Essays in the History
and Philosophy of Artificial Life

EDITED BY JESSICA RISKIN

GENESIS REDUX

THE UNIVERSITY OF
CHICAGO PRESS Chicago and London

2007

15 An Archaeology of Artificial Life, Underwater

STEFAN HELMREICH

During ethnographic fieldwork I conducted in the 1990s among Artificial Life researchers at the Santa Fe Institute for the Sciences of Complexity, I heard revisited time and again the history of the field, a history that usually started somewhere in the 1980s with Christopher Langton rediscovering John von Neumann's posthumously published 1949 results on self-reproducing automata, the work of McCulloch and Pitts on nerve-net models, and the investigations of Minsky and Papert on perceptrons. Langton, in his edited volume *Artificial Life*, dubbed the latter two of these research programs "common ancestors" of both Artificial Intelligence and Artificial Life.[1] I heard many stories that took this history back further, too. Langton's introductory essay in the proceedings of the first Artificial Life conference, held in 1987, placed ancient Egyptian water clocks, Hero of Alexandria's first-century *Pneumatics*, and Jacques de Vaucanson's eighteenth-century mechanical duck at the "roots" of Artificial Life.[2] Hans Moravec's contribution to the same volume framed the human creation of artificial life on a somewhat grander scale, as a culmination of the "evolution of terrestrial intelligence,"[3] and Doyne Farmer and Alletta d'A. Belin's "Artificial Life: The Coming Evolution," in the proceedings of the second Artificial Life conference, characterized the advent of Artificial Life as a hallmark of a phase shift from the Darwinian evolution of genetic information to the speedier Lamarckian evolution of cultural information.[4] Such narratives allowed Artificial Life scientists to ground their claims for the field not only in

a venerable intellectual lineage, but also in a *genealogy*—sometimes even an explicitly evolutionary one—leading up to their own endeavor.[5]

GENEALOGIES, BIOGRAPHIES, AND ARCHAEOLOGIES OF SCIENTIFIC OBJECTS

This essay offers a commentary on the practice of finding genealogies for Artificial Life. Such an enterprise carries historiographic and epistemological risks. If we simply claim that the notion of synthesizing "life" can be traced back to stories of Rabbi Löw's Golem or Paracelsian homunculi, for example, we overlook Foucault's famous caution about the recent origins of the biological concept of "life,"[6] that theoretical construct upon which Artificial Life arguably depends. If we offer an account of early automata without attention to the language that described them during their own period, we might easily mistake family resemblance to, say, present-day robots for direct family relation or even descent. In other words, as Lorraine Daston writes, "A history of the word without the thing risks degenerating into etymology; a history of the thing without the word risks anachronism."[7] Objects—like the scientific object of "life" with which Artificial Life has been concerned—come into being as at once material and semiotic entities. *Biography*, the term Daston has proposed,[8] might serve as a better concept to capture this process of coming-into-being; making *genealogies* risks essentializing scientific objects and finding ancestors everywhere one looks.

But of course *biography*—the writing of *a life*, after all—might get us into other hot waters when in comes to documenting the coming-into-being of an object like "artificial life." As Foucault argues in *The Archaeology of Knowledge*, obsessions with genesis can fool us into imagining clear historico-genetic lines culminating in consistent objects. Furthermore, a fixation on genesis results in "the analysis of silent births, of distant correspondences, of permanences that persist beneath apparent changes, of slow formations that profit from innumerable blind complicities, of those total figures that gradually come together and suddenly condense into the fine point of the work."[9] One might object to Foucault that any history is inevitably teleological and that keeping the rhizomatic character of possible histories constantly in focus is an impossible task. But I want to suggest that this task of keeping origins productively *out of focus* is especially necessary when dealing with such a slippery concept as "artificial life."

