



Biological Processes as Writerly?

An Ecological Critique of DNA-based Poetry

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Abstract This article examines the DNA-based biopoetry of Christian Bök in relation to its antecedents in the art-science experiments of Joe Davis, Pak Chung Wong, and Eduardo Kac. In particular, I develop an ecocritical analysis of the process of encipherment at the center of their works. Wong encoded lyrics from the song “It’s a Small World After All” within the DNA of a bacterium. Similarly, Kac employs encipherment in *Genesis*, a project aiming to demonstrate that “biological processes are now writerly.” In the same way, Bök’s *The Xenotext: Book 1*, published in 2015, involved enciphering poetry into the genome of the bacterium *Deinococcus radiodurans*. The organism’s cellular mechanisms “read” the encoded poem and produced a protein, the structure of which was then deciphered, resulting in another poem in response. In relation to these works, I ask the following: are biopoetry and the encipherment process merely conceptual and methodological experimentations, or do they reflect ecological consciousness and ethical imperative for life? Building on Foucault’s idea of the discourse of nature and Benjamin’s notion of a language of things, I explore how *The Xenotext*—and biopoetry more generally—reinscribe the power/knowledge relations implicit in the long-standing tropes of nature as a book, code, or cipher to be unraveled. Constructed as an inherently mute subject, nature is willed to speak purportedly on its own terms but through conspicuously human media and in inescapably androgenic terms. An ecologically directed evaluation of biopoetry ultimately affirms the indebtedness of all literary production, including biopoetry, to other-than-human lives and bodies.

Keywords biopoetry, material ecocriticism, *Deinococcus radiodurans*, Foucauldian discourse, Eduardo Kac, Christian Bök

Introduction

This article attempts to bring an ecocritical framework to bear on the emerging genre of biopoetry through a reading of Canadian poet Christian Bök’s *The Xenotext: Book I*, published in November 2015.¹ Bök’s recent biotext—which marks the culmination of more than ten years of combined genetic and literary experimentation by the poet—will

1. Bök, *Xenotext* (hereafter cited in the text).

be approached in relation to its biopoetic precedents in the works of genetic artists Joe Davis and Eduardo Kac and engineer Pak Chung Wong. Applying Michel Foucault's concept of the "discourse of nature,"² this article aims, in particular, to develop a critical perspective on the process, known as *encipherment*, that underlies DNA-based poetry such as Bök's. I explore how *The Xenotext*, and biopoetry more generally, reinscribe in a biotechnological context the power/knowledge relations implicit in the long-standing, gendered tropes of nature—in this instance, microorganisms and DNA structures—as books, codes, or ciphers to be unraveled. As Carolyn Merchant argues in *Reinventing Eden*, biotechnological inventions entail the "reading of nature's bible in sentences, books, and libraries comprising genetic sequences."³ Constructed as an inherently mute subject in biopoetic works, nature is willed to speak purportedly on its own terms but through conspicuously human media and in inescapably androgenic terms. In approaching biopoetry from an ecocritical perspective, the article aims to elicit some of the conceptions of microorganisms implicit within the relatively new artistic genre. In doing so, an ecologically directed evaluation of biopoetry ultimately affirms the indebtedness of all literary production to other-than-human lives and bodies. Engagement with the ethics of other-than-human beings could become more of an exigency for artists and bioartists alike in the present era of climate change, species loss, and biocultural fragmentation.

As a broadly encompassing category of interdisciplinary creative practice, bioart "adapts scientific methods and draws inspiration from the philosophical, societal, and environmental implications of recombinant genetics, molecular biology, and biotechnology."⁴ Although their productions tend to mimic, parallel, or critique contentious developments in the life sciences, bioartists have also been known to initiate new scientific concepts and technical innovations as part of their syncretic approaches to art and biology.⁵ Positioning living systems and organisms as its subjects, bioart characteristically involves artists working parallel to, or in direct collaboration with, laboratory scientists. Bioartists endeavor to transform the ways in which audiences think about creativity, nature, and science through the integration of biotechnologies and vital materials within artworks.⁶ First surfacing as a distinct genre during the 1980s in the art-science experimentations of Davis (b. 1951) and George Gessert (b. 1944),⁷ bioart differs from—but was influenced by—the environmental art movement of the 1960s and 1970s, which emphasized the imbrications among site-specific creative practice, environmental biology, and ecological ethics.⁸

2. Foucault, *Order of Things*, 157–62.

3. Merchant, *Reinventing Eden*, 146; also see Merchant, *Death of Nature*.

4. Yetisen et al., "Bioart," 724.

5. *Ibid.*

6. Lapworth, "Theorizing Bioart," 123–24.

7. Yetisen et al., "Bioart," 725.

8. Wallis and Kastner, *Land and Environmental Art*.

In distinction to *bioart* and *environmental art*, the term *biopoetry* was devised by male artists a decade later and, more specifically, by Kac in reference to his artwork *Genesis* (1999). According to his synopsis of the biopoetry genre in the *Johns Hopkins Guide to Digital Media* (2013), Kac went on to publish the first biopoetry manifesto in the anthology *Cybertext Yearbook 2002–03*.⁹ Given its origin in Kac's acutely genre-blurring work, biopoetry shares an intimate relationship with bioart. Not confined to the printed page or to verbal delivery, the poetic productions of Kac, Bök, and others typically demand audience participation. Accordingly, biopoems tend to be exhibited in a gallery space just as visual, sculptural, digital, or conceptual artworks might be. Biopoetry aims to recast notions of literary production and authorship by centralizing—and, in certain instances, constructing—the relationship between human author and other-than-human agent at the genetic scale. In its experimental focus, the genre also attempts to reformulate the act of “reading a text” through the use of a synthetic gene mediating between legible, typographic language and DNA-based processes, particularly transcription, taking place within a microorganism such as *Deinococcus radiodurans*. As Kac comments, in biopoetic works “the act of reading is procedural. In following the outlined procedure, the participant creates a new kind of life—one that is at once literal and poetic.”¹⁰ Indeed, it could be said that biopoetry entails the “reading” of organisms into being.

For the purposes of the ensuing discussion, the terms *biopoetry* and *DNA-based poetry* will be used interchangeably with *biological poetry*.¹¹ I suggest that, despite aligning language and genetics through experimentally innovative processes detailed below, biopoetry ultimately devises a language of things¹² with a subtext that perilously construes organisms as information vessels. Instead of illuminating the emergent biosemiosis of microorganisms, biopoetry risks imposing human language on other-than-humans. In his essay “On Language as Such and on the Language of Man,” written in 1916, Walter Benjamin posits a generalized language of things in which human verbal expression is but a more complex example of the world's broader semiotic fabric. Benjamin implies that everything—including bacteria—has the capacity for communication, which constitutes its particular language. For instance, such language can be embodied, sensory, affective, and corporeal. If the language of microorganisms is nonverbal and nonalphabetic, then, we must turn to their specific forms of articulation to gain even the most fleeting insight into their means of signifying in distinction to our own. However, rather than seeking imaginative and potentially less intrusive means to allow biosemiosis to emerge in its own right through frames of signification intrinsic to life forms, DNA-based poetry risks the forcible, technologically mediated imposition of human modes of linguistic expression on other-than-humans. In their affection for procedural

9. Kac, “Biopoetry” [b], 41.

10. *Ibid.*

11. While I recognize that the term *biological poetry* could apply to non-DNA, nonlaboratory-based expressions of ecological poetry that investigate biological processes, further elaboration of potential differences and similarities between terms is outside the scope of this article.

