

Chapter 5: “La vie impossible”

Germfree Life in the Microbiome Era

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David Vetter spent his entire life waiting for the future to arrive. Diagnosed prenatally with Severe Combined Immunodeficiency (SCID), he was delivered by sterile Cesarean section in 1971 and transferred immediately to the plastic-film isolator that would earn him the nickname “Bubble Boy.” The bubble was his refuge, a place of therapeutic safety against the microbes that would otherwise devastate his vulnerable body. And there he lived for twelve years, eating sterilized food and drinking sterilized water, reading sterilized books and doing schoolwork on sterilized paper, his entire world structured to preserve the integrity of the membrane surrounding him.

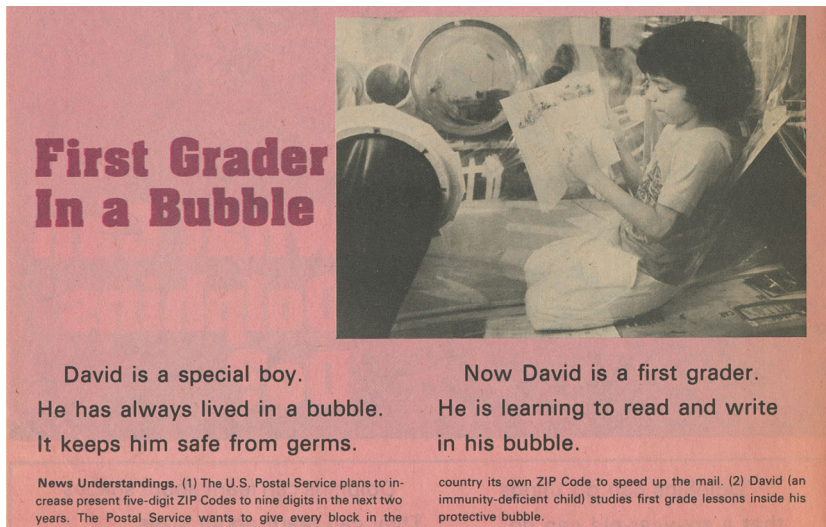


Figure 5.1: David Vetter featured in “First Grader in a Bubble,” Buddy’s Weekly Reader, January 1979.

David—and the worldwide audience following his story—looked toward his eventual exit from that bubble, as medical researchers searched for a cure that would liberate him to a coexistence with the germs, and the people, of the world. In the public eye, David's confinement was often bemoaned, with news reports and magazines emphasizing the experiences and social contacts he lacked. Yet above all, his life was a medical miracle, “a triumphal tale of technological innovation and medical mavericks” (Elman 2014: 30). His bubble was, if regrettable, a place of safety. It was a refuge, a haven in which to wait (fig. 5.1).

As the first child to be kept alive long-term in a germfree space, he was also the biomedical future made manifest. David's case—his survival, normal development, and general good health—seemed to prophesy the salvation of other immunodeficient children, whose bodies would otherwise be fatally wracked in infancy by contact with microorganisms. But even more people stood to benefit, as well, as doctors and scientists began to wonder whether the technology extending his life might be used to treat ailments spanning the entire lifespan.

David's bubble had been made possible by eight decades of progressive refinement of isolator technology in the field of *gnotobiology*, the study of organisms possessing either no microbes or only a small, specified contingent of them. With the creation of David's bubble, the *human* germfree future appeared both achievable and imminent. When David was a year old, the keynote speaker at a prominent conference on germfree research, Wallace Herrell, predicted “that gnotobiotic research may have some clinical application in nearly every medical specialty and sub-specialty ranging from pediatrics to geriatrics” (Herrell 1973: 11). He called for researchers “to immediately initiate extensive use of these germfree programs” (16). In the space age, that mission appeared as noble and as transformative as landing on the moon. Herrell asked, “if we can spend billions of dollars getting to the moon to find out among other things that it is germfree, why not spend a few million on the germfree programs?” (16–17). To many, David was an astronaut on Earth—a pioneer of life without germs.

Such boundless optimism in the saving power of medical technology was largely warranted in David's case. He lived to the age of twelve, fully a decade beyond the life expectancy of untreated SCID patients. The isolator technology was nearly flawless, and while he did acquire some microorganisms over time and was thus not strictly germfree, he evaded infection until the end of his life. His death, in fact, resulted from efforts to bring him out of the bubble: a bone marrow transplant meant to confer a functional immune system harbored an undetected virus that cost him his life. David emerged from his bubble only in his last days, already grievously ill. It was the cure, then, and not the enclosure that killed him. Until the end, his bubble remained a protective space within which to survive and to thrive. Or so the story used to go. But that is not the David Vetter story of today.

In this time of the human microbiome, living without germs seems a bizarre, even contradictory prospect. With large-scale genomic sequencing initiatives such as the Human Microbiome Project in the U.S., the sheer scope and variety of microorganisms associated with the human body—the microbiome—are coming into focus. It is increasingly clear that microbes confer vital health benefits and that reduced microbial biodiversity can propel illness. Such findings have driven a major shift in the public conversation surrounding microbes and disease, predominantly through the vast body of popular science writing on the microbiome. This discourse, which I term “microbiome writing” in this chapter, spans news reports, journalistic interviews, books, videos and other media narrating microbiome research and its applications. Microbiome writing generally shares a common persuasive goal of convincing readers to leave behind outdated ideas of microbes as disease-causing invaders, to recognize their necessity to human life, and to live more intentionally with them. We simply cannot do without our microbes, these texts insist. We are barely human at all, according to Alanna Collen’s book *10% Human: How Your Body’s Microbes Hold the Key to Health and Happiness* (2015). We must attend to the tiny legions inside, according to Ed Yong’s book *I Contain Multitudes: The Microbes within Us and a Grander View of Life* (2016). Or, as Rob Knight suggests in his TED talk, “How Our Microbes Make Us Who We Are” (2014), we must acknowledge our microbes, ourselves.

Even as microbiome writing celebrates the teeming abundance of microbial life, the thought of life without germs is never far from mind. Particularly in the book-length texts that are the focus of this chapter, authors almost universally argue that microbiome research overturns the pervasive modern attitude of what might be termed *antibiosis*: a philosophy of “anti-life” in which microorganisms are viewed chiefly as antagonists to be eliminated at all costs.¹ Antibiosis encompasses antibiotic therapy as well as a host of contemporary practices, from hand sanitizers and Clorox wipes to hospital birth and processed foods, that systematically exclude the organisms with which humans coevolved. Microbiome books assert that the regime of antibiosis has resulted in a dramatic rise of noncommunicable diseases associated with the loss of microbial diversity. Almost in unison, authors claim that modern humans are on the brink of antimicrobial crisis. In his book *Missing Microbes: How the Overuse of Antibiotics Is Fueling Our Modern Plagues*, Martin Blaser even predicts an “antibiotic winter” of apocalyptic suffering should we fail to correct course (Blaser 2014: 6).

