertheless, pregnancy manuals voiced considerable caution and warnings. If the goal of consumer rights activists and environmentalists was to

better inform the lay public about the various risks they faced from chemical products, creating informed patients, workers, and consumers, it's legacy was mixed. Did knowing more about the health risks that pregnant women face comfort and empower them or present an ever-expanding list of unconfirmed risks that they struggled to interpret? Were they better able to make informed and rational decisions based on the information they obtained, as consumer advocates imagined, or were they bombarded by diverse warnings based on slim evidence? What Linda Nash has characterized as environmentalists' "narrative of regret," in this instance, is a dystopic narrative of future reproductive impairment, which evoked new anxieties in some pregnant women yet inspired and sustained environmentalist scientists such as Vilma Hunt.[123] For environmental scientists, at least, unusual births continued to function as portents, as they had since antiquity. In this case, birth defects represented an omen of future catastrophe, though attributed to omnipresent, invisible, and insidious industrial chemical poisons.

[123] Linda Lorraine Nash, *Inescapable Ecologies: A History of Environment, Disease, and Knowledge* (Berkeley: University of California Press, 2006).

Chapter 4: Lead and Mercury: Heavy Metals, Chemical Brain Drain, and Epidemiological Epistemology (1960–1995)

In the 1980s, two groups of researchers set out to use large prospective epidemiological studies to determine the developmental neurotoxic effects of prenatal methylmercury (MeHg) exposure associated with eating sea food, one affiliated with the University of Rochester studying populations in the Seychelles, and the other a Harvard School of Public Health and University of Southern Denmark project in the Faroe Islands. The studies came to two very different conclusions about the impact of prenatal dietary methylmercury on development, inciting considerable controversy and raising questions about the study methodology, the developmental benefits of certain nutrients in sea food, and risk management recommendations for pregnant women about eating seafood, particularly large species of ocean fish such as swordfish or tuna.[1] Danish-born physician Philippe Grandjean and his Harvard-based colleagues, based on their study of 1,022 births from 1986–1987 in the Faroe Islands, concluded that "Overall, the results suggest that several domains of brain function may be affected by prenatal methylmercury exposure. The findings (especially those involving language) suggest that this exposure has widespread effect on cerebral function and they are consistent with the literature."[2] Based on such studies, the U.S.

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[1] A third study is often cited, based in New Zealand, but has been left out of this discussion for the sake of brevity and emphasis on scientists working in North America.

[2] Philippe Grandjean, et al., "Cognitive Deficit in 7-Year-Old Children with Prenatal Exposure to Methylmercury," *Neurotoxicology and Teratology* 19, no. 6 (1997): 426. Philippe Grandjean et al., "Adverse Effects of Methylmercury: Environmental

Environmental Protection Agency (EPA) changed recommendations for daily MeHg exposure, or the reference dose, to 0.1 μg MeHg/kg body weight/day, roughly a can of tuna per week depending on body weight. This conflicted with recommended doses from other agencies, such as the U.S. Food and Drug Administration (FDA), which had stipulated 0.5 μg Hg/kg/day yet had encountered legal cases with commercial fish purveyors about action levels of fish contamination that would be allowed for commercial sale.[3]

Debates about appropriate limits and action levels in the 1980s and beyond relied on large-scale prospective epidemiological studies that followed cohorts of people through time. The Seychelles study conducted by the University of Rochester began tracking 779 mothers and their children in 1989, subjecting the children to a battery of intelligence tests from six months of age (Initial surveys of mercury levels

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Health Research Implications," *Environmental Health Perspectives* 118, no. 8 (2010): 1137–45.

[3] When discussing methylmercury contamination, authors tend to refer to reference doses, no effect levels, and action levels. A reference dose refers to recommended daily dose of chemical consumption presumed to be safe throughout a human lifetime based on available evidence, estimated from the threshold limit value or no-effect level measured in various studies on animals and humans. In addition, scientists measure and debate the human health-related implications of MeHG concentrations in fish and human hair or blood. Action levels refer to the level of mercury contamination at which point the FDA will intervene in the sale of commercial fish, and it is based on legal trials with industry. Parameters set by various regulatory agencies state what levels of mercury in hair or blood are presumed to be associated with no symptoms, but there is considerable disagreement about what these levels should be, as Jane Hightower's book describes. Thomas W. Clarkson, "The Three Modern Faces of Mercury," *Environmental Health Perspectives* 110 (2002): 11; Jane M. Hightower, *Diagnosis Mercury: Money, Politics, and Poison* (Washington, DC: Island Press/Shearwater Books, 2009), 167–83. The case *United States of America vs. Anderson Seafoods, Inc.* is discussed in pages 167–183. Testimony for Anderson Seafood argued that the Iraqi data was sound, providing a demonstration of no effect levels at blood levels of 500-600 μg/l (compared to evidence from Japan that suggested effects would be evident at 150– 200μg/l), and that methylmercury in fish was "natural," at ordinary consumption level, was not injurious to health, and in addition, that it was impossible to enforce the levels FDA had set.

in the population had occurred as early as 1981). In 1998, the study group concluded that "the development of these children is proceeding well without any detectable adverse influence of MeHg."[4] Despite conflicting evidence, a review by the same authors in 2009 used modified language, arguing that the study results "do not provide clear evidence of adverse associations between the levels of MeHg exposure studied in this cohort and the children's development."[5] Why did these studies reach such different conclusions about the prenatal neurodevelopmental risks of MeHg in fish?

Was it a matter of influence from funders, different diets, study technique or location, or interacting detrimental chemical exposures? This chapter interrogates how mercury-tainted fish became conceived of as a risk to pregnant women and potential children and the role of epidemiological epistemology to define and assess risks to pregnancy in the later half of the twentieth century. I use published medical literature and monographs, autobiographical accounts from scientists, and the Marion Lamm Mercury Collection at the Environmental Science and Public Policy Archives at Harvard to examine the history of public and scientific alarm about undetected neurological impairment following mercury exposure *in utero* and debates within epidemiology and environmental science between 1960–2000 about how to assess these risks.

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[4] Philip W. Davidson et al., "Effects of Prenatal and Postnatal Methylmercury Exposure from Fish Consumption on Neurodevelopment: Outcomes at 66 Months of Age in the Seychelles Child Development Study," *Journal of the American Medical Association* 280, no. 8 (1998): 706.
[5] Gary J Myers et al., "Postnatal Exposure to Methyl Mercury from Fish Consumption: A Review and New Data from the Seychelles Child Development Study," *Neurotoxicology* 30, no. 3 (2009): 349.

The Faroe Island and Seychelles studies of the 1980s and 1990s tried to provide conclusive evidence of the neurological effects of prenatal dietary MeHg exposures on children in order to guide public policy. Expert panels convened at the end of the twentieth century by the White House Office of Science and Technology Policy and the National Academy of Sciences were not able to conclusively resolve the differences between the two studies (there was a third influential study in New Zealand not be covered here).[6] Researchers who argued for and against cognitive and developmental impairments associated with prenatal mercury exposure bring to mind the legacy of classic pharmacological and toxicological debate about the importance of dose in causing detrimental effects. Their arguments were framed anew in the 1980s and 1990s by modern epidemiological evidence of risk, by biological research into lower tolerance of subclinical neurological effects on children, and by refined analytical techniques for detecting trace mercury levels and linking them to developmental neurological impairment.

Philippe Grandjean, along with colleagues such as Philip Landrigan and Herbert Needleman, was a spokesman starting in the 1970s and 1980s for the dangers of subtle trace heavy metal exposures on the intelligence of children.[7] Born

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[6] Joseph L Jacobson et al., "Relation of Prenatal Methylmercury Exposure from Environmental Sources to Childhood IQ," *Environmental Health Perspectives*123, no. 8 (2015): 827; National Research Council (NRC), *Toxicological Effects of Methylmercury*, (Washington, DC: National Academy Press, 2000)*;* National Institute of Environmental Health Sciences (NIEHS), *Workshop on Scientific Issues Relevant to Assessment of Health Effects from Exposure to Methylmercury, Raleigh, November 18-20,* George Lucier and Robert Goyer, eds., (Raleigh, NC: U.S. Government Publication, 1998).

[7] American pediatrician and epidemiologist Philip Landrigan had looked at the neuropsychiatric effects of lead on children who lived near lead smelters in El Paso, Texas, and worked for a time at Environmental Hazards Activity, Cancer, and Birth Defects Division at the CDC. Philip J. Landrigan et al., "Neuropsychological Dysfunction in Children with Chronic Low-Level Lead Absorption," *The Lancet* 305,

in 1950, Grandjean was trained as a physician and toxicologist, and he was appalled by the relationships between low-level community-based heavy metal exposures and neurological impairment in children that were exposed in the 1970s.[8] Grandjean later wrote several reviews on the controversy over the differing conclusions obtained from fish-eating populations in the Faroe Islands and the Seychelles. He used mercury as a case study to examine conflict over the tentative nature of epidemiological evidence and as an example of a slow historical response to mercury as a hazard of pregnancy.[9]

Grandjean identified one paradox of epidemiological research on prenatal environmental exposures in the 1970s, explaining that it was considered unethical to perform a study where these substances were deliberately administered to pregnant women, even in very trace amounts. Thus, epidemiological studies were confined to observational studies of health effects on human groups. However, with insufficient evidence of prenatal harm and (in his view) insufficient regulatory action to control pollution, women of reproductive age were likely exposed to such

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no. 7909 (1975): 708-712; Philippe Grandjean and Philip J. Landrigan, "Developmental Neurotoxicity of Industrial Chemicals," *Lancet* 368, no. 9553 (2006): 2167-2178; Philip J. Landrigan and E. L. Baker, "Child Health and Environmental Lead," *British Medical Journal* 1, no. 6064 (March 26, 1977): 836.

[8] Grandjean was trained in medicine in Denmark and wrote his PhD dissertation on "Widening Perspectives of Lead Toxicity" in 1979. His earliest papers on lead toxicity were published in the mid-1970s. See his Harvard Faculty Profile or C.V. http://www.hsph.harvard.edu/philippe-grandjean/ (accessed June 2016). He began publishing on levels and neurological impacts of lead in the mid-1970s. Philippe Grandjean, "Possible Effect of Lead on Egg-Shell Thickness in Kestrels 1874–1974," *Bulletin of Environmental Contamination and Toxicology* 16, no. 1 (1976): 101–6; "Lead in Danes. Historical and Toxicological Studies," *Environmental Quality Safety S*2 (1975): 6–75.

[9] Philippe Grandjean, "Mercury Risks: Controversy or Just Uncertainty?," *Public Health Reports* 114, no. 6 (1999): 512 .

substances from exposures in the environment.[10] In other words, epidemiologists studying environmental pollution sometimes struggled with imperfect methods to scientifically demonstrate harmful effects from pollution-related exposure during pregnancy and define unexposed control groups, and they were dismayed that they might identify potential harms *post hoc,* after many people had potentially been exposed.

As these debates raged in the 1980s and 1990s, pregnant women were warned to avoid alcohol, certain types of fish, cigarettes, sushi, cheese, and many pharmaceuticals despite the ubiquity of unintentional exposures to diverse substances and apparent inevitability of their body burden of synthetic chemicals.[11] Despite emphasis on individual parental responsibility, it sometimes seemed that there was little that parents or consumers could really do to ensure that they were avoiding all insidious and ubiquitous chemical risks. Nevertheless, government actions halting sales or restricting commercial products (affecting corporate profits) in the face of contradictory evidence were controversial, and the evidence was nearly always contradictory. Obvious economic losses were often contrasted with uncertain harms from low-level chronic exposures, while at the same time environmentalists

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[10] Philippe Grandjean, *Only One Chance: How Environmental Pollution Impairs Brain Development-and How to Protect the Brains of the Next Generation* (Oxford: Oxford University Press, 2013).

[11]This argument is based principally on advice literature from the period. The most popular was *What to Expect* published starting in 1984, but there were many others in the 1970s and 1980s that warned about protecting against fetal hazards. See Ronald E. Gots and Barbara A. Gots, *Caring for Your Unborn Child*, (New York: Bantam Books, 1977); David W. Smith and Jean Knights, *Mothering Your Unborn Baby*, (Philadelphia: Saunders, 1979); or Norwood, *At Highest Risk: Environmental Hazards to Young and Unborn Children*. Later accounts linked low-level heavy metal exposure to autism. A. S. Dickerson et al., "Autism Spectrum Disorder Prevalence and Proximity to Industrial Facilities Releasing Arsenic, Lead or Mercury," *Science of the Total Environment* 536 (2015): 245–251.

and some parents expressed skepticism about the ability of regulatory efforts to prevent damage to children and future generations.[12]

One criticism that remained particularly salient was whether expert knowledge was compromised by industrial influence: To what extent did scientists or physicians affiliated with industry create and capitalize on uncertainty to delay regulatory action? Beyond issues of industrial bias or promulgation of uncertainty, there were many difficulties measuring subtle and possibly subjective symptoms or subclinical effects among populations who might themselves be invested in the outcomes of the research (such as fishermen and those working in the canning industry).[13] In addition, epidemiological research on the risks of MeHg in fish was influenced by nutritional and toxicological arguments about the detrimental or beneficial effects of various components of fish (such as selenium, nutrients, fatty acids, or other deleterious contaminants like PCBs).[14]

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[12] A commonly cited example of economic losses resulting from uncertain harms can be seen in Robert L. Brent's writings and testimony, such as his 1971 congressional testimony on efforts to prevent the sale of cranberries after they were found to be contaminated with amino triazole, "where the whole cranberry crop was destroyed because of trace amounts-that is ignoring the concept of dosage." *Chemicals and the Future of Man*, 92. Accounts of the cranberry "scare" can be seen in James C. Whorton, *Before Silent Spring; Pesticides and Public Health in Pre-DDT America* (Princeton, NJ: Princeton University Press, 1975). Robert L. Zimdahl, *A History of Weed Science in the United States*, 1st ed., (London; Burlington, MA: Elsevier, 2010), 96–97. For accounts specific to mercury fears, see the monograph written in 1971 by Ralph Nadar affiliates, Montague and Montague, *Mercury*.

[13] Jane Hightower makes this argument in reference to a 1970s study by Thomas Clarkson and his colleagues in American Samoa. David O. Marsh et al., "Methylmercury (MeHg) in Human Population Eating Large Quantities of Marine Fish. II. American Samoa: Cannery Workers and Fishermen" (paper presented at the Proceedings of the First International Mercury Conference, 1974); Hightower, *Diagnosis Mercury: Money, Politics, and Poison*.

[14] The issue of protective effects of selenium and other substances in fish was mentioned on many occasions, starting in the 1970s, and made the design of public policy around dietary consumption of potentially MeHg-tainted seafood particularly difficult. See Thomas H. Jukes, "Mercury in Fish," *JAMA* 233, no. 9 (1975): 1001–

Given these epidemiological debates, it was unclear how to communicate risk to pregnant women and other fish eaters. Women's health, labor, and consumer advocates had called for greater informed consent for patients and right-to-know legislation, yet how should such controversial and incomplete evidence of risk be communicated to pregnant women?[15] How should the precautionary principle function with respect to pregnant women? This was particularly difficult to determine if widespread public alarm might financially damage fish-related industries, as it had with the tuna recall of the 1970s.[16] One might argue that it did

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1002. Thomas Clarkson and others used the presence of other substances, like PCBs or nutritional elements of fish and different dietary sources (whale meat vs. fish) as a justification for different results between the studies in the Seychelles and Faroe Islands in the 1990s. Gary J. Myers et al., "Twenty-Seven Years Studying the Human Neurotoxicity of Methylmercury Exposure," *Environmental Research* 83, no. 3 (2000); Thomas W. Clarkson, Laszlo Magos, and Gary J. Myers, "The Toxicology of Mercury—Current Exposures and Clinical Manifestations," *New England Journal of Medicine* 349, no. 18 (2003): 1731–1737; Clarkson, "The Three Modern Faces of Mercury."; Myers et al., "Postnatal Exposure to Methyl Mercury from Fish Consumption: A Review and New Data from the Seychelles Child Development Study."

[15] Hightower, *Diagnosis Mercury: Money, Politics, and Poison*, 37. In the context of 1970s concern about environmental hazards, obstetricians didn't know how to advise pregnant women about prenatal exposures. See obstetrician Fritz Fuchs (who was a pioneer of prenatal genetic diagnosis) on the subject: "Generally speaking, the role of the obstetrician is to counsel his patients. He must warn them against drugs of any kind, not knowing exactly which ones are dangerous and which ones are not. He must have them vaccinated against rubella and other viral diseases before conception to avoid the risk of congenital toxoplasmosis… Of course, ideally all pregnant patients should be isolated in camps far away from the major cities with their carbon monoxide and other pollutants in the air. They should be put on a diet without any additives and of course be far away from pharmacists, so that no drugs could be given even if they were ill. And, they should, of course, be without tobacco, liquor and sex!" L'Institut de la Vie, "Methods for Detection of Environmental Agents That Produce Congenital Defects: Proceedings of the Guadeloupe Conference," 179.

[16] Jukes, "Mercury in Fish." Martin Waldron, "Mercury in Food: A Family Tragedy," *New York Times* August 6, 1970; Gladwin Hill, "Mercury Hazards Found Nationwide," September 11, 1970; Montague and Montague, *Mercury*. Anonymous, "FDA Checking Tuna Fish for High Levels of Mercury," *New York Times* December 8, 1970.

not serve the purposes of chemical companies, other industries that produced mercury as emissions or effluent, or fish purveyors to clearly demonstrate or widely publicize infant harm from mercury contamination—which by the 1990s was principally attributed to coal-burning plants producing energy.[17]

Some physicians warned that anxieties and abortions would result from widespread publicity about still-uncertain developmental effects of MeHg from fish, and there were historical examples where parents became alarmed about potential teratogens (such as LSD, Bendectin, caffeine, or potato blight) that were later largely discounted. Given that causes of infant disability were multifactorial, there was a baseline rate that could not be attributed to any cause, parental exposures were multiple, there were beneficial nutrients in fish, and it was difficult to definitely demonstrate that fish consumption was causing developmental impairment at average consumption and contamination levels, what message, if any, should be shared with pregnant women?[18] Since the 1970s, environmentalists, women's health advocates, concerned parents, and public health and consumer advocates requested information about the risks of methylmercury exposure to be communicated with women of reproductive age so that they could make informed decisions about their health risks and diet.[19] Some physicians and scientific experts were reticent to share this information with the public, assuming that they would be

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[17] Hightower, *Diagnosis Mercury: Money, Politics, and Poison*.
[18] Deborah C. Rice, "The U.S. EPA Reference Dose for Methylmercury: Sources of Uncertainty," *Environmental Research* 95, no. 3 (2004): 406–413.
[19] Hunt, "The Emergence of the Workers' Right to Know of Health Risks"; Montague and Montague, *Mercury*.

inappropriately alarmed.[20] Nevertheless, despite inconclusive evidence, many advised precautions for pregnant women.[21]

The history of mercury reflects a dramatic change in status. In some forms, it was a commonly prescribed component of medications, but twentieth-century industrial hygienists interpreted other compounds containing mercury as poisons in factories causing childhood crippling, abortion, and infant death. In the early 1960s, neurologists identified methyl mercury as a local water pollutant and environmental neurotoxin causing congenital injury in Japan. Environmental scientists, toxicologists and public health physicians characterized mercury as a persistent global environmental scourge, cycling in ecosystems and accumulating in wildlife and fish populations, that potentially was imperceptibly (or barely perceptibly) affecting the mental acuity or behavior of children. Mercury compounds had long

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[20] A toxicologist described public fears skeptically in 1985: "gloomy statistics support the implication of environmental agents as potential sources of reproductive failures and congenital malformations. Witness the real or imagined claims in contemporary history of hazardous events associated with organic mercury, alcohol, PBBs and PCBs, red dye #2, OCs, spray adhesives, DES, anesthetic gases, caffeine, 2,4,5-T and dioxin, lead, Bendectin, and of course, the notorious thalidomide." James L. Schardein, *Chemically Induced Birth Defects*, Drug and Chemical Toxicology (New York, NY: M. Dekker, 1985), viii.

[21] Anonymous, "Mercury Suspected as Pregnancy Peril," *New York Times* February 2, 1971. Brian J Koos and Lawrence D Longo, "Mercury Toxicity in the Pregnant Woman, Fetus, and Newborn Infant, A Review," *American Journal of Obstetrics and Gynecology* 126, no. 3 (1976): 390–409. A satirical essay in the *New York Times* in 1971 illustrated the barrage of fears about chemical exposure during pregnancy at the time, listing DDT, mercury, and MSG as potential sources of harm to the unborn. Her account illustrates these anxieties, "Ecological enthusiasms crest and wane like other diseases... I was distracted by several other front-page discoveries. The first was the possible danger to my as-yet-unborn infant by monosodium glutamate...Baby rats born of mothers fed the suspect foods had developed all varieties of disorders from crossed eyes to limb deformities. I was torn between the normal passion for a healthy child (the nightmares and hypochondria of any pregnancy) and a terrible, constant craving for Chinese food." Ann Richardson Roiphe, "The Mad Diary of a Manhattan Ecologist," *New York Times* October 17, 1971, 90.

been known as both remedies and poisons, not to a mention useful chemical tools. The history of therapeutic use of mercury and the long debate about proper therapeutic dosages and radiation dosimetry encouraged some pediatric physicians to dismiss harmful effects at "homeopathic" levels, particularly since the results that most environmentalists tracked were subclinical and didn't seem relevant to commonly seen infant disabilities. The myriad forms assumed by quicksilver, the mythical shape shifter of alchemists, resisted simple narratives.

Elemental mercury forms inorganic and organic mercury compounds. Organic mercury, most commonly MeHg, is the major toxic mercury contaminant of wildlife and water. Its history opens up questions of how threats once assumed to be occupational became understood to be a more widespread. Severe mercury poisoning of adults and children from industrial effluent in Japan raised concerns about widespread mercury pollution in wildlife and aqueous environments in the 1960s and 1970s. These concerns evolved into a debate about contested epidemiological evidence regarding fish consumption during pregnancy and subtle intellectual and developmental impairments of children in the 1980s and 1990s. The threat of damaged children from industrial negligence is not new, nor are narratives of pollution linked to disability (or as anthropologist Mary Douglas would describe it, "matter displaced"[22]), yet they were conceived differently as a result of 1960s and 1970s environmentalism, skepticism about medical authority and iatrogenic harm arising from the women's health movement, and criticism of regulatory policy and inadequate government oversight over harmful synthetic chemical products associated with the consumer rights movements. These complex critiques and

[22] Mary Douglas, *Purity and Danger: An Analysis of Concepts of Pollution and Taboo* (London: Routledge & K. Paul, 1966).

negotiated interchanges of the 1960s and 1970s, particularly what sociologists call the "embodied health movement" experienced by women, changed the status of patients and norms of medical practice surrounding the right to know and informed consent.[23] Concomitantly, medical risk-management practices became more prevalent during pregnancy in the late twentieth century, associated with increased antenatal monitoring of pregnant women, prenatal diagnosis, and the rising influence of risk-factor epidemiology as a form of scientific evidence. Thus, two parallel impulses framed the issue of risk-management practices during pregnancy in the late twentieth century: greater autonomy, more information, and increased medical decision-making powers for pregnant patients[24] combined with greater antenatal monitoring in the context of contested and complex expert-driven science of chemical risk derived from studies observing human groups.

Historians and scholars of rhetoric, such as Barbara Duden and Marika Seigel (and also, Michel Foucault) have noted, perceived social and political risks, and sanctions on female behavior, have long been mediated through the disciplining of the pregnant body, though some emphasize medical technologies transforming the experience of pregnancy and the others rhetoric.[25] My argument is that statistical calculations of risk and calls for informed consent, right to know, and greater patient autonomy arising in the late 1960s are fundamental to how risks for pregnant

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[23] Bell, *DES Daughters: Embodied Knowledge and the Transformation of Women's Health Politics*, 4–7.

[24] The impact of reproductive technologies has engaged many historians and social scientists, particularly ultrasound and prenatal genetic diagnostics. Women who consent to use prenatal diagnostics such as amniocentesis have been called "moral pioneers" as they engage with "technologies of the self" to perform "flexible eugenics." Michelle Murphy, *Seizing the Means of Reproduction*.

[25] Duden, *Disembodying Women: Perspectives on Pregnancy and the Unborn*; "The Fetus on the 'Farther Shore:' Toward a History of the Unborn."; Seigel, *The Rhetoric of Pregnancy*.

women were conveyed. Women, often caregivers of children, held particular and intimate knowledge about a fetus or child's symptoms and their own exposures. The statistical science of epidemiology sought to create a calculation of risk that would avoid reliance on fallible maternal memories, but issues of prenatal harm remained controversial, even among scientists.

To demonstrate these shifting perspectives on MeHg exposure during pregnancy, this chapter briefly outlines some of the early uses of mercury compounds and reproductive outcomes of heavy metal exposures examine by industrial hygienists. The following sections use archival materials from the Marion Lamm Mercury Collection at the Harvard Environmental Science and Public Policy Archives to follow the trajectory of alarm about congenital MeHg poisoning and pollution from Japanese fishing villages (1960s) to the Great Lakes and Canadian indigenous communities (1970s) to research on acute grain-related poisonings in Iraq and New Mexico (1970s) to large-scale and far-flung epidemiological studies on the effects of fish consumption during pregnancy (1980s-1990s). These complex and interconnected global stories provide a picture of evolving debates about the link between developmental damage and environmental pollution.

This chapter further examines the rise of public awareness that the fetus was vulnerable to heavy metals in the exogenous environment, and argues that the inconclusive nature of medical knowledge construction using risk-factor epidemiology amid heated environmental politics led to a framing of low-level chemical risks during pregnancy in the late twentieth century as subtle, omnipresent, and ever-changing, placing great responsibility on women of reproductive age to ward off and shoulder the burden of global environmental

pollution. This framing was often linked to a criticism derived from environmentalists and the women's health movement in the late 1960s that the science of low-level toxic exposure during pregnancy had been insufficiently explored, that women and workers needed more and better information about potential toxins, and that industrial pollution might have subtle subclinical effects or threaten future generations. Also, epidemiological science gained a greater role in understanding prenatal risks, but had a complex relationship with lay epistemologies of pregnant women, at times relying on and at times discounting maternal memories and experiences during pregnancy.

Industrial and Medical Uses of Mercury

The story of mercury's transformation from a useful product and medicine, to industrial poison, to a global ecosystem contaminant of particular concern for the development of healthy fetal brains, is complicated because there are many types of mercury. Mercury is typically categorized into three types: elemental mercury, organic compounds, or inorganic compounds. Inorganic compounds were used in products as diverse as cosmetics, paint, fungicides, and laxatives. Both elemental mercury and inorganic mercury compounds have industrial and medical uses and a wide range of potential health outcomes depending on the type exposure, among them, psychological disturbance, tremors, central nervous system or gastrointestinal symptoms, and kidney damage.

Liquid metallic elemental mercury, commonly known as quicksilver, was long prized for its shape-shifting capacities. The use of mercury to extract gold and its

shape-shifting capacities provoked awe and mysticism from medieval alchemists.[26] Both elemental and inorganic mercury compounds (such as mercuric chloride, mercuric sulfide, or mercurous chloride) have been used for myriad medical and industrial purposes, which have exploited each compound's unique properties. The industrial hygienist Leonard Goldwater's 1972 monograph on the history mercury traces the use of quicksilver and the red ore called cinnabar (mercury sulfide) to the Romans and probably the Greeks, for various purposes such as for intestinal obstructions, skin disorders, eye diseases, and in dyes (vermillion) and cosmetics.[27]

It was also described as a poison by eminent early physicians, such as Galen (Claudius Galenus) and Avicenna (Abu Ali al-Husain ben Abdallhal ibn Sina), the beginning of long and ancient debate within medicine about the relative benefits and harms of mercury as a therapy. Was it a poison or a useful therapy? Among its early champions by the sixteenth century was the father of iatrochemistry, Paracelsus (Phillippus T.A. Bombastus von Hohenheim). Although there has been considerable disagreement about the origins and nature of syphilis, the disease variously called French Pox, *lues venereas*, etc., mercury was in use as a treatment for symptoms of venereal disease by at least the late 15th century —initially colloidal mercury and inorganic mercury salts were used, but later, organomercurials.[28] Various compounds of mercury were thought to improve the flow of the liver and were used as a diuretic, cathartic, and laxative, particularly mercurous chloride, or calomel, named for its supposedly mild effects. Diverse conditions were treated with mercury

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[26] Bernadette; Stengers Bensaude-Vincent, Isabelle, *A History of Chemistry* (Cambridge, MA: Harvard University Press, 1996).
[27] Leonard J. Goldwater, *Mercury: a History of Quicksilver* (Baltimore: York Press, 1972).
[28] J. F. Afonso and R. R. De Alvarez, "Effects of Mercury on Human Gestation," *American Journal of Obstetrics and Gynecology* 80 (1960): 145–54.

compounds, from epilepsy, bellyache, ulcers of the tongue, and chronic tumors, to intestinal obstruction and skin conditions. During the age of heroic medicine in the eighteenth and nineteenth centuries, severe reactions such as salivation were seen as a sign of effectiveness.[29] Yet even during the peak popularity of mercury as a medicine, there were always detractors, both homeopaths and allopaths, such as Surgeon General William Hammond, who during the American Civil War thought that calomel was being abused in the army and causing melancholy and "mercurial gangrene," or severe inflammation and infections of mouth and jaw.[30]

At the turn of the twentieth century, the Scottish obstetrician and antenatal pathologist John Ballantyne saw mercury as particularly useful for treating maternal syphilis, an example of antenatal therapy. He was intrigued by the enigma of the placenta as a barrier or conduit for such therapeutics, mainly because he was excited at the prospect of antenatal therapy:

If there is one thing that is certain about antenatal therapeutics, it is the beneficial effect upon the unborn infant of the administration of mercury to the mother suffering from syphilis. It might at first sight be regarded as almost certain that it would be found that mercury passed freely into the feotal economy. Experiment, however, has shown that mercury is apparently transmitted not at all through the placenta but is entirely stored up in its substance. How, then, can the beneficial result be accounted for?[31]

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[29] Leonard J. Goldwater, *Mercury: a History of Quicksilver* (Baltimore: York Press, 1972), 199–246.
[30] Hightower, *Diagnosis Mercury: Money, Politics, and Poison*, 52–53.
[31] John W. Ballantyne, "On Antenatal Therapeutics," *The British Medical Journal* (1899): 889–93.