12. Benjamin, “On Language as Such.”

novelties and immersion in experimental processes, Kac, Bök, and their predecessors appear to marginalize the perils of artistically substantiating the capacity of microorganisms to serve as living archives for the storage of immense quantities of data in a future increasingly dependent upon bioengineered solutions to global problems.

In developing an ecocritical assessment of biopoetry, the guiding questions of the article center on ecological ethics and biopoetry. Do the works of Bök, Kac, Wong, Davis, and others forward an ethics encouraging us to reimagine and restructure human perceptions of, and interactions with, the natural world? In corporeally performing poetry on other-than-humans, do their biopoetic works morally consider the micro-organismic lives pivotal to the process of encipherment? Adopting an ecocritical tack, this paper considers the limits of the idea of microscopic life's speaking, writing, poetizing, and otherwise expressing itself, in human terms, via molecularly based technological interventions. Despite the potential pitfalls and criticisms I have already foreshadowed here, biopoetry in the final analysis—as the article's conclusion suggests—reaffirms that all poetry (genetic, written, spoken) is biological insofar as texts and their creation are invariably contingent on the materialities of entities and matter (larynxes, bacteria, trees, papyrus, metals, minerals). This entails both a simple reminder of human indebtedness to the materialities of other-than-humans as well as a potent critique of their being forgotten—two aspects made possible by the recent material turn in ecocriticism.¹³ Indeed, the material ecocriticism framework enables the agencies, physicalities, and ecologies of the bacteria and genetic substances involved in bioliterary experiments to be foregrounded. As a consequence, the conclusion avers that an overlooked value of biopoetry is how it tacitly asserts the biological basis of literary production—not only those relatively new specialized forms hinging on encipherment and necessitating laboratory conditions.

Biopoetry, the Cipher, and the Discourses of Nature

While the origin of biopoetry tends to be attributed to the late 1990s work of bioartist Kac (b. 1962), a number of influential mid-twentieth-century precursors and events have impacted the course of the genre. Building on the 1980s advent of digital poetry and the personal computer as both a compositional tool and a writing environment, Kac devised the term *biopoetry* to signify “poetry in vivo” that makes “use of biotechnology and living organisms in poetry as a new realm of verbal, paraverbal, and non-verbal creation.”¹⁴ Similarly, in the same manifesto, he proposes the idea of *transgenic poetry* to denote the possibility of a practice of writing based on synthesizing DNA for constructing words, sentences, and sequences of poetry in correspondence to nucleotide combinations.¹⁵ Such proposals clearly emerged from a privileged, Western context

13. See, e.g., Oppermann, “From Ecological Postmodernism.”

14. Kac, “Biopoetry” [a], 191.

15. *Ibid.*

that would allow artists access to biotechnologies in the first place. In support of his propositions, Kac offers a spectrum of artistic possibilities that would exemplify the range of biological and textual integrations allowable within the term. For instance, in “Microbot Performance” (2002), a robotic bee would facilitate the writing of a performative dance-text based on the “kinotations” (choreographies) of bee behavior. Kac’s other initiatives, however, depart from the readily perceivable world to engage the genetic domain of nucleotides. “Prophecy” (2002) would be a transgenic poem written in natural language but statistically emphasizing patterns of the letters A, C, G, and T standing in for the molecules adenine, cytosine, guanine, and thymine. The poem essentially would become a genetic sequence for molecular coding and the synthesis of DNA. In the same regard, “Proteopoetics” (2002) would assign linguistic values to amino acids enabling a poet to write a protein via a poem and vice versa.¹⁶

As Kac’s examples indicate, biopoetic projects tend to be process-oriented and procedural in that they attend less to direct literary expression and more to the constraints, concepts, inventions, and methodologies involved, specifically with respect to genetic transactions beyond ordinary human perception.¹⁷ Ecocritic and poet Adam Dickinson asks, “What is the ecocritical status of texts that turn to the strict methodologies of science for imagined, unreal or hyperreal ends?”—a question left principally unanswered in his analysis (“Pataphysics,” 137). Casting a generally positive light on the genre, Dickinson contends that biopoetry facilitates “symbiotic relationships . . . that challenge conventional distinctions between text and world as well as between human and non-human” (ibid.). Following the thinking of French Symbolist writer Alfred Jarry (1873–1907), Dickinson goes on to characterize biopoetic forms as *pataphysical* in that they endeavor to reveal or devise unique frames of signification and semiosis (ibid., 133). In distinction to the empirical processes of induction and deduction that underlie the “hard” genetic sciences, pataphysical experimentation, according to Dickinson, entails abductive processes marked by playful and spontaneous modes of investigation. Dickinson’s relatively uncritical stance on biopoetry as stochastic, symbiotic, mutualistic, participatory, and integrative belies some of the genre’s potential deficiencies, notably its rhetoric of microorganisms—living, vibrant matter—as information “storehouses” and “archives” (ibid., 141). As such, rather than unleashing new frames of signification, biopoetry risks closing off writing to the potentialities of language itself, conceived in the fundamentally inclusive Benjaminian sense already invoked and later explored in this article.

At the center of biopoetic works is the process known as *encipherment* and its pivot to genetic coding. The term *cipher* derives from the Old French *cifre*, for “nought or zero,” and signifies the mathematical symbol for absence of quantity or value. In the 1520s, *cipher* first came to denote, in English, a secret manner of writing involving a coded message. Accordingly, *cipher* refers to “a cryptographic system in which units of

16. Ibid.

17. Dickinson, “Pataphysics,” 137 (hereafter cited in the text).

text of regular length, usually letters, are transposed or substituted according to a pre-determined code.”¹⁸ In a modern context, a cipher is an algorithm for performing encryption—or *encipherment*, a less common synonym—and decryption. The cipher of modern genetics is foreshadowed in the Pythagorean belief in numerical codes as integral to unlocking—or decrypting—the perceived phenomena of the world.¹⁹ In the late 1950s, the term *genetic code* was first published in an article in *Nature*.²⁰ Thirty years later, in his book *What Mad Pursuit*, Nobel Prize-winning molecular biologist Francis Crick (1916–2004) would explain genetic code through linguistic equivalencies as “the little dictionary that shows how to relate the four-letter language of the nucleic acids to the twenty-letter language of the proteins, just as the Morse code relates the language of dots and dashes to the twenty-six letters of the alphabet.”²¹

Crick further elaborates that “the proper technical term for such a translation rule is, strictly speaking, not a code but a cipher.”²² For biopoets, the cipher and the encipherment process are comparably integral to the production of poetic texts. For instance, the biochemical correspondence between a preliminary DNA sequence and the resultant RNA pairings of amino acids is intrinsic to Bök’s biopoetic experiments whereby two poems become mutual ciphers (*Xenotext*). Considering Crick’s statements on the foundations of genetics, it is crucial to recognize the ideological dimensions of the cipher principle, or what Foucault articulates in terms of the discourse of nature underlying natural history. For Foucault, the interconnected tropes of nature as text, as cryptogram to be deciphered, and as language to be rendered into a human equivalent are part and parcel of the discourse of nature. He critiques the interrelationship as one of transference, explaining that “the great metaphor of the book that one opens, that one pores over and reads in order to know nature, is merely the reverse and visible side of another transference, and a much deeper one, which *forces* language to reside in the world, among the plants, the herbs, the stones, and the animals” (emphasis added).²³

A discourse of nature comprises a network of concepts, objectivizations, articulative modalities, and operative strategies that depend upon—and have the capacity to reinforce and extend—power/knowledge structures.²⁴ On this note, Foucault also theorizes “the rarefaction of the speaking subject”²⁵ necessitating subscription to a discourse (e.g., doctrines) and membership within an institution (e.g., research foundation, writerly society, human milieu). Hence enunciation fuses together the practices of

18. *The Free Dictionary*, s.v. “cipher,” n., 4.a., www.thefreedictionary.com/cipher (accessed April 8, 2016).