Germfree life emblemizes that threat. David Vetter appears frequently in microbiome books, alongside gnotobiotic mice in their miniature bubbles. Au-

1 While I draw this term from Landecker (2016: 20), where it is used specifically in the context of antibiotic drugs, it accurately describes a more comprehensive attitude of “anti-life” in microbiome writing.

thors recount visits to germfree animal facilities, cite research on gnotobiology, and delve into the history and technology of germfree isolators. Microbiome writers sometimes emphasize the research utility of germfree animals, namely, their role as negative controls in elucidating the influence of microorganisms on mammalian physiology, development, and neurobiology.² As research organisms, germfree animals are generally studied for their relevance to human biology; murine pathologies lead to inferences about human counterparts. In this sense, germfree mice serve as model organisms within biomedicine.³

In microbiome writing, however, germfree life is primarily deployed for its symbolic value. Gnotobiotic mice and David the Bubble Boy become figures for the microbially depleted modern body, products of the regime of antibiosis. This symbolism is made possible by a significant shift in their status. As represented in microbiome writing, the germfree state is no longer an achievement but rather a catastrophe, no longer lifegiving but rather intrinsically risky. If gnotobiotic organisms are model organisms in biomedicine, in microbiome writing they are more properly what anthropologists Heather Paxson and Stefan Helmreich have termed *model ecosystems*, functioning “in a prescriptive sense, as tokens of how organisms and human ecological relations with them *could, should, or might be*” (Paxson/Helmreich 2014: 165). In this chapter, I show how microbiome writing employs germfree bodies as model ecosystems in reverse, as non-ecosystems held up prescriptively to illustrate how humans and microbes should not be, that is, separate. Germfree life signals grave costs to body, psyche, and society; it germinates a moral imperative to live with germs in the wider world.

The David Vetter story of today is a parable for the folly of attempting to live without germs, in which their absence, not their presence, is lethal. In this chapter, I show how microbiome writers accomplish the rewriting of his life and legacy into a register suited to the microbiome era. Conducting a close-reading analysis of ten popular science microbiome books, I examine how the history and status of germfree life—animal and human—are subtly reframed to align with the authors’

2 For a scientific perspective on microbiomics and gnotobiology see Falk et al. (1998). For a more comprehensive view of gnotobiology’s applications, including in infectious disease research, see Carter/Foster (2006). The philosophers O’Malley/Skillings (2018) also discuss germfree animal research in relation to the history of microbiomics. Microbiome writing’s engagement with gnotobiology occurs almost exclusively in the more capacious space of full-length books. Such texts began appearing with frequency around 2008, after the launch of the Human Microbiome Project in the U.S.

3 They are model organisms in the sense that they produce findings generalizable beyond themselves and model whole-organism processes, such as human–microbe interactions (Ankeny/Leonelli 2011). See Davies (2013) on the structuring role of narrative in shaping relations between animal biology and human disease, and Rader (2004) on the standardization of laboratory mice.

critiques of antibiosis. Through a subtle web of historical disjunctions, recurring tropes, a touch of misquotation, and a dose of hyperbole, germfree life in the microbiome era becomes sick. Transforming the germfree isolator from a historical invention to a modern one, from a protective space to an imminently dangerous one, microbiome writers reconceptualize germfree bodies as profoundly suffering, urgently in need of reintegration with the microbial world.

I argue that reappraisal of germfree life in microbiome writing is unified by a recurrent speculative maneuver in which the germfree body signifies the materialized future, a small-scale perfection of antibiosis. Microbiome writers continually forge parallels between germfree organisms and human bodies overexposed to antibiotics, asking readers to identify the conditions of their own bodies replicated in the space of the gnotobiotic isolator. Germfree life comes not only to exemplify the present suffering of human bodies but also to foretell the devastating failures of body and society that are the terminus of antibiosis. As embodiments of a catastrophe already underway in the antibiotic-laden modern world, germfree mice and bubble boys are deployed as interventions in the present: they function as deterrents to the trajectory of antibiosis, revealing the crisis of life without germs as foretold by the bodies of germfree mice and David Vetter.

Germfree Dreaming

Germfree animals have a long scientific history that is seldom recognized in microbiome writing. They were first conceptualized in 1885 by Louis Pasteur, who proposed deriving a sterile chick in order to assess the impact of microorganisms on vertebrate biology. Supposing the interior of the egg to be free of microbes, he suggested that this state could be preserved by transferring the newborn chick to a chamber supplied with sterile air, water, and food. Pasteur believed microbes to be vital to the physiological functioning of higher organisms, especially in digestion; he hypothesized that the germfree state would be biologically untenable, "que la vie, dans ces conditions, deviendrait impossible" (Pasteur 1885: 68).

By 1895, two German researchers, George Nuttall and Hans Thierfelder, challenged that hypothesis by providing the first indication that the survival of germfree life was in fact possible. Adapting Pasteur's proposal to vertebrates, they surgically extracted a guinea pig fetus from the sterile space of its mother's uterus, raising it for eight days inside a massively complex apparatus of glass, metal, and rubber that was kept sterile using steam, chloroform, and wax (Nuttall/Thierfelder 1895). Across Europe, researchers modified these methods to isolate germfree goats, mice, tadpoles, insects and more, including at last Max Schottelius's derivation of the germfree chicken in 1899 (Schottelius 1899).

Germfree organisms in the early twentieth century were technological marvels, encased in meticulously engineered chambers that required constant and intensive maintenance to prevent the onslaught of environmental microbes. Still, they lived.

It was how they lived that now became controversial, as researchers found that these organisms generally failed to gain weight, suffered from malnutrition, exhibited a range of physiological anomalies, and lived only a short time. It seemed that microbes, while not strictly required for life, were indeed necessary for long-term health. Yet scientists gradually developed modified feeding and supplementation regimes to compensate for the loss of microbes. These, alongside refinements in isolator technology by the American machinist James Reyniers, enabled germfree organisms—especially mice—to be maintained long-term in breeding colonies by the mid-twentieth century. And with the engineering of flexible-film plastic incubators, they eventually became cheap and transportable, extensively used in biomedical research as tools for the study of host–microbe ecology.⁴ They now appear in laboratories around the world, still dependent on their isolators and careful nutritional management, but thriving.