The long-running hereditarian debate about the effects of paternal and maternal syphilis on the offspring was largely resolved in the early twentieth century when newer treatments such as salvarsan were able to reduce transmission of syphilis from a pregnant woman to her fetus or newborn, casting additional attention to maternal illness as a cause of infant malady.[32]

Mercury would continue to be used in various pharmaceuticals long into the twentieth century, despite debate about relative harms and benefits. In 1948, Josef Warkany and a colleague noted that children with a common skin disorder, "pink disease," had mercury in their urine and had probably been exposed to calomel in teething creams and other skin preparations or medications.[33] Two iatrogenic uses of mercury proved particularly controversial in the late twentieth century, mercury in dental amalgams and the use of the organomercurial compound thimerosal an adjuvant and preservative in vaccines.[34]

Mining of mercury and gold was one of the oldest recognized sources of occupational exposure to mercury. The unhealthy effects of mining were recognized by at least the early modern period.[35] In the nineteenth and early twentieth centuries, acute occupational poisoning, or mercurialism, was also seen in hat

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[32] Erich Hoffmann, "Congenital Syphilis: In the Light of Thirty Years' Investigation of the Spirochete And Twenty-Five Years' Experience with Salvarsan," *The Journal of Pediatrics* 9, no. 5 (1936): 569–603.
[33] Josef Warkany and Donald M. Hubbard, "Mercury in the Urine of Children with Acrodynia," *The Lancet* 251, no. 6509 (1948): 829–30.
[34] The thiomerosal debate is characterized by conflicting evidence of neurodevelopmental effects as well, from researchers such as Michael Pichichero of the University of Rochester and Mark and David Geier.
[35] George Rosen, *The History of Miners' Diseases: A Medical and Social Interpretation* (New York: Schuman's, 1943); Leonard J. Goldwater, *Mercury: A History of Quicksilver* (Baltimore: York Press, 1972); Alfredo Menéndez-Navarro, "Global Market and Local Conflicts in Mercury Mining," in *Dangerous Trade: Histories of Industrial Hazard Across a Globalizing World,* edited by Christopher Sellers, Joseph Melling, (Philadelphia: Temple University Press, 2011), 47–58.

making, mercury amalgams for dentistry, and the manufacture of various products that used elemental mercury or inorganic mercury compounds, such as thermometers, barometers, and electrical rods and wires. Mercury vapors posed a particular hazard when elemental mercury was used in occupational settings.[36] Generally, the symptoms of acute inorganic mercury poisoning include tremor, psychic disturbance, gum discoloration, ataxia, and other effects on the central nervous system and sometimes the liver or kidney.[37] Occupational accounts by progressives in the early twentieth century often note the conflation of the symptoms of occupational mercurialism with other types of mental illness or overuse of alcohol.[38]

In the twentieth century, organic mercury salts were used as fungicides starting in 1914, at times leading to large-scale poisonings, when seed products were used for food. Four occupational cases in a factory that produced MeHg nitrate seed dressing were described in England in 1940 and were named Hunter-Russell Syndrome after the authors**.** The four ill workers breathed MeHg dust from seed grain dressing and experienced tremor, ataxia, dysarthria, and constriction of the visual field. These accounts warned of the unique nervous system effects of MeHg

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[36] Alice Hamilton and Harriet Louise Hardy, *Industrial Toxicology*, 2nd ed. (New York: P.B. Hoeber, 1949), 104–26.
[37] Walton et al., *The Oxford Medical Companion*, 591.
[38] Erethism is a technical name for irritiblity or excitability associated with mercury poisoning. The difficulty differentiating the occupational effects from mental illness or alcoholism was noted both in Josephine Bates's survey of occupational mercury poisoning in New York and vicinities and Alice Hamilton's publications on industrial toxicology. Hamilton remarks of a student with experience metallurgical plant in South America, "he had had three laboratory workers develop mercurialism, one with tremors, one with marked neurasthenia and loss of confidence and capacity to work, the third morose, depressed, and melancholy... How many cases there had been among the native laborers he had no idea, for he had attributed tremors to alcoholism, and stomatitis and gastrointestinal symptoms to tropical parasites." Hamilton, *Industrial Toxicology,* (New York: Harper, 1934), 79.

and linked them to effects on animals and the experiences of chemists and laboratory technicians handling the extremely toxic substance dimethylmercury.[39] Organic mercury poisoning is typically associated with effects on the central nervous system: impaired vision, hearing, speech, coordination and balance, muscle weakness, and disturbing sensations such as tingling (parasthesia). But some environmental researchers posit more subtle and subjective symptoms at low dosages, such as headache or fatigue, memory difficulties, or subtle neurological impairment in exposed fetuses and infants.[40] In general, acute inorganic mercury poisoning is likely to cause more short-term effects and psychological disturbances and kidney or intestinal damage, in contrast to the permanent central nervous system damage associated with consumption of MeHg on grain treated with mercury fungicide or the nervous system effects of low-level and long-term exposures from mercury-laced seafood.

To complicate the matter still further, in the 1960s, scientistists demonstrated that emissions of elemental or inorganic mercury compounds were methylated by bacteria into mercury's more toxic organic form, which was then concentrated in food chains and thought to expand pollution far beyond the localized environment of aqueous industrial pollution.[41] This science was under heated debate

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[39] Donald Hunter, Richard R. Bomford, and Dorothy S. Russell, "Poisoning by Methyl Mercury Compounds," *Quarterly Journal of Medicine* 9, no. 3 (1940): 193–226.
[40] Agency for Toxic Substances and Disease Registry (ATSDR), Toxicological Profile for Mercury, 1997 (Accessed July 15, 2015), http://www.atsdr.cdc.gov/toxprofiles/tp46.pdf.
[41] Thomas W. Clarkson, "Epidemiological and Experimental Aspects of Lead and Mercury Contamination of Food," *Food and Cosmetics Toxicology* 9, no. 2 (1971): 231.

in the context of regulatory and legal efforts to define what constituted excessive MeHg concentrations in fish.

If occupational mercury poisoning had long been a concern, the political debates in North America in the late 1960s and early 1970s were often over the "natural" presence of mercury in the environment. Were mercury levels found in wildlife from industrial pollution or simply the result of mercury derived from the earth's crust? Unusually high MeHg levels in the wildlife of Great Lakes and Canadian river ways were attributed to pollution of the water supply by chemical or paper companies, such as Dow Chemical or Dryden Chemical companies. As mercury pollution turned up in more and more aqueous environments without obvious sources of pollution, such as pulp mills or chemical factories, some critics questioned whether mercury levels were produced by natural methods or were within "normal" parameters.[42]

The long history of mining and its use of mercury compounds left much room for debate about industry's influence on mercury levels in water or air. This effort to define typical, expected, natural, and normal levels of mercury reflects the debate about heavy metals that arose around lead poisoning (by 1965, geochemist Clair Patterson at the California Institute of Technology and others challenged the notion that existing levels of lead measured in most people were "natural" or normal,"

[42] An example can be seen in an editorial clipping from a local newspaper: "If mercury poisoning is not all caused by pulp mills, mines and factories, if Nature is going to continue polluting her own lakes and streams and if this natural mercury pollution has been going on for years and years and years..." Box 1, Folder 5, Marion Lamm Mercury Collection, Environmental Science and Public Policy Archives, Harvard College, Boston, MA.

instead describing them as "typical.")[43] Industrial representatives were inclined to highlight evidence that mercury was ubiquitous irrespective of industrial activities and other sources of mercury pollution, the implicit argument was that mercury wasn't a contaminant if it already existed in nature. Though mercury is present in the earth's crust, industry-generated sources in the environment include burning of coal or crude oil; manufacture of electrical apparatus, such as batteries and fluorescent lamps; industrial control instruments, for instance relays, gauges, seals, and valves; and manufacture of caustic soda and chlorine (mercury cell chloralkali plants can release large amounts of elemental mercury, which settles in waterways).[44] In addition, inorganic mercury compounds have been used in paint, in paper and pulp production, in dental materials and in medical fixatives.[45]

Mercury's use as a catalyst focused attention on mercury-contaminated water in Japan in the 1960s, because the Shin Nihon Chisso Company plant was using mercuric sulfate and chloride as catalytic agents to convert acetylene into acetaldehyde and vinyl chloride, draining the effluent into the Minamata Bay.[46] Put more simply, poisonous mercury was formed and distributed during the production of the new plastics. In short, the many forms of mercury have proved both useful and ubiquitous, at times with devastating consequences.

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[43] Herbert L Needleman, "Clair Patterson and Robert Kehoe: Two Views of Lead Toxicity," *Environmental Research* 78, no. 2 (1998): 79–85.
[44] D'Itri and D'Itri, *Mercury Contamination: A Human Tragedy*, 3.
[45] Phenyl mercuric acetate was used as a slimicide.
[46] D'Itri, "Sources of Mercury in the Environment."

1960s Environmentalism, Redefinitions of Normal Mercury, and the Link Between Childhood Neurological Impairment and Environmental Pollution

Warnings about disabling conditions of children visited upon errant women are not new territory, though it was given a modern cast in the mid-twentieth century. In his discussion of ideologies of heredity associated with constitutional disease in the nineteenth century, Charles Rosenberg noted that "It seems almost too apparent that heredity thus served as a sanction in the communication and enforcing of accepted gender roles; those women who failed to live as women should be threatened with punishment through moral and physical debility in their children."[47] Rosenberg described constitutional illness in the nineteenth century as a malleable and environmentally mediated ideology, in contrast to the determinism associated with eugenics in the late nineteenth and early twentieth centuries.

Occupational exposures to heavy metals to pregnant women, particularly lead, has been decried as potentially hazardous, resulting in miscarriage, infant death or disability, since at least the early part of the twentieth century (as described in Chapter 3). An early survey of mercury poisoning in the hatting industry (from mercury nitrate) in New York area circa 1911, Josephine Bates of the Women's Welfare Department of the National Civic Federation described the effects of mercury on reproduction as follows: "The tremor stage of mercurialism in women is often accompanied by menstrual suppression and miscarriage, and children born

[47] Charles E. Rosenberg, "Bitter Fruit: Heredity, Disease, and Social Thought," in *No Other Gods: Science and American Social Thought* (Baltimore: Johns Hopkins University Press, 1997).

are apt to be scrofulous, ricketic and mentally defective."[48] Likewise, historians of occupational health David Rosner and Gerald Markowitz quote a mother who wrote to Franklin Delano Roosevelt in the 1930s citing occupational exposures to lead as a cause of childhood disability: "How many babies are crippled each year—by lead?"[49] They argued that promoters and scientists allied with industry amplified uncertainty, used playful images of children painting in marketing materials, and blamed the pathological behavior of those children poisoned by lead for their behavioral or intellectual impairment. The lead toxicologist Robert Kehoe at the Kettering Institute presents a particularly illustrative example of the influence of industrial funding (mostly from Ethyl Corp) on lead toxicology.[50]

If early concerns were directed at occupational exposures, infant mortality, and overt childhood handicaps, by the 1960s environmentalists and journalists made explicit claims about harms to reproduction and threats to future generations and progeny from pesticides, herbicides, and industrial pollution. Environmentalists pointed to the threat of fetal damage, arguing that through the activities of industry, and release of specific chemical poisons into a broader environment, innocent children and future generations were harmed.

Environmentalist Rachel Carson had a particularly unique role popularizing fears about unexpected outcomes and impaired reproduction resulting from the dispersion of substances intended to control pests. The main thrust of her concern was directed at organochloride pesticides (e.g. DDT), though organophosphates used

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[48] Josephine White Bates, *Mercury Poisoning in the Industries of New York City and Vicinity* (National Civic Federation, New York and New Jersey Section, 1912), 22.
[49] Markowitz and Rosner, *Deceit and Denial: The Deadly Politics of Industrial Pollution*, 1.
[50] Needleman, "Clair Patterson and Robert Kehoe: Two Views of Lead Toxicity"

as substitutes were little better (e.g. parathion).[51] First published in 1962, *Silent Spring* exposed a larger public to a body of scientific work on the more subtle dangers of widely distributed synthetic substances used as pesticides, even as thalidomide was demonstrating that infant disability might result from prenatal pharmaceutical exposures. In particular, Carson warned that congenital malformations would increase as a result of chemical profligacy: "Some of the defects and malformations in tomorrow's children, grimly anticipated by the Office of Vital Statistics, will almost certainly be caused by these chemicals that permeate our outer and inner worlds."[52]

To summarize, eugenic concerns of large-scale impairment of the quality of children and the population were recast as an environmental problem from chemical pollution. Environmental historian Scott Frickel identifies this reshaping of eugenic fears as follows: "There is evidence to suggest that the genetic hazards frame succeeded in part because it effectively dressed old eugenicist fears of genetic degradation in the symbolic mantle of environmentalism."[53]

As Martin Pernick has argued, eugenics was a complex rhetoric, social movement, and ideology, at times associated with inherited environmental

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[51] Thomas R. Dunlap, *DDT, Silent Spring, and the Rise of Environmentalism: Classic Texts*, Weyerhaeuser Environmental Classics (Seattle: University of Washington Press, 2008); Davis, *Banned: A History of Pesticides and the Science of Toxicology*; Whorton, *Before Silent Spring; Pesticides and Public Health in Pre-DDT America*. Elena Conis, "Debating the Health Effects of DDT: Thomas Jukes, Charles Wurster, and the Fate of an Environmental Pollutant," *Public Health Reports* 125, no. 2 (2010): 337.
[52] Rachel Carson, *Silent Spring*, 40th anniversary ed. (Boston: Houghton Mifflin, 2002), 205.
[53] Frickel, *Chemical Consequences: Environmental Mutagens, Scientist Activism, and the Rise of Genetic Toxicology*, 104.

influences, or simply with good parenting.[54] The threat of damaged children and infants was a political trope with considerable weight that was shared by both the environmental movement and the eugenics movement. Both rhetorical efforts made an appeal to state and individual responsibility to the public and future generations, for different political ends (the legislative victories of the eugenics movement instituted involuntary sterilization policies and immigration restriction, while many environmentalists emphasized curbing and controlling externalities of industrial production, or at minimum testing and restricting the uses of chemicals).

To recap, early discussion of the dangers of heavy metal exposure to children revolved around lead paint consumption by children from occupational settings, painted interiors, or toys; later concern focused on leaded gasoline emissions and other sources of air pollution. dangers of heavy metal exposure to children revolved around lead paint consumption by children from occupational settings, painted interiors, or toys (later concern focused on leaded gasoline emissions and other sources of air pollution). Lead researchers such as Joseph Aub and Robert Kehoe a the Kettering Institute at the University of Cincinnati were funded by industry and tended to portray lead ingestion during childhood in low levels as normal and relatively harmless, with excessive exposure the result of pathological behavior such as pica, as opposed to the competing argument that pathological behaviors were the result of chemical exposure.[55]

In contrast, Teratology Society members were often supportive of defining and ameliorating childhood heavy metal hazards. Pediatricians Robert L. Brent and

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[54] Pernick, *The Black Stork: Eugenics and the Death of "Defective" Babies in American Medicine and Motion Pictures since 1915*.
[55] Markowitz and Rosner, *Deceit and Denial: The Deadly Politics of Industrial Pollution*, 46–47.

Robert W. Miller lent support to efforts to remove lead in paint in the early 1970s as part of the American Academy of Pediatrics Committee on Environmental Hazards.[56] Likewise, Josef Warkany linked a common skin condition of children, called pink disease (acrodynia), to calomel-based skin creams and teething powers.[57] Nevertheless, teratologists could also be called upon to summarize the opinion that there was little convincing evidence linking a particular pharmaceutical or low-dose toxic chemical exposure with congenital malformations.

Fishermen and Neurologists in Japan Confront Industrial Methylmercury Poisoning

When cats started dancing, crows and sea life dying, and humans exhibited strange symptoms in the Minamata Bay in the 1950s, there was considerable mystery surrounding these events. Fisherman and their families were reticent to acknowledge their illness, for fear it was contagious.[58] It was a mother who noticed strange symptoms in her child and brought her 6-year-old daughter, Matsuyio, into a pediatrics clinic in 1956. Initially, physicians suspected viral encephalitis.[59] In one of the first reports in the international medical literature, the Scottish multiple sclerosis expert Douglas McAlpine and Sukuro Araki at Kumamato University described a "mysterious nervous disorder" starting in 1953 that began to assume

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[56] American Academy of Pediatrics, "Lead Content of Paint Applied to Surfaces Accessible to Young Children. American Academy of Pediatrics, Committee on Environmental Hazards," *Pediatrics* 49 (1972): 918–921.
[57] Josef Warkany and Donald M. Hubbard, "Mercury in the Urine of Children with Acrodynia," *The Lancet* 251, no. 6509 (1948): 829–830.
[58] Brett L. Walker, *Toxic Archipelago: A History of Industrial Disease in Japan* (Seattle; London: University of Washington Press, 2010). Timothy S. George, *Minamata: Pollution and the Struggle for Democracy in Postwar Japan*, Harvard East Asian Monographs 194 (Cambridge, MA: Harvard University Press, 2001).
[59] D'Itri and D'Itri, *Mercury Contamination: A Human Tragedy*, 15–16.

epidemic proportions in 1956, when fifteen people were admitted to the hospital with unsteady gait, confusion, disturbances of vision, insomnia, and slurred speech. The authors also note that animals (cats, crows, pigs and one dog) had also died after moving unsteadily, made circling movements, or falling down. Though they stated that the cause wasn't established (and indeed, the Chisso factory would resist official blame, attribution of the source, and compensation for some time to come), it's clear that McAlpine and Araki already suspected that some toxicity in fish, probably a heavy metal, derived from the effluent of the nearby factory was the source of the problem.

To British and Japanese neurology experts in 1956, the outbreak in Minamata was a neurological disorder related to poisoning from eating contaminated fish. Only later, in the early 1960s, would some researchers point to congenital cases, manifested as cerebral palsy, among mothers who appeared to be minimally or completely unaffected.[60] Official acknowledgement of the source of pollution was slow in coming, and a factory physician initially kept silent when his own experiment, feeding company effluent to cats, produced similar neurological impairment. In the late 1950s, chemical analysis of discharge from the factory identified a number of potentially toxic substances, among them manganese and lead. Autopsy comparisons with older cases of occupational poisoning would verify that MeHg was the likely cause of the neurological and developmental impairments associated with Minamata Disease.[61]

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[60] Matsumoto, Koya, and Takeuchi, "Fetal Minamata Disease. A Neuropathological Study of Two Cases of Intrauterine Intoxication by a Methyl Mercury Compound." Daigaku Kumamoto and Kenkyuhan Minamatabyo, *Minamata Disease* (Kumamoto: Study Group of Minamata Disease, Kumamoto University, 1968).
[61] D'Itri and D'Itri, *Mercury Contamination: A Human Tragedy*, 18.

In the late 1950s, an unusual number of children (nine) suffering from cerebral palsy were reported in the area of Minamata, and some local physicians assumed there was a link to Minamata Disease, though the cases were puzzling because the children had eaten no fish or shellfish and the mothers seemed minimally affected. As activist Aileen Mioko Smith described it, the mothers were the closest observers of their children's symptoms: "Usually the mothers of those children began to notice that something was wrong when their babies had difficulty in holding up their heads even after they were six months old. In some cases…convulsion, failure of the eyes to follow, or weak response attracted the mothers' attention to the abnormality of the infants."[62]

The concerns and anxieties of the children's caregivers had to be translated into a verified knowledge of developmental disability. By the early 1960s, Tadeo Takeuchi, Goyo Koya, and Hideyo Matsumoto, autopsied the brains of children suffering from the symptoms of cerebral palsy, concluding, that "there was evidence of malformation of the brain," and "Since the two children never ate fish or shellfish, it is concluded that cerebral palsy was caused by mercury intoxication acquired prenatally from the mother, although the mother did not show manifestations of Minamata disease."[63] In 1964, Masazumi Harada recorded that 9% of infants born near Minamata Bay had cerebral palsy, when less than 3% would be expected.[64]

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[62] Bingham, ed., *Conference on Women and the Workplace, June 17–19, 1976, Washington, DC: Proceedings*, 76–77.
[63] Matsumoto, Koya, and Takeuchi, "Fetal Minamata Disease. A Neuropathological Study of Two Cases of Intrauterine Intoxication by a Methyl Mercury Compound," 574.
[64] Masazumi Harada, "Congenital Minamata Disease Intrauterine Methylmercury Poisoning," *Teratology* 18 (1978): 285–288; Masazumi Harada, "Minamata Disease: Methylmercury Poisoning in Japan Caused by Environmental Pollution," *Critical Reviews in Toxicology* 25, no. 1 (1995): 1–24.

Though reported in international journals, such as the *Journal of Neuropathy and Experimental Neurology,* these papers attracted little attention in the United States before environmentalism and mercury pollution of waterways became major public controversies in North America amid considerable social turmoil in 1969 and 1970. By 1971, roughly twenty-five fetal cases of MeHg poisoning had been cataloged in the area of Minimata, with a range of neurological damage, including microcephaly, blindness, mental retardation, and epilepsy.[65] A clinical review cataloged the symptoms of Minamata disease in children, noting that they were afflicted with "moderate spasticity, chorea, ataxia, coarse tremors, seizures, and severe intellectual deficiencies in various combinations."[66]

Tales of Innocence Lost: A Norwegian Graduate Student and Aqueous Environmental Mercury Pollution in North America in the 1970s

Congenital Minimata Disease caused severe neurological effects of MeHg poisoning from fish consumption by pregnant women was reported in fewer than thirty children. Though the effects were severe, the official numbers seemed very small. But were cases of more subtle or subjective impairment missed or deliberately obscured in industry-driven efforts to minimize compensatory damages? How did lower levels of environmental mercury pollution come to be seen as a problem for pregnant women and fetuses in North America?

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[65] There are divergence accounts of the number of congenital Minamata Disease cases, typically listed between 22 and 26. D'Itri and D'Itri, *Mercury Contamination: A Human Tragedy*; Fa Bakir et al., "Methylmercury Poisoning in Iraq," *Science* 181, no. 96 (1973): 231. Koos and Longo, "Mercury Toxicity in the Pregnant Woman, Fetus, and Newborn Infant. A Review," 391.
[66] Scanlon, "Clinical Review: Human Fetal Hazards from Environmental Pollution with Certain Non-Essential Trace Elements," 136.

Environmental MeHg pollution was slower to arise as a visible problem in the United States compared to other countries. It was Scandinavian farmers and scientists and Japanese fishermen and neurologists who first confronted contaminated food (mostly from organic mercury-based pesticides) and aqueous MeHg pollution. The poisoning of a farming family in Sweden in 1948 linked one child's cognitive impairment with consumption of mercury-treated grain during pregnancy, though the mother appeared largely unaffected.[67]

In the 1960s, environmentalists in Sweden argued that mercury-treated grain was affecting bird populations. Conservationists and radiobiologists who studied bird populations and developed analytical techniques for detecting MeHg, such as Göran Löfroth, at the University of Stockholm, demonstrated death and neurological impairment of raptorial birds.[68] Between 1964 and 1965, it became clear that fresh water fish contained elevated concentrations of methyl mercury.[69]

An interdisciplinary group of Swedish scientists formed what they called a Mercury Group, while seeking to vernacularize toxicological science and disseminate information on the implications of mercury pollution to the public. Rather than focusing on detailed quantification of mercury levels in wildlife, they described mercury contamination in chicken eggs, widely eaten for breakfast.[70] Further alerting the public, mass poisonings were reported in Iraq, Guatemala, the U.S.S.R,

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[67] Koos and Longo, "Mercury Toxicity in the Pregnant Woman, Fetus, and Newborn Infant. A Review."
[68] Göran Löfroth and Margaret E Duffy, "Birds Give Warning," *Environment: Science and Policy for Sustainable Development* 11, no. 4 (1969): 10–17.
[69] Göran Löfroth, "A Review of Health Hazards and Side Effects Associated with the Emission of Mercury Compounds into Natural Systems," *Report of the Radiobiology Division of the Department of Biochemistry, University of Stockholm* (1969).
[70] Michael Egan, "Historicizing a Scientific Interdiscipline: Swedish Mercury Science in the 1960s." Presented at the American Society for Environmental History Conference, Madison, WI, 2012.

and Pakistan in the 1950s and 1960s, which dramatically linked consumption of seed grain treated with alkyl mercurial fungicides to neurological impairment.[71] In a publication prepared for the Swedish Ecological Research Committee in 1969, Göran Löfroth voiced caution about congenital neurological injury from mercury among infants, even when mothers appeared unaffected (he would also serve as a witness in U.S. courts, testifying about the presence of DDT in breast milk).[72] The process of vernacularizing environmental science and raising public awareness consisted of both universalizing risks (such as advertisements about mercury in eggs) and highlighting that infants and pregnant women were particularly susceptible.