In *On the Origin of Objects*, Brian Cantwell Smith offers a theory of ontology-in-the-wild that is organized—happily, for our purposes—around the coming-into-being of computational objects. Smith argues that the very existence of computer programs is completely enmeshed in our social, material, and linguistic world, and that how disk drives, Windows programs, file systems, and RAM caches work is the result of many scientific, cultural, and economic decisions.[10] To treat computers as entities that can harbor "life" ignores the work and decisions that have produced them, labor that may not have a single originary moment. "Life" *in silico* is an object that emerges at the intersection of a heterogeneity of practices—in taxonomy, molecular biology, computer science, for starters, and probably also in cinema, the politics of fetal imaging, and psychedelics, to continue this list in a somewhat aleatory fashion. Silicon life is *not*, as Moravec and others would have it, simply the spirit of evolutionary history made digital.

If "life" is a fact on which biology is made, it is one of the sort that Mary Poovey writes of in her argument about the rise of the very idea of the fact: "*A History of the Modern Fact* insists that texts and events generate effects in multiple domains, even those distant from the domain a writer intended to affect."[11] Artificial Life can have *many* histories, not all of which are about vitality, or even machines. I think Foucault's *archaeological* method is congenial to the telling of these histories and allows us not to mistake one story for the true tale of artificial life. Foucault's archaeology does not lapse into genealogy and does not try to restore "original" meaning, for it recognizes that every history is a rewriting, a "regulated transformation of what has already been written."[12] As an ethnographer, I find this approach has the added benefit of preserving the historical specificity and multiplicity of Artificial Life as a late twentieth-century formation.

Archaeologies are always partial and interested, of course.[13] And what I propose here is a shallow dig whose aims are perhaps more anthropological and philosophical than historical. I want to focus on the time depth at which we can begin to see simulations *in silico*. More narrowly, I want to center my attention on simulations that have visual interfaces through which we are invited to "see" into virtual universes and, more narrowly still, those that offer us artificial life forms visible through the computer screen understood as a kind of virtual aquarium. I argue that "life" surfaces in such simulations as an ontologically and epistemologically liminal—and *therefore*, to people interested in the boundary object that artificial life forms necessarily represent, as a particularly *persuasive*—object. If the reader will follow me deeper into the metaphor of archaeology, what I am interested in here is a sort of *underwater archaeology* of recent Artificial Life—an archaeology that operates though the remote sensing of its object, an object partially obscured by the

medium in which it sits, which may in some sense be inaccessible to direct theoretical touch.[14]

ARTIFICIAL WATERWORLDS

Claus Emmeche means in the title of his book *The Garden in the Machine* to call attention to the ways "nature" has been imported into the computer simulations of Artificial Life.[15] Such creations as *SimLife* have offered a kind of green Edenic space in the machine. Conceiving computers as spaces within which "nature" can reside has many historical moorings. Peter Galison has offered the invention of Monte Carlo simulations as a moment when computer simulations came to occupy a floating place between theory and experiment: "data" generated by such simulations could be given the same epistemic status as data from "real" experiments.[16] On a deeper level, these simulations—using pseudorandom numbers as starting points for the emulation of physical processes—could be seen to share a "fundamental affinity" with "the statistical underpinnings of the world itself."[17] Galison writes, "The computer began as a 'tool'—an object for the manipulation of machines, objects, and equations. But bit by bit (byte by byte), computer designers deconstructed the notion of a tool itself as the computer came to stand not for a tool, but for nature itself."[18]

I want to extend this historical analysis with an observation from symbolic anthropology. When computers came to have monitors, and particularly when these began to display computer graphics representing the unfolding of programmed procedures, the idea that computers contained worlds in which life might emerge was provided with a visually persuasive rhetorical armature.[19] Further, as I have argued in *Silicon Second Nature*, simulations that use the computer screen as a "window" into another world have influenced how people have come to "see" artificial life forms in computers. In this section I look more closely at simulations that fashion the computer into a kind of fish tank that users can peer into and in which they can see artificial life forms swimming about.