The existence of breeding colonies of germfree animals, as documented in the scientific literature, demonstrates that life without microbes is quite possible. Contemporary microbiome writers, however, have recurrently resurrected Pasteur’s hypothesis to affirm the sentiment that we simply cannot do without our microbes. “La vie impossible” thereby comes to signify not the life and death of a particular, isolator-bound chicken but rather the impossibility of human life in the absence of microorganisms—technical achievability aside. Pasteur’s prediction becomes detached from his task of proposing the strategic exclusion of microbes, becoming remade into a claim, in the model-ecosystem mode, about the absent modern microbiome in an age of antibiotics.

The twenty-first-century rewriting of Pasteur is accomplished through a distortion of the historical development of germfree life that situates it in our more recent past. The misrepresentations I detail below are largely innocuous, likely arising from the simple fact that science writers are not historians; nor are they specialists in gnotobiology. Nevertheless, their renarrations of the historical record matter, helping to articulate an imminent crisis of post-microbial life looming large in microbiome writing.

Although they almost universally reference Pasteur’s 1885 hypothesis, microbiome writers consistently obscure the long and largely successful early history of gnotobiology; the proposed experiment is generally suggested to have been left unexplored. In *Good Germs, Bad Germs: Health and Survival in a Bacterial World*, Jessica Snyder Sachs writes that “Pasteur’s greatest protégé, the Nobel Prize-winning

4 On the history of gnotobiology, see Kirk (2012a, 2012b) and Luckey (1963).

Elie Metchnikoff," believed that people would be better off without their bacteria, and he "openly scoffed at what he considered his mentor's naïveté" (Sachs 2007: 29). Sachs frames Metchnikoff's rejection as the disdain of an insolent student, with material consequences: identifying Metchnikoff as leading the "winning" side in gnotobiological debates, she implies an institutional diminishing of the proposal, setting Pasteur in opposition to the (prize-winning, great) microbiological mainstream (30).

More broadly, microbiome writers steadily minimize the substantial successes of gnotobiology in the early nineteenth century. Sachs neglects to mention Metchnikoff's own deep investment in germfree animal research, casting him solely as critic of Pasteur. Similarly, she entirely overlooks his wife Olga's derivation of germfree tadpoles, crediting her instead with an "unsuccessful attempt to keep tadpoles alive under sterile conditions" (30).⁵ Other microbiome writers repeat the pattern. In *The Psychobiotic Revolution: Mood, Food, and the New Science of the Gut-Brain Connection*, Scott C. Anderson and his coauthors note the eventual implementation of the germfree chicken isolation proposed by Pasteur. But rather than mentioning that germfree guinea pigs and other animals had already been isolated by 1899, they describe only the "decade of failure" before Schottelius was "finally able to breed germ-free chickens" (Anderson et al. 2017: 31–32). Likewise, in *The Wild Life of Our Bodies: Predators, Parasites, and Partners That Shape Who We Are Today*, Rob Dunn depicts early experiments in gnotobiology as relying on ineffective, low-tech methods of "scrubbing the germs off [...] a kind of Mr. Clean approach [...] Those attempts had failed" (Dunn 2011: 68).

After decades of neglect or failed efforts, this narrative goes, germfree life finally emerged with force in the mid-twentieth century. While it is true that germfree research accelerated at this time, with specimens becoming more transportable and more commonly studied, microbiome writers generally suggest them to have been *invented* or even conceived of at this moment. The timeline is a point of general consensus among microbiome writers. Anderson as well as Yong place its origins in the 1940s, while others are somewhat less precise. In *I, Superorganism: Learning to Love Your Inner Ecosystem*, Jon Turney says "50 years ago" (Turney 2015: 55). In *The Human Superorganism: How the Microbiome Is Revolutionizing the Pursuit of a Healthy Life*, Rodney Dietert says "forty to fifty" years ago (Dietert 2016: 44). In *An Epidemic of Absence: A New Way of Understanding Allergies and Autoimmune Diseases*, Moises Velasquez-Manoff simply puts it in the "mid-twentieth century" (Velasquez-Manoff 2012: 169).

In this vein, Dunn suggests Reyniers's isolator technology to have been the invention of a lone genius, first dreamed up in a heady era of technological innovation. He writes, "the iron lung had just been invented, as had the first robot.

5 Five of Metchnikoff's tadpoles lived, and remained sterile, beyond 63 days (Metchnikoff 1901).

What if, Reyniers thought, he used the same sorts of technologies to construct a microbe-free world?” (Dunn 2011: 68). Dunn’s account assigns key insights from the first decade of gnotobiology, including Pasteur’s recognition of the sterility of the chicken egg and the extension of this concept to the guinea pig by Nuttall and Thierfelder, to Reyniers himself.⁶ He concludes, “if Reyniers could accomplish his goal, he might be the first person in history to produce an animal devoid of germs [...] Such an animal would be fascinating and modern” (68–69). In light of the longer history of gnotobiology I have been discussing, of course, such an animal was neither modern, nor invented by Reyniers.

If Dunn frames gnotobiology as a continuation of the technological advances of the mid-twentieth century, other authors link it more specifically to the antimicrobial advances of the same period. Anderson and his colleagues introduce Pasteur’s hypothesis but only mention the actual existence of germfree animals following their section on penicillin, implying that it was only in the wake of antibiotics that germfree mice were “finally created” via C-section birth (Anderson et al. 2017: 33). Similarly, Velasquez-Manoff writes,

Beginning in the mid-twentieth century, following a hundred years of almost miraculous progress in medicine—including the triumph of germ theory, the advent of antibiotics, and the polio vaccine—scientists finally looked into Pasteur’s idea. They delivered mice by C-section, fed them sterile food, and raised them in germ-free bubbles [...] (Velasquez-Manoff 2012: 169)

Velasquez-Manoff suggests Pasteur’s vision to have lain dormant for a half century, emerging only after the solidification of a systemic program of microbial eradication, and from a cultural moment in which such progress was hailed as “miraculous” and a “triumph.” Each of these books, then, suggests that Pasteur’s vision of germfree animals could only be realized in the wonder-drug era.⁷ Gnotobiology, disjointed from its historical origins, becomes symptomatic of a prevailing attitude of antibiosis.

Indeed, microbiome writers share a preoccupation with antibiotic drugs, which often function as symbolic distillations of a less-than-rational quest for control over germs and disease. Antibiotics metonymize an obsessive vision of

6 The suggestion that the Cesarean delivery of germfree mice was an innovation of the mid-twentieth century is also made in Anderson/Cryan/Dinan (2017: 33) and Velasquez-Manoff (2012: 169).