19. Gleiser, *Tear*, 24.

20. Zubay, “A Possible Mechanism.”

21. Crick, *What Mad Pursuit*, 90.

22. *Ibid.*

23. Foucault, *Order of Things*, 39.

24. Giblett, *People and Places*, 160.

25. Quoted in Sheridan, *Michel Foucault*, 125.

saying and seeing, legitimizing a privileged cohort of individuals (and, by extension, beings) while excluding others, specifically other-than-humans devoid of the powers of active, audible vocalization: plants, fungi, bacteria. Accordingly, the expressive potential of the mute other is conceived as latent rather than immanent. As a consequence, highly engineered procedures, such as those pioneered in biopoetic works, intervene, rendering the unheard *heard*, the unwritable *written*, and, consequently, the other-than-human subject *writerly*. To greater or lesser extents, the discourses of nature as code or structure to be coded, as text to be deciphered or rendered, as instrument for information storage, and as mute force to be ventriloquized all manifest in the biopoetic experimentations of Davis, Wong, Kac, and Bök, notwithstanding the positions of poet-critics such as Dickinson on the emerging genre.

A Bacterial View of the DNA-Based Poetry of Davis, Wong, and Kac

Considering ecocriticism's recent material focus, which has shifted attention to "vibrant matter"²⁶ and the materially based exigencies of human and other-than-human beings, it is imperative to begin with the agents involved in the biopoetic episodes. *D. radiodurans* is an extremophilic red spherical bacterium discovered in the 1950s in corned beef that spoiled despite having been irradiated. The bacterium is infamous for its unparalleled resistance to radiation, UV light, desiccation, acidity, and cold. In fact, it can survive up to 1.6 million rad (a unit of absorbed radiation), where 0.1 percent of such radiation is fatal to human life. Moreover, the bacterium contains between four and ten copies of its genome at any given time, providing a reliable reservoir of undamaged DNA for supporting repair processes, including postradiation impacts.²⁷ Controversially, astrobiologists have suggested that the bacterium's radioresistance is indicative of its evolution on Mars and subsequent transmission to the Earth via Martian meteorites.²⁸ Bioartists such as Davis have also used pathogenic strands of the bacterium *Escherichia coli* (or *E. coli*) in their biopoetic works. Describing the microorganism's evolutionary processes as "bacterial innovation," scientists have shown that *E. coli* and other bacteria obtain a substantial proportion of their genetic makeup from distantly related genomes through an inventive mechanism of lateral gene transfer.²⁹ The consequence of bacterial innovation is the ecologically dynamic and highly adaptive genetic constitution of the microorganism, notable for the rapid cycling of DNA in and out of its genome.

Davis is known for his close collaborations with scientists in the Department of Biology at the Massachusetts Institute of Technology. His work is distinctive for combining traditional, genetic, and digital art forms. He has catalyzed scientific breakthroughs in his use of DNA code, electron beams, centrifuges, prosthetics, and other unconventional media. Before Kac's *Genesis* (1999), Davis was the first artist-experimenter to

26. Bennett, *Vibrant Matter*.

27. Lockhart and DeVeaux, "Essential Role."

28. Pavlov et al., "Was Earth Ever Infected?"

29. Ochman, Lawrence, and Groisman, "Lateral Gene Transfer."

employ DNA sequencing technologies to encipher biblical passages. He also pioneered the use of genotypic mutations to exploit errors in the translations of codes for aesthetic purposes.³⁰ Davis's installation *The Riddle of Life* (1994–95) embodies the vital role of encipherment in the development of modern genetics and its creative interpretations and experimental interventions. The physical exhibition featured strains of live *E. coli* with engineered DNA constituting the statement "I am the riddle of life" when deciphered. The project was based on an actual cryptogrammatic exchange between renowned geneticists. In 1958, the biophysicist Max Delbrück (1906–81) issued a telegram to George Beadle (1903–89) at the Nobel Prize ceremonies in Stockholm where Beadle was due to receive the prize for medicine and physiology.³¹

In an early biopoetic instance, Delbrück composed the telegram in a form based on then-emerging ideas concerning the structure of DNA and the translational operations of the genetic code. The asynchronous exchange of coded messages pointed to the possibility that "extrabiological" information—such as the linguistic units of letters, words, and sentence fragments—could be transposed to genetics. Delbrück sent the telegram to Beadle as one continuous, unspaced, 229-character block of text consisting of the letters A, B, C, D, and X. Subsequently, Beadle and his team recognized that the means to deciphering the message rested in its semblance to DNA code. The message's structure paralleled the triplet formation of amino acids, which constitute nucleobase variations of adenine (A), cytosine (C), guanine (G), and thymine (T). Having cracked the code, Beadle retorted with the following command: "Break this code or give back Nobel Prize Lederberg Go Home Max Marko Sterling." (The original message was entirely capitalized with hyphens in lieu of spaces.) The transmission alludes to the molecular biologist Joshua Lederberg (1925–2008), who in 1958 shared the prize with Beadle and the geneticist Edward Tatum (1909–75).³²

The cryptogrammatic dialogue continued when, the following day, Beadle, in Stockholm, responded with another biocommunication: a triplet-based cipher unraveled by Delbrück's team in Pasadena, California, as "GWB [George Wells Beadle] to MD [Max Delbrück] I'm sure it's a fine message if I could do the final step." (The actual transmission was all in caps and lacked word spacings and punctuation.) In response, so the story goes, Delbrück upped the ante by airmailing a DNA model to Beadle, made of toothpicks painted one of four colors to signify the four nucleobases. A physical extension of the ethereal telegrams, the model conveyed a final message in English that invoked the story of the Riddle of the Sphinx from Greek mythology—"Which creature has one voice and yet becomes four-footed and two-footed and three-footed?"—reputedly solved by Oedipus, who answered "man," a creature that crawls as a baby, walks as an adult, and hobbles with a cane in old age. Delbrück's decoded toothpick

30. Willet and Bailey, "BIOTEKNICA," 130.

31. Davis, "Riddle of Life."

32. *Ibid.*

model contained the message, “I am the riddle of life. Know me and you will know yourself.”³³ This high-profile scientific exchange from the mid-twentieth century prefigures the central use of Western urtexts in biopoetic experimentations.