Let me begin with what I take to be a canonical artifact in this genre: Demetri Terzopoulos, Xiaoyuan Tu, and Radek Grzeszczuk's simulation of fish locomotion, written up in "Artificial Fishes with Autonomous Locomotion, Perception, Behavior, and Learning in a Simulated World" (see figure 15.1).[20] I first saw a presentation of this model at the fourth conference on Artificial Life in 1994. Terzopoulos enraptured the audience when he showed a video of simulated fish acting out their genetic-algorithm-programmed

FIGURE 15.1 | Artificial fishes in a simulated world, from Demetri Terzopoulos, Xiaoyuan Tu, and Radek Grzeszczuk, "Artificial Fishes with Autonomous Locomotion, Perception, Behavior, and Learning in a Simulated Physical World," in *Artificial Life IV*, ed. R. Brooks and P. Maes (Cambridge, MA: MIT Press, 1994). Courtesy of Demetri Terzopoulos.

capacities to "swim" and "hunt." His presentation ended with some of the simulations strung together in an extended (and soundtracked) parody of a Jacques Cousteau nature documentary (thus summoning up, alongside the medium of water, the medium of film, understood to "capture" reality). As the audience laughed at the video and at the movements of the artificial fish on the screen, it became clear that the "lifelike" quality of these simulations produced an unease and a sense of wonder that were themselves precisely the cultural resources that made these creatures seem lively. The laughter bespoke a set of unarticulated intuitions and untheorized thoughts about autonomy and agency. We were meant to see the computer screen as a kind of aquarium, itself a technology that has fashioned for us a way of manufacturing, thinking about, and seeing self-contained ecologies. The aquarium is an exhibitionary technology that creates what Paul Edwards has called a

"closed world."[21] The simulation of Terzopoulos and his colleagues summons forth a sense that worlds are just bigger aquaria or terraria.

There are a host of technological features of such computer simulations that can be used to motivate belief in the fidelity of artificial life creations to real life. Most invisible, perhaps, is the fact that computer processing power is used to make images unfold in what looks like real time, in the same temporality in which observers observe.[22] But also important for fishy Artificial Life simulations—and Terzopoulos and his colleagues are not alone: Aqua Zone™ is an Artificial Life toy that invites us to treat our computer as a fish tank (we even feed the artificial fish through the disk drive!)—is the very notion that we are watching "life" *suspended* in another *medium*. Artificial Life scientist Walter Fontana, who in the 1990s paid careful attention to defining computers as worlds, told me in an e-mail interview, "Computers are candidates for *being* worlds, not just describing them. The computer is not just a tool for fast calculations, sequence analysis, data base management, etc. The computer is a medium." The contention that computers are *media* enables the evocation of the *medium* of water as a proxy for the alternative world computers are meant to represent/materialize. Water is a persuasive rhetorical referent in the visualization of these simulations. In addition to the symbolic association of water with life (which has water as the medium within which life began), there is the imagery of floating, about which more below.

Wateriness shows up again in Karl Sims's simulated genetic-algorithm organisms, represented on his computer screen as inhabiting a three-dimensional world and having boxes for arms, legs, torsos, and heads. During a video Sims showed at the same conference at which Terzopolous spoke, his skillful graphics presented a set of clumsy creatures engaging in competitions for the possession of a small cube.[23] As they went about their Darwinian wrestling matches, competing for the right to have their constitutive programs reproduced, these boxy critters again elicited laughter from the audience. I joined the scientists in their pleasure at these images and experienced the activity of the simulated creatures as cute, especially when they could be interpreted as valiantly failing at their tasks. What made the images funny was a sense that Sims was not fully in control; he had programmed a three-dimensional artificial world (and a visual representation of it) that simulated Newtonian physics, gravity, fluid dynamics, and surface friction, and he had introduced into this world a set of virtual creatures visualized as made of three-dimensional, rigid parts that could interact with this world. Different creatures had different characteristics and could do more or less well at the task of capturing the box from competitors. Because