The work of these Scandinavian scientists anticipated concern about environmental mercury contamination in North American landscapes and wildlife. Sweden banned the use of the alkyl mercury seed treatments (one of the most common was methylmercury dicyandiamide, or Panogen) by 1966 due to adverse effects on wildlife and accidental poisonings associated with seed treatment.[73] In the same year, a professor at the Krolinska Institute, Lars Friberg, told occupational health researcher Bertram D. Dinman that if Americans looked for mercury contamination in air, food, and water, they would "most assuredly find the problem

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[71] Koos and Longo, "Mercury Toxicity in the Pregnant Woman, Fetus, and Newborn Infant. A Review."
[72] Göran Löfroth and Bengt Lundholm, "Methylmercury," *Bulletins from the Ecological Research Committee*, no. 4 (1970). Other mass poisonings were reported in Iraq, Guatamala, the U.S.S.R, and Pakistan in the 1950s and 1960s typically linked to consumption of seed grain treated with alkyl mercurial fungicides. Use of these organic-mercury-based fungicides as seed treatments and use of phenylmercury acetate in paper manufacturing was curtailed in Sweden by 1966 and in the U.S. in the early 1970s.[72]
[73] Jukes, "Mercury in Fish."

lurking there, awaiting discovery."[74] Likewise, when a Norwegian graduate student, Norvald Fimreite at the University of Western Ontario, took on a project examining Canadian wildlife for mercury, he reported in March 1969, "In this area we must expect mercury contamination, the ecosystems most likely to be contaminated being aquatic, with the highest amounts found at the top of the food chains—fish and fish-eating birds and animals."[75]

Motivated by the alarm that followed Canada's publicity about mercury levels in the Great Lakes (in particular, Lake St. Clair), a team of U.S. scientists was sent to visit to Sweden under the auspices of the HEW Secretary's Pesticide Advisory Committee and the FDA. The team decided that there was not conclusive evidence of immediate concerns about mercury-related disease, though some individuals with high fish consumption might suffer subclinical effects such as delayed neurologic and intellectual damage, and infants and children "may have impaired development." The scientists decided that human health effects were remote yet the United States should follow the Swedes in more widespread surveillance of mercury in the environment and improve their analytical methods for detecting MeHg.[76]

Environmental historian Michael Egan described the states of knowing and unknowing associated with environmental pollutants such as mercury, relating them to Bruno Latour's observation that the long existence of microbes became self-

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[74] Rolf Hartung and Bertram D. Dinman, *Environmental Mercury Contamination* (Ann Arbor, MI: Ann Arbor Science Publishers, 1972).
[75] Peter Calami, "Comment" *Science Forum,* Box 34, Folder 314, Series I, Marion Lamm Mercury Collection.
[76] Study Group on Mercury Hazards, "Hazards of Mercury: Special Report to the Secretary's Pesticide Advisory Committee, Department of Health, Education, and Welfare, November 1970."

evident after Pasteur made his case. Egan argued convincingly that Pasteur's germs are analogous to chemicals in environmental settings, and that the reason why mercury pollution was not perceived as a problem in the United States until the late 1960s was simply because nobody was looking for it, despite earlier warnings.[77] Owning up to the problem and making attempts to restrict contaminated fish consumption in Canada resulted in seemingly inevitable conflict over compensation, legal claims from damaged businesses and indigenous communities, and discussions of how much information about the dangers of fish consumption to reproduction to provide to potential tourists, indigenous populations who subsisted on fish or marine animals, and pregnant women.[78]

Among physicians and officials in the 1960s, concerns about teratogenesis in the 1960s had primarily swirled around pharmaceuticals following the thalidomide tragedy.[79] Widespread attention to teratogenic effects of MeHg was tied to the environmental movement and the shift of medical and scientific attention to sub-clinical neurotoxicity of heavy metals, particularly lead, on children in the 1960s, rather than simply focusing on acute poisoning events. However, concern about

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[77] Michael Egan, "Toxic Knowledge: A Mercurial Fugue in Three Parts," *Environmental History* 13 (2008): 636–642.
[78] The Marion Lamm Mercury Collection at Harvard University consists of a large volume of material collected by American sport fishing entrepreneurs Barney and Marion Lamm. They closed their establishment and sued the government in the 1970s based on the levels of contamination they encountered in local fish populations, after they hired Norvald Fimreite to test their local fish. Their advocacy about mercury did not make them particularly popular with sports fishing operators who chose to keep their operations open and some other residents of the area. Local indigenous populations in particular suffered the economic consequences of the collapse in the sport fishing industry and possibly also suffered insidious health outcomes, although that was under much debate. D'Itri and D'Itri, *Mercury Contamination: A Human Tragedy*.
[79] Brynner and Stephens, *Dark Remedy: The Impact of Thalidomide and Its Revival as a Vital Medicine*.

heavy metals' harmful effects on the fetus existed previously within certain spheres of knowledge—among some parents working in industries that used heavy metals, neurologists, toxicologists and industrial hygienists, who did not typically engage with teratologists.

How did understanding of the particular vulnerability of the fetus to heavy metals in the environment come to America in the 1960s? Was there a delay in recognition of mercury pollution as a concern for pregnant women, despite progressive-era industrial hygienists' attention to lead and other "race poisons" and considerable public concern in the early 1960s about birth defects related to pharmaceuticals? How did the fetus come to be constructed as vulnerable to subtle and chronic effects of trace amounts of heavy metals in the exogenous environment? The answers to these questions can be found in the scientific discourse about "environmental" causes of infant anomalies in the medical community, environmental health research on more subtle neurological effects of heavy metals during pregnancy (mostly related to lead and MeHg), and subsequent changing public perceptions about both severe and subclinical toxic effects from industrial pollutants, which were linked to a veritable public panic about alkyl mercury fungicide seed treatment and pollution of waterways and food supplies in the early 1970s.

The Japanese story of congenital MeHg poisoning became national news in the United States in the context of robust public engagement in the environmental movement and concern over mercury pollution of the Great Lakes. As previously noted, graduate student Norvald Fimreite reported mercury pollution of wildlife in Canada in the late 1960s. He had considerable training in zoology and agricultural

studies and work experience with the Norwegian Water Resources and the Toxicological Committee on Pesticides when he started his PhD program at the University of Western Ontario. His mentor, Bill Holsworth, a population ecologist, wrote to the head of the pesticide section of the Canadian Wildlife Service in 1967, soliciting a research project on the "effects of pesticides on wildlife."[80] The project that J. A. Keith wanted to see mercury contamination addressed, inspired by the Swedish example: "In Sweden, mercury contamination has produced more wildlife problems than has organochlorine pesticide contamination, the mercury coming from both agricultural uses—e.g. seed dressings—and from industrial uses—e.g. pulp factories."[81] Mercury was presented as equally hazardous as DDT to wildlife populations, and the project would entail systematic examination of mercury use in Canada, with analysis of mercury in parts of ecosystems or trends in mercury levels in raptorial bird feathers. The assumption was that mercury-treated seed might affect rodent and bird populations, as it had in Sweden.

Fimreite reported to the Canadian government that he found alarmingly high rates of mercury in some fish populations, causing it to ban the sale of fish from Lake St. Clair in the March of 1970. The mercury contamination of wildlife and water in the Great Lakes was widely publicized, whereupon fishing was restricted starting in the spring of 1970 and both the fishing industry and the livelihoods of local populations were affected. Considerable effort was invested in testing wildlife in aquatic sites across North America, as well as regulating and reducing localized

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[80] W. N. Holsworth to J. A. Keith, 28 September 28 1967, Box 27, Folder 263, Marion Lamm Mercury Collection.
[81] J.A. Keith to William N. Holsworth, 20 November 1967, Box 27, Folder 263, Marion Lamm Mercury Collection.

industrial emissions of mercury and use of organic mercury in slimicides and fungicides. Nevertheless, other sources of mercury pollution, such as from coal-based energy, continued largely unabated.

Diverse standards for daily consumption of seafood were negotiated at federal agencies, reflecting various models of fish consumption, estimated no-effect levels, and levels of mercury contamination, but enforcement was often lax. On the basis of the FDA's 0.5 ppm standard, in the early 1970s certain lots of canned tuna were recalled, fish consumption declined, and the commercial and tourist fishing industries suffered losses. When wildlife in various U.S. states was tested, the problem proved to be more widespread than expected, but it wasn't clear if levels of mercury in wildlife were significantly higher than expected from what were considered baseline natural levels of mercury.[82]

When mercury pollution turned up widely dispersed in the lakes and waterways of North America with no obvious local source of mercury pollution, some local residents rejected claims that mercury pollution was the result of man's activities. Federal regulations set limits for commercial fish sales at 0.5 ppm, but as a contemporary newspaper account put it, "these limits are admittedly arbitrary rather than realistic correlations with specific known health effects in humans."[83] Indeed, regulatory limits such as reference doses, action levels, or threshold limit values were often politically or legally negotiated compromises only loosely based on scientific estimates. In response to the apparent widespread contamination of

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[82] Various lawsuits were initiated from indigenous residents near the English and Wabigoon Rivers in the Grassy Narrows and White Dog Reservations, and efforts were made to collect blood samples and link deaths and infant anomalies to mercury poisoning. See Box 14, Series I-IV, Subject V. Indians, Marion Lamm Mercury Collection.

[83] Hill, "Mercury Hazards Found Nationwide."

aqueous ecosystems with mercury and public alarm, scientists, environmentalists, and consumer advocates wrote monographs and popular articles or held conferences, and on the problem of mercury, and consequently, certain uses of elemental mercury or inorganic mercury compounds, were restricted or banned—in particular seed grain treatment with organomercurials.[84]

The Hucklebys and Mercury Treated Seed

After the banning of fishing in parts of the Great Lakes raised public alarm, the shocking 1969 poisoning of seven members of the Hucklebys, a New Mexican family, was widely reported. Initially, this cluster of illness was treated like an infectious disease outbreak, possibly viral encephalitis. Acute inorganic mercury poisoning was more typically associated with gastrointestinal symptoms and kidney damage. Only further laboratory investigations and eventual comparisons with Minamata disease led a local epidemic intelligence officer, Paul Edward Pierce, to conclude that the children's severe impairments were due to MeHg. The Hucklebys had consumed pork from hogs fed sweepings from seed treated with mercury-based fungicide (despite being coated with red dye intended to warn that the seed was inedible), which resulted in severe neurological complications in several of their

[84] Montague and Montague, *Mercury*; Hartung and Dinman, *Environmental Mercury Contamination*; D'Itri, "Sources of Mercury in the Environment."; Goldwater, *Mercury; a History of Quicksilver*; Friberg and Vostal, *Mercury in the Environment; an Epidemiological and Toxicological Appraisal*; D'Itri and D'Itri, *Mercury Contamination: A Human Tragedy*.

children and their newborn, which became part of the public and medical outcry about the dangers of mercury, along with Minamata disease.[85]

The local investigator of the poisoning, Paul E. Pierce, wrote to a Canadian professor requesting further laboratory evaluation of hair samples. Dr. Jervis, who analyzed the children's hair and identified mercury content as high as 1,000 ppm (compared to 2–6 ppm in normal controls), gave dire warnings for the fate of the fetus: "Based on the tragedies of Japan it would seem probable that the fetus will be irreparably damaged because of the mercury intoxication of the mother. Is she still carrying the baby or has it been delivered already?" Jervis thought serious health effects might occur around 150-200 ppm in hair.[86] An infant, Michael, was born to the Hucklebys without apparent anomaly, but later reports demonstrated neurological impairment.[87] At the age of 5, Michael could crawl, but he was blind, had no speech or sphincter control, and suffered seizures.[88] In the context of the widespread publicity about mercury contamination of the Great Lakes, the Huckleby story was picked up and widely disseminated. The *National Enquirer,* characteristically hyperbolic, published an article trumpeting the risks of mercury in eggs: "Shocking Results of Government Studies Reveal… Everybody in U.S. is being

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[85] Waldron, "Mercury in Food: A Family Tragedy." Berton Roueche, "Annals of Medicine: Insufficient Evidence," *New Yorker* August 22, 1970, 64–81. See also, Box 25, Folder 241, Marion Lamm Mercury Collection.
[86] R.E. Jarvis to Paul E. Pierce, June 9, 1970. (R.E. Jarvis was a professor of Chemical Engineering at University of Toronto) Box 25, Folder 241, IX. Scientific Matters, Marion Lamm Mercury Collection.
[87] Russell D Snyder, "Congenital Mercury Poisoning," *New England Journal of Medicine* 284, no. 18 (1971): 1014–1016.
[88] Noel C. Sorrell to Jill Torry, 30 December 1975. Box 25, Folder 241, IX. "Scientific Matters," Marion Lamm Mercury Collection.

Poisoned by Mercury."[89] More circumspect news outlets expressed fears that the severe mercury poisonings seen in Japan would be repeated in a large scale elsewhere; yet others emphasized the economic loses associated with regulatory restrictions on recreational and commercial fishing sales. It seemed an open question whether mercury exposure might result in the subsequent identification of more widespread childhood neurological impairment at a later date.

Underlying the political controversy over who should pay when such accidental damages occurred and the implications of a contaminated food supply was the question of knowledge construction around issues of developmental damage resulting from environmental exposures. In particular, questions of how corporate interests aided or impeded the construction of scientific knowledge and uncertainties, and subsequent regulatory policy, plagued those who studied mercury. Many of these battles played out in the media and the courts. In the 1970s, Japanese activist physicians such as June Ui served as international ambassadors sounding alarm about Minamata disease. He gave compelling critiques of the slow response of government and industry to human health concerns related to mercury. In a much-quoted editorial, he compared the symptoms of mercury poisoning (tunnel vision, lack of coordination) with the apparent paralysis, impaired vision, and disorganization of government bodies in response to mercury poisoning.[90]

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[89] Harold Martin, "Shocking Results of Government Studies Reveal… Everybody in U.S. Is Being Poisoned by Mercury," *National Enquirer* 1970. Constantine Raffin to Dr. Jervis, 3 February 1971, Box 25, Folder 241, IX. "Scientific Matters," Marion Lamm Mercury Collection.

[90] Grandjean, *Only One Chance: How Environmental Pollution Impairs Brain Development-and How to Protect the Brains of the Next Generation*, 63; D'Itri and D'Itri, *Mercury Contamination: A Human Tragedy*.

Sport Fishing and Indigenous Communities in Canada

In Northwestern Canada, mercury pollution in lakes and rivers was linked to pulp mills and chemical companies. Ambiguous reports of mercury pollution in the Kenora area prompted Barney Lamm, the owner of a local fishing lodge catering to American tourists, to hire Fimreite to test wildlife populations for mercury in the summer and fall of 1970. Mercury levels in fish from the English-Wabigoon river system were high, comparable to mercury levels reported in Minamata. Some species of fish in Clay Lake and the English River had mercury concentrations between 12 ppm and 28 ppm. For comparison, levels around 24 ppm were reported for in fish in Minimata Bay and 7 ppm in Lake Saint Clair.[91] Considerable local litigation was initiated in the 1970s by the Ontario and Manitoba governments against corporations such as Dow Chemical and Dryden Chemical, as well as by private fish tourism operators such as Barney Lamm.[92] Yet was mercury pollution of fish causing infant health effects or childhood impairment among indigenous populations with high fish consumption?

First nation communities who had catered to the fishing tourism industry, such the Ojibway Indians of Grassy Narrows and White Dog Reservations found themselves bereft of their livelihood and prohibited from eating fish from their local lakes on the English-Wabigoon river system in Northwestern Ontario. They tried to prove deleterious health effects and obtain damages from the industry and the government for the loss of employment and food sources, even as health effects

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[91] These numbers were obtained from a draft of "The Sacrificial Lamms," a chapter on the Lamms written by chemist Frank D'Itri, and Patricia D'Itri in the 1970s, *Mercury Contamination: A Human Tragedy*. The drafts are in Box 1, Folder 2, Series 1, Marion Lamm Mercury Collection, HU.

[92] George Hutchinson, "Mercury Pollution: Not Even a Penny of Compensation Has Changed Hands," *London Free Press* 1975.

remained uncertain. Childhood developmental delays were later reported in other indigenous populations with high fish consumption, such as Cree children in Quebec and Inuits in Greenland; scientists tracked delays in development, poor coordination, ataxia, paralysis, hearing loss, blindness, abnormal muscle tone or reflexes.[93]

While economic losses were obvious, perspectives were diverse on the possibility of mercury-related harm to these Ojibway communities—ranging from confidence that there were no demonstrable health effects to criticisms that the government and scientists had failed to adequately test the indigenous communities, explaining why so little evidence specifically linking health effects to mercury was available. Attempts to test for and link mercury exposure to a specific case of one young boy, Keith Pahpasay, with a cerebral-palsy-like anomaly among the Grassy Narrows population were unsuccessful, despite the efforts of visiting Japanese physicians, the Lamms, and a Quaker physician, Peter Newberry.[94] Nevertheless, reportage in *Nature* in 1976 juxtaposed Japanese physician Masarumi Harada's conclusion that there were at least thirty-seven cases with demonstrable visual impairment consistent with mercury poisoning with a local government consultant's

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[93] Gail E. McKeown-Eyssen, John Ruedy, and Alan Neims, "Methyl Mercury Exposure in Northern Quebec: Neurological Findings in Children," *American Journal of Epidemiology* 118, no. 4 (1983): 470–479; Gina Muckle and Pierre Ayotte, "Prenatal Exposure of the Northern Quebec Inuit Infants to Environmental Contaminants," *Environmental Health Perspectives* 109, no. 12 (2001): 1291–99; Anastasia M. Shkilnyk, *A Poison Stronger Than Love: The Destruction of an Ojibwa Community* (New Haven: Yale University Press, 1985).

[94] "I want my baby Keith Brian, 3 years old, to be tested by the Japanese doctors that are at Grassy Narrows. I give permission for Barney Lamm or Peter Newberry to bring my boy to Grassy [sic] for testing." Signed [?] and Marcel Pahpasay, 12 August 1975. F133, B14, Marion Lamm Mercury Collection, HU.

assessment that "to date no Indian has been diagnosed as having mercury poisoning."[95]

Poisoned Iraqi Pregnant Women and Fetuses: The Ultimate Susceptible Humans

In the winter of 1971–1972, another severe poisoning incident linked to seed grain occurred in Iraq, sending more than 6,500 people to the hospital (unofficial reports suggested ten times as many people may have been affected). This mass poisoning included pregnant women, which was seen as an opportunity by some toxicologists to attempt to identify the lowest levels of mercury exposure harmful for human health. Researchers Farhan Bakir and Thomas Clarkson and their colleagues concluded in 1973 that, "one problem that should be given immediate priority is that of identifying the mothers… Once identified, the infants that have been exposed to methylmercury should be studied for many years for signs of effects of such poisoning. Information from such study should help in determining the lowest concentrations of methylmercury that can have toxic effects when consumed by man."[96] As in the case of occupational settings, by the early 1970s poisoned pregnant women and their fetuses were understood by toxicologists as the most susceptible humans, the parameter to determine rational regulatory policies, reference dose standards, and threshold limits under which no human health effects were thought likely.

This topic received extensive study. Indeed, MeHg and radiation have been described as the most well-established and best-documented environmental

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[95] David Spurgeon, "Merury Poisoning in Ontario," *Nature* 260, (April 8, 1976): 476.
[96] Bakir et al., "Methylmercury Poisoning in Iraq," 181.

teratogens in humans.[97] Physician scientists studying perinatal heavy metal poisoning and lead poisoning of children saw the effects of everyday dosages of MeHg as problematic, unknown, and uncertain. It was "potentially the most hazardous trace element for the human fetus. The biological effects upon human beings of lower levels of mercury, as might be encountered in the daily environment, are unknown."[98] Yet research findings were subject to controversy.

There were multiple attempts to re-examine the question of prenatal effects of MeHg using the Iraqi study to illuminate the levels at which there appeared to be no effect on infants born to exposed women. Prenatal exposure to MeHg was linked to cerebral palsy, altered muscle tone, poor reflexes and delayed developmental milestones. Rochester-based researchers and British-trained Iraqi pediatrician Laman Amin-Zaki identified twenty-nine children who had been exposed in utero, and tried to determine developmental effects. Though a number of problems arose—including difficulty determining exact ages and assessing appropriate developmental milestones in rural Iraq—the authors concluded that psychomotor retardation had occurred; yet it was impossible to determine the threshold of effect due to their small numbers.[99] Laman Amin-Zaki and her colleagues published a later report in 1979, which reviewed prenatal effects of methylmercury poisoning after following thirty-

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[97] Thomas W. Clarkson, Gunnar F. Nordberg, and Polly R. Sager, "Reproductive and Developmental Toxicity of Metals," *Scandinavian Journal of Work, Environment & Health* 11, no. 3 (1985): 145–154.
[98] Scanlon, "Clinical Review: Human Fetal Hazards from Environmental Pollution with Certain Non-Essential Trace Elements."
[99] David O. Marsh et al., "Fetal Methylmercury Poisoning: Clinical and Toxicological Data on 29 Cases," *Annals of Neurology* 7, no. 4 (1980): 348–53.

two infants for five years.[100] Later recommendations for safe levels of fish consumption are in part based on the baseline levels at which these poisoned Iraqis seemed to have symptoms.

If, in the early 1970s, Thomas Clarkson and his colleagues thought that they would establish the threshold under which no human health effects were evident by studying pregnant women and their infants in Iraq, providing evidence to establish definitive and uncontroversial guidelines for how much mercury exposure was dangerous, they would be sorely disappointed. Further analysis would trace the health outcomes for roughly eighty pregnant women who had consumed contaminated seed grain, concluding that there were more subtle psychomotor retardation effects that might have been missed by studies that focused only on identifying severe cases of cerebral palsy and that fetal effects might occur at concentrations as low as 10 ppm in maternal hair.[101] However, the threshold of effect for detrimental cognitive impairment from prenatal exposures, if one existed, remained controversial and in flux.

Thomas Clarkson was based at the toxicology program at the University of Rochester, which had undergone a considerable transformation in purpose. The department originated with secret Manhattan Project studies of the human health effects of defense-related exposures. Under the leadership of radiology professor Stafford L. Warren, researchers were asked to assess the acute effects of radioactive

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[100] Laman Amin-Zaki et al., "Prenatal Methylmercury Poisoning: Clinical Observations over Five Years," *American Journal of Diseases of Children* 133, no. 2 (1979): 172–77.
[101] Thomas W. Clarkson, "Mercury: Major Issues in Environmental Health," *Environmental Health Perspectives* 100 (1993): 31–38. Myers et al., "Twenty-Seven Years Studying the Human Neurotoxicity of Methylmercury Exposure," 275-85.

materials.[102] Studies of mercury vapor at the University of Rochester were initiated because it was a byproduct of the production of fuel for the hydrogen bomb.[103] Prenatal radiation had been associated with microcephaly since at least the 1920s.[104] While at the University of Rochester in the 1940s and 1950s, teratologist James G. Wilson had been funded by the Atomic Energy Commission to assess the risks of *in utero* exposures to radiation in rats.[105] By the late 1960s, the University of Rochester Department of Radiation Biology and Biophysics had found new purpose in assessing the impact of pesticides on human health.[106] Nevertheless, despite their technical expertise, toxicologists had a difficult time insisting that their science was free of taint.

Thomas Clarkson was recruited to the University of Rochester in 1965, and he hoped to develop a resin-based antidote with Dow Chemical to ameliorate acute mercury poisoning. Due to his involvement in early studies used to establish initial parameters for safe levels of fish consumption, in this unfolding story his is a voice of conservativism (and possibly unholy alliances with industry) with respect to

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[102] Faden, "The Human Radiation Experiments: Final Report of the President's Advisory Committee." For further information on the history of evolving medical and radiation safety standards, see Bettyann Kevles, *Naked to the Bone: Medical Imaging in the Twentieth Century* (New Brunswick, NJ: Rutgers University Press, 1997); Samuel Walker, *Permissible Dose: A History of Radiation Protection in the Twentieth Century* (Berkeley: University of California Press, 2000); or Barton Hacker, *The Dragon's Tail: Radiation Safety in the Manhattan Project, 1942-1946* (Berkeley: University of California Press, 1987). Journalist Eileen Welsome has told the story of the individuals affected by these efforts to test low-level dosages of substances such as plutonium in *The Plutonium Files*.
[103] Ned Ballatori, Victor G. Laties, and Thomas A. Gasiewicz, "Toxicology at the University of Rochester: From the Manhattan Project to the Environmental Basis of Human Diseases," Department of Environmental Medicine University of Rochester.
[104] Goldstein and Murphy, "Microcephalic Idiocy Following Radium Therapy for Uterine Cancer During Pregnancy."
[105] Wilson, "Differentiation and the Reaction of Rat Embryos to Radiation."
[106] Miller, Berg, and University of Rochester, Department of Radiation Biology and Biophysics, "Chemical Fallout; Current Research on Persistent Pesticides."

mercury's potential harms, defending his prior work against claims of even lower-level effects or no threshold of effect. In this respect, he characterizes some toxicologists' long allegiance to Paracelsus's familiar maxim that "the dose makes the poison," or rather, "the right dose differentiates a poison and a remedy."[107]

Ties to industrial (and defense) funding was seen by later critics, such as physician Jane Hightower, as reason to suspect scientific data produced by the University of Rochester team, despite their obvious expertise in studying the toxicology of acute mercury poisoning. Data collection on this acute mass poisoning were also called into question, due to the repressive political conditions of Iraq under Saddam. As in the case of Minamata-based poisoning, critiques retrospectively some wondered about whether study methodology was suboptimal in such instances of acute MeHg poisoning: Were exposed people comprehensively included in studies and were proper survey methods observed? It seemed probable that only the most acute cases had been identified, so health effects at lower levels had not been properly explored. How could threshold limits of effect for all human fetuses be properly defined under such conditions?

Research methods and results from Iraq were challenged on the grounds that the study population was not reflective of typical exposures or that milder cases of mercury poisoning had been excluded for reasons both practical and political. Critiques like Jane Hightower argued that no-effect levels based on the Iraq poisoning were likely inaccurate as the cases were derived mostly from severe cases that arrived at Baghdad Hospital, and were filtered by physicians loyal to Saddam

[107]Davis, *Banned: A History of Pesticides and the Science of Toxicology*, xii.

Hussein amid political pressure to downplay the epidemic.[108] Critics of research on health effects of heavy metals tended to identify increasingly more subtle evidence of impaired health, calling for more comprehensive studies reporting of neurological symptoms, such as cognitive impairment, fatigue, headaches, or forgetfulness, in order to properly identify no-effect levels, if they existed.[109] There were other issues with the data on prenatal effects. It was possible that birth dates were inaccurate and developmental milestones culture-specific. However, if the data from Iraqi studies were applicable to all pregnant women consuming contaminated fish, estimations suggested that there might be a grave public health hazard from consuming average levels of certain species of fish, like tuna and swordfish.

Some physicians were disinclined to accept evidence of prenatal neurological damage from mercury at low doses and wanted to dismiss them as alarmist fiction or fantasy. The poisonings from fish in Minamata and Niigata, Japan and from seed grain in Iraq and other sites seemed like acute tragic accidents, not applicable to low dose and chronic trace exposures. It wasn't clear to what extent it was realistic to use estimates derived from sudden acute epidemic mercury poisoning from alkyl mercury compounds used as fungicides and consumed in flour products made from treated seed grain with the low-level long-term chronic exposures associated with average U.S. fish consumption. Indeed, the Iraqi research was increasingly was viewed as an aberration from the expected outcomes of mercury exposures from fish

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[108] Hightower, *Diagnosis Mercury: Money, Politics, and Poison*, 131–41.
[109] San Francisco-based physician Jane Hightower argued that there are still populations in the U.S. who are affected by methylmercury poisoning from fish consumption at much lower exposure levels than are admitted by the FDA and other regulatory agencies. Ibid.

consumption during pregnancy.[110] Comprehensive prospective epidemiological studies seemed the best way to answer questions about the longer-term developmental effects of seafood contaminated with trace amounts of mercury, and Thomas Clarkson and his colleagues at the University of Rochester were again on the forefront of this research.

Congenital Mercury Poisoning in Popular Media in the Early 1970s

During the mercury scare of the 1970s, the risks of mercury poisoning portrayed in popular media often highlighted risks to future generations. Given the dramatic poisonings in Japan and Iraq, it seemed possible that severe consequences of more long-term chronic exposures might become evident too late to be prevented. Scientists and activists concerned about environmental mercury pollution, such as Norvald Fimreite and Kenora-based fishing tourism entrepreneurs, Marion and Barney Lamm, explicitly highlighted pregnant women as at risk of harm from such pollution, despite the difficulties in marshaling confirmatory evidence of congenital damage from lower-level exposures. Environmental activists emphasized the potential genetic and teratogenic risks of industrial chemicals. In the *Toronto Star* in August 1970, Norvald Fimreite warned, "[w]e don't really know the extent of genetic damage that can be caused by mercury poisoning' …I would say it is very likely that even one meal of contaminated fish taken by a pregnant woman would cause harm to the fetus." Marion Lamm expressed anxieties about her children: "'I am frightened… I worry about my daughters, I have five of them, and whether the contamination will have an effect on their children. I have read where doctors have

[110] John L Cicmanec, "Comparison of Four Human Studies of Perinatal Exposure to Methylmercury for Use in Risk Assessment," *Toxicology* 111, no. 1 (1996): 157–62.

said that mercury is particularly dangerous to pregnant women, that it concentrates in the placenta and can cause the baby to be born with things like epilepsy and mongolism. That's a terrible thing to think about but it's something we have to think about if something is really going to get done to put a stop to this mercury pollution."[111] Like Rachel Carson, these advocates and scientific activists linked widespread pollution to reproductive damage, and highly stigmatized congenital disabilities.

An influential journalistic effort to publicize the plight of poisoned Japanese fishermen was made by photojournalist Eugene W. Smith, who represented Minamata Bay as a site of corporate conflict and industrial tragedy that foreshadowed later industrial accidents and raised questions about how an environmental suffering was constructed on a world stage. Certainly, the imagery and language that Eugene W. Smith and Aileen Mioko Smith published in their *Life Magazine* article in 1972 and book *Minamata* in 1974 speak to the power of images to evoke a visceral and empathetic response to such experiences of debility, disability, and suffering, particularly the Pieta-like image of seventeen-year-old Tomoko Uemura being bathed by her mother.[112] She is described in the *Life* caption as "maimed by mercury poisoning in her mother's womb… blind, speechless, crippled and deformed." Japan, particularly Minamata Bay and the case of Tomoko, represented a parable of future disaster: "A crowded and heavily industrialized country with simple fishing villages wedged in between mammoth factories. Japan is

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[111] "Mother of Five Worries about Her Grandchildren," *Toronto Star* August 8, 1970. Clipping from Box 1, Folder 6, Series V, Subject I, Marion Lamm Mercury Collection.
[112] Paul Theroux, "The Dirty Hand of Industry in Southern Japan," *New York Times Review of Books* June 1975.

desperately vulnerable to pollution in a way that luckier and larger countries have not been." [113] In this depiction, tragedy in Japan is read as a forecast for other industrialized nations.[114]

The Huckleby family's story also became a case study of damage from environmental pollution, related to fungicide-treated seed but also mercury-contaminated wildlife. In addition to a 1970 *New Yorker* medical-detective-style article by science writer Berton Roueche, titled "Insufficient Evidence," the Huckleby children were highlighted in monographs specific to environmental pollution. In 1971, a wide-eyed image of Ernestine Huckleby clutching a teddy bear was featured in the *National Geographic*'s publication "As We Live and Breathe, The Challenge of Our Environment."[115]

Yet by the 1970s, MeHg poisoning had been conclusively linked to less than sixty cases worldwide of severe prenatal poisoning, causing microcephaly, cerebral

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[113] W. Eugene Smith and Aileen Smith, "Death-Flow from a Pipe: Mercury Pollution Ravages a Japanese Village," *Life*, June 2, 1972, 74–81.