7 The historian Robert Bud has documented the robust cultural legacy of penicillin, namely, the drug’s “associat[ion] with unprecedented power, science, and modern medicine” (2007: 74). Microbiome writers inherit these associations, with the gnotobiotic isolator recapitulating the familiar linkage between antibiotics and technological achievement.

microbial transcendence pursued at any cost. Transported into the era of wonder drugs and vaccines, then, germfree animals become products of an ill-advised desire for life beyond germs.

For microbiome writers, germfree fantasy rather than technological rationality has guided the development of gnotobiology. Dunn's account in *The Wild Life of Our Bodies* features a Reyniers driven to the pursuit of germfree steel isolators by a fantasy of both personal and biological transcendence: he "dreamed of germfree rats and, with them, grandeur" (Dunn 2011: 68). A lengthy discussion of Reyniers's work describes him as nearly crazed in his obsessive pursuit of the "dream" of germfree life, "interested, beyond reason" (67) in Pasteur's hypothesis and irrationally driven to disprove it. Dunn repeatedly emphasizes Reyniers's youth—he was nineteen—and calls him "a boy" (69, 70). Dunn also plays up Reyniers's unorthodox training as a machinist rather than as a biologist and his appointment to academic posts without the expected degrees. Dunn's Reyniers is an audacious dreamer, carried beyond reason in his imagination of germfree life. While other microbiome writers treat Reyniers with more circumspection, the situation of gnotobiology in a post-antibiotic world is widely echoed: the germfree animal in its germfree world is framed as the terminus, and culmination, of antibiosis.

Accusations such as Dunn's—that the pursuit of germfree life is rooted in unreasonable fantasy—recur throughout microbiome writing, particularly in discussions of the material elimination of microorganisms through antibiotics. In microbiome-era retellings of gnotobiological history, the discovery of penicillin is said to have launched the persistent imagination of a germfree human future. As Anderson and his collaborators put it,

The world began to wonder: Could germs be completely eliminated? The idea of living in a sterilized world—a world free of disease—was tantalizing. People fantasized about a future in which children would be brought up as superkids, liberated by their germ-free environment. Without bacteria, they would never be sick and could live for hundreds of years. It was a vision of purity, a sparkling biological utopia. (Anderson et al. 2017: 32–33)

Wonder, fantasy, vision: penicillin gives rise irresistibly to the possibility of germ-free utopia, to the wild dream of liberation from illness and death.

With germfree animals, microbiome writers suggest, the dream became real. Dunn attributes an irresistible allure to Reyniers's animals, suggesting that even scientists were led astray by the discovery that it was, after all, possible to live without microbes:

Reyniers spoke often and with the weight of his institute and accomplishments. His voice came to dominate the field [...] Each new talk or study added punctua-

tion until one could almost hear it, a drumming chorus of “Kill the germs!” “*Kill the germs!*” and we would be free of our past. Kill the germs and we would be healthier and happier, just like the guinea pigs in their giant metal worlds. (Dunn 2011: 74)

The scientific response to Reyniers’s guinea pigs, Dunn implies, has actually been a collective mania in which biologists’ own antibiotic fantasies are recursively amplified by the materialization of germfree animals. Significantly, Dunn presents the scientific aspiration toward microbial transcendence as being motivated by an explicit desire to kill the germs, not merely to study life without them: gnotobiology is synonymous with microbicide.

The public, Dunn suggests, has been similarly affected by appearance of germfree animals. Noting that germfree animals generally outlive their conventional counterparts, he writes that Reyniers “had inspired the imagination of the masses, inspired them to believe that we all might live like his guinea pigs, germ-free and nearly forever” (73). Germfree guinea pigs were more than scientific model organisms, becoming also “a model of what was possible” and foretelling “the chambers of the future, where we were completely removed from the plagues of our past” (72–74). But the imagined germfree future does not remain hypothetical: Dunn suggests that it has also driven efforts to manifest a germfree state in the present. For the public, such efforts take shape not as elaborate isolators but rather as more ordinary antimicrobial compulsions, attempts to “make our lives more like the lives in those guinea pig chambers” (74). Dunn declares antimicrobial actions to be attempts toward a literal germfree bubble, reinforced by the “barriers we attempt to erect with antibiotic wipes, antibiotic sprays, and the like” (76).

For Dunn, the familiar antimicrobial practices of daily human life are consistent with the same germfree dreaming that produced gnotobiology. This sentiment recurs across microbiome books, with authors continually equating modern life with a deeply rooted and irrational desire to eliminate, not just to manage, microorganisms. Dietert, in *The Human Superorganism*, laments our “modernized world of antibiotic-administered, formula-fed, cesarean-delivered babies growing up in urban environments, surrounded by hand sanitizers and antibacterial wipes” (Dietert 2016: 6). Dietert suggests a spatial boundedness to this antibiotic lifestyle in which babies, not unlike germfree mice, are born and raised within strict barriers keeping germs at bay—as if living in a bubble.

The scientific literature characterizes the effects of depleted microbiome biodiversity as *dysbiosis*: a lost biodiversity reflected in an imbalance in the expected proportions, but not the total volume, of species comprising a body’s microflora.⁸ In popular science writing, however, dysbiosis is often reinvented as a state of microbiological barrenness. Microbes are not imbalanced, but rather gone entirely

8 For a philosophical critique of the explanatory potential of dysbiosis: O’Malley/Skillings (2018).

in an "epidemic of absence" (Velasquez-Manoff 2012) and a crisis of "missing microbes" (Blaser 2014). The human body perceives the loss: Blaser describes "a dance without a partner," Dunn a "longing" or "an ache for the context you miss," like the "pain of a missing limb" (Blaser 2014: 122; Dunn 2011: 23, xii, xiii). These tropes are supplemented by microbiome writing's proliferation of environmental destruction metaphors, such that the antibiotic-laden modern body is said to suffer like a landscape that is scorched, deforested, desolate without its extinct species, and polluted by nuclear fallout.⁹ Contained within antibiotic barriers rigorously maintained, the human body becomes figuratively germfree.

Microbiome writers do not hold that our bodies are literally germfree, but rather that the germfree imagination continues unabated in a continual striving toward germfree utopia. It is in this trajectory that they seek to intervene. The solution to germfree fantasy, according to these authors, is scientific rationality. They suggest that microbiome science, with its sobering attention to the consequences of microbial depletion, can puncture the inflated dream of life beyond germs. Microbiomic rationality exposes the germfree dream to be a germfree nightmare; it defines the microbeless body as disastrous rather than transcendent.