In 1994, Davis’s project *The Riddle of Life* interpreted—and, by all accounts, augmented—the intertextuality of the Delbrück-Beadle incident with new genetic techniques, resulting in a DNA version of the toothpick structure. An artist-scientist, Davis cloned the DNA sequence of Delbrück’s model and sequestered it within a noncoding segment of the *E. coli* genome. Alongside the advances he made in DNA modeling, Davis devised a novel methodology for employing biological material for data archiving—a theme that recurs in ensuing biopoetry projects by Wong, Kac, and Bök. A “supercode” ensured the stability of the “infogene” (i.e., the data plus the biological matter) while inhibiting its translation into a protein.³⁴ The Delbrück-Beadle transaction and the follow-on work by Davis echoed the twentieth-century Dadaist use of communications technologies for conveying messages of cultural critique.³⁵ In 1919, Dada artists issued a telegram to the poet and soldier Gabriele D’Annunzio in response to his participation in the military invasion of the Free State of Fiume in what is now known as Croatia. Although not encrypted per se, the telegram read, in Dadaist fashion, “Please phone the Club Dada, Berlin, if the allies protest. Conquest a great Dadaist action, and will employ all means to ensure its recognition. The Dadaist world atlas Dadaco already recognizes Fiume as an Italian city.”³⁶ In this sense, Davis—via Delbrück and Beadle—extends the genetic process of encipherment to Dadaist expressions of poetry, both comparably based on call-and-response and asynchronous, geographically dispersed poetic exchanges.

Another salient incident within the history of biopoetry further reveals the imbrication of textuality, the process of encipherment, and the prospect of DNA-based information storage. Engineer Wong and a team of researchers at the Pacific Northwest National Laboratory enciphered the lyrics of the song “It’s a Small World after All” within the DNA of *D. radiodurans*.³⁷ Written in 1962 by Robert and Richard Sherman in the wake of the Cuban Missile Crisis, the song rose to prominence as the anthem for Disney’s Fantasyland amusement park. Wong and colleagues enciphered the song lyrics as DNA base pairs and then inserted the genetic material into the bacterium. The scientists subsequently deciphered the messages using a polymerase chain reaction modulated by heating and cooling cycles. Their process comprised four discrete phases: (a) enciphering the lyrics as artificial DNA sequences; (b) inserting the sequences into *D. radiodurans*; (c) facilitating the growth and proliferation of the bacteria; and (d) removing the data intact

33. Ibid.

34. Gibbs, “Art as a Form of Life.”

35. Hope and Ryan, *Digital Arts*, 40.

36. Kac, *Telepresence*, 28.

37. Wong, Wong, and Foote, “Organic Data Memory.”

from the organisms.³⁸ A trial experiment used seven bacteria to store segments of the song in their genomes. In a schematic of the process, a recombinant plasmid—defined as DNA molecules synthesized through genetic recombination—bears two molecular fragments, which function as “sentries” protecting the song data. Invoking the potential for organisms to become data storage media, the team asserts that “living organisms, including weeds and cockroaches, that have lived on Earth for hundreds of millions of years represent excellent candidates for protecting critical information for future generations.”³⁹

Returning to the question of the ethics of such experiments, I ask: is an ecological sensibility evident in the biotextual investigations of Wong and associates? Conducted for the United States Department of Energy as part of an initiative to protect information from the threat of nuclear catastrophe, the project appears to include virtually no indication of an environmental ethics, motivation, or awareness. Conceptualized in exclusively utilitarian terms, the other-than-human (e.g., bacterium and, by extension, its symbionts, such as weed and cockroach) is reduced to an alternative medium for solving the world’s future crisis of data storage. Intimations of human exceptionalism, nonhuman reductionism, and technological utopianism surface in similar biotextual initiatives, specifically Kac’s *Genesis* (2001). Kac is distinguished for his innovative techniques in a broad range of media (video, photography, the Internet, satellites, robotics, and genomes, to name a few) and has devised numerous appellations for genres of art, including bioart, biopoetics, holopoetry, telepresence, and transgenic art.⁴⁰ His transgenic artwork *GFP Bunny* (2000) involved his creation of a living green fluorescent rabbit, marking a new form of creative practice using genetic engineering techniques to produce unusual living creatures.⁴¹ *Genesis* explores the artist’s tendentious assertion that “biological processes are now witterly [sic] and programmable, as well as capable of storing and processing data in ways not unlike digital computers.”⁴² The raising of equivalence between the living, conscious matter of organisms and dead, ersatz “consciousness” of computers is prominent in Kac’s statement. Moreover, the practices of writing and programming are fused, in that mutation serves as a mode of translation. Invoking the universalizing metanarrative of the Western Judeo-Christian tradition, Kac created the core feature of *Genesis*, known as an “artist’s gene,” by translating a sentence from the biblical book of Genesis into Morse code. He proceeded to convert the Morse code to DNA base pairs.⁴³ The selected sentence—“Let man have dominion over the fish of the sea, and over the fowl of the air, and over every living thing that moves upon the earth”—has remained the bugbear of environmental philosophers at least since Lynn White Jr.’s provocative essay “The Historical Roots of Our Ecologic Crisis,”

38. *Ibid.*, 95.

39. *Ibid.*, 98.

40. Kac, *Telepresence*.

41. *Ibid.*, 264.

42. Kac, quoted in Osthoff, “Eduardo Kac’s *Genesis*.”

43. Kac, “*Genesis*.”

which traced the ideological foundation of the increasing environmental problems of the 1960s to the Christian beliefs and practices of the Middle Ages.⁴⁴

With its textual foundation, *Genesis* demonstrates how the categories of biopoetry and bioart tend to blur through the integration of digital, performative, hybrid, conceptual, translational, intertextual, and polyvocal aspects. Kac, then, incorporated the artist's gene into bacteria exhibited in the gallery. Web-based participants were able to manipulate an ultraviolet light, initiating bacterial mutations and transforming the controversial biblical passage in real time. As critic Steve Tomasula observes, "The gallery space is thus transformed into a polyglot in which the same passage is presented in three languages: a natural language, a language of chemicals, and Morse code."⁴⁵ In the early 2000s, during the years of Internet technology proliferation, the project underscored the increasingly porous boundaries between organic life and digital data (Dickinson, "Pataphysics," 140). On an implicit level, *Genesis* could be seen to critique the commodification of life and the predominance of anthropocentrism that would render "every living thing that moves" subservient to human needs. In contrast, as other critics point out, the project could also be understood to reinscribe human dominion over the other-than-human world through technological manipulation of the genetic alphabet A, G, C, and T.⁴⁶ In the final analysis, the ecological ethics of Kac's project of biblical encipherment remain—perhaps intentionally—ambiguous: does "man" have dominion, do other creatures hold power over us, or is the interspecies norm a semimutualistic state of dynamic (dis)equilibrium?

Bök's *The Xenotext* as Environmental Text?