[114] As Brett Walker and others have observed, Japan has experienced a number of unique industrial poisoning incidents affecting infants and pregnant women. Among them, methylmercury, cadmium, tetrachlorobiphenyl, and arsenic poisonings. Cadmium poisoning from rice grown downstream from mining operations was reported as early as 1912. In 1955, developmental neurotoxicity due to arsenic-contaminated milk powder was reported in Japan. Cerebral palsy like symptoms of congenital MeHg poisoning were conclusively linked to fish consumption in apparently unaffected pregnant women at Minamata Bay in the early 1960s. In 1968, tetrachlorobiphenyl-contaminated cooking oil resulted in children born with dark staining of their skin and small size. Japan was so commonly linked to prenatal environmental poisoning by 1973 that Joseph Fraumeni from the National Institute of Cancer argued, "it seems unlikely that Japan is the only country in the world where pollutants in the external environment are harmful to the fetus." Fraumeni, "Chemicals in Human Teratogenesis and Transplacental Carcinogenesis," 811; Grandjean and Landrigan, "Developmental Neurotoxicity of Industrial Chemicals." Miller, "Cola-Colored Babies. Chlorobiphenyl Poisoning in Japan."

[115] National Geographic Society. *As We Live and Breathe: the Challenge of Our Environment* (Washington: National Geographic Society, 1971).

palsy, blindness, psychomotor retardation, developmental delays, and other severe neurological complications in infants exposed *in utero* to fish or seed grain contaminated with MeHg. Were less obvious developmental impairments from eating mercury-contaminated fish going unrecorded, particularly as a control group with no exposure was difficult to designate? This was a salient question that was difficult to answer using the available (ethical) tools of epidemiological science, leaving ambiguity and uncertainty open to the interpretations of diverse audiences.

The Dangers of Eating Fish: Epidemiology and Subtle Cognitive and Behavioral Effects of Mercury-Contaminated Fish

Severe acute permanent neurological effects of congenital MeHg poisoning from accidental poisonings or environmental sources such as fish had been reported in the medical literature for less than 100 children by the 1970s. However, arguably only the most severe cases had been counted. Were more subtle symptoms of mercury exposure during pregnancy being missed in children, such learning disabilities, behavioral problems, motor skill impairment, autism, or poor memory?[116]

In the 1980s, at least two groups of researchers set out to answer these questions. For simplicity, I will highlight the work of Philippe Grandjean and Thomas Clarkson and their colleagues. To recap, Grandjean was trained as both a physician and toxicologist, graduating from medical school in 1973 and successfully

[116] Norwood, *At Highest Risk: Environmental Hazards to Young and Unborn Children*. Robert W. Miller expresses concern about these effects, quoted in Norwood's book, but by 2006 Philip Landrigan and Philippe Grandjean argue that a broad range of chemical exposures to the developing brain could impair cognition. Grandjean and Landrigan, "Developmental Neurotoxicity of Industrial Chemicals."

defending a PhD dissertation on lead toxicity. He and other environmental scientists and concerned physicians of his generation (such as Philip Landrigan) pointed to what they called chemical brain drain: a "pandemic of subclinical subtle neurotoxicity…not apparent from standard health statistics," reflecting impairment of the fetal brain, developmental delays, and behavioral effects as outcomes of prenatal environmental exposures to heavy metals, and other substances, probably with no threshold of effect.[117] In his book and other publications exploring the implications of developmental neurotoxins, Grandjean emphasized that one out of every six children were thought to have some kind of developmental disorder. Yet questions persisted: was this an artifact of increased societal attention to such diagnoses and lower tolerance of minor behavioral deviations, evidence of widespread effects of environmental toxins, or some other coincident factor? When modeling epidemiological data from the Seychelles and Faroe Islands in an effort to create a reference dose, EPA officials also noted that, based on models of data from the Faroe Islands study, there was no evidence of a threshold of effect for MeHg, as with lead. This presented EPA scientists with a dilemma because of the known nutritional benefits of fish and because a reference dose assumed that there was a threshold under which there was no effect.[118]

In this debate, the researchers at the University of Rochester remained unconvinced of subtle developmental impairments due to fish-based diet, arguing that that mercury-laden whale meat was consumed more frequently in the Faroe Islands, that maternal or fetal bodies could repair cellular damage from small doses

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[117] Grandjean and Landrigan, "Developmental Neurotoxicity of Industrial Chemicals."
[118] Rice, "The U.S. EPA Reference Dose for Methylmercury: Sources of Uncertainty."

of mercury, that there were other types of contamination causing detrimental effects in the two studies, such as PCBs or alcohol, and that there were protective effects of beneficial nutrients (among them, selenium) in fish. Since the 1970s, scientists such as Thomas Jukes, had weighed in on the political debates about the dangers of mercury, which they saw as alarmist, showing skepticism about the harmful effects of average levels of dietary consumption of mercury in fish, and citing selenium as a protective element that reduced the impact of MeHg contamination.[119]

British biochemist Thomas Clarkson had been a key researcher on the developmental effects of mercury. He trained as a toxicologist in the 1950s and 1960s, had a long history investigating the human effects of mercury. In the 1960s, he worked on toxicological animal models before he became involved with studies of mercury poisonings affecting people around the world in the 1970s, including some with prenatal effects—from poisoning due to treated seeds in Iraq, to the effects of mercury contamination on fish-consuming populations in Samoa, Peru, the Seychelles, and Canada. He was also interested in developing remedies for mercury poisoning. Was Clarkson overly influenced by his sources of financial support, from the fishing and chemical industries, or other research organizations affiliated with mercury-polluting industries? San Francisco-based physician Jane Hightower, accused the authors of the Seychelles study of allowing funding sources, study site and population, and industry contacts to influence their negative conclusions. These researchers had received funding from organizations such as the Tuna Research Foundation (TRF) and the Electric Power Research Institute (EPRI), though much of

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[119] Jukes, "Mercury in Fish." Constantine G. Lyketsos, "Should Pregnant Women Avoid Eating Fish? Lessons from the Seychelles," *Lancet* 361, no. 9370 (2003): 1667-8.

their funding came from the National Institute of Environmental Health Science (NIEHS).

When questioned about the research methods and politics behind the surveys of the 1971 Iraqi poisoning, Clarkson was invested in the integrity of his own previous research and portrayed the developing fetus as responsive and adaptive. He thought that the body might accommodate low doses of mercury poisoning without permanent damage, assuming some threshold of effect. He, in turn, pointed to the difficulties associated with conflicting and somewhat arbitrary standards from different agencies for what daily levels of mercury-contaminated fish were thought safe to consume, presented a biochemical rational for the existence of a threshold level of effect, and enumerated differences between the Seychelles and Faroe Island studies and populations that could explain their disparate results.

Clarkson saw mercury-related industrial disasters and accidental seed grain poisonings as opportunities to observe the most sensitive indicator of human health effects, in order to determine a threshold under which no health effects were observed. Others (e.g. Grandjean) were less concerned with determining such a no-effect level or thought there was no threshold of effect and wanted to demonstrate this by studying pregnant women. With the growing evidence of pathological behaviors associated with less acute types of lead exposure for children, what concerned such scientists were less the threshold of effect, assumed to very low if it existed, but the social justice implications of potentially subtle neurological or behavioral effects of substances such as MeHg and lead and the prospect of industrial genocide of residents of substandard urban housing (in the case of lead)

and subsistence fishermen such as indigenous Canadian populations, or even citizens who consumed slightly higher than average levels of fish.[120]

Different approaches attempted to resolve these questions of the human health and neurological effects of prenatal mercury exposure. For instance, Joan Spyker had demonstrated that mice could show irregular behavior after prenatal mercury exposure by 1971.[121] Scientists based at the University of Rochester (among them Thomas Clarkson) examined fish-consuming populations in Peru, Canada, and Samoa, and the Seychelles, largely concluding that they could not detect severe developmental problems among populations eating diets of mercury-contaminated fish.[122]

By the mid-1970s, inspired by revelations about the implications of lead poisoning in children, environmentalists called for greater investigation of the subtle behavioral implications in humans of mercury exposures during pregnancy. In the context of a heated 1976 workshop on occupational exposures to women, Kathy Hunninen, a health inspector for the Tennessee OSHA, wanted more information about the subtle effects of heavy metals like mercury:

> One area I think we should probably look at a little bit more in depth is the behavioral effects that have been touched on, particularly in the presentation of mercury. Some of the evidence [from] animal studies show[s] that because of the immaturity of the developing nerve cells even in the late stages of pregnancy, the fetus is very susceptible to

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[120] Eugene W. and Aileen Smith's photo essay, *Minamata* uses this language, quoted in Paul Theroux's review. Theroux, "The Dirty Hand of Industry in Southern Japan."
[121] Spyker, "Methymercury, Mice and Men."
[122] Michael D Turner et al., "Methylmercury in Populations Eating Large Quantities of Marine Fish," *Archives of Environmental Health: An International Journal* 35, no. 6 (1980). Myers et al., "Twenty-Seven Years Studying the Human Neurotoxicity of Methylmercury Exposure."

subtle behavioral effects that might not even show up until five or ten years later.[123]

Prenatal exposure to mercury was thought likely to have long-term subtle neurological or behavioral consequences, not the obvious anomaly visible at the birth of a child that teratologists defined as their field. Concerned neurologists and environmental scientists hypothesized that permanent damage might occur during the intricate unfolding of the nervous system, dependent on a delicate and coordinated migration of cells to their appropriate places. These changes might be easily missed, but were awaiting detection. Subtle and permanent effects of intelligence and behavior might be inscribed in children by heavy metal exposures, particularly those living in communities near waste sites or factories.

The Contested Nature of Epidemiological Evidence on the Environmental Risks Facing Pregnant Women

The differential results of the Faroe Island and Seychelles studies illustrated the challenges of using epidemiology to demonstrate reproductive damage. If the response to MeHg poisoning during pregnancy was slow in coming, it partially rested on the nature of science in the mid-twentieth century. Among the issues that complicated mercury research were the growing technical specialization of the medical profession, specialties directed at particular categories of effect being studied (e.g., anatomical malformation vs. neurological outcomes), and the limited disciplinary spheres in which medical knowledge circulated. Teratologists were interested in acute and obvious clinical infant disability and pharmaceutical-level dosages, and they wanted to avoid controversy and excessive alarm about

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[123] Bingham, ed., *Conference on Women and the Workplace, June 17-19, 1976, Washington, DC: Proceedings*, 143.

improbable exposures. They were also enmeshed in relationships with their governmental, philanthropic and industrial funding sources and committed to solid scientific proof on which to base their knowledge claims about clinical outcomes such as infant anomalies.[124] However, there were considerable limitations of the methodological tools increasingly used in the construction of generalizable medical knowledge—namely, large-scale epidemiological studies of prenatal hazards.[125]

These prospective studies of chronic disease originated from the concerns of preventative medicine and follow a tradition of risk factor epidemiology of chronic disease as it had developed post-WW II in landmark studies such as Bradford Hill and Richard Doll's studies of the etiology of lung cancer.[126] Cohort studies such as the Framingham Heart Study were suited to making causal inferences about behavioral risk factors on populations assumed to be normative (often white middle-class males) that could be examined using individual surveys and for which there was a clear mechanism for quantifying doses and comparing groups.[127]

Epidemiology increasingly became a tool for analyzing risks of chronic disease. For example, Thomas McKeown and collaborators in the Department of Social Medicine in Birmingham, England, began using methods of chronic-disease epidemiology to study congenital malformation in the early 1950s.[128] Likewise, Abraham Lilienfeld at the New York State Department of Health (and later, at

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[124] See Chapter 1.
[125] Doll, "Hazards of the First Nine Months: An Epidemiologist's Nightmare."
[126] Richard Doll and Austin Bradford Hill, "Mortality in Relation to Smoking: Ten Years' Observations of British Doctors," *British Medical Journal* 1, no. 5395 (1964).
[127] Oppenheimer, "Becoming the Framingham Study 1947–1950."
[128] Leck et al., "The Incidence of Malformations in Birmingham, England, 1950–1959."; Leck, "Mckeown, Record, and the Epidemiology of Malformations." Al-Gailani, "Making Birth Defects 'Preventable': Pre-Conceptional Vitamin Supplements and the Politics of Risk Reduction."; "Ciba Foundation Symposium on Congenital Malformations."

Johns Hopkins University) made early efforts to study chronic diseases and disabilities such as cerebral palsy with epidemiological studies, and postulating that there was a range of lethal and other cognitive impairments resulting from difficult births, which they called a "continuum of reproductive wastage," that informed the National Institute of Neurological Disease and Blindness's enormous prospective study on infant neurological impairment, the Collaborative Perinatal Project of the early 1960s.[129] This study would be fodder for a number of subsequent data re-analyses, to address growing concerns about prenatal chemical or pharmaceutical exposures.

Epidemiology is often subject to the criticism that it merely identifies correlations rather than causal relationships.[130] Two approaches are generally taken to study relationships between developmental anomalies and exposures, retrospective and prospective studies. Prospective studies follow cohorts of study participants over time, while retrospective studies often start with current cases and look backwards at exposures.[131] Prospective epidemiological studies such as the Collaborative Perinatal Project, which begun in the late 1950s, are typically

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[129] Abraham M. Lilienfeld and Elizabeth Parkhurst, "A Study of the Association of Factors of Pregnancy and Parturition with the Development of Cerebral Palsy; a Preliminary Report," *American Journal of Hygiene* 53, no. 3 (1951): 262–82.
[130] Austin Bradford Hill, "The Environment and Disease: Association or Causation?," *Proceedings of the Royal Society of Medicine* 58, no. 5 (1965). Philippe Grandjean cites Yale professor Alvan Feinstein as a critique of the epidemiological evidence linking smoking and cancer. Grandjean, *Only One Chance: How Environmental Pollution Impairs Brain Development-and How to Protect the Brains of the Next Generation*, 121. Claire Ernhart was a particular critic of Landrigan and Needleman's studies of neurotoxicity. See Claire B. Ernhart, Beth Landa, and Norman B. Schell, "Subclinical Levels of Lead and Developmental Deficit—a Multivariate Follow-up Reassessment," *Pediatrics* 67, no. 6 (1981): 911–19.
[131] Philippe Grandjean, Roberta F. White, and Pal Weihe, "Neurobehavioral Epidemiology: Application in Risk Assessment," *Environmental Health Perspectives* 104 (1996): 397–400.

expensive and present problems of data validity and comparability, and smaller epidemiological studies are subject to dispute about their relevance and generalizability, particularly given the diversity and thorny categorical complexity of congenital malformations (for instance it was not uncommon for infants to be born with multiple anomalies, which posed classificatory problems).[132] There were additional problems with epidemiology as a tool for illuminating environmental teratogens. To use Rosner and Markowitz's paraphrasing of the problems with environmental cancer epidemiology, "epidemiology was weak and inadequate, *post hoc* in nature, and was likely to underestimate risk."[133] Even the heroic figure of public health epidemiology, Richard Doll, acknowledged in the early 1970s the difficulties of epidemiological study of the prenatal period, calling it an "epidemiologist's nightmare." Even though he stated that the prospect of early prevention of congenital malformation was small, he urged caution nevertheless.[134]

By the 1980s, there was a growing criticism within epidemiology about the problem of "black-box" epidemiology, often characterized as a difference between mechanistic biological approaches and strategies that ignored biology in favor of

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[132] My sources for the Collaborative Perinatal Project include: Klebanoff, "The Collaborative Perinatal Project: A 50-Year Retrospective." Kenneth R. Niswander, Myron Gordon, and National Institute of Neurological Diseases and Stroke., *The Women and Their Pregnancies: the Collaborative Perinatal Study of the National Institute of Neurological Diseases and Stroke*, DHEW Publication No (NIH) 73–379 (Washington: National Institute of Health; for sale by the Supt. of Docs., U.S. Govt. Print. Off., 1972). Discussion of the difficulty in setting up surveillance and registries for birth defects was common, evident in Virginia Apgar's diaries and a symposium put on by the New York Birth Defects Institute: Ernest B. Hook, Dwight T. Janerich, and Ian H. Porter, eds., *Monitoring, Birth Defects and Environment: The Problem of Surveillance: Proceedings*.

[133] David Rosner and Gerald E. Markowitz, *Dying for Work: Workers' Safety and Health in Twentieth-Century America* (Bloomington: Indiana University Press, 1987), 202.

[134] Doll, "Hazards of the First Nine Months: An Epidemiologist's Nightmare."

mathematical models used to identify behavioral correlates of health and disease (but might also be unable to capture larger societal issues or effects).[135] The criticism has been traced to a 1984 article by R. Peto, but it's probably older. Harvard epidemiologist and McKeown's mentee, Brian MacMahon used the term in 1980.[136] Yet mathematical models were inherently imperfect representations of reality, and epidemiologists like Mervin Suser argued for humanist, eco-epidemiological, or systems biology approaches as ways to reinvigorate the field.[137] Epidemiology is by definition a science of statistics applied to human groups. As such, it is less helpful for determining an individual's risk than defining average levels thought to be within certain risk tolerances. Individuals may respond to various substances outside the typical risk ranges, particularly as there is likely considerable variability in individual dietary consumption and exposures to other substances.[138] For example reactions to mercury-based creams is different for individuals, and only some children exhibited sensitivities that lead to pink disease upon exposure to mercury-based compounds.[139]

With respect to environmental exposures related to industrial pollution, one of the major concerns of epidemiological studies set up to study the problem was how accurately they were reflective of the exposed public or community (i.e., the study

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[135] Malcolm Maclure and Brian MacMahon, "An Epidemiologic Perspective of Environmental Carcinogenesis," *Epidemiologic Reviews* 2, no. 1 (1980): 19–48.
[136] Douglas L. Weed, "Epidemiology, the Humanities, and Public Health," *American Journal of Public Health* 85, no. 7 (1995): 914–918; Douglas L Weed, "Beyond Black Box Epidemiology," 88, no. 1 (1998): 12–14.
[137] Susser, "Epidemiology in the United States after World War II: The Evolution of Technique."; Susser and Susser, "Choosing a Future for Epidemiology: II. From Black Box to Chinese Boxes and Eco-Epidemiology."; Weed, "Beyond Black Box Epidemiology."
[138] Hightower, *Diagnosis Mercury: Money, Politics, and Poison*.
[139]D. W. Austin et al., "Genetic Variation Associated with Hypersensitivity to Mercury," *Toxicology International* 21, no. 3 (2014): 236–41.

population's representativeness and study generalizability).[140] In the case of epidemic poisoning such as at Minamata and Iraq, physicians and scientists were most likely to identify those most severely affected, particularly when there were political and economic incentives to minimize the epidemic.

Questions arose starting in the 1970s about the appropriate way to identify exposed children. Cerebral palsy was linked to congenital mercury poisoning in Japan, but they initially identified only the most severely affected children. Did emphasis on obvious clinical effects such as cerebral palsy compromise the data collected on human tolerance of methylmercury and other possible developmental effects of exposure *in utero*? It was challenging to define an appropriate control group when studying widely dispersed environmental chemicals. Due to widespread contamination, researchers inevitably were comparing two groups exposed to environmental pollution, just greater and lesser exposures.[141] In particular, the

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[140]Critiques of Neel and Schull's studies of the mutagenic effects of atomic radiation in the 1950s sometimes hinged on how they had defined exposed and unexposed control groups. The Secretary's Commission on Pesticides (known as the Mrak Committee, as it was chaired by microbiologist Emil Mrak) examined harmful effects of pesticides in the late 1960s and identified mutagenicity and teratogenicity as potential issues to consider, decrying the lack of adequate data, difficulties in designing prospective studies, and querying how unusual clusters of birth defects might be identified. Environmental epidemiological studies in the mid-1970s set out to link industrial exposures to health outcomes in infants or children living in communities nearby. See Peter Infante's work on vinyl chloride manufacturing and adverse birth outcomes, or Philip Landrigan's work on the health of children near lead smelters in Texas. Lindee, *Suffering Made Real: American Science and the Survivors at Hiroshima*; Mrak, "Report of the Secretary's Commission on Pesticides and Their Relationship to Environmental Health, Department of Health, Education and Welfare Publication." Infante, "Oncogenic and Mutagenic Risks in Communities with Polyvinyl Chloride Production Facilities." Landrigan et al., "Neuropsychological Dysfunction in Children with Chronic Low-Level Lead Absorption."; Landrigan and Baker, "Child Health and Environmental Lead."

[141] This problem was particularly well explored with respect to lead and radiation. One of the local criticisms of geneticist James V. Neel and William Schull's large epidemiological study of potential genetic effects on Japanese children born to

1980s studies in the Seychelles and Faroe Islands raised the prospect that other confounding chemicals, such as PCBs or selenium were affecting outcomes, either contributing to the correlation between mercury and developmental effects or diminishing it.[142]

There were also potential biases associated with the study populations who were exposed to mercury: they were often dependent on fishing for food or livelihood. Researchers in Samoa, Peru, the Faroe Islands, and the Seychelles asked populations that ate seafood to participate in various studies, laying aside their own personal and local interests and concerns to collect data and create universalizing scientific knowledge. Yet how could fishermen and their families living in areas where canning was the major industry be entirely objective about the outcomes of the study?

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survivors was that their control group had also been exposed to radiation. In the case of lead, geochemists such as Clair Patterson noted that lead was contaminating his laboratory experiments when using mineral isotopes to estimate the age of the earth, and set out to demonstrate that lead pollution in air was in excess of pre-industrial levels (e.g. lead concentrations measured in humans should be considered "typical" rather than "normal" or "natural"). Lindee, *Suffering Made Real: American Science and the Survivors at Hiroshima*. Grandjean, *Only One Chance: How Environmental Pollution Impairs Brain Development-and How to Protect the Brains of the Next Generation*. Needleman, "Clair Patterson and Robert Kehoe: Two Views of Lead Toxicity."

[142] These questions about the beneficial effects of fish were interrogated most forcefully with respect to the disparate results of the Seychelles Island and Faroe studies in the 1990s, but the issue of how to designate exposed and unexposed in epidemiological studies of trace or low-level chronic environmental chemical or radiation-related prenatal exposures had been raised since Neel and Schull's studies of the genetic and reproductive effects of exposures to the atomic bomb explosions in the 1950s, and by the 1970s were a common refrain of proponents of regulatory reform of chemical policy, such as pediatric oncologist Samuel Epstein. Some rejected recalls of canned fish as unnecessary or erroneous, evident in Thomas Jukes' 1975 dismissal of the mercury scare of the early 1970s. He argued that mercury existed in the environment and in fish regardless of man's activities and that selenium in fish had a protective effect. Jukes, "Mercury in Fish."

Were the studies large enough (adequately powered) to measure the differences between expected and baseline neurological or anatomical impairment? The problem of power, or expected study population number sufficient to have statistical validity, was generally a major concern for studies of rare outcomes that were unable to reject the null hypothesis that there was no effect.[143] Epidemiological studies might simply be insufficiently sensitive to detect deleterious effects. Or were outliers with severe developmental problems attributed to other causes removed from analysis inappropriately?[144] Research decisions made during study design and epidemiological data analysis could greatly affect the outcomes of the study, particularly the size of the study and decisions to include or exclude certain outlying cases (such as severe neurological impairment presumably associated with other factors, like a difficult birth).

Critics implied that industrial interests, such as the Tuna Research Foundation or the Electric Power Research Institute, had far too much influence in contributing to the expertise of researchers and the deliberations of regulatory agencies and were amplifying uncertainty in an effort to forestall negative publicity and maintain profits.[145] Thomas Clarkson and the Rochester team examined the question and came out with conflicting evidence that did not support the conclusion

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[143] Strobino, Kline, and Stein, "Chemical and Physical Exposures of Parents: Effects on Human Reproduction and Offspring."

[144] As one epidemiologist in the 1980s described the issue of genetic effects of radiation exposure, it was difficult to distinguish an effect of low-level exposure against a considerable variability in the outcomes of human development. Gilbert Beebe "risks are apparently so small following low doses of sparsely ionizing radiation that they cannot easily be seen in the presence of the intrinsic variation characteristic of human health. In short, the signal cannot rise above the noise." Gilbert W. Beebe, "The Atomic Bomb Survivors and the Problem of Low-Dose Radiation Effects," *American Journal of Epidemiology* 114, no. 6 (1981): 761.

[145] This argument was coming from Jane Hightower, among others. I have no further evidence to support or reject this conclusion.

that dietary mercury exposures from fish consumption during pregnancy caused developmental delays. In their opinion, the differences in intellectual acuity or development among the more and less mercury-exposed, if they existed, were likely very small. Nevertheless, to some environmentalists, parents, and consumer advocates, it seemed reasonable to be skeptical of the ability of medicine and the federal government to protect populations from industrial harms, particularly about topics that were likely politically controversial, where industrial secrecy was common and uncertainty reverberated.

In some respects, the 1970s panic over mercury pollution diminished as some of the most egregious sources of mercury poisoning (such as mercury products used as slimicides, fungicides, or in chloralkali processes to produce chlorine or as catalyst to produce vinyl chloride and acetaldehyde) were somewhat curtailed, accompanied by concerns about new chemicals, complaints that the cost of reduced emissions was too great given the number affected, long-running lawsuits, and relatively toothless regulations with respect to many sources of pollution. The worst fears of environmentalists in the 1970s about potentially widespread severe Minamata-like neurological effects of low-level chronic dietary mercury exposure within ten to fifteen years seemed largely unrealized. By the 1980s and 1990s, toxicologists and environmental scientists attempted to assess more subtle risks and benefits of fish consumption for pregnant woman as demonstrated by epidemiological cohort studies, constructing data on risk in efforts to inform practices of avoidance during pregnancy.