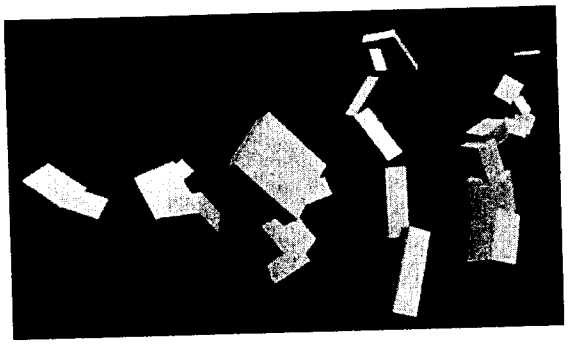

FIGURE 15.2 | An evolutionary sequence of Sims's virtual creatures, selected for "swimming." Courtesy of Karl Sims.

the simulated physics and creatures were programmed together, most behaviors looked realistic and purposeful. But because Sims occasionally made errors in modeling physics, sometimes behaviors came off completely wrong, as when creatures bounced out of the world because of his mistakes in modeling gravity. In a brilliant bit of showmanship, Sims showed videotapes of malfunctioning creatures, explaining that creatures were "exploiting" bugs in the program and were "making fun of [his] physics." Sims's ventriloquism delighted the audience and added a sense that his creatures were not only mimicking familiar behaviors, but also were mimicking behaviors associated with the playfulness of some life forms, a playfulness perhaps most readily compared with that of mammalian babies. This became more effective still when he sought to teach the creatures to "swim," an activity associated with early activity in many mammalian lives (figure 15.2). In this simulation, images of artificial life forms swimming in the medium of an alternative world allow the category and performance of "life" to "float" in front of our eyes. Life becomes both floating signifier *and* signified, something, to borrow from one of the OED's definitions of the intransitive senses of "float," that moves "unsteadily to and fro like an object on the surface of a liquid." Philosophers of artificial life would do well, I think, to attend to such rhetorical productions of "floating" in Artificial Life. "Emergence" is not quite the same thing as this neutrally buoyant submergence. Emergence is meant to direct our attention to how low-level dynamics produce processes that summon realities at higher levels, for which interpretation—the eye of the beholder—is a crucial component. Floating rather shows us how the *effect* of empiricity can be sustained through the medium of interpretation itself.

BRAINS IN VATS AND MINDS IN WATERS

I now want to take an orthogonal detour into a different realm of modeling, that of cognition in Artificial Intelligence. Artificial Life was named on analogy to Artificial Intelligence, and many practitioners see Artificial Life as a field growing from the discipline of Artificial Intelligence, even as Artificial Life means to leave behind the overly representational commitments that have hampered the attempts of Artificial Intelligence researchers to re-create intelligence *in silico*. However, rather than thinking about Artificial Intelligence as "ancestral" to Artificial Life (a "lineage" that has been explored elsewhere—sometimes in ways that assimilate the philosophical problems of Artificial Life to Artificial Intelligence, sometimes in ways attempting to distinguish them),[24] I want to turn to the object of Artificial Intelligence—intelligence—and think about it "underwater," using this meditation to think further about what it means to simulate life in floating worlds. My first example comes from Daniel Dennett's "Brain in a Vat" thought experiment—canonical in philosophy of mind—and my second comes from John Lilly's 1960s work on dolphin intelligence.

In his 1978 essay "Where Am I?" Dennett offered a thought experiment meant to help think through the possibility that a physically instantiated mind could exist separate from the body and, indeed, could be replicated in a computer.[25] In the fable Dennett offers, his brain has been removed from his body and placed in a vat. He recounts seeing his brain, from the vantage point of his newly brainless body, suspended in water: "I peered through the glass. There, floating in what looked like ginger ale, was undeniably a human brain, though it was almost covered with printed circuit chips, plastic tubules, electrodes, and other paraphernalia."[26] Dennett then details successive disorientations as his brain is replaced by a digital double into which his consciousness can switch without signal. Throughout this piece, Dennett's consciousness floats, the briny substance in which his gray matter is floating becoming a kind of pointer to the rhetorical at-sea-ness of his mind. As he asks, "Where am I?" again and again, the answer slides around, suspended between the various material substances—the vat, a computer, and so on—into which his being has been distributed. His "mind," his "soul," his "life" all float.