Aspects of technological intervention, nature as "writerly," and microorganisms as potential data storage vessels persist—although in slightly different manifestations—in Bök's *The Xenotext: Book I* (2015), an experimental text that takes the science-poetry concourse to an unprecedented level. Unlike Davis and Kac, Bök more readily identifies as an experimental poet than as a transdisciplinary bioartist, although he trained in genetics for more than ten years and worked closely with scientists in order to execute *The Xenotext*. One of the bestselling Canadian poets currently in practice, Bök established his reputation for unconventional, methodology-driven verse with his linguistic experiment *Eunoia* (2001), in which each of five chapters relates a story by using only words of the same vowel throughout.⁴⁷ For instance, Chapter E of the text singularly employs words in which the sole vowel is e, hence setting a precedent for the essential place of compositional limitations and procedures in Bök's oeuvre as a whole.⁴⁸ Prior to *Eunoia*,

44. White, "Historical Roots."

45. Tomasula, "(Gene)sis."

46. Hayles, "Who Is in Control Here?"

47. Bök, *Eunoia*.

48. Wershler, "Xenotext Experiment," 46.

Bök published the poetry and prose work *Crystallography* (1994), instigated by the science of crystals and the etymology of the term itself.⁴⁹ Rather than exhibit the stream-of-consciousness poetic style attributed characteristically to its Dadaistic precedents, Bök's verse is tightly wrought by the limits of self-imposed rubrics: crystals, vowels, DNA molecules. The vital nature of constraint and the disintegration of Romantic vestiges of divine insight in—and through—poetry come to the fore in *The Xenotext*, which is part of a larger biotextual experiment commenced by Bök in 2008.

Similarly evident in the examples of Kac and Wong, *The Xenotext* hinges on the encipherment of an original poem written by Bök into the genome of *D. radiodurans*. Subsequently, the microorganism is said to “read” the encoded poem and then to “reply” poetically (and, to be sure, corporeally) in the form of a protein, which, when deciphered, results in another poem that reflects, but diverges from, the original source text. In essence, the author's poem serves as a genetic template for catalyzing the bacterium to produce another legible poem via DNA-RNA translational processes (Dickinson, “Pataphysics,” 140). The engineered precision of encipherment—coupled to lexical algorithms—ensures correspondence between the poem's original DNA sequence and the complementary RNA analogue. This results in two mutually enciphering poems and the facilitation of lyrical interplay between poet and bacterium. Although comprehensible poetry of different forms and styles is an outcome of genetic transcription, Bök also avers that “the bacterium [*D. radiodurans*] would, in effect, be the poem” (quoted in *ibid.*).

In the project, the agency of microorganisms derives from their construction as creative, authorial subjects engaged in intimate—and technically novel—poetic exchanges with a human writer. Authorship is construed as distributed, voices are purported to be polyvocal and multispecies, and transactions occur at the DNA scale beyond everyday awareness. Bök brings new light to age-old speculations on nature's having the capacity to write, speak, utter, converse, and contemplate—attributes dismissed by critics since John Ruskin in the nineteenth century as instantiations of “pathetic,” or “affective,” fallacy.⁵⁰ Not only is *D. radiodurans* the poem; in Bök's somatic-semantic terms, the bacterium also “learns” to write verse, expressing its otherwise mute voice through the fused processes of laboratory trialing and biotextual encipherment. As Bök has conceded, during the eight-year life span of *The Xenotext* to date, unforeseen incidents caused him and his scientific associates grave uncertainty over the project's potential success or failure, specifically when the bacterium consumed the protein, and the poem, too rapidly.⁵¹

However, in the lineage of the work of Davis, Wong, and Kac, *The Xenotext* carries an overt archival impetus that risks eroding the agency of *D. radiodurans* and the

49. Bök, *Crystallography*.

50. Ruskin, “Of the Pathetic Fallacy.”

51. Souppouris, “Prose.”

ecological ethics of the project. In “writing” its own poetic responses to Bök, the bacterium merely inscribes its potential to amass data and immunize future generations from societal collapse and environmental apocalypse. Indeed, *The Xenotext* is touted as “the world’s first living poem” and a poem that “stored in the genome of such a resilient bacterium might outlive every civilisation, persisting on the planet until the very last dawn, when our star finally explodes” (151). But as Bök explains in an interview, “the organism doesn’t get to do whatever it wants. I don’t want the text to evolve: part of the project is to produce an enduring artefact [i.e., an archive in the form of a poem].”⁵² In this regard, the project appears to privilege scientific ratiocination over poetic outcomes or bioethical implications. By all accounts, the power/knowledge dynamic within *The Xenotext* is weighted toward the peculiarity of the encipherment process itself, signified even in the predominance of critical reviews—including the present one you are reading, to a degree—that emphasize the work’s methodology over its lyrical structure or content.⁵³ Bök’s work begs the questions: Do the agency, creativity, and intelligence of *D. radiodurans* emerge in a refreshing and unusual way through *The Xenotext*? Or is other-than-human (i.e., bacterial) “voice” ventriloquized via the mechanisms of transcription and translation, in a state of what Donna Haraway calls “gene fetishism”?

According to Haraway, gene fetishism is a pseudo-objective mindset that mistakes “heterogenous relationality for a fixed, seemingly objective thing” and marginalizes the actual energies that maintain “material-semiotic bodies in the world.”⁵⁴ To put it differently, gene fetishism amplifies the reductive, extractive epistemologies of the scientific method in the domains of DNA and RNA. Technological utopianism—in the case of *The Xenotext*, one linked to poetics—underlies the ideologies of cracking codes and giving voice to nature through lexically aligned genetic encipherment. Following Haraway’s argument, I suggest that the power/knowledge relations of Foucault’s discourse of nature preclude the possibility of material-semiotic expression of other-than-human life in the Benjaminian sense of a “language of things.” Foucault’s model helps to disclose gene fetishism’s implicitly gendered and explicitly utilitarian reduction of microorganisms to archival structures, to mute subjects willed to speak, and to enigmas that can be deciphered through precise technological applications. Merchant scrutinizes the gendered basis of gene fetishism: “While mechanistic science deciphered the book of nature, biotechnology decides the book of life. It ‘improves’ on nature’s heritage, correcting ‘her’ mistakes by removing genetic flaws, cloning genetically perfect organisms, and banking designer genes for future human brains and bodies.”⁵⁵ Such a perspective problematizes Bök’s claim to facilitate *D. radiodurans*’s participation in the biotextual process through the insertion of synthesized nucleotides, encoding a poem. The

52. Quoted in Avasilichioaei, “Vital Endeavour.”

53. E.g., Schuster, “On Reading”; Souppouris, “Prose”; and Wershler, “Xenotext Experiment.”

54. Haraway, *Modest*, 142.

55. Merchant, *Reinventing Eden*, 145–46.

nucleotides are thought to become functional elements of the bacterium's genetic makeup and thus to wake its latent capacity to respond in verse. Despite such assertions for a kind of bioengineered bacterial voice through verse, the source text will always be predetermined by the human author. Hence, insofar as translational constraints fix encipherment, nature's locution resonates as a distinctly scripted and ventriloquized one in *The Xenotext*.