In advocating for a saner approach to germs, microbiome writers take on the rhetorical mantle of historical antibiotic reformers: mid-twentieth-century infectious disease researchers who sought to curb the overzealous use of antibiotics. According to Scott H. Podolsky, reformers defined the overuse of antibiotics as driven by a deep-seated irrationality, and they advocated for "therapeutic rationality" in response (Podolsky 2015: 2). For microbiome writers, too, accusations of irrationality sharpen arguments for a more sparing use of antibiotics as well as a more deliberate approach to living with microorganisms.¹⁰ Time and again, the yearning for life without microbes is countered by an emphasis on the risks of such a life. As we will see, the "impossible life" of the germfree organism comes to mean something worse than death: a life of unbearable suffering.

9 Blaser (2014) employs these metaphors relentlessly, but they abound across microbiome writing. They are inherited, in part, from antibiotic reformers' tendency toward natural destruction metaphors (Podolsky 2015) and contemporary catastrophe discourse in microbiology (Nerlich 2009).

10 On hysteria surrounding microbes and the "gospel of germs," see Tomes (1998); on American culture's particular obsession with cleanliness, see Hoy (1996).

Germfree Suffering

Living without germs leaves a mark. From the outset of gnotobiology, scientists have identified multiple physiological and immunological anomalies of gnotobiosis: altered anatomical features, digestive and metabolic anomalies, heightened nutrient requirements, and more.¹¹ Yet these anomalies are familiar, well characterized, and manageable. When successfully accommodated with the appropriate supplements and care, germfree animals thrive. In itself, germfreeness is not an obstacle to long-term survival. Gnotobiotic animals even tend to outlive their conventional counterparts.

The gnotobiotic isolator might reasonably be considered a triumph of engineering and, given its success in medicine, a lifesaving innovation. But microbiome writers define the technology almost exclusively as transgressive—as Dunn writes, “monstrous” (Dunn 2011: 73). Monstrosity, not achievement, characterizes the mission to separate an organism from its microbes. Other authors also describe germfree isolators as violations of the natural order, emphasizing their strangeness, awkwardness, or sheer technological immensity: Ed Yong calls them “some of the strangest environments in the world” (Yong 2016: 112); Turney, “an expensive and awkward business” (Turney 2015: 55). The monstrous space of the isolator extends to the bodies enclosed within, as microbiome writers consistently transform the familiar physiological anomalies of the germfree mouse into indicators of suffering. Difference becomes abnormality; isolation becomes pathology. Germfree mice are remade as victims, irreparably harmed and decisively artificial.

The artifice of germfree life, for instance, is highlighted in microbiome writers’ frequent assertion that all germfree mice are Cesarean-delivered before being transferred to their isolators.¹² While this procedure has remained in use since the nineteenth century, it has largely been eliminated—except in the establishment of new colonies—due to the development of breeding colonies in which animals give birth without intervention. Rampant C-section birth is a convenient suggestion, however, for writers wishing to establish these animals as thoroughly artificial—reproductively inviable—from birth to death. With assisted obstetrics a condition of their very existence, they embody a horrifying vision of technological intrusion: babies wrested from mothers, skin replaced with iron.

The pattern repeats in discussions of the distinctive physiologies of germfree mice. Microbiome writers seldom acknowledge that scientists modify the care of germfree animals to ensure their long-term survival, instead defining difference itself as pathological. Influential microbiologist and proto-microbiome writer

11 See Carter/Foster (2006) and, for a historical perspective, Gordon/Pesti (1971).

12 E.g. Turney (2015); Rosebury (1969); and Velasquez-Manoff (2012).

Theodor Rosebury set this tone in his 1969 book, *Life on Man*, writing that germfree animals "turn out to be puny and deformed [...] with deficiencies and weaknesses yet to be counted" (Rosebury 1969: 149).¹³ Contemporary writers follow Rosebury's lead, almost always portraying these animals as both deformed and deficient. Sachs recites a litany of defects: "unusually thin" intestinal tracts, and bodies "unusually vulnerable" to toxins and "unusually susceptible to deadly infections" (Sachs 2007: 45). Sachs does not mention that these differences are managed by researchers; rather, the unusual physiology of the germfree mouse becomes intrinsically problematic.

Germfree mouse bodies are sometimes more overtly characterized as grotesque. Yong notes the "weird biology of germ-free animals" (Yong 2016: 54), while Velasquez-Manoff depicts them as having a "really weird" physiology that is "off," "abnormal," "malformed," "strange," "shrunken," and "arrested" (Velasquez-Manoff 2012: 169–170). For Collen, they are revolting: an animal researcher she interviews recalls "that the first time she dissected a germ-free mouse, she was horrified by the size of the caecum, which took up most of the space in the abdomen" (Collen 2015: 128). The researcher's horror is recreated for the reader thanks to the inclusion of colored images of flayed mouse guts, in which the conventional as well as the germfree cecum might well be repulsive to the average reader. For these writers, the normal physiological differences of the germfree body are equated with suffering.

Significantly, in these accounts the research utility of germfree animals is rarely discussed; their crucial contributions to the study of human-microbial ecology go unnoticed. Instead, they are deployed primarily for their symbolic value. Transformed into bodily victims of a regime that values germfreeness above function and accepts countless deformities as the cost of its achievement, germfree mice are meant to be startlingly familiar. As depicted by microbiome writers, the grotesque germfree body is both alien and deeply resonant with the human bodies also suffering the consequences of antibiosis. Mice and humans are common victims of the dream of a germfree world.

Microbiome writers generally suggest that the microbially-depleted human body suffers profoundly in its "dance without a partner." Blaser even describes the lost biodiversity of the human microbiome as "exacting a terrible price":

We are suffering from a mysterious array of what I call "modern plagues": obesity, childhood diabetes, asthma, hay fever, food allergies, esophageal reflux and cancer, celiac disease, Crohn's disease, ulcerative colitis, autism, eczema [...] Un-

13 I include Rosebury's work in this chapter because it has been particularly influential for microbiome scientists as well as popular science writers, and because it prefigures many of the themes and narratives of contemporary microbiome books.

like most lethal plagues of the past that struck relatively fast and hard, these are chronic conditions that diminish and degrade their victims' quality of life for decades. (Blaser 2014: 6, 2)

In Blaser's assessment, these modern plagues are unleashing an unprecedented misery that is subtler than infectious diseases—the “lethal plagues of the past”—but no less profound. He suggests an urgent need to become attuned to these newer, more nuanced illnesses produced by the damaged microbiome.