Conclusion

Why were knowledge and communications about the potential health risks of mercury for pregnant women so contested? The issue of chemical exposure of pregnant women lies at the nexus of three contentious issues in the history of the mid-to-late-twentieth-century medicine: reproduction, disability, and environmental (in)justice.[146] Earlier debates about childhood heavy metal poisoning tended to frame the problem as one of individual pathological behaviors, but amid a burgeoning environmental movement in the 1970s, debates revolved around uncertainty associated with lower doses, subclinical toxic effects, and contested evidence of harm from prenatal exposures.[147] Childhood anatomical disability linked to chemical harm was compelling in the courtroom, sometimes winning settlements for the plaintiffs, but what about less obvious subclinical toxic effects like those that started to receive attention in the late 1960s? Were testing systems adequate to indicate all health effects of industrial subtances? It is tempting to point to the malfeasance, obfuscation, and emphasis on scientific uncertainty and self-serving classifications of teratogenesis, illness, or disability that was characteristic of some corporate representatives, lobbyists, and industry-funded academics in debates of industrial health effects.[148] Indeed, there were considerable politics surrounding the evidence

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[146] Sarah Franklin and Helena Ragoné, *Reproducing Reproduction: Kinship, Power, and Technological Innovation* (Philadelphia: University of Pennsylvania Press, 1998), 65.
[147] Warren, *Brush with Death: A Social History of Lead Poisoning*. Markowitz and Rosner, *Deceit and Denial: The Deadly Politics of Industrial Pollution*.
[148] There are a range of environmentalists, social scientists, historians, and others who have examined how scientific uncertainty is manipulated in different contexts and the intimate relationships that sometimes form between scientific authority and industrial funding. Uses of the precautionary principle often hinged on differing interpretations of scientific uncertainty. Vilma Hunt, Jane Hightower, David Rosner, Gerald E. Markowitz , Naomi Oreskes and Erik M. Conway come to mind.

required to indicate harm from chemicals, with environmentalists arguing for *in vitro* or animal studies that identified hazards before they occurred in humans and representatives of industry often wanting demonstrations of human illness to verify claims, arguing that claims about more subtle symptoms were due to excessive alarm, spurious extrapolation of animal data to humans, or erroneous epidemiological correlations.[149] Industry at times stooped to character assassination of scientists who were vocal about environmental injustice. Eminent scholars who wanted to advertise the risks of lead poisoning from sources such as leaded gasoline, such as Herbert Needleman and Clair Patterson, were alternatively pillaried in the press in efforts to discredit their work, or offered research grants by industrial giants such as Ethyl Corporation.[150]

Others historians and social scientists, such as Lynn Morgan, Sarah Dubow and Monica Casper, identify changing notions of fetal patient and personhood that allowed claims to be made on behalf of the fetus, a widely recognized and politically contentious figure as a result of the debates over the morality and legality of abortion. Pregnancy defined by maternal interpretations and symptoms and recognized based on perceptions of internal movement, as it was in the early twentieth century, discouraged prohibitions and legal claims on behalf of the fetus, which changed with growth of medical technology and the rise of the fetus as a legal

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[149] David Rosner and Gerald E. Markowitz, *Deadly Dust: Silicosis and the Politics of Occupational Disease in Twentieth-Century America* (Princeton, NJ: Princeton University Press, 1991); Markowitz and Rosner, *Deceit and Denial: The Deadly Politics of Industrial Pollution*. 201–202

[150] Needleman, "Clair Patterson and Robert Kehoe: Two Views of Lead Toxicity."; Rosner and Markowitz, "Standing up to the Lead Industry: An Interview with Herbert Needleman."

claimant, person, and patient in the second half of the twentieth century.[151] Certainly, in the context of conflict about women's rights and reproductive autonomy that supercharged the politics of fetal harm and provoked debates about the rights of women and the rights of the fetus, the topic of fetal environmental exposures became volatile and politically powerful in the 1970s.[152]

This was also a global story, with much of the initial research on congenital exposure to mercury taking place in settings far from the United States: Sweden, Japan, and Iraq. The slow response to prenatal mercury exposure wasn't only the result of biases or emphasis on scientific uncertainty introduced by industrial funding of toxicology and other sciences. In the 1950s America, teratologists and other physician scientists preoccupied with the immediate concerns of treating developmentally disabled children often saw the social-structural problems of industrial pollution or atomic fallout as intractable problems with insignificant impact on most severe spontaneously occurring childhood disability. Nevertheless, they also shared with industry representatives what environmental historian Nancy Langston calls "a modernist worldview that combined faith in scientific expertise with the belief that technological progress could and should control nature."[153]

Underlying differing opinions were philosophies about the promise of technology: did scientists look with optimism or despair at the prospect of

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[151] Notably, prenatal torts were first recognized in 1946 with the case of *Bronbrest v. Kotz* following serious injuries derived from delivery with forceps, marking a significant shift in the concept of fetal personhood and the rise of fetal rights, not to mention physicians' fears about liability. Dubow, *Ourselves Unborn: A History of the Fetus in Modern America*. Morgan, *Icons of Life: A Cultural History of Human Embryos*. Casper, *The Making of the Unborn Patient: A Social Anatomy of Fetal Surgery*.
[152] Reagan, *When Abortion Was a Crime: Women, Medicine, and Law in the United States, 1867–1973*.
[153] Langston, *Toxic Bodies: Hormone Disruptors and the Legacy of DES*, xi.

humankind's ability to engineer a technological solution to social and environmental problems? Physicians concerned about congenital malformation often tended to emphasize individual behavior and science-based medical tools of prevention and rehabilitation that seemed within medicine's control. Within medicine, there was considerable pressure to focus on clinically relevant problems. A generational effect is evident as identification of subclinical harms evolved. Older pediatric physicians and scientists were initially dismissive of low-dose chemical concerns as superstitious and lacking sufficient evidence. Younger scientists and politicized public health physicians trained during civil rights and other youth movements amidst the unrest of the 1960s, often interrogated lower doses and subclinical effects, particularly with respect to issues of social injustice raised by poor children apparently impaired by aqueous sources of mercury, lead poisoning in substandard housing, or air pollution.

Medical emphasis on behavior over questions of social welfare in part reflected the biases of risk factor epidemiology as it arose as a favored epistemology in the second half of the twentieth century.[154] Epidemiology was sometimes capable of illuminating subtle relationships but was unable to conclusively resolve society's controversies about low-level chronic exposures to heavy metals or other substances, particularly as the parameter for harm was changing. Even as medicine became more preoccupied with lifestyle choices and biochemical, molecular, and genetic causes of developmental disability, industrial hygienists, environmentalists and consumer movements of the late 1960s emphasized the permeability of bodies and

[154] Sellers, "Discovering Environmental Cancer: Wilhelm Hueper, Post-World War II Epidemiology, and the Vanishing Clinician's Eye."; Gerald M. Oppenheimer, "Becoming the Framingham Study 1947–1950,"

wombs to pollutants and harmful chemicals in food products, using damaged fetal bodies as a trope (echoing the tactics of eugenics and the pro-life movement) and calling for a societal response to ill health and infant disability produced by man-made pollutants.

The postwar period is often thought of as the ascendant period of medical authority, when physicians had particular optimism about their ability to intervene upon individual bodies to cut out or cure disease.[155] By the 1960s, critical voices arose that emphasized bodies' contiguousness with a local environment and similarities to animal populations, destabilized by radiation or specific toxic chemical pollutants. Public outcry about teratogens and chemical toxin harmful to development had tended to emphasize an evolving array of high-profile substances (thalidomide, cyclamates, mercury, lead, DDT, PCBs, Agent Orange/2,4,5-T/dioxin, DES, BPA, and specific endocrine disruptors) and ignore the more complex and pervasive presence of numerous other exposures or substances in combination—the politics of plastics.[156] Stories about environmentally caused birth defects sold newspapers in a way that accounts of chemical regulatory policy did not. The trope of birth defects caused by malicious polluting corporations tends to present a simple story that hides the broader issues of lower tolerance of health risks amidst insatiable consumer demand for the products of chemical ingenuity, as a higher

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[155] Paul Starr, *The Social Transformation of American Medicine* (New York: Basic Books, 1982). Specific examples of ascendant medical authority may be seen in midcentury medical attempts to treat breast cancer, intersex conditions, or conjoined twins. See Barron H. Lerner, *The Breast Cancer Wars: Hope, Fear, and the Pursuit of a Cure in Twentieth-Century America* (New York: Oxford University Press, 2001). Alice Domurat Dreger, *One of Us: Conjoined Twins and the Future of Normal* (Cambridge, MA: Harvard University Press, 2004); *Hermaphrodites and the Medical Invention of Sex* (Cambridge, MA: Harvard University Press, 1998).
[156] Vogel, "The Politics of Plastics: The Making and Unmaking of Bisphenal a 'Safety'."; Vogel, *Is It Safe?: BPA and the Struggle to Define the Safety of Chemicals*.

standard of living for all became synonymous with having wider access to cheaply produced industrial products and inexpensive energy.

Infant or fetal imperfection, impaired intelligence, or functional disabilities linked to industrial exposures were major outcomes of concern for some environmentalists. Antihereditarian narratives of environmental harm are typically assumed to be arguments for social amelioration juxtaposed against the transformative discourses of medical genetics that pinpointed bodily defect in genes and paved the way for prenatal diagnosis with the option of abortion. Yet antihereditarian voices were complicated, and largely differed over whether they saw science and technology as human progress capable of resolving problems or a source of future peril.

In some respects, it makes little difference whether infant imperfections are genetic or caused by the maternal environment if systematic examination for undesired characteristics and abortion are the primary tools of addressing various severe developmental anomalies, reducing the number of infants born severely disabled. In the context of medical abortions that appeared to reduced the probability of infant disability, subtle disability from poisoning and damage to future children became a are more salient problem, and was conceived of as a worst-case scenario of industrial negligence. This galvanized women to participate in environmental causes, but at times demonstrated a myopic attention to specific chemicals and the fetus or embryo and minimized the overlapping toxic exposures faced by adults.

Often, the target of environmentalists was, aptly, many corporations' unwillingness to pay for cleaner technologies and proper waste disposal and the

negligence and obfuscation associated with industrial emphasis on scientific uncertainty. However, the use of eugenic tropes for the purposes of galvanizing political will to address environmental issues in the context of contested epidemiological evidence of harm placed potentially pregnant women at the nexus of this contested debate and increased scrutiny of their behaviors and working life. If some informed parents practiced habits of avoidance during pregnancy, this can be partially attributed to government, medicine, and industry's apparent reluctance to alarm them, despite their inability to ensure safety, amid contested laboratory and epidemiological evidence of prenatal harm.

Conclusion

In 1971, a journalist named Sue Reilly warned readers of the *Los Angeles Times* that "simply by breathing the air a pregnant woman can permanently cripple her unborn child for life."[1] Later, Ronald and Barbara Gots warned expectant women in an advice manual that by "the aspirin she takes, the aerosol she sprays she breaths, the nicotine, caffeine and artificial sweeteners she consumes are swiftly shuttled into her baby's delicate tissues," but they could only hope to "point out some of the potentially hazardous chemicals that you might encounter at work or at home. Most often, we won't be able to tell you, 'Yes, this is known to be dangerous to the fetus,' because no one has looked into it."[2] In the 1970s, pollution-related toxic exposures in the home or community were constructed in popular media as a ubiquitous and insidious, yet uncertain, problem to be managed by pregnant women.

By the 1980s, pregnant women faced a deluge of risk information and daily decisions about how to make their bodies a "healthy environment" for their unborn babies. They became responsible for interpreting and managing diverse environmental exposures, even as they became "moral pioneers" grappling with the implications of genetic diagnostics and new reproductive technologies.[3] For those who had access to technologies such as prenatal diagnosis and ultrasound observation of anatomical anomalies, the probability of having a child with an

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[1] Sue Reilly, "Grim Findings: Spotlight on Birth Defects" *Los Angeles Times*, March 29, 1971, 1, 12.
[2] Barbara A. Gots and Ronald E. Gots, *Caring for Your Unborn Child* (Stein and Day, 1977), 4, 201.
[3] Rayna Rapp, "Moral Pioneers: Women, Men and Fetuses on a Frontier of Reproductive Technology," *Women's Health* 13, no. 1–2 (1987): 101–16.

anomaly seemed less likely. Concomitantly, risk tolerance for environmental exposures to pharmaceuticals and toxic chemicals declined and fears about the detrimental effects of hidden exposures on future children became more vivid. How did the womb become seen as a risky environment? How did women's bodies become a key focus site for managing knowledge and anxieties about environmental risks? What politics, scientific methods, and social movements shaped this sense of pregnant women's responsibility to protect future generations from toxic exposures?

In this dissertation, I illustrated how between 1950 and 1980 pregnancy was constructed as a risky period and the uterus as a potentially toxic environment, a place of particular vulnerability to teratogenic pharmaceutical or chemical exposure. Using archival resources, published literature, and interviews, I drew upon diverse narratives of scientists, physicians, advocates, and environmentalists who tried to manage how the effects of environmental exposures on fetal or infant disability were described in popular print media and understood by parents (particularly expectant mothers). Delving into sources such as the Teratology Society Records, the March of Dimes Archives, the personal papers of Virginia Apgar and Vilma Hunt as well as popular and scientific publications, I traced the rise of anxiety about teratogenic exposures during pregnancy.

In the 1950s, pediatric physician scientists, geneticists, and embryologists grappled with the long history of nature vs. nurture debates on the origins of anomalous children, seeking to define biological mechanisms for how environmental factors affected development, mostly in animal models. They were influenced by the ancient medical and scientific fascination with generation and apparently naturally occurring severe anatomical anomalies in infants, termed "monsters." Their

engagement in the longstanding debate about nature and nurture was also influenced by wartime research on radiation safety and postwar cultural expectations about reproduction and motherly protection and responsibility in the midst of the baby boom.

In particular, my work contrasts the worldview of teratologists, who were initially engaged with defining environmental origins of diverse, severe, spontaneously occurring congenital malformations in the 1950s with a vision linked to toxicology, occupational health, and environmental science in the 1960s and 1970s. In the late 1960s and early 1970s, consumer advocates, environmentalists and some feminists looked to subclinical neurological or long-term outcomes on the fetus as the most sensitive indicator of industrial damage and radiation- or chemical-associated mutagenesis or teratogenesis, from an ever-shifting array of substances, but particularly from pesticides, food additives, and industrial accidents, effluent, or waste. Some teratologists, particularly pediatric epidemiologists such as Robert W. Miller, were also engaged with the possibility of more long-term or subtle neurological or carcinogenic effects from such trace exposures.

I examine the interaction and narrowing distance between two disciplinary fields that mobilized scientific evidence about environmental exposures: teratology and environmental science. Teratology was linked to embryology, radiobiology, and medicine. Teratologists were initially concerned with naturally occurring mechanisms of infant malformation. In contrast, environmental science was derived from studies of occupational disease that by the 1950s and 1960s interrogated the subtle or long-term health effects of chronic occupational chemical exposures. They were united by their shared interest in reproductive toxicology in the 1960s and

early 1970s, amid debates about industrial fetal protection policies and risks to the fetus from pharmaceuticals, the workplace, and the broader environment. Environmental scientists interrogated the methodologies developed by teratologists and others to assess the risks of prenatal exposures as the definition of teratogen expanded to include transplacental carcinoma, cognitive impairment, and other more long-term or subtle effects.

Teratologists, particularly physician scientists such as Josef Warkany and Virginia Apgar, saw themselves as advocates for severely disabled children. They turned to narratives of environmental damage to counter eugenic approaches to disability (sterilization and other types of coercively controlled reproduction or euthanasia), even as they reframed eugenics to emphasize individual parental responsibility and decision making (often directed at mothers). They cared deeply about environmental factors affecting infant disability and were both swayed by popular anxieties about infant anomalies and ambivalent about the ways in which their research was interpreted amid the influence of the popular environmental movement in the 1960s and 1970s. Teratologists sometimes saw the concerns of journalists, environmentalists and parents as alarmist, and emphasized cases where the public was alerted unnecessarily, even when there was little definitive proof that a given pharmaceutical or chemical (or potato blight, caffeine, or air travel) was causing developmental disabilities. Occasionally, they seemed to be a foil to scientific activists from biophysics and genetics who speculated about dire consequences of dispersed radiation from nuclear testing or chemical mutagens and posited that infant or childhood disability would be associated with mutagenesis of germ line material.

Teratologists defined environmental factors affecting development broadly to include physical or mechanical injury and infectious disease along with biochemical interactions. The Teratology Society and its members were initially engaged with questions of radiation safety and inadequate nutrition and were affiliated with philanthropic efforts intended to ameliorate or prevent crippling conditions of children. Several key members had trained at the University of Rochester during World War II, when the Manhattan Engineering District (later known as the Manhattan Project) funded wartime projects to assess the acute health effects of the atomic bombs. Mobilized by industrial, public, and government concerns about thalidomide in 1962, teratologists' expertise was then directed at reproductive toxicology, pre-marketing testing of pharmaceuticals, and the diverse infant congenital malformations they encountered in clinics, particularly infants born with severe anatomical anomalies (spina bifida, anencephaly, hydrocephalus, pyloric stenosis, etc.).

They often represented the voice of medicine, a clinical and anatomical perspective, in a field increasingly defined by molecular approaches. As a result, in the 1970s, teratologists sometimes appeared to be counting fingers and toes of newborns and malformed bodies of baby rats, while others queried more long-term or insidious consequences of environmental pollution. Indeed, the very definition of teratogenesis expanded to include transplacental carcinoma, long-term health effects, and or neurobehavioral deficit. There is evidence that genetic toxicology and epidemiological modeling provided more useful, popular, and enduring methods for assessing chemical mutagens and human teratogenic hazards than experimental

teratology.[4] Nevertheless, teratology proved resilient, and the Teratology Society remains a professional society in the early twenty-first century continuing to publish journals, called *Birth Defects Research Part A, B, and C,* since 2003.[5]

One theme in midcentury discourses about birth defects resulting from prenatal toxic exposures is the bluntness and inadequacy of the methodological tools used to assess safety of low-dose radiation or chemical substances. Scientific uncertainty was a looming shadow that served to fan the fears of expectant parents. There was sufficient underlying variability in human anatomical and functional congenital or neonatal deficit that low-level effects of radiation-related, pharmaceutical, or toxic industrial chemical exposures could be difficult to demonstrate scientifically, leaving epistemological chasms between the claims of affected parents, consumer advocates or environmentalists, and the voices of scientific authority. Most members of the Teratology Society that formed in 1960 practiced experimental teratology, and typically used radiation and chemical substances in laboratory experiment on mammalian models to demonstrate deviations in form, which were thought to mimic naturally occurring disorders. Experimental teratology struggled with challenges to causal inference, particularly the issue of how animal results could be extrapolated to humans.

With increased public anxiety over the possibility of pharmaceutical or chemical exposures affecting infants, risk-factor epidemiology gained ground. British researchers studying social or preventative medicine pioneered surveillance and

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[4] Frickel, *Chemical Consequences: Environmental Mutagens, Scientist Activism, and the Rise of Genetic Toxicology*; Edmond and Mercer, "Litigation Life: Law-Science Knowledge Construction in (Bendectin) Mass Toxic Tort Litigation."
[5] Philip E. Mirkes, "Editorial," *Birth Defects Research Part A: Clinical and Molecular Teratology* 67, no. 1 (2003): 1–2.

statistical calculations of the risk of congenital anomalies.[6] Neither experimental teratology or risk-factor epidemiology engaged extensively with the increasingly influential genetic and molecular vision of life and human development. They could both be seen as counter narratives to genetic and biochemical determinism.

Focusing narrowly on teratogenesis and the concerns of the 1950s–1980s obscures more recent theories of developmental effects of environmental exposure to industrial chemicals. Subsequent theories and lines of inquiry arising since the 1990s raised questions about gene-environment interactions during development, demonstrated differential gene expression depending on environmental exposures (such as DNA unfolding dependent on methylation of histone proteins), and elucidated diverse effects of prenatal exposures on chronic disease later in life, derived from hypotheses on the fetal origins of disease (also known as Barker's Hypothesis),[7] theories of endocrine disruption,[8] and theories of epigenetics.[9] Each of these deserves a thorough historical analysis of its own, which this dissertation cannot provide. In this dissertation I emphasize teratogenesis between 1950 and 1990, which was overshadowed by the subsequent theories and molecular mechanisms in the 1990s.

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[6] Oppenheimer, "Becoming the Framingham Study 1947–1950."; Doll, "Hazards of the First Nine Months: An Epidemiologist's Nightmare."
[7] D. J. P. Barker, *Mothers, Babies, and Health in Later Life*, 2nd ed. (Edinburgh; New York: Churchill Livingstone, 1998); T. J. Roseboom et al., "Effects of Prenatal Exposure to the Dutch Famine on Adult Disease in Later Life: An Overview," *Mol Cell Endocrinol* 185, no. 1–2 (2001).
[8] Krimsky, *Hormonal Chaos: The Scientific and Social Origins of the Environmental Endocrine Hypothesis*; Colborn, Dumanoski, and Myers, *Our Stolen Future: Are We Threatening Our Fertility, Intelligence, and Survival? A Scientific Detective Story*.
[9] Waddington, "Embryology, Epigenetics and Biogenetics"; D. Haig, "The (Dual) Origin of Epigenetics," in *Cold Spring Harbor Symposia on Quantitative Biology* (Cold Spring Harbor: Cold Spring Harbor Laboratory Press, 2004).

The question of why pregnancy was fraught with fears of prenatal chemical dangers since the 1950s and 1960s is a complex one, and many professional groups and authors of prescriptive literature have weighed in on the pharmaco-chemical risks to the fetus. Questions of infant disability linked to environmental damage were analyzed amid rapidly changing medical approaches to pregnancy and childhood disability and vociferous debates about reproductive autonomy, the limits of reproductive technologies, and women's increasing economic and social empowerment. Although cultural assumptions about masculinity and fatherhood influenced research on reproduction and teratogenesis, nevertheless, there were also vastly fewer professionals charged with studying or protecting male reproduction.[10] Pediatric medical professionals with specialized expertise in laboratory science or epidemiological methodologies, such as Theodore Ingalls or Josef Warkany, cannot be discounted in the discussion of the rise of the fetal patient and pathologization of pregnancy in the latter half of the twentieth century. Researchers in the 1950s who wanted to move beyond deterministic genetic perspectives on inherited disability defined environmental factors broadly and often advocated for social measures to protect pregnant women, via care of maternal disease, better nutrition, or pharmaceutical avoidance. Philanthropies and affiliated clinician advocates, such as Virginia Apgar, called for scientific approaches acting during the prenatal period to prevent infant disability. These efforts helped coin the term "birth defects" constructed as a common and preventable problem, which was often considered the special responsibility of expectant women.

[10] Daniels, *Exposing Men: The Science and Politics of Male Reproduction*.

I show that the public environmentalism of the 1960s and 1970s called into question the threat of radiation and industrial chemicals to susceptible fetuses and interrogated the methodologies used to make claims about reproductive hazards, asking whether they were inadequate. Most of these claims were related to mutageneic or other reproductive hazards defined more broadly than simply teratogenesis, and even the term “teratogenic” expanded to encompass not just anatomical anomalies, but other long-term or neurological outcomes.

Environmental science emphasized the possibility of damaged children resulting from nuclear or industrial "matter displaced."[11] The fetus acted as a metaphor for the human race, with some advocates arguing that it was adaptive, resilient, and apparently relatively healthy despite the assault of chemical hazards and others arguing that undetected neurological impairments to children were widespread. This placed a heavy burden on pregnant women but also shifted the cultural frames around pregnancy to emphasize empowerment and female control over environmental risks. The susceptibility of the human race to industrial chemical effects is often conceived as a particular problem for the period of fetal development and childhood, which has made pregnancy seem dangerous and has also mobilized mothers, like Lois Gibbs and Bonnie Hill, to respond to environmental problems.[12]

I want to reemphasize the irony that despite the relative safety and comfort of twentieth-century American life and lower infant and maternal mortality, by the 1970s some advice manuals for pregnant women emphasized insidious prenatal poisons. This vision of pregnancy as a particularly risky state fraught with hidden

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[11] Douglas, *Purity and Danger: An Analysis of Concepts of Pollution and Taboo*.
[12] Hay, "Recipe for Disaster: Motherhood and Citizenship at Love Canal."

chemical hazards can be attributed to ameliorative efforts from the pediatric sciences to describe, explain, and prevent developmental disability and environmental scientists' emphasis on fetuses and children as the ultimate susceptible humans. Infrequently were fears about health risks of toxins directed at the health and well-being of adult pregnant women; rather it was the specter of harm to the fetal patient and future humans that animated these debates. Nevertheless, advice and advocacy that pathologized pregnancy and presented the future fetus as particularly vulnerable to environmental hazards shaped the health citizenship of all women, expectant or otherwise, and continues to do so today.

Bibliography

Primary Sources:

Archival

Teratology Society Records, 1954–?, Historical Medical Library of The College of Physicians of Philadelphia, PA

Virginia Apgar Papers, 1880–1975, Mount Holyoke College Archives and Special Collections, South Hadley, MA

March of Dimes Archives, White Plains, NY

Vilma R. Hunt Papers, 1952–1993, (also, Vilma R. Hunt Additional Papers) The Arthur and Elizabeth Schlesinger Library on the History of Women in America, Radcliffe Institute at Harvard University, Boston, MA

Jeanne Mager Stellman Papers, 1971–1990, The Arthur and Elizabeth Schlesinger Library on the History of Women in America, Radcliffe Institute at Harvard University, Boston, MA

Barbara Seaman Papers, 1920–1985, The Arthur and Elizabeth Schlesinger Library on the History of Women in America at Harvard University, Boston, MA

Marion Lamm Mercury Collection, Environmental Science and Public Policy Archives at Harvard University, Boston, MA

Henry R. Winkler Center for the History of the Health Professions, University of Cincinnati, OH

Ecology Center Newsletter, The Bancroft Library, Berkeley, CA.

Jean Spencer Felton Papers, Archives & Special Collections, UCSF, CA.

Endocrinology Society Oral History Collection, at The Clarke Sawin Library

Oral Histories

Myn (Nancy) Adess, July 3, 2015, Inverness, California

Ernest Hook, February 18, 2015; April 1, 2015, Berkeley, California

Peter Infante, June 18, 2015, telephone interview.

James Nora, June 17, 2015, telephone interview.

Joseph Warkany, Jr., June 4, 2015, telephone interview.

Josef Warkany, interviewed by Benjamin Felson and William Schubert, December 8, 1980, Oral History of Medicine Series, Henry R. Winkler Center for the History of the Health Professions, University of Cincinnati, OH

Melvin M. Grumbach, MD, an oral history conducted on January 10, 2000 by Adolph Friedman, MD, The Endocrine Society, The Clark Sawin Library, Chevy Chase, Maryland, 2011.

Schull, William J. "Schull, William "Jack" Interview, June 2005." By Andrea Maestrejuan. *Oral History of Human Genetics Project* (2005).

F. Clarke Fraser Interview, October 27, 2004, By Andrea Maestrejuan. *Oral History of Human Genetics Project* (2005). UCLA Oral History of Human Genetics Project, Los Angeles, CA. Accessed in December 31, 2015. http://ohhgp.pendari.com

Medical and Scientific Reports

Afonso, J. F., and R. R. De Alvarez. "Effects of Mercury on Human Gestation." *American Journal of Obstetrics and Gynecology* 80 (1960): 145–54.

Alexander, G. J., B. E. Miles, G. M. Gold, and R. B. Alexander. "LSD: Injection Early in Pregnancy Produces Abnormalities in Offspring of Rats." *Science* 157, no. 3787 (July 28, 1967): 459–60.

Altshuller, Lillis F., Delmar B. Halak, Benjamin H. Landing, and Robert A. Kehoe. "Deciduous Teeth as an Index of Body Burden of Lead." *The Journal of Pediatrics* 60, no. 2 (1962): 224–29.

Amin-Zaki, Laman, Mohammed A. Majeed, Sami B. Elhassani, Thomas W. Clarkson, Michael R. Greenwood, and Richard A. Doherty. "Prenatal Methylmercury Poisoning: Clinical Observations over Five Years." *American Journal of Diseases of Children* 133, no. 2 (1979): 172–77.

Anonymous. "Review: Primer for Pregnancy: An Informal and Practical Guide for the Expectant Mother." *Journal of the American Medical Association*, no. 1 (1952): 95–95.

———. "Teratology." *The Lancet* 2, no. 7619 (September 6, 1969): 530.

Apgar, Virginia. "A Proposal for a New Method of Evaluation of the Newborn Infant." *Current Researches in Anesthesia & Analgesia* 32, no. 4 (Jul–Aug 1953): 260–7.

———. "Human Congenital Anomalies." *Anesthesia & Analgesia* 47, no. 4 (1968).

Apgar, Virginia, and E. M. Papper. "Transmission of Drugs across the Placenta." *Current Researches in Anesthesia & Analgesia* 31, no. 5 (Sep–Oct 1952): 309–20.

Auerbach, R. "LSD: Teratogenicity in Mice." *Science (New York, N.Y.)* 170, no. 3957 (1970): 558.

Bakir, Fa, S. F. Damluji, L. Amin-Zaki, M. Murtadha, A. Khalidi, N. Y. Al-Rawi, S. Tikriti*, et al.* "Methylmercury Poisoning in Iraq." *Science* 181, no. 96 (1973): 230–41.

Ballantyne, John W. "On Antenatal Therapeutics." *The British Medical Journal* (1899): 889–93.

Beebe, Gilbert W. "The Atomic Bomb Survivors and the Problem of Low-Dose Radiation Effects." *American Journal of Epidemiology* 114, no. 6 (1981): 761-83.

Bender, Lauretta, D. V. Siva Sankar, Samuel Irwin, and Jose Egozcue. "Chromosome Damage Not Found in Leukocytes of Children Treated with LSD-25." *Science* 159, no. 3816 (1968): 749.

Brent, Robert L. "Drug Testing in Animals for Teratogenic Effects. Thalidomide in the Pregnant Rat." *The Journal of Pediatrics* 64 (1964): 762–70.

———. "Protecting the Public from Teratogenic and Mutagenic Hazards." *The Journal of Clinical Pharmacology and New Drugs.* 12, no. 2 (Feb–Mar 1972): 61–70.

———. "James G. Wilson (1915–1987)." *Teratology* 39, no. 4 (1989): 317–19.

Brent, Robert L., and David A. Beckman. "Environmental Teratogens." *Bulletin of the New York Academy of Medicine* 66, no. 2 (1990): 123.

Callahan, Justin. "Review: Primer for Pregnancy." *Obstetrics & Gynecology* 2, no. 3 (1953): 334.

Children's Bureau, Women's Bureau. "Standards for Maternity Care and Employment of Mothers in Industry." *Journal of the American Medical Association* 120, no. 1 (1942): 55–56.

Chisolm, J. Julian, Jr. "Increased Lead Absorption: Toxicological Considerations." *Pediatrics* 48, no. 3 (Sep 1971): 349–52.

Chisolm, J. Julian, Jr., and H. E. Harrison. "The Exposure of Children to Lead." *Pediatrics* 18, no. 6 (Dec 1956): 943–58.

Cicmanec, John L. "Comparison of Four Human Studies of Perinatal Exposure to Methylmercury for Use in Risk Assessment." *Toxicology* 111, no. 1 (1996): 157–62.