If Kac's *Genesis* exposed the organism to mutagenic elements, Bök's work aims audaciously for a condition of symbiosis and dispersed authorship reflecting the biological composition of the bacterium. In the years before the recent publication of *The Xenotext: Book I*, Bök commented during experimental trials on the outcomes of coding and decoding poems via protein synthesis. Initially in the form of Petrarchan sonnets, the human and bacterial poems became mutually encipherable via a "bijective substitution-cipher" enabling the replacement of one letter for another.⁵⁶ Rather than appearing bio-mechanically churned out or nonsensical, the bacterial versifying conveys what one would expect of poetry: meter, rhyme, mood, affect, humor, metaphysical intimations, historical allusions, and so on. In 2011, Bök commented, in intensely gendered language that discloses the genetic call-and-response paradigm at the core of the project, "The encoded text is a very short poem; a very masculine assertion about the aesthetic creation of life. The organism reads the poem, and writes in response a very melancholy, feminine—almost surreal in tone—poem about the aesthetic loss of life. The two poems are in dialogue with each other."⁵⁷ While the use of gendered voices amplifies the human-bacterial resonances of Bök's composition, it could also be read as reinforcing the power asymmetries inherent to Haraway's concept of gene fetishism. The encoded text, which he names Orpheus, opens with the lines "any style of life / is prim." The bacterium's response, which he calls Eurydice, follows as "the faery is rosy / of glow."⁵⁸ Here, the letters *e* and *y* are mutually enciphering. Certain constraints during the early phases of the project became less important later on. For instance, the poems were initially short because longer poems would interfere with encipherment. Additionally, poems implied the contexts of their creation: "rosy / of glow" refers to the bacterium's luminescence when producing the gene.⁵⁹

Bök continues the biopoetic precedent of invoking canonical texts, notably the Bible and ancient Greek narratives. He attempts to assemble a universal narrative positing "the human" firmly in the context of masculinist Western discourse. *The Xenotext: Book I* consists of five main sections: "The Late Heavy Bombardment," "Colony Collapse Disorder," "The March of the Nucleotides," "The Virelay of the Amino Acids," and "Alpha Helix." A coda, "Vita Explicata," provides a self-reflexive elaboration of the technological and textual methodologies integrated during the long course of the work. Comprising

56. Colangelo, "Christian Bök."

57. Avasilichioaei, "Vital Endeavour."

58. Bök, quoted in Colangelo, "Christian Bök."

59. *Ibid.*

eight unnamed prose poems of fifteen lines each, part 1, set within the Hadean epoch 3.8 billion years ago, serves as an “infernal grimoire [book of incantations]” invoking the pastoral legacies of Western poetry within a context of “biogenesis and extinction” (151). The bold assertion unifying the introductory poems is both cataclysmic and archival: a poetry that outlasts human civilization is a living one in which bodies and language are rendered indecipherable. *A message in a bacteria*. An immediately striking feature of the first poem of part 1 is its extensive use of internal off-rhymes—“Hadean Eon,” “bombs,” “bronze,” “swan-dove,” “gigaton,” and “firebombs” (12, lines 1–9)—imparting syntactic rhythm to a miasmatic and preternatural scene consisting of aerolites and supervolcanoes. The second prose poem in part 1 employs a series of seven rhetorical questions that probe the brutality of biogenesis, followed by two anaphoric declaratives: “Even now, the astronauts have marshalled their forces to march. . . . Even now, they forge ahead, onward, through / war games of wildfire (unaware that, far away, a doomsayer / murmurs prayers against them from a fiendish grimoire)” (13, lines 11–15). Rather than a device for instigating dialogue, the repetitious deployment of questions serves a critical, cross-examinational function. The final prose poem in the sequence opens with a direct address to “Wraith and Reader” in the first line before lodging another series of questions, including the provocative yet fatalistic, “What if the message, when / decoded, says nothing but a single phrase repeated: ‘We / despise you! We despise you!’ What if we find the / evidence for such hate embedded in our genomes?” (19, lines 8–11). Haraway’s notion of gene fetishism is apropos: like the Delbrück-Beadle exchange nearly sixty years before it, knowledge, revelation, and extreme affective states adhere within, and are elicited through, the process of decipherment—the unraveling of nature’s syntax. The final poem concludes with the extra line, “Come with me, and let me show you how to *break my heart*” (19, line 16; emphasis added). What at first strikes as gushingly sentimental ends up carrying much less emotional gravitas when understood in terms of nature’s relinquishing, through our technological interventions, the means to “break its code.”

Part 2, “Colony Collapse Disorder,” begins with a fourteen-line alexandrine sonnet, “The Nocturne of Orpheus,” composed in blank verse as an anagram of John Keats’s 1818 melancholic Elizabethan sonnet “When I Have Fears That I May Cease To Be” (152). The allusion to Orpheus in the title (presumably the source poem of this sequence) invokes the exchange between Bök’s catalyzing text and the posttranscriptional verse of *D. radiodurans*, mediated at the genetic level. The section derives from Virgil’s long poem *The Georgics* (ca. 29BCE), the crystallization of the Western pastoral tradition. More specifically, Bök extends Virgil’s meditations on bees, which “takes on special meaning for a modern reader in an era when bees are threatened with extinction” (153). Through appreciable apiarian themes, “Colony Collapse Disorder” most closely, in the context of *The Xenotext*, approximates an “environmental text” (one that represents the environment, critiques ecological issues, or advocates for the importance of other-than-human lives as an antidote to the staid anthropocentrism of most literary

works).⁶⁰ Including a reference to a scientific article on bee colony collapse, the poem “Exordium” bears its ecological themes unequivocally in prosaic terms, lacking pretense or classical allusion: “The disorder threatens this species of insect / with extinction—thus posing a danger to the welfare of / humanity, which relies upon such bees to pollinate crops” (23, lines 13–15). In contrast to direct, pared-back diction, mellifluously symbolic, sensuous, and ecological interpretations of bee ecology ensue in other sonnets: for example, “Let leas of fragrant saffrons lure the bees / homeward, and put thy faith in Priapus / to safekeep the propolis with his scythe” (33, lines 11–13) and “the honey packed so tightly in its cells / that the columbarium drips with dew” (38, lines 13–14). In addition to strict thirty-three-letter lines that employ acrostics, the poems of part 2 exhibit self-referential aspects conveying the circumstances of their DNA-level genesis, including the occurrence of transcription-level luminescence: “grim glow in his gaze, / his teeth gnashing in a spasm of rage, / his voice intoning the fate of the gods” (63, lines 12–14).

Part 3, “The March of the Nucleotides,” consists of “poetic primers” (153) on the mechanics of genetics as well as pastoral verse composed in accordance with the molecular structure of DNA. Intertextual references include the 1970s English synthpop group *Orchestral Manoeuvres in the Dark* and the poem “Death Sets a Thing Significant,” by the nineteenth-century American poet Emily Dickinson. In the preamble to the sequence, Bök states, “The layout of each poem mimics the zigzag in a helix of DNA, complete with an internal sequence of codons, indicated by the queued letters that extend along the leftmost interior of the interstice, from the 5′-end to the 3′-end . . . the poems thus replicate the translation of nucleotides into a polypeptide” (98). Aesthetically, part 3 is replete with molecular schematics and color models of DNA folding patterns, offering readers a glimpse into the advanced methods of three-dimensional modeling with which Bök needed to become familiar throughout the life span of the project. In a similar way, the following section, “The Virelay of the Amino Acids,” uses acrostic constraints and a vocabulary restricted to words beginning with either *c* (carbon), *h* (hydrogen), *n* (nitrogen), *o* (oxygen), or *s* (sulphur). Each of the twenty poems is accompanied by a molecular schematic; each verse ends with the two-line refrain “(no hummingbirds have / copied our opulent hymns),” mimicking the common “backbone” of all the acids (156). Thus the extreme integration of poetics and genetics, beyond the mere representation of unseen processes in words, is the essence of *The Xenotext*.