We are meant to recognize ourselves within the space of the germfree isolator, identifying the bodily afflictions wrought by our own antimicrobial dreams. Contemporary human bodies mirror the “monstrous” germfree mice in microbiome writing, even if they do not (yet) appear so grotesque. In this sense, germfree animals might be understood as serving a *diagnostic* function, presenting afflictions that allow humans to identify their own dysbiotic suffering even in a not-quite-germfree world. The gnotobiotic isolator and the modern human world thereby become parallel spaces, limned spatially or rhetorically by a sterile boundary within which life suffers.

But the key innovation of microbiome writing's reappraisal of germfree life is that it is more than merely diagnostic of present human illness, also serving a crucial *deterrent* function; the virtual witnessing of germfree catastrophe is mobilized to intervene in the future. Microbiome writers generally suggest that the crisis of noncommunicable diseases, already dangerously out of control, threatens to worsen as the germfree fantasy draws ever closer to completion. Germfree mice and David Vetter, as early manifestations of that dream, suggest humanity's trajectory. Revealing the germfree dream to be a biological catastrophe, they are deployed to startle the reader into a more rational apprehension of microbial life and to forestall the devastations of antibiotics.

There is abundant cultural precedent for this speculative neutralization of the germfree dream. Science fiction authors pioneered the narration of germfree life's damages as a means of critiquing dominant, eradicated attitudes toward microorganisms. For instance, Michael Crichton's novel *The Andromeda Strain* (1969) imagines the development of Kalocin, a “universal antibiotic” that fully eliminates a patient's microbial load to horrifying effect. Crichton emphasizes the risk of superinfection, the uncontrolled influx of microorganisms into the germfree body. In the novel, the clinical volunteers who test this powerful antibiotic suffer painful deaths upon discontinuing treatment:

The forty volunteers each had died of obscure and horrible diseases no one had ever seen before. One man experienced swelling of his body, from head to foot, a hot, bloated swelling until he suffocated from pulmonary edema. Another man

fell prey to an organism that ate away his stomach in a matter of hours. A third was hit by a virus that dissolved his brain to a jelly. And so it went. (Crichton 1969: 266)

This side effect is so severe that the drug is ultimately denied even to a key scientist who becomes infected with the gruesome Andromeda Strain. "It might cure you for a while," the lead researcher explains, "but you'd never survive later, when you were taken off" (267). Germfreeness is the greater evil, a state not to be pursued even under the gravest circumstances—not even in the face of a ghastly death.

Scientific discourse has also historically relied on the power of the apocalyptic imagination to counter prevailing germphobias, through thought experiments exploring the catastrophic disappearance of microorganisms in the global ecosystem. The foundational example is bacteriologist Otto Rahn's 1945 popular press book *Microbes of Merit*, featuring an epilogue that summarizes the diverse roles of bacteria by imagining their disappearance in the wake of an antimicrobial comet. Rahn observes that the immediate resolution of bacterial diseases would be welcomed, but any celebration would quickly cease with the unfolding of successive global crises: stalled agriculture, the accumulation of undecomposed bodies, devastated landscapes, undrinkable water. These consequences reveal the demonization of microorganisms to be short-sighted, thinkable only by those who "take the cooperation of microbes for granted" (Rahn 1945: 274). The imagined hellscape of a world without microbes is meant to return readers to a more holistic attitude in which they join Rahn in concluding: "Let us hope that we never collide with the tail of such a comet" (274).

In their engagements with germfree life, microbiome writers largely reprise the lessons of Crichton's *Kalocin*, Rahn's antimicrobial comet, and countless other devices historically recruited to illustrate graphically the toll of the germfree aspiration. Yet where these precursors have always announced themselves as thought experiments or as science fiction, microbiome writers extract the same insight from real, embodied organisms. One need no longer turn to the imagination, it would seem; looking into the gnotobiotic isolator brings the germfree nightmare to life before our very eyes. As perfections of an abiotic state dreamed of but not hitherto attained in the human world, germfree animals materialize antibiosis and its costs.

Rosebury first brought this speculative maneuver to microbiome writing in his discussion of gnotobiology. He writes that the numerous deficiencies of germfree animals demand we "abolish at once any notion we might have had that the animal would be generally better off without his germs [...] The germ-free animal is, by and large, a miserable creature" (Rosebury 1969: 49). Rosebury here comments on more than simply the status of germfree animals: his detailing of their miseries serves to rebut the notion that life without germs might be desirable—for humans. Animal misery forebodes human misery. He continues, "Knowing

things like this, would you willingly separate your infant from his microbes if you could? Or ought you to be glad you can't?" (54). The paired questions affirm the stubborn persistence of gnotobiotic fantasy, despite the recognition that its achievement would be devastating. For Rosebury, that aspiration might only be dispelled by a speculative intervention: by asking the reader to imagine their own infant as germfree and therefore subject to the atrocities wreaked upon gnotobiotic animals.

Contemporary microbiome writers also turn to germfree animals as indicators of human suffering, though they generally assert a stronger potency for the deterrent possibilities of germfree imagination. Dietert is perhaps the most explicit in identifying the speculative mode animating microbiome writers' engagements with germfree life. He explicates at some length a 1971 gnotobiology review article summarizing the physiological anomalies of germfree animals.¹⁴ Significantly, Dietert interprets the article as a catalogue of present and future *human* horrors, despite the fact that it makes no claims about human applications. He argues that it "foretells exactly what happens when we are a single mammalian species. Without those microbes, we face a life of biological deficiencies, illnesses, and death" (Dietert 2016: 44). From the bodies of gnotobiotic animals, he extrapolates to a dire human future of required nutritional supplements, swelling, immune susceptibility, and imminent death. It is germfree animals that lead him to conclude that "there are consequences to degrading or damaging the human microbiome garden," which is absolutely required in order "to have a healthy and prolonged life" (45).

For Dietert, germfree animals are more than model organisms; they also foretell our impending germfree future. It is a vision from which the reader is meant to recoil, to be surprised into a new appreciation of microbial life. Recognizing the kinship of this maneuver with the sorts of science fictional devices I mentioned above, Dietert explains his symbolic use of germfree organisms through the lens of speculative fiction:

A wealth of studies in rodents and other animals shows us what happens when the microbiome is degraded, damaged, or even lost. The storyline strikes me as a little similar to the classic Frank Capra movie *It's a Wonderful Life*. We have the information to look ahead and see what the future brings for living with a damaged microbiome. It is not pretty. It is not something we would want for ourselves or our children. (44)

Germfree animals, then, are our future. In them we are meant to glimpse the culmination of antibiotic fantasy, and to find it so appalling that we are provoked to

14 The review, which goes uncited, is likely Gordon/Pesti (1971).

reject such fantasy. With this digression, Dietert asks his readers to take on the role of George Bailey, the protagonist of *It's a Wonderful Life* (1946) who wishes he'd never been born. The film narrates Bailey's glimpsing of a world without him—that is, a world in which impulsive dreams of absence are actualized. Merely a glimpse is enough to affirm for Bailey the necessity of reintegrating with his social and familial context. The same is meant to be true for readers of Dietert's book: merely a glimpse of the post-microbial future, as embodied in germfree mice, should affirm the necessity of reintegrating with one's micro-ecological context. An apocalyptic vision of the future thus comes to prevent that vision coming true.