Clarkson, Thomas W. "Epidemiological and Experimental Aspects of Lead and Mercury Contamination of Food." *Food and Cosmetics Toxicology* 9, no. 2 (Apr 1971): 229–43.

———. "Mercury: Major Issues in Environmental Health." *Environmental Health Perspectives* 100 (1993): 31–38.

———. "The Three Modern Faces of Mercury." *Environmental Health Perspectives* 110 (2002): 11–23.

Clarkson, Thomas W., Gunnar F. Nordberg, and Polly R. Sager. "Reproductive and Developmental Toxicity of Metals." *Scandinavian Journal of Work, Environment & Health* 11, no. 3 (1985): 145–54.

Clarkson, Thomas W., Laszlo Magos, and Gary J. Myers. "The Toxicology of Mercury—Current Exposures and Clinical Manifestations." *New England Journal of Medicine* 349, no. 18 (2003): 1731–37.

Cohen, Maimon M., Kurt Hirschhorn, and William A. Frosch. "In Vivo and in Vitro Chromosomal Damage Induced by LSD-25." *New England Journal of Medicine* 277, no. 20 (November 16, 1967): 1043–9.

David, Timothy J. "Nature and Etiology of the Poland Anomaly." *New England Journal of Medicine* 287, no. 10 (September 7, 1972): 487–9.

Davidson, Philip W., Gary J. Myers, Christopher Cox, Catherine Axtell, Conrad Shamlaye, Jean Sloane-Reeves, Elsa Cernichiari*, et al.* "Effects of Prenatal and Postnatal Methylmercury Exposure from Fish Consumption on Neurodevelopment: Outcomes at 66 Months of Age in the Seychelles Child Development Study." *Journal of the American Medical Association* 280, no. 8 (1998): 701–07.

DiPaolo, J. A., and G. J. Alexander. "LSD: Effects on Offspring." *Science* 158, no. 3800 (October 27, 1967): 522.

Doll, Richard. "Hazards of the First Nine Months: An Epidemiologist's Nightmare." *Journal of the Irish Medical Association* 66, no. 5 (1973): 117–26.

Doll, Richard, and Austin Bradford Hill. "Mortality in Relation to Smoking: Ten Years' Observations of British Doctors." *British Medical Journal.* 1, no. 5395 (1964): 1399–410.

Ernhart, Claire B., Beth Landa, and Norman B. Schell. "Subclinical Levels of Lead and Developmental Deficit—a Multivariate Follow-up Reassessment." *Pediatrics* 67, no. 6 (1981): 911–19.

Fraumeni, Joseph F. "Chemicals in Human Teratogenesis and Transplacental Carcinogenesis." *Pediatrics* 53, no. 5 (1974): 807-12.

Goldstein, Leopold, and Douglas P. Murphy. "Microcephalic Idiocy Following Radium Therapy for Uterine Cancer During Pregnancy." *American Journal of Obstetrics & Gynecology* 18, no. 2 (1929): 189–95.

Gordon, John E., and Theodore H. Ingalls. "Death, Defect, and Disability in Prenatal Life. An Epidemiologic Consideration." *American Journal of Public Health and the Nation's Health* 38, no. 1 (1948): 66–74.

———. "Preventive Medicine and Epidemiology." *The American Journal of the Medical Sciences* 225, no. 3 (1953).

Grandjean, P. "Lead in Danes. Historical and Toxicological Studies." *Environmental Quality and Safety* S2 (1975): 6–75.

———. "Possible Effect of Lead on Egg-Shell Thickness in Kestrels 1874–1974." *Bulletin of Environmental Contamination and Toxicology* 16, no. 1 (July 1976): 101–6.

Grandjean, P., and Philip J. Landrigan. "Developmental Neurotoxicity of Industrial Chemicals." *Lancet* 368, no. 9553 (Dec 16, 2006): 2167–78.

Grandjean, Philippe, Hiroshi Satoh, Katsuyuki Murata, and Komyo Eto. "Adverse Effects of Methylmercury: Environmental Health Research Implications." *Environmental Health Perspectives* 118, no. 8 (2010): 1137–45.

Grandjean, Philippe, Pal Weihe, Roberta F. White, Frodi Debes, Shunichi Araki, Kazuhito Yokoyama, Katsuyuki Murata, Nicolina Sørensen, Rasmus Dahl, and Poul J. Jørgensen. "Cognitive Deficit in 7-Year-Old Children with Prenatal Exposure to Methylmercury." *Neurotoxicology and Teratology* 19, no. 6 (1997): 417–428.

Grandjean, Philippe, Roberta F. White, and Pal Weihe. "Neurobehavioral Epidemiology: Application in Risk Assessment." *Environmental Health Perspectives* 104 (1996): 397–400.

Gregg, Norman. "Congenital Cataract Following German Measles in Mother." *Tropical Opth. Society Australia* 3 (1941).

Hale, Fred. "Pigs Born without Eye Balls." *Journal of Heredity* 24, no. 3 (March 1, 1933 1933): 105–06.

Harada, M. "Congenital Minamata Disease Intrauterine Methylmercury Poisoning." *Teratology* 18 (1978): 285–88.

Harada, Masazumi. "Minamata Disease: Methylmercury Poisoning in Japan Caused by Environmental Pollution." *Critical Reviews in Toxicology* 25, no. 1 (1995): 1–24.

Haskin, David. "Some Effects of Nitrogen Mustard on the Development of External Body Form in the Fetal Rat." *The Anatomical Record* 102, no. 4 (1948): 493–511.

Hauschka, Stephen D, and Thomas H Shepard. "Human Fetal Research." *Science* 182, no. 4119 (1973): 1295–95.

Herbst, Arthur L., Howard Ulfelder, and David C Poskanzer. "Adenocarcinoma of the Vagina: Association of Maternal Stilbestrol Therapy with Tumor Appearance in Young Women." *New England Journal of Medicine* 284, no. 16 (1971): 878-81.

Hicks, Samuel P, Regina C O'Brien, and Alice A Williams. "The Effects of Ionizing Radiation, Certain Hormones, and Radiomimetic Drugs on the Developing Nervous System." *Journal of Cellular and Comparative Physiology* 43, no. S1 (1954): 151–78.

Hicks S., O'Brien R. C. Newcomb E. C. "Developmental Malformations Produced by Radiation; a Timetable of Their Development." *The American Journal of Roentgenology, Radium Therapy, and Nuclear Medicine* 69, no. 2 (1953): 272–93.

Hill, Austin Bradford. "The Environment and Disease: Association or Causation?". *Proceedings of the Royal Society of Medicine* 58, no. 5 (1965): 295.

Hoffmann, Erich. "Congenital Syphilis: In the Light of Thirty Years' Investigation of the Spirochete And Twenty-Five Years' Experience with Salvarsan." *The Journal of Pediatrics* 9, no. 5 (1936): 569–603.

Hollaender, Alexander. "Introduction: Effects of Radiation and Other Deleterious Agents on Embryonic Development." *Journal of Cellular and Comparative Physiology* 43, no. Supplement 1 (May 1954).

Hunt, Vilma R. "A Brief History of Women Workers and Hazards in the Workplace." *Feminist Studies* (1979): 274–85.

Hunt, Vilma R., and William L. Cross. "Infant Mortality and the Environment of a Lesser Metropolitan County: A Study Based on Births in One Calendar Year." *Environmental Research* 9, no. 2 (1975): 135–51.

Hunter, Donald, Richard R. Bomford, and Dorothy S. Russell. "Poisoning by Methyl Mercury Compounds." *QJM* 9, no. 3 (1940): 193–226.

Infante, Peter F. "Oncogenic and Mutagenic Risks in Communities with Polyvinyl Chloride Production Facilities." *Annals of the New York Academy of Sciences* 271, no. 1 (1976): 49–57.

Ingalls, Theodore H. "The Study of Congenital Anomalies by the Epidemiologic Method: With a Consideration of Retrolental Fibroplasia as an Acquired Anomaly of the Fetus." *New England Journal of Medicine* 243, no. 3 (1950): 67–74.

———. "Causes and Prevention of Developmental Defects." *Journal of the American Medical Association* 161, no. 11 (July 14, 1956): 1047–51.

———. "Congenital Malformations: Environmental Influences That Act to Cause Them." *Yale Journal of Biological Medicine* 32, no. 1 (September 1959): 51–7.

———. "Modern Concepts of Communicable Disease." *American Journal of Public Health and the Nations Health* 43, no. 12 (1953): 1586–87.

———. "Mongolism." *Scientific American* 186, no. 2 (1952): 60–66.

Irwin, S., and J. Egozcue. "Chromosomal Abnormalities in Leukocytes from LSD-25 Users." *Science* 157, no. 3786 (July 21, 1967): 313–4.

Jacobson, Joseph L., Gina Muckle, Pierre Ayotte, Éric Dewailly, and Sandra W. Jacobson. "Relation of Prenatal Methylmercury Exposure from Environmental Sources to Childhood IQ." *Environmental Health Perspectives* 123, no. 8 (2015): 827.

Jones, Kenneth L., and David W. Smith. "Recognition of the Fetal Alcohol Syndrome in Early Infancy." *The Lancet* 302, no. 7836 (1973): 999–1001.

Jukes, Thomas H. "Mercury in Fish." *Journal of the American Medical Association* 233, no. 9 (1975): 1001–02.

Kalter, Harold. "Developmental Defects." *Journal of the American Medical Association* 163, no. 4 (1957): 303–03.

Karnofsky, David A. "Drugs as Teratogens in Animals and Man." *Annual Review of Pharmacology* 10 (1965): 447–72.

Kelsey, Frances O. "Thalidomide Update: Regulatory Aspects." *Teratology* 38, no. 3 (1988): 221–26.

Kolata, Gina Bari. "Behavioral Teratology: Birth Defects of the Mind." *American Association for the Advancement of Science. Science* 202 (1978): 732–34.

Koos, Brian J., and Lawrence D. Longo. "Mercury Toxicity in the Pregnant Woman, Fetus, and Newborn Infant. A Review." *American Journal of Obstetrics and Gsynecology* 126, no. 3 (1976): 390–409.

Landrigan, Philip J., and E. L. Baker. "Child Health and Environmental Lead." *British Medical Journal* 1, no. 6064 (March 26, 1977): 836.

Landrigan, Philip J., Robert W. Baloh, William F. Barthel, Randolph H. Whitworth, Norman W. Staehling, and Bernard F. Rosenblum.

"Neuropsychological Dysfunction in Children with Chronic Low-Level Lead Absorption." *The Lancet* 305, no. 7909 (1975): 708–12.

Leck, Ian, R. G. Record, Thomas McKeown, and J. H. Edwards. "The Incidence of Malformations in Birmingham, England, 1950–1959." *Teratology* 1, no. 3 (1968): 263-80.

Lenz, W. "Kindliche Missbildungen Nach Medikament-Einnahme Während Dergravidität?" *Deutsche Medizinische Wochenschrift* 86, no. 52 (1961): 2555–56.

Lilienfeld, Abraham M., and Elizabeth Parkhurst. "A Study of the Association of Factors of Pregnancy and Parturition with the Development of Cerebral Palsy; a Preliminary Report." *American Journal of Hygiene* 53, no. 3 (May 1951): 262–82.

Löfroth, Göran. "A Review of Health Hazards and Side Effects Associated with the Emission of Mercury Compounds into Natural Systems." *Report of the Radiobiology Division of the Department of Biochemistry, University of Stockholm* (1969).

Löfroth, Göran, and Bengt Lundholm. "Methylmercury." *Bulletins from the Ecological Research Committee*, no. 4 (1970): 1–57.

Lyketsos, C. G. "Should Pregnant Women Avoid Eating Fish? Lessons from the Seychelles." *Lancet* 361, no. 9370 (May 17 2003): 1667–8.

Lyons Jones, Kenneth. "From Recognition to Responsibility: Josef Warkany, David Smith, and the Fetal Alcohol Syndrome in the 21st Century." *Birth Defects Research Part A: Clinical and Molecular Teratology* 67, no. 1 (2003): 13–20.

Maclure, Malcolm, and Brian MacMahon. "An Epidemiologic Perspective of Environmental Carcinogenesis." *Epidemiologic Reviews* 2, no. 1 (1980): 19–48.

MacMahon, Brian, R. G. Record, and Thomas McKeown. "Congenital Pyloric Stenosis; an Investigation of 578 Cases." *British Journal of Social Medicine* 5, no. 3 (Jul 1951): 185–92.

———. "Secular Changes in the Incidence of Malformations of the Central Nervous System." *British Journal of Social Medicine* 5, no. 4 (Oct 1951): 254–8.

Mall, Franklin. "A Study of Causes Underlying the Origin of Human Monsters." *Journal of Morphology* XIX, no. 1 (1908).

Mall, Franklin P., and Arthur William Meyer. "*Studies on Abortuses: A Survey of Pathologic Ova in the Carnegie Embryological Collection*." *Contributions to Embryology* 12, no. 56, Carnegie Institution of Washington, 1921.

Marsh, David O., Gary J. Myers, Thomas W. Clarkson, Laman Amin-Zaki, Sadoun Tikriti, and Muhammed A Majeed. "Fetal Methylmercury Poisoning: Clinical and Toxicological Data on 29 Cases." *Annals of Neurology* 7, no. 4 (1980): 348–53.

Marsh, David O., M.D. Turner, J. Crispin Smith, J. Wun Choi, and Thomas W. Clarkson. "Methylmercury (Mehg) in Human Population Eating Large Quantities of Marine Fish. II. American Samoa: Cannery Workers and Fishermen." Paper presented at the *Proceedings of the First International Mercury Conference*, 1974.

Matsumoto, H., G. Koya, and T. Takeuchi. "Fetal Minamata Disease. A Neuropathological Study of Two Cases of Intrauterine Intoxication by a Methyl Mercury Compound." *Journal of Neuropathology & Experimental Neurology* 24, no. 4 (Oct 1965): 563–74.

McAlpine, Douglas, and Sukuro Araki. "Minamata Disease: An Unusual Neurological Disorder Caused by Contaminated Fish." *Lancet* 2, no. 7047 (Sep 20 1958): 629–31.

McBride, William Griffith. "Thalidomide and Congenital Abnormalities." *The Lancet* 278, no. 7216 (1961): 1358.

McKeown, Thomas, Brian MacMahon, and R. G. Record. "The Incidence of Congenital Pyloric Stenosis Related to Birth Rank and Maternal Age." *Annals of Eugenics* 16, no. 3 (Dec 1951): 249–59.

———. "Size of Tumour in Infantile Pyloric Stenosis Related to Age at Operation." *Lancet* 2, no. 6683 (Sep 29 1951): 556–8.

McKeown-Eyssen, Gail E., John Ruedy, and Alan Neims. "Methyl Mercury Exposure in Northern Quebec: Neurological Findings in Children." *American Journal of Epidemiology* 118, no. 4 (October 1, 1983): 470–79.

Miller, Robert M. "Prenatal Origins of Mental Retardation: Epidemiological Approach." *The Journal of Pediatrics* 71, no. 3 (September 1967): 455–58.

Miller, Robert W. "Cola-Colored Babies. Chlorobiphenyl Poisoning in Japan." *Teratology* 4, no. 2 (1971): 211–12.

———. "Pollutants in Breast Milk." *The Journal of Pediatrics* 90, no. 3 (1977): 510–11.

———. "Teratology in 1970: The National Scene." *Teratology* 3 (1970): 223–28.

———. "Susceptibility of the Fetus and Child to Chemical Pollutants." *Science* 184, no. 4138 (1974): 812–14.

———. "I'm from the Government and I'm Here to Help You: Field Work at Times Beach and Other Missouri Dioxin Sites." In *Society for the Study of Social Problems*, 1984.

———. "Review: The Chemical Feast." *Teratology* 4, no. 3 (1970): 381–82.

———. "My Half-Life in Teratology." In *Issues and Reviews in Teratology*, edited by Harold Kalter, 1–46. Boston: Springer, 1993.

Mirkes, Philip E. "Editorial." *Birth Defects Research Part A: Clinical and Molecular Teratology* 67, no. 1 (2003): 1–2.

Monie, Ian W. "Influence of the Environment on the Unborn." *Calif Med* 99 (Nov 1963): 323–7.

Muckle, Gina, and Pierre Ayotte. "Prenatal Exposure of the Northern Quebec Inuit Infants to Environmental Contaminants." *Environmental Health Perspectives* 109, no. 12 (2001): 1291–99.

Müller, Herman J. "Human Evolution by Voluntary Choice of Germ Plasm." *Science* 134 (1961): 643–49.

Murakami, U. "Embryo-Fetotoxic Effect of Some Organic Mercury Compounds." *Annu Rep Res Inst Environ Med Nagoya Univ* 18 (1970): 33–43.

Murphy, Douglas P., and L. Goldstein. "Etiology of the Ill-Health of Children Born after Maternal Pelvic Irradiation." *American Journal of Roentgenology* 22 (1929): 207–19.

Myers, Gary J., Sally W. Thurston, Alexander T. Pearson, Philip W ., Christopher Cox, Conrad F Shamlaye, Elsa Cernichiari, and Thomas W Clarkson. "Postnatal Exposure to Methyl Mercury from Fish Consumption: A Review and New Data from the Seychelles Child Development Study." *Neurotoxicology* 30, no. 3 (2009): 338–49.

N.W. "Dow Redefines a Word It Doesn't Like." *Science* 176, no. 4032 (1972): 262.

Needleman, Herbert L., Charles Gunnoe, Alan Leviton, Robert Reed, Henry Peresie, Cornelius Maher, and Peter Barrett. "Deficits in Psychologic and Classroom Performance of Children with Elevated Dentine Lead Levels." *New England Journal of Medicine* 300, no. 13 (1979): 689–95.

Needleman, Herbert L., and John Scanlon. "Getting the Lead Out." *New England Journal of Medicine* 288, no. 9 (1973): 466–67.

Needleman, Herbert L, Orhan C Tuncay, and Irving M Shapiro. "Lead Levels in Deciduous Teeth of Urban and Suburban American Children." *Nature* 235, no. 5333 (January 4, 1972): 111–2.

Pasamanick, Benjamin. "Association of Maternal and Fetal Factors with Development of Mental Deficiency: Abnormalities in the Prenatal and Paranatal Periods." *The Journal of the American Medical Association* 159, no. 3 (1955): 155.

Pediatrics, American Academy of. "Lead Content of Paint Applied to Surfaces Accessible to Young Children. American Academy of Pediatrics, Committee on Environmental Hazards." *Pediatrics* 49 (1972): 918–21.

Plummer, George. "Anomalies Occurring in Children Exposed in Utero to the Atomic Bomb in Hiroshima." *Pediatrics* 10, no. 6 (1952): 687–93.

Raphael, K. "Recall Bias: A Proposal for Assessment and Control." *International Journal of Epidemiology* 16, no. 2 (Jun 1987): 167–70.

Reiss, Louise Z. "Baby Tooth Survey—First Results." *Nuclear Information* (1961): 1–6.

Rice, Deborah C. "The U.S. EPA Reference Dose for Methylmercury: Sources of Uncertainty." *Environmental Research* 95, no. 3 (July 2004): 406–13.

Robbins, Frederick C. "Overview: The Effects of Chemical Pollutants on the Fetus and Child." *Pediatrics* 53, no. 5 (1974): 860–62.

Roseboom, T. J., J. H. van der Meulen, A. C. Ravelli, C. Osmond, D. J. Barker, and O. P. Bleker. "Effects of Prenatal Exposure to the Dutch Famine on Adult Disease in Later Life: An Overview." *Molecular and Cellular Endocrinology* 185, no. 1-2 (Dec 20 2001): 93–8.

Scanlon, J. "Fetal Effects of Lead Exposure." *Pediatrics* 49, no. 1 (Jan 1972): 145–6.

Scanlon, John. "Umbilical Cord Blood Lead Concentration: Relationship to Urban or Suburban Residency During Gestation." *American Journal of Diseases of Children* 121, no. 4 (1971): 325–26.

———. "Clinical Review: Human Fetal Hazards from Environmental Pollution with Certain Non-Essential Trace Elements." *Clinical Pediatrics* 11, no. 3 (1972): 135–41.

Schull, William J. "The Somatic Effects of Exposure to Atomic Radiation: The Japanese Experience, 1947–1997." *Proceedings of the National Academy of Sciences* 95, no. 10 (1998): 5437–41.

Schull, WJ, DJ Mc Donald, NE Morton, and M Kodani. "The Effect of Exposure to the Atomic Bombs on Pregnancy Termination in Hiroshima and Nagasaki: Preliminary Report." *Science* 118 (1953): 537–41.

Shepard, Thomas H. *Catalog of Teratogenic Agents*. Baltimore,: Johns Hopkins University Press, 1973.

Smith, Clement A. "Effects of Maternal Undernutrition Upon the Newborn Infant in Holland (1944–1945)." *The Journal of Pediatrics* 30, no. 3 (1947): 229–43.

Smith, David W. "Dysmorphology (Teratology)." *The Journal of Pediatrics* 69, no. 6 (12// 1966): 1150–69.

Smithells, R. W. "The Challenges of Teratology." *Teratology* 22, no. 1 (1980): 77–85.

Snyder, Russell D. "Congenital Mercury Poisoning." *New England Journal of Medicine* 284, no. 18 (1971): 1014–16.

Spyker, J. M., and M. Smithberg. "Effects of Methylmercury on Prenatal Development in Mice." *Teratology* 5, no. 2 (Apr 1972): 181–90.

Stewart, Alice. "A Note on the Obstetric Effects of Work During Pregnancy." *British Journal of Preventive and Social Medicine* 9, no. 3 (1955): 159–61.

Stockard, CR. "The Origin of Certain Types of Monsters." *American Journal of Obstetrics* 59 (1909): 1–12.

Strobino, Barbara Reiber, Jennie Kline, and Zena Stein. "Chemical and Physical Exposures of Parents: Effects on Human Reproduction and Offspring." *Early Human Development* 1, no. 4 (1978): 371–99.

Study Group on Mercury Hazards. "Hazards of Mercury: Special Report to the Secretary's Pesticide Advisory Committee, Department of Health, Education, and Welfare, November 1970." *Environmental Research* 4, no. 1 (March 1971): 1–69.

Sturtevant, Alfred H. "Social Implications of the Genetics of Man." *Science* 120, no. 3115 (1954): 405–07.

Sullivan, F. M., S. M. Barlow, D. G. Wibberley, Richard Doll, K. P. Duncan, G. Kazantzis, and Anne McLaren. "Congenital Malformations and Other Reproductive Hazards from Environmental Chemicals [and Discussion]." *Proceedings of the Royal Society of London. Series B, Biological Sciences* 205, no. 1158 (1979): 91–110.

Thienes, Clinton H. "Report of the Commision on Drug Safety." *California Medicine* 103, no. 2 (1965): 159.

Thiersch, John B. "Therapeutic Abortions with a Folic Acid Antagonist, 4-Aminopteroylglutamic Acid (4-Amino PGA) Administered by the Oral Route." *American Journal of Obstetrics and Gynecology* 63, no. 6 (1952): 1298–304.

Turner, Michael D, David O Marsh, J Chrispin Smith, James B Inglis, Thomas W Clarkson, Carlos E Rubio, Jorge Chiriboga, and Carlos Collazos Chiriboga. "Methylmercury in Populations Eating Large Quantities of Marine Fish." *Archives of Environmental Health: An International Journal* 35, no. 6 (1980): 367–78.

Vaisman, AI. "Working Conditions in Surgery and Their Effect on the Health of Anesthesiologists." *Eksp khir anesteziol* 3 (1967): 44–9.

Waddington, CH. "Embryology, Epigenetics and Biogenetics." *Nature* 177, no. 4522 (1956): 1241.

Warkany, Josef. "Trends in Teratologic Research. Epilogue to the Third International Conference on Congenital Malformations." *Teratology* 3, no. 1 (1970): 89–91.

———. "The Medical Profession and Congenital Malformation (1900–1979)." *Teratology* 20 (1979): 201–04.

———. "Why I Doubted That Thalidomide Was the Cause of the Epidemic of Limb Defects of 1959 to 1961." *Teratology* 38, no. 3 (1988): 217–19.

———. "Story of a Teratologist." *Issues and Reviews in Teratology* 4 (1988): 1–79.

———. "Disturbance of Embryonic Development by Maternal Vitamin Deficiencies." *Journal of Cellular and Comparative Physiology* 43, no. S1 (1954): 207–36.

Warkany, Josef, and Donald M. Hubbard. "Mercury in the Urine of Children with Acrodynia." *The Lancet* 251, no. 6509 (1948): 829–30.

Warkany, Josef, and Rose C Nelson. "Appearance of Skeletal Abnormalities in the Off Spring of Rats Reared on a Deficient Diet." *American Association for the Advancement of Science. Science* 92 (1940): 383–84.

Warkany, Josef, Carolyn B Roth, and James G Wilson. "Multiple Congenital Malformations: A Consideration of Etiologic Factors." *Pediatrics* 1, no. 4 (1948): 462–71.

Wilkins, Lawson. "Masculinization of Female Fetus Due to Use of Orally Given Progestins." *Journal of the American Medical Association* 172, no. 10 (1960): 1028–32.

Wilson, James G. "Differentiation and the Reaction of Rat Embryos to Radiation." *Journal of Cellular and Comparative Physiology* 43, no. S1 (1954): 11–37.

Monographs

Apgar, Virginia, and Joan Wagner Beck. *Is My Baby All Right? A Guide to Birth Defects*. New York: Trident Press, 1972.

Baetjer, Anna M. *Women in Industry: Their Health and Efficiency*. Philadelphia; London: W. B. Saunders company, 1946.

Barker, D. J. P. *Mothers, Babies, and Health in Later Life*. 2nd ed. Edinburgh; New York: Churchill Livingstone, 1998.

Batstone, Gifford F., Alastair W. Blair, and Jack M. Slater. *A Handbook of Pre-Natal Paediatrics for Obstetricians and Paediatricians*. Aylesbury: Medical and Technical Publishing Co. Ltd, 1971.

Berrill, N. J. *The Person in the Womb*. New York: Dodd, 1968.

Boston Women's Health Course, Collective. *Our Bodies, Our Selves: A Course by and for Women*. Boston, Mass.: Boston Women's Health Course Collective, 1971.

Brewer, Gail Sforza, and Janice Presser Greene. *Right from the Start: Meeting the Challenges of Mothering Your Unborn and Newborn Baby*. Emmaus, PA: Rodale Press, 1981.

Brown, Muriel Whitbeck Crane Marian Minor United States Children's Bureau. *Prenatal Care*. Washington, D.C.: U.S. Department of Health, Education, and Welfare, Social Security Administration, Children's Bureau, 1962.

Buck, Pearl S. *The Child Who Never Grew*. New York: J. Day Co., 1950.

Carrington, William John. *Safe Convoy: the Expectant Mother's Handbook*. Philadelphia: Lippincott, 1944.

Carson, Rachel. *Silent Spring*. 40th anniversary ed. Boston: Houghton Mifflin, 2002.

Colborn, Theo, Dianne Dumanoski, and John Peterson Myers. *Our Stolen Future: Are We Threatening Our Fertility, Intelligence, and Survival? : A Scientific Detective Story*. New York: Dutton, 1996.

Corner, George Washington. *The Seven Ages of a Medical Scientist: An Autobiography*. Philadelphia: University of Pennsylvania Press, 1981.

D'Itri, Patricia Ward, and Frank M. D'Itri. *Mercury Contamination: A Human Tragedy*. Environmental Science and Technology. New York: Wiley, 1977.

Davis, Adelle. *Let's Have Healthy Children*. New York: Harcourt, Brace, 1959.

De Normandie, R. L. *The Expectant Mother, Care of Her Health*. The National Health Series, edited by the National Health Council. New York and London: Funk & Wagnalls company, 1924.

Eastman, Nicholson J. *Expectant Motherhood*. Boston: Little, Brown and company, 1942.

Eastman, Nicholson J., and Keith P. Russell. *Eastman's Expectant Motherhood*. 6th ed. Boston: Little, Brown, 1977.

Eisenberg, Arlene, Heidi Eisenberg Murkoff, and Sandee Eisenberg Hathaway. *What to Expect When You're Expecting*. New York: Workman Pub., 1984.

Elkington, John. *The Poisoned Womb: Human Reproduction in a Polluted World*. Harmondsworth, Middlesex, England ; New York, N.Y., U.S.A.: Viking, 1985.

Featheringill, Eve Stanton. *Primer for Pregnancy: an Informal and Practical Guide for the Expectant Mother*. New York: Simon and Schuster, 1951.

Fishbein, Morris. *Birth Defects*. Philadelphia: Lippincott, 1963.

Flanagan, Geraldine Lux. *The First Nine Months of Life*. New York: Pocket Books, 1965.