Concluding on an Ecological Note: The Biological Basis of Literary Production

In light of Benjamin’s notion of the language of things, I return to my original suggestion that biopoetry echoes—in its engineered procedurality—the biological basis of all manifestations of poetry, not only the DNA-based kind. Bök’s mind-bogglingly surreal attempt to forge discourse with other-than-human subjects at the genetic scale is laudable,

60. Buell, *Environmental Imagination*.

novel, and, to some extent, pataphysical, although the work is also deadly serious. However, as I have aimed to articulate in this article, there are gendered discourses at work within *The Xenotext* that warrant critical inspection and that raise questions about the genre of biopoetry's tacit ecological dimensions. Such discourses—for instance, nature as mute archive, mechanism, and cipher, elicited in relation to the Foucauldian critique of nature constructed as a text—likewise inhere in the biopoetic antecedents of Davis, Wong, and Kac. Utilitarian and anthropocentric regard for microbial life—strongly apparent in Wong's Department of Energy rhetoric—similarly appears embedded in biotextual experiments of this kind, irrespective of differences in style, content, depth, or complexity. Particularly through allusions from the Western pastoral tradition, *The Xenotext* dramatizes the potential of living beings to become information archives for the betterment of a universalized (and, by default, masculine) humankind and to serve as versifying mouthpieces for the agendas of a global society in crisis. The question of whether engineered microorganisms will carry vast amounts of genetic information about extinct plants and animals (and insects, like bees), so that our beleaguered descendants will be able to reconstruct the planetary biome for the benefit of our species and others, is left unaddressed in the biotextual narratives of these artist-poet-experimenters. Thus audiences could be left cogitating about the ambivalent ecological ethics of *The Xenotext* and its precedents; perhaps even Bök himself is wondering. While the project aims boldly to partner literary production with the bacterium through the allegedly dialogical composition of poetry sans the mutation of Kac's *Genesis*, *The Xenotext* nevertheless scripts microscopic life, ventriloquizing the charismatic *D. radiodurans* by asserting its writerliness through bioengineered interventions.

Regardless of the technically elaborate (though, for general audiences, largely cryptic) process developed, the tenor is unavoidably *human*: for instance, the distinctly Western modes of melancholic internally rhyming alexandrine and Petrarchan sonnets. Perhaps it is a matter of the poets' claims making. Construing a bacterium and the biological processes of which it is part as writerly or a poem in itself as a microorganism or vice versa could strike discordantly with the pataphysical domain of playful linguistic experimentation and conceptualism. For Benjamin, "there is no happening, no entity in either organic or inorganic nature that does not participate in some sense in language."⁶¹ Recognizing the immanence of expression in all things, he argues against the reduction of the language of things to mere human language or to convenient metaphor. Rather than being etched in the architecture of language as we exercise it, the language of things exists at the limit of the sayable and nameable.⁶² One might, then, wish to know, impatiently, the nature of the language of *D. radiodurans*, other microorganisms, and other-than-human forms of life for that matter. Without a clear idea themselves but open to the possibility of the language of things, ecocritics might instead advocate judiciousness around claims that a biotextual intervention, such as *The*

61. Benjamin, quoted in Witte, *Walter Benjamin*, 36.

62. Benjamin, "On Language as Such."

Xenotext, elicits the language of *D. radiodurans*—or that a microorganism could be rendered a speaking subject through something as “simple” as a ten-year experiment in literary genetics.

Issues of other-than-human address and an ambivalent ecological ethics aside, *The Xenotext* does underscore the biological underpinnings of literary production, and this is the project’s unsung value. In its technical, lab-based complexity, in which poetic events transpire out of the purview of everyday human consciousness, *The Xenotext* reminds audiences of the obvious yet potent relationship between poetry and other-than-human bodies. As we are aware, print-based verse entails the impregnation of words into the surface of a tree’s cellular makeup, transformed into paper. Ancient poets did the same with vellum and other animal materials. The inscription of ink or lead onto tree or animal flesh transposes ideas from the mind to spatially articulated symbols on an organic surface. Language, thereby, becomes comprehensible to others; DNA is another medium for the same process. Nevertheless, after thousands of years of recruiting animals, trees, and now microorganisms for the literary agendas of humankind, the world’s forests and other reserves of other-than-human life are worse for wear. For illustration, according to *The State of the World’s Plants Report* (2016), by Kew Gardens, one in five plant species on earth is nearing extinction.⁶³ Considering the ecologically ominous context of the Anthropocene, literary production and producers, including biopoets, might turn their attention to how writing—as a material process, whether on vellum, plant fiber, or bacteria—is implicated in the exponential decline of species diversity.

The ethical premise that we should respect, cherish, and seek to preserve trees and the other living beings for their having provided our literary media remains unrendered in *The Xenotext* and its precursors. In its bold archival and linguistic vision, biopoetry as instantiated in these works underscores literature’s historically complex and, at times, troubled relationship to the natural world, notwithstanding the vigilant efforts of the environmental writing tradition⁶⁴ and recent posthumanist attempts to recast nature in agentic—rather than “writerly”—terms.⁶⁵ I suggest that biopoets of the future might critically consider how DNA-based poetry could become a material vector for ecological preservation alongside data archiving, with its potential for valuable present and future interventions into the global ecological crisis. As part of the structure of their biotextual investigations, poet-artist-experimenters might invoke the moral complexities surrounding humanity’s ferocious guarding of its ascent and assumption of a right-to-flourish above all else. Such shifts in ethical emphasis would be requisite for the emergence of an ecologically attentive form of biopoetics that would regard the bodies and lives of other-than-humans, including bacteria, as significantly more than vessels for data archiving.