At around the same time Artificial Intelligence was being consolidated as a named field of inquiry, John Lilly was investigating nonhuman cognition in another world, that of the dolphin. Lilly's work on the consciousness of cetaceans unfolded in the 1960s as he sought to communicate with dolphins. Lilly was engaged with his dolphin charges in what we might call

an underwater version of the Turing test. In his 1962 essay "A Feeling of Weirdness," published in Joan McIntyre's 1974 *Mind in the Waters: A Book to Celebrate the Consciousness of Whales and Dolphins*, Lilly writes of "a very peculiar effect which we have noticed in the laboratory while working with the bottlenose dolphin (*Tursiops truncatus*)."[27] He reports that as he and his compatriots navigated the "rough sea of the unknown,"

> we began to have feelings which I believe are best described by the word "weirdness." The feeling was that we were up against the edge of a vast uncharted region in which we were about to embark with a good deal of mistrust concerning the appropriateness of our own equipment. The feeling of weirdness came on us as the sounds of this small whale seemed more and more to be forming words in our own language. We felt we were in the presence of Something, or Someone, who was on the other side of a transparent barrier which up to this point we hadn't even seen.[28]

According to Lilly, his dolphins began to repeat English phrases. Lilly gained access to the "mind in the waters" though tools that rhyme with Dennett's "printed circuit chips, plastic tubules, electrodes, and other paraphernalia": "We first obtained the mimicry effect in 1957 by the use of electrodes implanted deep within the rewarding sites in the brain structures in these animals." Such "direct" access was later complemented by the use of recording devices to replay dolphin sounds. Lilly and his colleagues began to replay tapes, speeding them up, slowing them down, and taking into account what happens to sounds underwater. Direct apprehension was aided by a mediation meant to reveal what dolphins were really up to. Lilly was aware, of course, of the possibility that the communication that he heard emerged from his interpretive relationship with the dolphin. He did not allow that he might be imagining voices, but did permit his interpretative impulse to contribute to his observations. Later, Lilly would turn away from dolphins and move to self-experiment in isolation tanks, where he would float, attempting to achieve the altered states that might give insight into what the mind was made of.

Both Dennett and Lilly are accessing a process, and research object, that floats elusively in water. "Mind" is suspended in relations of interpretation sited in a medium, liquid, that comes to stand for the ambiguities of the object and for the fluid relationships between the empirical and interpretive. We might usefully classify both experimental projects as trysts with what Richard Doyle has called "wetwares," "encounter[s] with flesh as a refrain, a repetition of algorithms or recipes of sufficient complexity that

only through instantiation can they be experienced."[29] "Mind" cannot exist apart from its contingent, slippery experience.

Artificial Life, of course, has been no stranger to epistemological debates about the relation between the world and the agent that knows it.[30] The vacillation between strong and weak claims in Artificial Life, between the idea that Artificial Life practice synthesizes or simulates vitality, organizes much of the field. Some of the strong claims for life *in silico* are grounded in the claim that properties like "life," "fire," and "wetness" only exist with respect to patterned relationships and that these can be suitably—and genuinely—instantiated in virtual worlds. As one Artificial Life scientist put it to me in an interview, "'Life' can only be defined *with respect to a particular physics*." In this view, processes can be alive, on fire, wet, or infectious (like computer viruses) with respect to the computational realm. The "wetness" evoked by simulations such as that of Terzopolous supports the possibility that his artificial fish have artificial life. They and the "life" they represent float—to lift again from the OED—"suspended in a liquid with freedom to move." As such, the "wetness" of these entities is not the same as the wetness of the wetwares of which Doyle writes—nor, it would seem, as those Riskin has documented in her "Eighteenth-Century Wetware."[31] Riskin tells us that in their construction of automata, the Jaquet-Droz family used "lifelike materials such as leather, cork, and papier-mâché to give their machines the softness, lightness, and pliancy of living things."[32] For *in silico* artificial life, being "lifelike" requires performative, not textural, simulation; after all, Langton canonically defines "life" as "a property of the organization of matter, rather than a property of matter itself."[33] Intriguingly, however, the ghost of "matter itself" is constantly summoned forth, and perhaps in its most insidious—because invisible—and persuasive form when it appears as virtual water surrounding the fishy software of artificial fish and their kin.