Friberg, Lars, and Jaroslav J. Vostal. *Mercury in the Environment; an Epidemiological and Toxicological Appraisal*. Cleveland: CRC Press, 1972.

Garrod, Archibald E. *Inborn Errors of Metabolism*. 2nd ed. London: H. Frowde and Hodder & Stoughton, 1923.

Geoffroy Saint-Hilaire, Isidore. Histoire générale et particulière des anomalies de l'organisation chez l'homme et les animaux. Paris: J.B. Baillière, 1832.

Gibbs, Lois Marie, and Murray Levine. *Love Canal: My Story*. Albany: State University of New York Press, 1982.

Goldwater, Leonard J. *Mercury: a History of Quicksilver*. Baltimore: York Press, 1972.

Gots, Ronald E. and Barbara A. Gots. *Caring for Your Unborn Child*. New York: Bantam Books, 1977.

Gould, Joan and L. Emmett Holt. "Will My Baby Be Born Normal?" Public Affairs Pamphlets, no. 272. New York: Public Affairs Committee, 1958.

Guttmacher, Alan F. *Pregnancy and Birth: A Book for Expectant Parents*. New York: Viking Press, 1957.

Hamilton, Alice, and Harriet Louise Hardy. *Industrial Toxicology*. 2nd ed. New York: P.B. Hoeber, 1949.

Heinonen, Olli P, Dennis Slone, and Samuel Shapiro. *Birth Defects and Drugs in Pregnancy*. Publishing Sciences Group Inc., Littleton, Massachusetts, USA, 1977.

Hollaender, Alexander, and U.S. National Research Council, Committee on Radiation Biology. *Radiation Biology*. 3 Vols. New York,: McGraw-Hill, 1954.

Hunt, Vilma R., Kathleen Lucas-Wallace, and Jeanne M. Manson. *Work and the Health of Women*. Boca Raton, FL: CRC Press, 1979.

———. "The Emergence of the Workers' Right to Know of Health Risks." In *Strategies for Public Health: Promoting Health and Preventing Disease*, edited by Lorenz K. Y. Ng and Devra Lee Davis, 183–94. New York: Van Nostrand Reinhold, 1981.

Jablon, Seymour, Hiro Kato, and Commission Atomic Bomb Casualty. *Sex Ratio in Offspring of Survivors Exposed Prenatally to the Atomic Bombs, Hiroshima-Nagasaki*. Hiroshima: Atomic Bomb Casualty Commission, 1970.

Jeans, Philip. *Better Homes and Gardens Baby Book*. Des Moines, Iowa: Meredith Publishing Company, 1951.

Kalter, Harold, ed. *Issues and Reviews in Teratology* Vol. 1. New York: Plenum Press, 1983.

Kato, Hiroo, William J. Schull, James V. Neel, and Hiroshima Atomic Bomb Casualty Commission. *Survival in Children of Parents Exposed to the Atomic Bomb: A Cohort-Type Study*. Japan, 1965.

Kumamoto, Daigaku, and Kenkyuhan Minamatabyo. *Minamata Disease* Kumamoto: Study Group of Minamata Disease, Kumamoto University, 1968.

Lewis, Abigail. *An Interesting Condition; the Diary of a Pregnant Woman*. Garden City, NY: Doubleday, 1950.

Meaker, Samuel Raynor. *Preparing for Motherhood; a Manual for Expectant Parents*. Chicago: Year Book Publishers, 1956.

Mintz, Morton. *The Therapeutic Nightmare: a Report on the Roles of the United States Food and Drug Administration, the American Medical Association, Pharmaceutical Manufacturers, and Others in Connection with the Irrational and Massive Use of Prescription Drugs That May Be Worthless, Injurious*. Boston: Houghton Mifflin, 1965.

Montagu, Ashley. *Prenatal Influences*. Springfield, IL: C. C. Thomas, 1962.

———. *Life before Birth*. New York: New American Library, 1964.

Montague, Katherine, and Peter Montague. *Mercury*. San Francisco: Sierra Club, 1971.

Murphy, Douglas Power. *Congenital Malformations; a Study of Parental Characteristics with Special Reference to the Reproductive Process*. 2nd ed. Philadelphia: Lippincott, 1947.

———. "Congenital Malformations a Study of Parental Characteristics with Special Reference to the Reproductive Process." 1st ed. Philadelphia: University of Pennsylvania Press, 1940. Accessed July 8, 2016. http://catalog.hathitrust.org/api/volumes/oclc/5656162.html.

National Geographic Society (U.S.). Special Publications Division. *As We Live and Breathe; the Challenge of Our Environment*. Washington, DC: National Geographic Society, 1971.

Needham, Joseph. *A History of Embryology*. New York: Abelard-Schuman, 1959.

Neel, James V. *Physician to the Gene Pool: Genetic Lessons and Other Stories*. New York: J. Wiley, 1994.

Neel, James V. Schull William J. *The Effect of Exposure to the Atomic Bombs on Pregnancy Termination in Hiroshima and Nagasaki*. Washington, DC: National Academy of Sciences, National Research Council, 1956.

Nelson, Waldo Emerson, and Arthur Graeme. Mitchell. *Mitchell-Nelson Textbook of Pediatrics*. 5th ed. Philadelphia: Saunders, 1950.

Nicely, Ellen D., Charlotte M. Webster, Marie Lehti, and the Cleveland Child Health Association. *Manual for the Conduct of Classes for Expectant Parents, Cleveland, Ohio*. Cleveland, OH: Cleveland Child Health Association, 1942.

Norwood, Christopher. *At Highest Risk: Environmental Hazards to Young and Unborn Children*. New York: McGraw-Hill, 1980.

O'Riordan, Timothy, and James Cameron. *Interpreting the Precautionary Principle*. London: Earthscan Publications Ltd., 1994.

Phillips, Marion G. *More Than Pregnancy*. New York: Coward-McCann, 1955.

Rogers, Martha E., Abraham M. Lilienfeld. *Prenatal and Paranatal Factors in the Development of Childhood Behavior Disorders*. Copenhagen: Munksgaard, 1955.

Roosevelt, Anna Doyle Leo. *Your Pregnancy*. New York: Holt, 1950.

Schardein, James L. *Chemically Induced Birth Defects*. Drug and Chemical Toxicology. New York, NY: M. Dekker, 1985.

Schull, William J. *Song among the Ruins*. Cambridge, MA: Harvard University Press, 1990.

Sever, John L., and Robert L. Brent. *Teratogen Update: Environmentally Induced Birth Defect Risks*. New York: A. R. Liss, 1986.

Skinner, Cornelia Otis. *Tiny Garments*. New York: Farrar and Rinehart, 1932.

Snow, William. *Roentgenology in Obstetrics and Gynecology*. Springfiled, IL: Thomas, 1952.

Stein, Zena. *Famine and Human Development: The Dutch Hunger Winter of 1944–1945*, New York: Oxford University Press, 1975.

Stein, Zena, Jennie Kline, and Martin Kharrazi. "What Is a Teratogen? Epidemiological Criteria." In *Issues and Reviews in Teratology*, edited by Harold Kalter, 23–58. New York: Plenum Press, 1984.

Stellman, Jeanne Mager. *Women's Work, Women's Health: Myths and Realities*. New York: Pantheon Books, 1977.

Strean, Lyon Peter. *The Birth of Normal Babies*. New York: Twayne, 1958.

Van Blarcom, Carolyn Conant Corbin Hazel. *Getting Ready to Be a Mother*. New York: The Macmillan Company, 1940.

Warkany, Josef. *Congenital Malformations: Notes and Comments*. Chicago: Year Book Medical Publishers, 1971.

Weiser, Eric. *Pregnancy, Conception and Heredity*. New York: Blaisdell, 1965.

Whiteside, Thomas. *Defoliation*. New York: Ballantine Books, 1970.

———. *The Withering Rain; America's Herbicidal Folly*. New York: Dutton, 1971.

Wilson, James G. *Environment and Birth Defects*. Environmental Sciences. New York: Academic Press, 1973.

Wilson, James G., Josef Warkany, Commission on Drug Safety and University of Florida. *Teratology: Principles and Techniques*. Chicago: University of Chicago Press, 1965.

Wood, J. W., K. G. Johnson, Yoshiaki Omori, Sadahisa Kawamoto, R. J. Keehn, and Hiroshima Atomic Bomb Casualty Commission. *Mental Retardation in Children Exposed in Utero to the Atomic Bomb--Hiroshima and Nagasaki*. Japan 1966.

News Sources and Periodicals

Anonymous. "A Happy Twin, Rodney Brodie." *Life*, May 31, 1954, 45–46.

———. "Will the Baby Be Normal?" *Time* 76, August 1, 1960, 40–41.

———. "Old Maternity Myths That Should Fade Away." *Good Housekeeping* 156, June 1963, 150.

———. "U.S. Report Linking NTA, Birth Defects in Rats Seen Killing Role in Detergents." *Wall Street Journal*, December 21, 1970, 8.

———. "Row over Fetal Research." *Newsweek* 83, June 24, 1974, 74.

———. "FDA Checking Tuna Fish for High Levels of Mercury." *New York Times*, December 8, 1970, 51.

———. "Mercury Suspected as Pregnancy Peril." *New York Times*, February 2, 1971, 35.

———. "Atomic Bomb May Create 'Freak Crop'." *Los Angeles Times*, January 1, 1947 January 1947, 4.

———. "Radcliffe Names 24 for Institute." *New York Times*, June 5, 1961.

———. "Old Wive's Tale Confirmed? Abnormalities in Newborn Children." *Time Magazine*, September 17, 1956, 65.

———. "Expert Suspects Even Aspirin in Pregnancy." *Omaha World Herald* May 23, 1963.

Apgar, Virginia. "What Every Mother-to-Be Should Know." *Today's Health*, 1966, 35.

———. "Letter to the Editor." *New York Times*, January 29, 1967, 12, 17.

———. "New Ways to Save Your Unborn Child." *Ladies Home Journal* 83, August 1966, 46.

———. "Medicine's Next Frontier." *PTA Magazine*, January 1962, 20–2.

Balio, Tino T. "The Public." *Bulletin of Atomic Scientists* 23, no. 9, November 1967, 8–12.

Blakeslee, Alton L. "Stress and Abnormalities." *Today's Health* 34, November 1956, 14.

Bruckner, Leona. "Triumph of Love." *Ladies Home Journal*, January 18, 1953, 88–102.

Burnham, David. "Rise in Birth Defects Laid to Job Hazard; Studies Attribute Increases in Birth Defects to Hazards in Work." *New York Times*, March 14, 1976, 1, 42.

Cary, Eve. "Pregnancy without Penalty." *Civil Liberties Review* 1, Fall 1973, 31–47.

Hill, Gladwin. "Mercury Hazards Found Nationwide." *New York Times*, September 11, 1970, 1, 27.

Hutchings, Harold. "Broadening Goals of Foundation to Fight Polio: Arthritis, Birth Defect Study Planned." *Chicago Tribune*, July 23, 1958, B5.

Hutchinson, George. "Mercury Pollution: Not Even a Penny of Compensation Has Changed Hands." *London Free Press*, 1975.

Ingalls, Theodore H. "The Strange Case of the Blind Babies." *Scientific American*, 1955, 40–45.

Ingalls., T.H. "No Race of Monsters: Excerpt from Address." *Science News Letter* 68, December 10, 1955, 371.

Kerr, Alix. "Protecting the Unborn Baby." *McCall's*, July 1967, 48–50.

Lake, Alice. "Medicine's Newest Patients." *Saturday Evening Post*, February 12, 1966 1966, 39–42.

Löfroth, Göran, and Margaret E Duffy. "Birds Give Warning." *Environment: Science and Policy for Sustainable Development* 11, no. 4, 1969, 10–17.

Lovell, Phillip M. "Care of the Body: Birthmarks." *Los Angeles Times*, December 31, 1931, D20–22.

Lyons, Richard. "Rise in Chemicals Is Causing Alarm." *New York Times*, September 26, 1971, 92.

Maisel, Albert Q. "We're Winning the Battle against Birth Defects " *Reader's Digest*, 1961, 89–93.

Martin, Harold. "Shocking Results of Government Studies Reveal… Everybody in U.S. Is Being Poisoned by Mercury." *National Enquirer*, 1970, 3–4.

McCarty, Frankie. "Smoking by Expectant Mother Can Decrease Child's Size at Birth, Perinatalist Says Here." *Albuquerque Journal,* February 20, 1963.

Mclaughlin, Loretta. "Will Your Cigarette Smoking Bring Harm to Generations of Children yet Unborn?" *Boston Sunday Herald*, 1965.

Mintz, Morton. "Widely Used Herbicide Tied to Birth Defects." *Washington Post*, April 8, 1970, A3.

Pacher, Sara. "Bonnie Hill: Oregon Environmental Activist." *Mother Earth News*, December/November 1981.

Reilly, Sue. "Grim Findings: Spotlight on Birth Defects." *Los Angeles Times*, March 29, 1971, 1, 12.

Roiphe, Ann Richardson. "The Mad Diary of a Manhattan Ecologist." *New York Times*, October 17, 1971, 350, 425, 435, 436.

Rosenbaum, Davis E. "Monsanto Plans to Curb Chemical: Sales Limited on Substance Linked to Birth Defects." *New York Times*, July 15, 1970, 27.

Roueche, Berton. "Annals of Medicine: Insufficient Evidence." *New Yorker*, August 22, 1970, 64–81.

Seeman, Bernard. "New Hope for Perfect Babies." *Coronet*, August 1961, 30–5.

Shultz, Gladys Denny. "The Uninsulated Child." *Ladies' Home Journal*, June 1956, 60–63, 133–36.

Smith, Eugene W., and Aileen Smith. "Death-Flow from a Pipe: Mercury Pollution Ravages a Japanese Village." *Life*, June 2, 1972, 74-81.

Sullivan, Walter. "Wider Detection of Prenatal Flaws Expected to Spur Abortions." *New York Times*, June 13, 1970, 11.

Theroux, Paul. "The Dirty Hand of Industry in Southern Japan." *New York Times Review of Books*, June 8, 1975, 249.

Usher, A. "Research Indicates That Mother's Smoking Can Harm an Unborn Baby." *Better Homes and Gardens* 36, January 1958, 24.

Waldron, Martin. "Mercury in Food: A Family Tragedy." *New York Times*, August 6, 1970, 1, 24.

Watson, E.M.D. "How to Have a Perfect Baby." *Cosmopolitan* 147, December 1959, 74–7.

Whiteside, Thomas. "A Reporter at Large. Defoliation." *New Yorker,* February 7, 1970, 32–69.

Hearings, Reports, Pamphlets, Theses, Advertisements, and Conference Papers

American College of Obstetrics and Gynecology (ACOG). *Manual of Standards in Obstetric-Gynecologic Practice*. Chicago, 1959.

Association for the Aid of Crippled Children (AACC). *Mechanisms of Congenital Malformation: Proceedings of the Second Scientific Conference of the Association for the Aid of Crippled Children*. New York, 1954.

Association for the Aid of Crippled Children (AACC) and Emmett L. Holt. *Prematurity, Congenital Malformation, and Birth Injury: Proceedings of a Conference at the New York Academy of Medicine, June 5–6, 1952*. New York, 1953.

National Institute of Environmental Health Sciences (NIEHS), *Workshop on Scientific Issues Relevant to Assessment of Health Effects from Exposure to Methylmercury, Raleigh, November 18-20*, George Lucier, Robert Goyer, eds. Raleigh, NC: U.S Government Publication, 1998.

Scientific Issues Relevant to Assessment of Health Effects from Exposure to Methylmercury. Raleigh, NC, 1998.

National Research Council (NRC). *Toxicological Effects of Methylmercury*. Washington (DC): National Academy Press, 2000.

Atomic Bomb Casualty, Commission. *The Atomic Bomb Casualty Commission, 1947–1975: A General Report on the ABCC-JNIH Joint Research Program*. Hiroshima: ABCC, 1978.

Bates, Josephine White. *Mercury Poisoning in the Industries of New York City and Vicinity*. National Civic Federation, New York and New Jersey Section, 1912.

Bingham, Eula, ed. *Conference on Women and the Workplace, June 17–19, 1976,* Washington, DC: The Society for Occupational and Environmental Health, 1977.

Birth Defects Institute, New York State Department of Health, *Monitoring, Birth Defects and Environment: The Problem of Surveillance; Proceedings (*Symposium held 19-20 October 1970, in Albany, New York). Edited by Ernest B. Hook, Dwight T. Janerich, Ian H. Porter. London: Academic Press, 1971.

D'Itri, Frank. "Sources of Mercury in the Environment." In *Environmental Mercury Contamination*, edited by Rolf Hartlung and Bertram D. Dinman, 5–25. Ann Arbor: Ann Arbor Science Publishers, Inc., 1972.

Dardanoni, Luigi, and Robert W. Miller. *Plans for Clinical and Epidemiologic Follow-up after Area-Wide Chemical Contamination: Proceedings of an International Workshop, Washington, D.C., March 17–19, 1980.* Washington, DC, 1982.

Epstein, Samuel S., ed., *Drugs of Abuse: Their Genetic and Other Chronic Nonpsychiatric Hazards, Based on a Conference Cosponsored by the Center for Studies of Narcotic and Drug Abuse, NIMH, and the Environmental Mutagen Society, San Francisco, October 29–30, 1969.* Cambridge, London: M.I.T. Press, 1971.

———. "Chemicals in the Environment [Sound Recording] " *Man and Molecule*. Washington, D.C.: American Chemical Society, 1974.

Hamilton, Alice. *Women in the Lead Industries. February, 1919.* Vol. 253: U.S. Government Printing Office, 1919.

Hamilton, Alice, and Charles H. Verrill. "Hygiene of the Printing Trades." Industrial Accidents and Hygiene Series, no. 12.; Bulletin of the United States Bureau of Labor Statistics, no. 209. Washington, DC: U.S. Department of Labor, Bureau of Labor Statistics, Government Printing Office, 1917.

Hartung, Rolf, and Bertram D. Dinman, eds., *Environmental Mercury Contamination*, (based on the proceedings of the International Conference on Environmental Mercury Contamination, Ann Arbor, Mich., Sept. 30-Oct. 2, 1970*)*. Ann Arbor, MI: Ann Arbor Science Publishers, 1972.

Hunt, Vilma R. *Occupational Health Problems of Pregnant Women: A Report and Recommendations for the Office of the Secretary, Department of*

Health, Education and Welfare, April 30, 1975. University Park: Pennsylvania State University, 1975.

Hunt, Vilma R., M. Kate Smith, Dorothy Worth, and Cold Spring Harbor Laboratory. *Environmental Factors in Human Growth and Development*. Banbury Report. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory, 1982.

Kelsey, Francis O. "Present Guidelines for Teratogenic Studies in Experimental Animals." In *Congenital Defects: New Directions in Research*, edited by Dwight T. Janerich, Richard G. Skalko, Ian H. Porter, Birth Defects Institute, New York State Department of Health. New York,: Academic Press, 1974.

L'Institut de la Vie. "Methods for Detection of Environmental Agents That Produce Congenital Defects: Proceedings of the Guadeloupe Conference," edited by Shepard, Thomas H., James R. Miller, M. Marois. Amsterdam; North-Holland Pub. Co.; New York: American Elsevier Pub. Co. 1975.

Miller, Morton W., George G. Berg, eds., and the Department of Radiation Biology and Biophysics, University of Rochester. "Chemical Fallout; Current Research on Persistent Pesticides." Springfield, IL: Thomas, 1969.

Mintz, Beatrice, ed., *Environmental Influences on Prenatal Development: Proceedings of a Conference held at the Roscoe B. Jackson Memorial Laboratory at Bar Harbor, Maine, August 2-4, 1956.* The Developmental Biology Conference Series. Chicago: National Academy of Sciences National Research Council, 1958.

Montagu, Ashley. "Constitutional and Prenatal Factors in Infant and Child Health." In *Symposium on the Healthy Personality: transactions of special meetings of Conference on Infancy and Childhood June 8-9 and July 3-4, 1950*, edited by Milton J. E. Senn. New York: The Josiah Macy Jr. Foundation, 1950.

Mrak, Emil M. "Report of the Secretary's Commission on Pesticides and Their Relationship to Environmental Health." Washington, DC: U.S. Department of Health, Education, and Welfare, 1969.

National Academy of Sciences. "How Safe Is Safe? The Design of Policy on Drugs and Food Additives." Washington, DC: National Academy of Sciences, 1974.

Niswander, Kenneth R., Myron Gordon, and the National Institute of Neurological Diseases and Stroke. *The Women and Their Pregnancies; the Collaborative Perinatal Study of the National Institute of Neurological Diseases and Stroke*. DHEW Publication No (NIH) 73–379. Washington: National Institute of Health; U.S. Government Printing Office, 1972.

Oakley, Godfrey. "Birth Defect Surveillance in the Search of and Evaluation of Possible Human Teratogens." In *Cytogenetics, Environment, and Malformation Syndromes*, edited by Daniel Bergsma and Neil Shimke. Birth Defects Original Article Series, 1–6: National Foundation-March of Dimes, 1976.

U.S. Congress. Senate. Committee on Government Operations. *Chemicals and the Future of Man: Hearings before the Subcommittee on Executive Reorganization and Government Research.* 92 Cong., 1st Session, April 6 and 7, 1971.

Spyker, Joan M. "Methymercury, Mice and Men." PhD Diss., University of Minnesota, 1971.

Wolstenholme, G.E.W. and Cecilia M. O'Connor, eds. *Ciba Foundation Symposium on Congenital Malformations* (Proceedings of a conference held in London, January 19-21, 1960). London: J. & A. Churchill;, 1960.

World Health Organization, *Principles for the Testing of Drugs for Teratogenicity: Report of a WHO Scientific Group*. World Health Organization Technical Report Series. Geneva: World Health Organization, 1967.

Secondary Sources

Adams, Rachel. *Sideshow U.S.A: Freaks and the American Cultural Imagination*. Chicago: University of Chicago Press, 2001.

Al-Gailani, Salim. "Making Birth Defects 'Preventable': Pre-Conceptional Vitamin Supplements and the Politics of Risk Reduction." *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences* 47 (2014): 278–89.

———. "Teratology and the Clinic: Monsters, Obstetrics and the Making of Antenatal Life in Edinburgh, C. 1900." PhD diss., University of Cambridge, 2010.

Alberti, Samuel J. M. M. *Morbid Curiosities: Medical Museums in Nineteenth-Century Britain*. Oxford; New York: Oxford University Press, 2011.

Apple, Rima D. *Women, Health, and Medicine in America : A Historical Handbook*. Garland Reference Library of the Social Sciences. New York: Garland Pub., 1990.

———. *Perfect Motherhood: Science and Childrearing in America*. New Brunswick, NJ: Rutgers University Press, 2006.

Apple, Rima D. *Mothers and Medicine: A Social History of Infant Feeding, 1890–1950*. Madison, WI: University of Wisconsin Press, 1987.

Apple, Rima D., and Janet Lynne Golden. *Mothers & Motherhood: Readings in American History*. Columbus: Ohio State University Press, 1997.

Armstrong, Elizabeth M. *Conceiving Risk, Bearing Responsibility: Fetal Alcohol Syndrome and the Diagnosis of Moral Disorder*. Baltimore: Johns Hopkins University Press, 2003.

Asma, Stephen. *On Monsters an Unnatural History of Our Worst Fears*. New York: Oxford University Press, 2009.

Austin, D. W., B. Spolding, S. Gondalia, K. Shandley, E. A. Palombo, S. Knowles, and K. Walder. "Genetic Variation Associated with Hypersensitivity to Mercury." *Toxicology International* 21, no. 3 (Sep–Dec 2014): 236–41.

Bale, Anthony. "Women's Toxic Experience." In *Women, Health, and Medicine in America: A Historical Handbook*, edited by Rima D. Apple, 403–431. New Brunswick, NJ: Rutgers University Press, 1992.

Ballatori, Ned, Victor G Laties, and Thomas A Gasiewicz. "Toxicology at the University of Rochester: From the Manhattan Project to the Environmental Basis of Human Diseases." edited by Department of Environmental Medicine University of Rochester, circa 2010.

Barker, David JP. "The Biology of Stupidity: Genetics, Eugenics, and Mental Deficiency in the Inter-War Years." *British Journal for the History of Science* 22 (1989): 347–75.

Bates, Tony. "Emblematic Monsters: Unnatural Conceptions and Deformed Births in Early Moden Europe." *Clio Medica* 77 (2005).

Bearn, Alexander G. *Archibald Garrod and the Individuality of Man*. Oxford, New York: Clarendon Press; Oxford University Press, 1993.

Beatty, John. "Genetics in the Atomic Age: The Atomic Bomb Casualty Commission, 1947-1956." In *The Expansion of American Biology*, edited by Keith Rodney Benson, Jane Maienschein and Ronald Rainger, 284–324. New Brunswick, NJ: Rutgers University Press, 1991.

Becker, Mary E. "From Muller v. Oregon to Fetal Vulnerability Policies." *The University of Chicago Law Review* 53 (1986): 1219–73.

Bell, Susan E. *DES Daughters: Embodied Knowledge and the Transformation of Women's Health Politics*. Philadelphia: Temple University Press, 2009.

Bensaude-Vincent, Bernadette; Stengers, Isabelle. *A History of Chemistry* Cambridge, MA: Harvard University Press, 1996.

Biehl, Janet, and Peter Staudenmaier. *Ecofascism: Lessons from the German Experience*. Edinburgh; San Francisco: AK Press, 1995.

Bondeson, Jan. *A Cabinet of Medical Curiosities*. Ithaca, New York: Cornell University Press, 1997.

———. *The Two-Headed Boy, and Other Medical Marvels*. Ithaca, NY.: Cornell University Press, 2000.

Braidotti, Rosi. "Signs of Wonder and Traces of Doubt: On Teratology and Embodied Differences." In *Between Monsters, Goddesses, and Cyborgs : Feminist Confrontations with Science, Medicine, and Cyberspace*, edited by Nina Lykke and Rosi Braidotti, 135–52. London; Atlantic Highlands, NJ: Zed Books, 1996.

Brent, Robert L. "Biography of Josef Warkany." *Teratology* 25, no. 2 (1982): 137–44.

———. "In Memoriam: Robert Warwick Miller." *Birth Defects Research Part A: Clinical and Molecular Teratology* 79 (2007): 253–56.

Brynner, Rock, and Trent D. Stephens. *Dark Remedy: The Impact of Thalidomide and its Revival as a Vital Medicine*. New York: Basic Books, 2001.

Carpenter, Daniel P. *Reputation and Power: Organizational Image and Pharmaceutical Regulation at the FDA*. Princeton: Princeton University Press, 2010.

Casper, Monica J. *The Making of the Unborn Patient: A Social Anatomy of Fetal Surgery*. New Brunswick, NJ: Rutgers University Press, 1998.

Chavkin, Wendy. "Occupational Hazards to Reproduction: A Review Essay and Annotated Bibliography." *Feminist Studies* 5 (1979): 310–25.

Childs, Barton. "Sir Archibald Garrod's Conception of Chemical Individuality: A Modern Appreciation." *New England Journal of Medicine* 282, no. 2 (1970): 71–77.

Clark, Claudia. *Radium Girls, Women and Industrial Health Reform: 1910-1935*. Chapel Hill, NC: University of North Carolina Press, 1997.

Clarke, Adele. *Disciplining Reproduction: Modernity, American Life Sciences, and "the Problems of Sex."* Berkeley: University of California Press, 1998.

———. "Reproductive Science, 1913–1971." In *Centennial History of the Carnegie Institute of Washington: Volume V, the Department of Embryology*, edited by Jane Maienschein, Marie Glitz and Allen Garland E. Boston: Cambridge University Press, 2004.

Conis, Elena. "Debating the Health Effects of DDT: Thomas Jukes, Charles Wurster, and the Fate of an Environmental Pollutant." *Public Health Reports* 125, no. 2 (2010): 337–342.

———. *Vaccine Nation: America's Changing Relationship with Immunization*. Chicago; London: University of Chicago Press, 2015.

Corner, George W. "Exploring the Placental Maze. The Development of Our Knowledge of the Relation between the Bloodstreams of Mother and Infant *in Utero*." *American Journal of Obstetrics and Gynecology* 86 (1963): 408–18.

Correia, Clara Pinto. *The Ovary of Eve: Egg and Sperm and Preformation*. Chicago: University of Chicago Press, 1997.

Cowan, Ruth Schwartz. *More Work for Mother: The Ironies of Household Technology from the Open Hearth to the Microwave*. New York: Basic Books, 1983.

———. *Heredity and Hope: The Case for Genetic Screening*. Cambridge, MA: Harvard University Press, 2008.

Cronin, John F., and Robert Aaron Lyon. *Albert Graeme Mitchell*. Cincinnati: Cincinnati Children's Hospital, 1964.