The Germs That Bind

Nowhere is the imminent futurity of gnotobiosis more evident than in the case of David Vetter, whose bubble-bound form is continually recruited by microbiome writers to define the costs of life without germs. Where gnotobiotic animals generally illustrate physiological effects, however, David's humanity enables an argument for the social consequences of germfree life. Paxson and Helmreich write that as model ecosystems, microbial communities are "made to signify larger biological worlds and socialities, wider perils and promises, in worlds imagined yet to come" (Paxson/Helmreich 2014: 171). David's story is only nominally about a celebrity of the past. As told by microbiome writers, it also entails a model-ecosystem claim in which David signifies the promises and, especially, the perils of imagined worlds without germs. As with the germfree mice discussed above, his story is retold as a deterrent: the recitation of his struggles is intended to guide readers to step out of their own bubbles and into a life interconnected with human and microbial bodies.

In microbiome writing, David's enclosure in the bubble is generally suggested to have been motivated by irrational germophobia more than any therapeutic agenda. He becomes the product of the persistent dream of life beyond germs first realized in gnotobiology. In *The Psychobiotic Revolution*, Anderson and his coauthors claim that penicillin launched dreams of "superkids" raised in "a sparkling biological utopia" (Anderson et al. 2017: 32–33)—and David seemed to materialize those dreams. They write that "in 1971 the ultimate germ-free animal was created: a human."¹⁵ As *ultimate* germfree animal, David here becomes the culmination—the dream come true—of both antibiotics and gnotobiology. It is a claim echoed by Dunn in *The Wild Life of Our Bodies*, writing that David's life and eventual death

15 Kirk details the early history of gnotobiological therapeutics, writing that these precedents "helped determine David's role as an object of scientific interest, comparable, if not directly akin, to the laboratory animal" (2012a: 269).

resulted from the belief that “we might achieve some germ-free utopia for ourselves” (Dunn 2011: 76).¹⁶

Framed as the achievement of germfree utopia, David is transformed into gnotobiotic specimen. His SCID diagnosis recedes; his dramatically improved lifespan is forgotten. Instead, he is made to exemplify the catastrophically missing contemporary microbiome. In reality, he was not germfree, possessing a limited microflora due to leaks and contaminations (Williamson 1977). Microbiome writers consistently disregard that fact. Anderson and his colleagues insist that this “ultimate germ-free animal” was “freed from germs” (Anderson et al. 2017: 34). That point is echoed by Dietert, who asserts that he had “no immune system and no microbiome to co-mature with him and to enable him to function biologically in the environment of the world” (Dietert 2016: 73–74)—a phrasing that strongly implies that it was gnotobiosis, rather than SCID, from which David suffered.

In the context of microbiome writing’s preoccupation with gnotobiology, readers are encouraged to consider David’s putative germfreeness with the deformity and physiological suffering so consistently attributed to germfree animals. No longer an engineering triumph, no longer a safe space, the bubble comes to signify a violation of the natural order. Crucially, though, David’s own story complicates this narrative: microbiome writers must confront the inconvenient fact of his physiological normalcy. Physically healthy, typically developing, charismatic and curious even under the circumstances of his confinement, David fails to exhibit the deficiencies so insistently associated with germfree life in microbiome writing.

In *10% Human*, Collen reconciles this contradiction by allowing David to have been less-than-fully germfree. She explains his microflora as the result of medical failure: “[D]espite their best efforts to keep David germ-free, from birth onward his gut had been colonised by more and more species of bacteria” (Collen 2015: 127). Collen suggests those bacteria to have been his salvation; had the bubble been executed as intended, the results would have been disastrous. The hypothetical here becomes an occasion to invoke the speculative-deterrent mode of germfree life once more:

Had David been truly germ-free, the coroner at his autopsy might have discovered that David’s digestive system was drastically out of proportion. The first tennis-ball-like section of the large intestine—the caecum—to which the appendix is attached, might have been more like a football than a tennis ball. The folded surface of the small intestine would probably have had a much smaller surface area than normal, and fewer blood vessels supplying it. As it was, David’s digestive system was as normal as any other child’s. (128)

16 Weinstein (2010: 17–27) describes gnotobiology’s perennial invitation of utopian dreaming.

Might have been, but was not: Collen composes an alternative history in which David's body, enclosed in a perfected germfree isolator, bears identity with the anomalies of germfree mice. Her enumeration of digestive aberrancies that might have been is reinforced by her description and graphic illustration of the 'horrifyingly' enlarged mouse cecum, as noted above. Gnotobiotic disaster has been forestalled by the lifesaving presence of a few accidental microbes. It is a maneuver meant to correct the course of germfree dreaming, not only for David but also for the reader.

Other microbiome writers resolve the apparent contradiction of healthy germfreeness by rewriting his biography into a story of unrelenting anguish that is not physical but rather social, emotional, and societal. In this they align with the robust cultural censure of isolator life and bubble boys that has emerged since David's death. Movies, songs, and literature have for decades portrayed bubble boys as both miraculous and victimized, heroically surviving in the face of profound, if intangible costs. More generally, the phrase "living in a bubble" has come to signify a perspective that is sheltered or shortsighted, divorced from intellectual context.¹⁷ Microbiome writers harness these diverse meanings, transmuting them into a condemnation of antibiosis. The bubble is not the problem; the missing microbiome is the problem. Taking David to be the embodiment of the epidemic of absence, these authors rewrite his legacy, together crafting a consistent narrative of profound social suffering.

In these accounts, David is simply "bubble boy," sometimes anonymous beyond this familiar nickname, and always defined by deprivation. Collen narrates a life of total social isolation:

David was born in 1971 by Caesarean section into a sterile plastic bubble. He was handled through plastic gloves and fed sterilised infant formula. He never knew the scent of his mother's skin, or the touch of his father's hand. He never played with another child without plastic sheeting preventing the sharing of toys and laughter. (127)

Collen narrates his life almost exclusively in the negative, through a list of things never known and sensations never felt. Gone is the celebratory tone with which the media documented David's story while he lived; here and elsewhere, microbiome writers emphasize only lack.