63. Royal Botanic Gardens, *State*, 3.

64. Buell, *Environmental Imagination*.

65. Haraway, *When Species Meet*.

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References

- Avasilichioaei, Oana. "Vital Endeavour: A Transcription." *Jacket 2*, October 31, 2011, jacket2.org/commentary/viral-endeavour-transcription.
- Benjamin, Walter. "On Language as Such and on the Language of Man." In *Selected Writings*, vol. 1, 1913–1926, edited by Marcus Bullock and Michael Jennings, 62–74. Cambridge, MA: Belknap Press of Harvard University Press, 1996.
- Bennett, Jane. *Vibrant Matter: A Political Ecology of Things*. Durham, NC: Duke University Press, 2010.
- Bök, Christian. *Crystallography*. Toronto: Coach House, 1994.
- . *Eunoia*. Toronto: Coach House, 2001.
- . 2015. *The Xenotext: Book I*. Toronto: Coach House, 2015.
- Buell, Lawrence. *The Environmental Imagination: Thoreau, Nature Writing, and the Formation of American Culture*. Cambridge, MA: Belknap Press of Harvard University Press, 1995.
- Colangelo, Jeremy. "Christian Bök Makes His Poetry Come Alive." *Open Book*, Toronto, July 18, 2012, staff.openbooktoronto.com/christian_b%C3%B6k_makes_his_poetry_come_alive.
- Crick, Francis. *What Mad Pursuit: A Personal View of Scientific Discovery*. New York: Basic, 1988.
- Davis, Joe. "The Riddle of Life." National Institutes of Health, profiles.nlm.nih.gov/ps/access/BBADHL.pdf (accessed April 8, 2016).
- Dickinson, Adam. "Pataphysics and Postmodern Ecocriticism: A Prospectus." In *The Oxford Handbook of Ecocriticism*, edited by Greg Garrard, 133–50. Oxford: Oxford University Press, 2014.
- Foucault, Michel. *The Order of Things: An Archaeology of the Human Sciences*. London: Tavistock, 1970.
- Gibbs, W. Wayt. "Art as a Form of Life." *Scientific American*, April 1, 2001, www.thegatesofparadise.com/joe_davis.htm.
- Giblett, Rod. *People and Places of Nature and Culture*. Bristol: Intellect, 2011.
- Gleiser, Marcelo. *A Tear at the Edge of Creation: A Radical New Vision for Life in an Imperfect Universe*. New York: Free Press, 2010.
- Haraway, Donna. *Modest_Witness@Second_Millennium. FemaleMan@_Meets_OncoMouse™: Feminism and Technoscience*. New York: Routledge, 1997.
- . *When Species Meet*. Minneapolis: University of Minnesota Press, 2008.
- Hayles, N. Katherine. "Who Is in Control Here? Meditating on Eduardo Kac's Transgenic Art." In *The Eighth Day: The Transgenic Art of Eduardo Kac*, edited by Sheilah Britton and Dan Collins, 79–86. Tempe: Arizona State University Press, 2003.
- Hope, Cat, and John Ryan. *Digital Arts: An Introduction to New Media*. New York: Bloomsbury, 2014.
- Kac, Eduardo. "Biopoetry" [a]. In *Media Poetry: An International Anthology*, edited by Eduardo Kac, 191–96. Bristol: Intellect, 2007.

- . “Biopoetry” [b]. In *Johns Hopkins Guide to Digital Media*, edited by Marie-Laure Ryan, Lori Emerson, and Benjamin Robertson, 41–42. Baltimore, MD: Johns Hopkins University Press, 2013.
- . “Genesis,” 2001, Kac, www.ekac.org/geninfo2.html (accessed April 8, 2016).
- . *Telepresence and Bio Art: Networking Humans, Rabbits, and Robots*. Ann Arbor: University of Michigan Press, 2005.
- Lapworth, Andrew. “Theorizing Bioart Encounters after Gilbert Simondon.” *Theory, Culture, and Society* 33, no. 3 (2016): 123–50.
- Lockhart, J., and Linda DeVeaux. “The Essential Role of the *Deinococcus radiodurans* *ssb* Gene in Cell Survival and Radiation Tolerance.” *PLOS ONE* 8, no. 8 (2013). doi:10.1371/journal.pone.0071651.
- Merchant, Carolyn. *The Death of Nature: Women, Ecology, and the Scientific Revolution*. San Francisco: Harper and Row, 1980.
- . *Reinventing Eden: The Fate of Nature in Western Culture*. 2nd ed. New York: Routledge, 2013.
- Ochman, Howard, Jeffrey Lawrence, and Eduardo Groisman. “Lateral Gene Transfer and the Nature of Bacterial Innovation.” *Nature* 405 (2000): 299–304. doi:10.1038/35012500.
- Oppermann, Serpil. “From Ecological Postmodernism to Material Ecocriticism: Creative Materiality and Narrative Agency.” In *Material Ecocriticism*, edited by Serenella Iovino and Serpil Oppermann, 21–36. Bloomington: Indiana University Press, 2014.
- Osthoff, Simone. “Eduardo Kac’s Genesis: Biotechnology between the Verbal, the Visual, the Auditory, and the Tactile.” *Leonardo Reviews*, October 2, 2001, leonardo.info/reviews/oct2001/ex_GENESIS_osthoff.html.
- Pavlov, A. K., V. L. Kalinin, A. N. Konstantinov, V. N. Shelegedin, and A. A. Pavlov. “Was Earth Ever Infected by Martian Biota? Clues from Radioresistant Bacteria.” *Astrobiology* 6, no. 6 (2006): 911–18.
- Royal Botanic Gardens. *The State of the World’s Plants Report*. Kew, UK: Royal Botanic Gardens, 2016.
- Ruskin, John. “Of the Pathetic Fallacy.” In *The Genius of John Ruskin: Selections from His Writings*, edited by John Rosenberg, 61–72. Charlottesville: University of Virginia Press, 1998.
- Schuster, Joshua. “On Reading Christian Bök’s *The Xenotext: Book 1 Ten Thousand Years Later*.” *Jacket 2*, February 17, 2016, jacket2.org/reviews/reading-christian-boks-xenotext-book-1-ten-thousand-years-later.
- Sheridan, Alan. *Michel Foucault: The Will to Truth*. London: Routledge, 2003.
- Souppouris, Aaron. “The Prose at the End of the Universe: Programming ‘Indestructible’ Bacteria to Write Poetry.” *Engadget*, December 30, 2015, www.engadget.com/2015/12/30/christian-bok-the-xenotext-bacteria-poetry/.
- Tomasula, Steve. “(Gene)sis.” Kac, www.ekac.org/tomasulgen.html (accessed April 8, 2016).
- Wallis, Brian, and Jeffrey Kastner. *Land and Environmental Art*. London: Phaidon, 1998.
- Wershler, Darren. “The Xenotext Experiment, So Far.” *Canadian Journal of Communication*, no. 37 (2012): 43–60.
- White, Lynn, Jr. “The Historical Roots of Our Ecologic Crisis.” *Science* 155, no. 3767 (1967): 1203–7. doi:10.1126/science.155.3767.1203.
- Willet, Jennifer, and Shawn Bailey. “BIOTEKNICA: Organic Tissue Prototypes.” In *The State of the Real: Aesthetics in the Digital Age*, edited by Damian Sutton, Susan Brind, and Ray McKenzie, 125–34. London: Tauris, 2007.
- Witte, Bernd. *Walter Benjamin: An Intellectual Biography*. Translated by James Rolleston. Detroit, MI: Wayne State University Press, 1991.
- Wong, Pak Chung, Kwong-kwok Wong, and Harlan Foote. “Organic Data Memory Using the DNA Approach.” *Communications of the ACM* 46, no. 1 (2003): 95–98.
- Yetisen, Ali, Joe Davis, Ahmet Coskun, George Church, and Seok Hyun Yun. “Bioart.” *Trends in Biotechnology* 33, no. 2 (2015): 724–34.
- Zubay, Geoffrey. “A Possible Mechanism for the Initial Transfer of the Genetic Code from Deoxyribonucleic Acid to Ribonucleic Acid.” *Nature* 182, no. 4628 (1958): 112–13.