Daemmrich, Arthur. "A Tale of Two Experts: Thalidomide and Political Engagement in the United States and West Germany." *Social History of Medicine: the Journal of the Society for the Social History of Medicine* 15, no. 1 (2002): 137–58.

Daemmrich, Arthur A. *Pharmacopolitics: Drug Regulation in the United States and Germany*. Chapel Hill: University of North Carolina Press, 2004.

Daniels, Cynthia R. *Exposing Men: The Science and Politics of Male Reproduction*. Oxford; New York: Oxford University Press, 2006.

Davis, Frederick Rowe. *Banned: A History of Pesticides and the Science of Toxicology*. New Haven: Yale University Press, 2014.

Dickerson, A. S., M. H. Rahbar, I. Han, A. V. Bakian, D. A. Bilder, R. A. Harrington, S. Pettygrove*, et al.* "Autism Spectrum Disorder Prevalence and Proximity to Industrial Facilities Releasing Arsenic, Lead or Mercury." *Sci Total Environ* 536 (Dec 1 2015): 245–51.

Douglas, Mary. *Purity and Danger: An Analysis of Concepts of Pollution and Taboo*. London: Routledge & K. Paul, 1966.

———. *Purity and Danger: An Analysis of Concepts of Pollution and Taboo*. Pelican Books. Harmondworth: Penguin, 1970.

Dowbiggin, Ian Robert. "'A Rational Coalition': Euthanasia, Eugenics, and Birth Control in America, 1940-1970." *Journal of Policy History* 14, no. 3 (2002): 223–60.

Dreger, Alice Domurat. *Hermaphrodites and the Medical Invention of Sex*. Cambridge, MA: Harvard University Press, 1998.

———. *One of Us: Conjoined Twins and the Future of Normal*. Cambridge, MA: Harvard University Press, 2004.

Dubow, Sara. *Ourselves Unborn: A History of the Fetus in Modern America*. Oxford; New York: Oxford University Press, 2011.

Duden, Barbara. *Disembodying Women: Perspectives on Pregnancy and the Unborn*. Cambridge, MA: Harvard University Press, 1993.

———. "The Fetus on the 'Farther Shore:' Toward a History of the Unborn." In *Fetal Subjects, Feminist Positions*, edited by Lynn Morgan and Meredith Michaels, 13-25. Philadelphia: University of Pennsylvania Press, 1999.

Dunlap, Thomas R. *DDT, Silent Spring, and the Rise of Environmentalism: Classic Texts*. Seattle: University of Washington Press, 2008.

Durbach, Nadja. *Spectacle of Deformity: Freak Shows and Modern British Culture*. Berkeley; Los Angeles; London: University of California Press, 2009.

Edmond, Gary, and David Mercer. "Litigation Life Law-Science Knowledge Construction in (Bendectin) Mass Toxic Tort Litigation." *Social Studies of Science* 30, no. 2 (2000): 265–316.

Egan, Michael. "Toxic Knowledge: A Mercurial Fugue in Three Parts." *Environmental History* 13, no. 4 (2008): 636–42.

Evans, Suzanne Elizabeth. "Parental Eugenics: Congenitally Anomalous Newborns and the Continuing Debate over Selective Non-Treatment and Neonatal Euthanasia in the United States." PhD diss., University of California, Berkeley, 2008.

Faden, Ruth R. "The Human Radiation Experiments: Final Report of the President's Advisory Committee." New York: Oxford University Press, 1996.

Fleck, Ludwik. *Genesis and Development of a Scientific Fact*. Chicago: University of Chicago Press, 1979.

Franklin, Sarah. "Fetal Fascinations: New Dimensions to the Medical-Scientific Construction of Fetal Personhood." In *Off-Centre: Feminism and Cultural Studies*, edited by Sarah Franklin, Celia Lury and Jackie Stacey, 190–205. Hammersmith, London, UK; New York, NY, USA: HarperCollins Academic, 1991.

Franklin, Sarah, and Helena Ragoné. *Reproducing Reproduction : Kinship, Power, and Technological Innovation*. Philadelphia: University of Pennsylvania Press, 1998.

Frickel, Scott. *Chemical Consequences: Environmental Mutagens, Scientist Activism, and the Rise of Genetic Toxicology*. New Brunswick, N.J.: Rutgers University Press, 2004.

Garland-Thomson, Rosemarie. *Freakery: Cultural Spectacles of the Extraordinary Body*. New York: New York University Press, 1996.

George, Timothy S. *Minamata: Pollution and the Struggle for Democracy in Postwar Japan*. Harvard East Asian Monographs 194. Cambridge MA: Harvard University Press, 2001.

Golden, Janet Lynne. "'An Argument That Goes Back to the Womb': The Demedicalization of Fetal Alcohol Syndrome, 1973-1992." *Journal of Social History* 33, no. 2 (1999): 269–98.

———. *Message in a Bottle: The Making of Fetal Alcohol Syndrome*. Cambridge, MA: Harvard University Press, 2005.

Grandjean, Philippe. "Mercury Risks: Controversy or Just Uncertainty?". *Public Health Reports* 114, no. 6 (1999): 512.

Grandjean, Philippe, *Only One Chance: How Environmental Pollution Impairs Brain Development—and How to Protect the Brains of the Next Generation*. Oxford: Oxford University Press, 2013.

Greene, Gayle. *The Woman Who Knew Too Much: Alice Stewart and the Secrets of Radiation*. Ann Arbor, MI: University of Michigan Press, 1999.

Hagner, Michael. "Enlightened Monsters." In *The Sciences in Enlightened Europe*, edited by William Clark, Jan Golinski and Simon Schaffer, 174–87. Chicago: University of Chicago, 1999.

Haig, D. "The (Dual) Origin of Epigenetics." In *Cold Spring Harbor Symposia on Quantitative Biology*. Cold Spring Harbor: Cold Spring Harbor Laboratory Press, 2004.

Halpern, Sydney A. *American Pediatrics: The Social Dynamics of Professionalism, 1880–1980*. Berkeley: University of California Press, 1988.

Hanson, Clare. *A Cultural History of Pregnancy: Pregnancy, Medicine, and Culture, 1750– 2000*. Hampshire; New York: Palgrave Macmillan, 2004.

Hay, Amy, M. "Recipe for Disaster: Motherhood and Citizenship at Love Canal." *Journal of Women's History* 21, no. 1 (2009): 111–34.

Hayden, Cori. *When Nature Goes Public: The Making and Unmaking of Bioprospecting in Mexico*. Princeton: Princeton University Press, 2003.

Hays, Samuel P. *A History of Environmental Politics since 1945*. Pittsburgh: University of Pittsburgh Press, 2000.

Hays, Samuel P., and Barbara D. Hays. *Beauty, Health, and Permanence: Environmental Politics in the United States, 1955–1985*. Cambridge; New York: Cambridge University Press, 1987.

Heidel, William Arthur. *Hippocratic Medicine, Its Spirit and Method*. New York: Columbia University Press, 1941.

Hepler, Allison L. *Women in Labor: Mothers, Medicine, and Occupational Health in the United States, 1890–1980*. Women and Health. Columbus: Ohio State University Press, 2000.

Hightower, Jane M. *Diagnosis Mercury: Money, Politics, and Poison*. Washington, DC: Island Press/Shearwater Books, 2009.

Hippocrates, G. E. R. Lloyd, John Chadwick, W. N. Mann, and Hippocrates. *Hippocratic Writings*. Pelican Classics. Harmondsworth; New York: Penguin, 1978.

Hopwood, Nick. "Producing Development: The Anatomy of Human Embryos and the Norms of Wilhelm His." *Bulletin of the History of Medicine* 74, no. 1 (2000): 29–79.

Hubbard, Ruth. *The Politics of Women's Biology*. New Brunswick, NJ: Rutgers University Press, 1990.

Hubbard, Ruth, Mary Sue Henifin, and Barbara Fried. *Biological Woman--the Convenient Myth: A Collection of Feminist Essays and a Comprehensive Bibliography*. Cambridge, MA: Schenkman Pub. Co., 1982.

Hunter, Jack. *Freak Babylon: An Illustrated History of Teratology and Freakshows*. London: Glitter Books, 2005.

Jacobson, Joseph L, Gina Muckle, Pierre Ayotte, Éric Dewailly, and Sandra W Jacobson. "Relation of Prenatal Methylmercury Exposure from Environmental Sources to Childhood IQ." *Environmental Health Perspectives* 123 (2015): 827–833.

Jenkins, Philip. *Decade of Nightmares: The End of the Sixties and the Making of Eighties America*. New York: Oxford University Press, 2006.

Kalter, Harold. "Teratology in the Twentieth Century Congenital Malformations in Humans and How Their Environmental Causes Were Established." Amsterdam: Elsevier, 2003.

Kandall, Stephen R. *Substance and Shadow: Women and Addiction in the United States*. Cambridge, MA: Harvard University Press, 1996.

Kay, Lily E. *The Molecular Vision of Life: Caltech, the Rockefeller Foundation, and the Rise of the New Biology*. Monographs on the History and Philosophy of Biology. New York: Oxford University Press, 1993.

———. *Who Wrote the Book of Life?: A History of the Genetic Code*. Writing Science. Stanford, CA: Stanford University Press, 2000.

Kessler-Harris, Alice. *Out to Work: A History of Wage-Earning Women in the United States*. New York: Oxford University Press, 1982.

Kevles, Bettyann. *Naked to the Bone: Medical Imaging in the Twentieth Century*. The Sloan Technology Series. New Brunswick, NJ: Rutgers University Press, 1997.

Kevles, Daniel J. *In the Name of Eugenic : Genetics and the Uses of Human Heredity*. New York: Knopf, 1985.

———. *In the Name of Eugenics: Genetics and the Uses of Human Hereditys*. Cambridge, Mass.: Harvard University Press, 1995.

Klaus, Alisa. *Every Child a Lion: The Origins of Maternal and Infant Health Policy in the United States and France, 1890–1920*. Ithaca: Cornell University Press, 1993.

Klebanoff, Mark A. "The Collaborative Perintal Project: A 50-Year Retrospective." *Paediatric and Perinatal Epidemiology* 23, no. 1 (2009): 2–8.

Kline, Wendy. *Building a Better Race: Gender, Sexuality, and Eugenics from the Turn of the Century to the Baby Boom*. Berkeley: University of California Press, 2001.

———. *Bodies of Knowledge : Sexuality, Reproduction, and Women's Health in the Second Wave*. Chicago; London: The University of Chicago Press, 2010.

———. "Communicating a New Consciousness: Countercultural Print and the Home Birth Movement in the 1970s." *Bulletin of the History of Medicine* 80, no. 3 (2015): 527–56.

Kolata, Gina Bari. *The Baby Doctors: Probing the Limits of Fetal Medicine*. New York, NY: Delacorte Press, 1990.

Krimsky, Sheldon. *Hormonal Chaos: The Scientific and Social Origins of the Environmental Endocrine Hypothesis*. Baltimore, MD: Johns Hopkins University Press, 2000.

Kroll-Smith, J. Stephen, Phil Brown, and Valerie J. Gunter. *Illness and the Environment: A Reader in Contested Medicine*. New York: New York University Press, 2000.

Kudlick, Catherine J. "Disability History: Why We Need Another 'Other,'." *American Historical Review* 1083 (June 2003): 763–93.

Ladd-Taylor, Molly. *Mother-Work: Women, Child Welfare, and the State, 1890–1930*. Urbana: University of Illinois Press, 1994.

Ladd-Taylor, Molly, and Lauri Umansky. *"Bad" Mothers: The Politics of Blame in Twentieth-Century America*. New York: New York University Press, 1998.

Langston, Nancy. "The Retreat from Precaution: Regulating Diethylstilbestrol (DES), Endocrine Disruptors, and Environmental Health." *Environmental History* 13, no. 1 (2008): 41–65.

———. *Toxic Bodies: Hormone Disruptors and the Legacy of DES*. New Haven: Yale University Press, 2010.

Latour, Bruno. "Give Me a Laboratory and I Will Raise the World." In *The Science Studies Reader*, edited by Mario Biagioli, 258–75. New York: Routledge, 1999.

Leavitt, Judith Walzer. *Brought to Bed: Childbearing in America, 1750–1950*. New York: Oxford University Press, 1986.

Leck, Ian. "Mckeown, Record, and the Epidemiology of Malformations. "*Paediatric and Perinatal Epidemiology* 10, no. 1 (1996): 2–16.

Lerner, Barron H. *The Breast Cancer Wars: Hope, Fear, and the Pursuit of a Cure in Twentieth-Century America*. New York: Oxford University Press, 2001.

Ley, Barbara L. *From Pink to Green: Disease Prevention and the Environmental Breast Cancer Movement*. New Brunswick, NJ: Rutgers University Press, 2009.

Lindee, M. Susan. *Suffering Made Real: American Science and the Survivors at Hiroshima*. Chicago: University of Chicago Press, 1994.

———. *Moments of Truth in Genetic Medicine*. Baltimore, MD: Johns Hopkins University Press, 2005.

Linker, Beth. "On the Borderland of Medical and Disability History: A Survey of the Fields." *Bulletin of the History of Medicine* 87, no. 4 (2013): 499–535.

Longmore, Paul K. "Uncovering the Hidden History of Disabled People." In *Why I Burned My Book, and Other Essays on Disbility*, edited by Paul K. Longmore, 41–52. Philadelphia: Temple University Press, 2003.

———. *Why I Burned My Book and Other Essays on Disability*. American Subjects. Philadelphia: Temple University Press, 2003.

Longmore, Paul K., and Lauri Umansky. *The New Disability History: American Perspectives*. The History of Disability Series. New York: New York University Press, 2001.

Lykke, Nina, and Rosi Braidotti. *Between Monsters, Goddesses, and Cyborgs: Feminist Confrontations with Science, Medicine, and Cyberspace*. London; Atlantic Highlands, NJ, USA: Zed Books, 1996.

Maienschein, Jane, Marie Glitz, and Garland E. Allen, eds. *Centennial History of the Carnegie Institution of Washington*: *Volume V, The Department of Embryology*. Cambridge, UK: Cambridge University Press, 2004.

Marcus, Alan I. *Cancer from Beef: DES, Federal Food Regulation, and Consumer Confidence*. Baltimore: Johns Hopkins University Press, 1994.

Markowitz, Gerald E., and David Rosner. *Deceit and Denial: The Deadly Politics of Industrial Pollution*. Berkeley, CA: University of California Press, 2002.

Marmorstein, Gary. *"Steel and Slurry: Dr. Philip M. Lovell, Architectural Patron." Southern California Quarterly*, Vol. 84, no. 3–4, (2002): 241–270.

Martin, Aryn, and Kelly Holloway. "'Something There Is That Doesn't Love a Wall': Histories of the Placental Barrier." *Studies in History and Philosophy of Biological and Biomedical Sciences* 47 (2014): 300–10.

McLaughlin, Loretta. *The Pill, John Rock, and the Church: The Biography of a Revolution*. 1st ed. Boston: Little, Brown & Co., 1982.

Meyerowitz, Joanne J. *Not June Cleaver: Women and Gender in Postwar America, 1945-1960*. Critical Perspectives on the Past. Philadelphia: Temple University Press, 1994.

Mills, James L. "Heinz Berendes, 1925–1999." *American Journal of Public Health* 89, no. 8 (1999): 1156–57.

Mitman, Gregg. *The State of Nature: Ecology, Community, and American Social Thought, 1900–1950*. Chicago: University of Chicago Press, 1992.

Mitman, Gregg, Michelle Murphy, and Christopher C. Sellers, eds. *Landscapes of Exposure: Knowledge and Illness in Modern Environments* Vol. 19, Orisis. Chicago: University of Chicago Press, 2004.

Morantz-Sanchez, Regina Markell. *Sympathy and Science: Women Physicians in American Medicine*. New York: Oxford University Press, 1985.

Morgen, Sandra. *Into Our Own Hands: The Women's Health Movement in the United States, 1969–1990*. New Brunswick, NJ: Rutgers University Press, 2002.

Murphy, Michelle. *Seizing the Means of Reproduction: Entanglements of Feminism, Health, and Technoscience*. Durham, NC: Duke University Press, 2012.

———. *Sick Building Syndrome and the Problem of Uncertainty : Environmental Politics, Technoscience, and Women Workers*. Durham NC: Duke University Press, 2006.

Murphy, M. L., and J. A. Osmundsen. "David A. Karnofsky: A Biographical Sketch." *Teratology* 3, no. 1 (1970): 1–5.

Myers, Gary J., Philip W. Davidson, C. Cox, C. Shamlaye, E. Cernichiari, and Thomas W. Clarkson. "Twenty-Seven Years Studying the Human Neurotoxicity of Methylmercury Exposure." *Environmental Research* 83, no. 3 (Jul 2000): 275–85.

Nash, Linda Lorraine. *Inescapable Ecologies: A History of Environment, Disease, and Knowledge*. Berkeley: University of California Press, 2006.

Needleman, Herbert L. "Clair Patterson and Robert Kehoe: Two Views of Lead Toxicity." *Environmental Research* 78, no. 2 (1998): 79–85.

Nichols, Janice E. *Twin Voices: A Memoir of Polio, the Forgotten Killer*. Bloomington: iUniverse, 2007.

Nicolson, Malcolm, and John E. Fleming. *Imaging and Imagining the Fetus: The Development of Obstetric Ultrasound*. Baltimore: Johns Hopkins University Press, 2013.

Oakley, Ann. *The Captured Womb: A History of the Medical Care of Pregnant Women*. Oxford Oxfordshire; New York, NY: B. Blackwell, 1984.

Oakley, Godfrey P., and Clark W. Heath. "Cancer, Environmental Health, and Birth Defects—Examples of New Directions in Public Health Practice." *American Journal of Epidemiology* 144, no. S8 (1996): S58–S64.

Oaks, Laury. *Smoking and Pregnancy: The Politics of Fetal Protection*. New Brunswick, NJ: Rutgers University Press, 2001.

Oppenheimer, G. M. "Becoming the Framingham Study 1947–1950." *American Journal of Public Health* 95, no. 4 (2005): 602–10.

Oppenheimer, Jane M. "Some Historical Relationships between Teratology and Experimental Embryology." *Bulletin of the History of Medicine* 42, no. 2 (1968): 145.

Oudshoorn, Nelly. *Beyond the Natural Body: An Archaeology of Sex Hormones*. New York ; London: Routledge, 1994.

Park, Katharine, and Lorraine J. Daston. "Unnatural Conceptions: The Study of Monsters in Sixteenth- and Seventeenth-Century France and England." *Past & Present*, no. 92 (1981): 20–54.

Patterson, James T. *Grand Expectations: The United States, 1945–1974*. The Oxford History of the United States. New York: Oxford University Press, 1996.

Paul, Diane B. *Controlling Human Heredity, 1865 to the Present*. Atlantic Highlands, NJ: Humanities Press, 1995.

Pauly, Philip J. *Biologists and the Promise of American Life: From Meriwether Lewis to Alfred Kinsey*. Princeton, NJ: Princeton University Press, 2000.

Pernick, Martin S. *The Black Stork: Eugenics and the Death of "Defective" Babies in American Medicine and Motion Pictures since 1915*. New York: Oxford University Press, 1996.

Petchesky, Rosalind P. *Abortion and Woman's Choice: The State, Sexuality, and Reproductive Freedom*. Longman Series in Feminist Theory. New York: Longman, 1984.

Petchesky, Rosalind Pollack. "Fetal Images: The Power of Visual Culture in the Politics of Reproduction." *Feminist Studies* (1987): 263–92.

Pfeffer, Naomi. *The Stork and the Syringe: A Political History of Reproductive Medicine*. Feminist Perspectives. Cambridge, MA: Polity Press; Blackwell Publishers, 1993.

Picart, Caroline Joan, and John Edgar Browning. *Speaking of Monsters: A Teratological Anthology*. Basingstoke: Palgrave Macmillan, 2012.

Plant, Rebecca Jo. *Mom: The Transformation of Motherhood in Modern America*. Chicago; London: The University of Chicago Press, 2010.

Porter, Dorothy. *Social Medicine and Medical Sociology in the Twentieth Century*. Vol. 43: Rodopi, 1997.

Proctor, Robert. *Cancer Wars: How Politics Shapes What We Know and Don't Know About Cancer*. New York: Basic Books, 1995.

Proctor, Robert, and Londa L. Schiebinger. *Agnotology: The Making and Unmaking of Ignorance*. Stanford, CA: Stanford University Press, 2008.

Putnam, Frank W. "The Atomic Bomb Casualty Commission in Retrospect." *Proceedings of the National Academy of Sciences* 95, no. 10 (1998): 5426–31.

Ramsey, Paul. *The Ethics of Fetal Research*. New Haven: Yale University Press, 1975.

Rapp, R. "Moral Pioneers: Women, Men and Fetuses on a Frontier of Reproductive Technology." *Women & Health* 13, no. 1–2 (1987): 101–16.

Reagan, Leslie J. *When Abortion Was a Crime: Women, Medicine, and Law in the United States, 1867–1973*. Berkeley: University of California Press, 1997.

———. "From Hazard to Blessing to Tragedy: Representations of Miscarriage in Twentieth-Century America." *Feminist Studies* 29, no. 2 (2003): 357–78.

———. *Dangerous Pregnancies: Mothers, Disabilities, and Abortion in America*. Berkeley: University of California Press, 2010.

Rego, Brianna. "The Polonium Brief: A Hidden History of Cancer, Radiation, and the Tobacco Industry." In *Science and the American Century: Readings from Isis*, edited by Sally Gregory Kohlstedt and David Kaiser, 432–59. Chicago; London: The University of Chicago Press, 2013.

Reilly, Philip. *The Surgical Solution: A History of Involuntary Sterilization in the United States*. Baltimore: Johns Hopkins University Press, 1991.

Reiter, Rayna R. *Testing Women, Testing the Fetus: The Social Impact of Amniocentesis in America*. The Anthropology of Everyday Life. New York: Routledge, 1999.

Rosen, Ruth. *The World Split Open: How the Modern Women's Movement Changed America*. New York: Viking, 2000.

Rosenberg, Charles E. "Bitter Fruit: Heredity, Disease, and Social Thought." In *No Other Gods: Science and American Social Thought*, 25–52. Baltimore: Johns Hopkins University Press, 1997.

Rosner, David, and Gerald Markowitz. "Standing up to the Lead Industry: An Interview with Herbert Needleman." *Public Health Reports* (2005): 330–37.

Rosner, David, and Gerald E. Markowitz. *Dying for Work: Workers' Safety and Health in Twentieth-Century America*. Bloomington: Indiana University Press, 1987.

———. *Deadly Dust: Silicosis and the Politics of Occupational Disease in Twentieth-Century America*. Princeton, NJ: Princeton University Press, 1991.

Rothman, Barbara Katz. *The Tentative Pregnancy: Prenatal Diagnosis and the Future of Motherhood*. New York: Viking, 1986.

Roux, Olivier. *Monstres: Une histoire générale de la tératologie des origines a nos jours*. Paris: CNRS, 2008.

Ruzek, Sheryl Burt. *The Women's Health Movement: Feminist Alternatives to Medical Control*. New York: Praeger, 1978.

Schiebinger, Londa L. *The Mind Has No Sex?: Women in the Origins of Modern Science*. Cambridge, MA: Harvard University Press, 1989.

Seigel, Marika. *The Rhetoric of Pregnancy*. Chicago; London: The University of Chicago Press, 2013.

Sellers, Christopher. "Discovering Environmental Cancer: Wilhelm Hueper, Post-World War II Epidemiology, and the Vanishing Clinician's Eye." *American Journal of Public Health* 87, no. 11 (1997): 1824–35.

Sellers, Christopher C. *Hazards of the Job: From Industrial Disease to Environmental Health Science*. Chapel Hill: University of North Carolina Press, 1997.

Shepard, Thomas H., Mason Barr, Robert L. Brent, Andrew Hendrickx, Devendra Kochhar, Godfrey Oakley, William J. Scott, and John M. Rogers. "An Updated History of the Teratology Society." *Birth Defects Research Part A: Clinical and Molecular Teratology* 88, no. 5 (2010): 263–85.

Shkilnyk, Anastasia M. *A Poison Stronger Than Love: The Destruction of an Ojibwa Community*. New Haven: Yale University Press, 1985.

Skocpol, Theda. *Protecting Soldiers and Mothers: The Political Origins of Social Policy in the United States*. Cambridge, MA: Belknap Press of Harvard University Press, 1992.

Starr, Paul. *The Social Transformation of American Medicine*. New York: Basic Books, 1982.

Stellman, Jeanne Mager, Steven D Stellman, Richard Christian, Tracy Weber, and Carrie Tomasallo. "The Extent and Patterns of Usage of Agent Orange and Other Herbicides in Vietnam." *Nature* 422, no. 6933 (2003): 681–87.

Susser, Mervyn. "Epidemiology in the United States after World War II: The Evolution of Technique." *Epidemiologic Reviews* 7, no. 1 (1985): 147–77.

Susser, Mervyn, and Ezra Susser. "Choosing a Future for Epidemiology: II. From Black Box to Chinese Boxes and Eco-Epidemiology." *American Journal of Hublic health* 86, no. 5 (1996): 674–77.

Thistle, Susan. *From Marriage to the Market: The Transformation of Women's Lives and Work*. Berkeley: University of California Press, 2006.

Todd, Dennis. *Imagining Monsters: Miscreations of the Self in Eighteenth-Century England*. Chicago: University of Chicago Press, 1995.

Toossi, Mitra. "Century of Change: The U.S. Labor Force, 1950–2050, A." *Monthly Labor Review* 125 (2002): 15 (15–28).

Trent, James W. *Inventing the Feeble Mind: A History of Mental Retardation in the United States*. Medicine and Society. Berkeley: University of California Press, 1994.

Tromp, Marlene. *Victorian Freaks: The Social Context of Freakery in Britain*. Columbus: Ohio State University Press, 2008.

Vicedo, Marga. *The Nature and Nurture of Love: From Imprinting to Attachment in Cold War America*. Chicago; London: The University of Chicago Press, 2013.

Vogel, Sarah. "The Politics of Plastics: The Making and Unmaking of Bisphenal a 'Safety'." *American Journal of Public Health* 99, no. S3 (2009): S559–S66.

———. *Is It Safe?: BPA and the Struggle to Define the Safety of Chemicals*. Berkeley: University of California Press, 2013.

Wailoo, Keith. *Three Shots at Prevention: The Hpv Vaccine and the Politics of Medicine's Simple Solutions*. Baltimore, MD: Johns Hopkins University Press, 2010.

Walker, Brett L. *Toxic Archipelago: A History of Industrial Disease in Japan*. Seattle; London: University of Washington Press, 2010.

Walker, J. Samuel. *Permissible Dose: A History of Radiation Protection in the Twentieth Century*. Berkeley: University of California Press, 2000.

Walton, John Nicholas, Jeremiah A. Barondess, Stephen Lock, and Oxford University Press. *The Oxford Medical Companion*. Oxford; New York: Oxford University Press, 1994.

Warren, Christian. *Brush with Death: A Social History of Lead Poisoning*. Baltimore, MD: Johns Hopkins University Press, 2000.

Wassom, John S. "Origins of Genetic Toxicology and the Environmental Mutagen Society." *Environmental and Molecular Mutagenesis* 14 Suppl. 16 (1989): 1–6.

Weed, Douglas L. "Beyond Black Box Epidemiology." *American Journal of Public Health* 88, no. 1 (1998): 12–14.

_____. "Epidemiology, the Humanities, and Public Health." *American Journal of Public Health* 85, no. 7 (1995): 914–18.

Wertelecki, Wladimir. "Of Dreaming on Solid Grounds and Silent Triumphs of One Man: A Story About Josef Warkany." *American Journal of Medical Genetics* 33, no. 4 (1989): 522–536.

Whorton, James C. *Before Silent Spring; Pesticides and Public Health in Pre-DDT America*. Princeton, NJ,: Princeton University Press, 1975.

Willett, Walter. "A Conversation with Brian MacMahon." *Epidemiology* 15, No. 4 (2004): 504–08.

Williams, David. *Deformed Discourse: The Function of the Monster in Mediaeval Thought and Literature*. Montreal, Canada: McGill-Queen's University Press, 1999.

Wilson, Emily K. "Ex Utero: Live Human Fetal Research and the Films of Davenport Hooker." *Bulletin of the History of Medicine* 88, no. 1 (2014): 132–60.

Wilson, James G., and Josef Warkany. "The History of Organized Teratology in North America." *Teratology* 31, no. 2 (Apr 1985): 285–96.

Wilson, Philip K. "Eighteenth-Century 'Monsters' and Nineteenth-Century 'Freaks': Reading the Maternally Marked Child." *Literature and Medicine* 21, no. 1 (2002): 1–25.

Zimdahl, Robert L. *A History of Weed Science in the United States*. Elsevier Insights. 1st ed. London; Burlington, MA: Elsevier, 2010.

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