And from that lack follows an encompassing desolation. In *The Psychobiotic Revolution*, Anderson and his colleagues emphasize the boy's psychological distress:

¹⁷ Elman (2014) has extensively charted the cultural memory of Vetter's life. For the political resonances of "living in a bubble," see Safire (1993).

David didn't take long to realize that he was doomed to be cut off from the world, and he started questioning his life. He was depressed, but whether that was from being germ free or just because he lived in a plastic bubble with no physical human contact is debatable. (Anderson et al. 2017: 34)

Again, David is defined exclusively by isolation and lack. His depression is suggested to be due either to his germfree state or to his isolation; it is therefore remediable only by integration with the human and germy world, an integration incompatible with his own survival.



Figure 5.2: David Vetter with his parents, sister, and family dog. Photograph archived in the David Vetter Collection (1971–1986): Box 9 (David Vetter and Family, 1976–1983). Courtesy of Archives Center, National Museum of American History, Smithsonian Institution, Washington, DC.

In Dunn's *The Wild Life of Our Bodies*, social isolation appears to be the indirect cause of death. Omitting the contributions of David's very involved parents and sister (fig. 5.2), Dunn writes that "inside his chamber, he was raised by doctors until the age of twelve" (Dunn 2011: 76).

Like some Mowgli raised by wolves, this David exists entirely beyond the human realm, a separation that he attempts to transcend with grave consequences. Dunn continues, "at twelve, he wanted out. At twelve, something needed to change and so he was given a bone marrow transplant in an attempt to restore his

immune system" (76).¹⁸ That this transplant ultimately ended his life consolidates David's status as a sufferer of the fatal pathology of isolation. To live with people is to live with germs; their lack is unsustainable on any level.

In retelling David's story, these authors highlight the denial of desires universal to human experience—for a parent's touch, for friendly interaction, for shared laughter and a bit of teenage rebellion—and so forge an argument for the *social* suffering of the germfree state. Microbiome writers generally describe the toll of dysbiosis for ordinary people in similar terms, suggesting that the resulting illnesses resulting from a too-clean environment force sufferers into conditions of social withdrawal. In *Good Germs, Bad Germs*, Sachs details the plights of two young boys whose severe food allergies force them to withdraw from friends, classmates, and even family (Sachs 2007: 7, 73). In *An Epidemic of Absence*, Velasquez-Manoff describes "asthmatic teenagers wondering if they'll be able to join friends in a game of baseball" (Velasquez-Manoff 2012: 6). David's case shows this social cost at its most extreme. Once more, germfree life is invoked as a deterrent to the dream of life beyond germs.

In microbiome writing, however, David symbolizes more than merely individual isolation. His germfreeness also forebodes a societal breakdown felt well beyond his bubble. In *The Human Superorganism*, Dietert pivots from David to expansive claims about the consequences of microbial depletion at the societal level, depicting a dramatic rise in "microbially incomplete" babies—an entire "incomplete generation" (Dietert 2016: 73). Dietert takes David's bubble to be an outward indicator of his own "microbial incompleteness," a state that kept him "removed from the world's normal environment and segregated into a completely artificial environment" (74). Dietert, in other words, identifies David's segregation as the fate awaiting the incomplete generation. He observes that the skyrocketing rate of dysbiotic illness means that "increasing numbers of us may have severely restricted environments in which we can safely function" and "restrict[ed] access to the full environment normally enjoyed by others" (74). The result is a widespread "social fracturing," detectable in a breakdown of social cohesion (76). With food allergies, for instance, familiar social rituals come unglued:

Individuals may [...] have to withdraw from what used to be routine social gatherings and interactions with friends, family, and business colleagues [...] Holiday dinner celebrations, wedding receptions, community dinners, summer picnics, conference meals, and even single-family meals are increasingly affected. (76)

18 Dunn's implication of adolescent rebellion is consistent with representations of David's life as a coming-of-age tale, especially in film adaptations (Elman 2014).

Dietert calls these deprivations a “new cost in human capital, our capacity to congregate around a meal, and a type of freedom humans used to have” (77).

David thus portends the looming societal disasters produced by the pursuit of life beyond germs. Echoing his description of Vetter as “segregated” into his bubble, Dietert suggests that the social withdrawal necessitated by dysbiotic illness threatens to solidify into full-fledged institutionalized injustice. He predicts a recapitulation of the “physical segregation of people in the course of human history” due to factors such as “race, religion, lifestyle [...] politics, and wealth” (77). Invoking leper colonies and the Indian caste system, Dietert here articulates the most sweeping extrapolation possible from David’s isolator, looking to a future fractured by “an ever-increasing divide among humans” (78).

In microbiome writing, then, David represents both the individual and the social costs of antibiotics. Further, his life comes to represent a germfree catastrophe threatening all of society, in which people are held apart from one another as from the germs that bind—from the germs that constitute the very fabric of functional society.

David’s story comes to represent how much we stand to lose should we fail to stop dreaming of a world without microbes. He thus becomes, for Anderson and his colleagues, the “ultimate germ-free animal” in a second sense: the last and final germ-free animal, such that there will be no more bubble boys. The authors write of his death:

The public was taken aback by this human experiment that had gone so wrong, and at a stroke, it seemed, we awoke from the dream of a germ-free world. David, freed from germs, was not a superkid. The microbes, it seemed, had won a reprieve. (Anderson et al. 2017: 34)

A sudden, unified awakening: this is the impact of witnessing David’s life and death, in a phrasing that encapsulates the use of germfree life in microbiome writing more broadly. David and his various miseries, like the deformities attributed to germfree mice, are suggested to carry with them the power to rouse an entire society (or at least, a diligent reader) from a decades-long dream of life beyond germs. Fantasy is countered with a speculative glimpse of our own future and, at a stroke, we awake.

Conclusion

The specter of germfree life haunts our dreams of the future. As this chapter has shown, in microbiome writing the miseries of microbeless bodies—whether animal or human—reflect onto the present. Authors identify the deformities of the

germfree mouse, or the social ruptures of David the Bubble Boy, as the terminus of a trajectory already in progress. Glimpsing our own germfree futures, microbiome writing suggests, we are compelled to intervene.

In this context, it is unsurprising that microbiome writers unanimously suggest ways of emerging from the bubbles of our modern, sanitized existence. They champion responsible means of rewilding bodies devastated by antibiotics, whether through consumption of fermented foods, through "natural" ways of birthing and feeding babies, or through the dictum to *get your hands dirty*. As we have seen, not only human bodies but the very functioning of society and community are at stake. In the post-microbiome vision of the future, we step out of our bubbles, awaken from the dream, and build for ourselves better, and germier, lives.

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