THE UNDERWATER ARCHAEOLOGY OF KNOWLEDGE

Doing a sort of underwater archaeology of knowledge, then, we could transport Peter Galison's arguments about the philosophical status of artificial realities into the virtually aqueous domain of such simulations as Terzopoulos's fish worlds and see that wateriness is an important rhetorical float for the suspension of belief in artificial life itself.

Why underwater archaeology? Engineer and historian of technology David Mindell argues that a special characteristic of deep-water archaeology is that it must be enabled by techniques of remote sensing. For example,

high-frequency, narrow-beam, sub-bottom sonar and remotely operated vehicles (ROVs) outfitted with cameras can retrieve data from the seafloor with which archaeologists can build up models of what might be buried down below, at great depth, pressure, and in darkness. Trying to sound out the outlines of "life" using an underwater archaeology of knowledge requires us to admit that we cannot finally lay our hands on the buried treasure of "life itself." Life is a material-semiotic relationship between tools and interpretations, not a thing-in-itself.

To conclude this meditation, let me go off the deep end and suggest, following Mario Biagioli's analysis of the Museum of Jurassic Technology in Los Angeles, that Artificial Life "confabulates" life.[34] "Confabulations," according to Valentine Worth—a writer whose publications seem only to be available from the Museum of Jurassic Technology and who may or may not exist—are "artificial constructions of our own design built around sterile particles of retained experience which we attempt to make live again by infusions of imaginations."[35] Like the Museum of Jurassic Technology, an institution that reproduces, repurposes, parodies, and confuses the very notion of a museum by archiving and displaying knowledge and artifacts that may or may not be part of actual human history, Artificial Life simulations may be "a setting of and for confabulation where hermeneutics is suspended."[36] "Life" floats suspended in the medium in which it swims.

NOTES

1. Christopher G. Langton, "Artificial Life," in *Artificial Life*, ed. Christopher G. Langton (Redwood City, CA: Addison-Wesley, 1989), 1–47, at 19.

2. Ibid., 6–9. And see Jessica Riskin, "The Defecating Duck, or, the Ambiguous Origins of Artificial Life," *Critical Inquiry* 29, no. 4 (2003): 599–633.

3. Hans Moravec, "Human Culture: A Genetic Takeover Underway," in Langton, *Artificial Life*, 167–99, at 178.

4. J. Doyne Farmer and Alletta d'A. Belin, "Artificial Life: The Coming Evolution," in *Artificial Life II*, ed. Christopher G. Langton, Charles Taylor, J. Doyne Farmer, and Steen Rasmussen (Redwood City, CA: Addison-Wesley, 1992), 815–40.

5. See Stefan Helmreich, *Silicon Second Nature: Culturing Artificial Life in a Digital World*, updated with a new preface (Berkeley: University of California Press, 2000).

6. Here is Foucault on the matter:

> Historians want to write histories of biology in the eighteenth century; but they do not realize that biology did not exist then, and that the pattern of knowledge that has been familiar to us for a hundred and fifty years is not valid for a previous period. And that,

if biology was unknown, there was a very simple reason for it: that life itself did not exist. All that existed was living beings, which were viewed through a grid of knowledge constituted by natural history.

See Michel Foucault, *The Order of Things: An Archaeology of the Human Sciences* (New York: Random House, 1970), 127–28; first published in French as *Les mots et les choses* in 1966.

7. Lorraine Daston, "Objectivity and the Escape from Perspective," in *The Science Studies Reader*, ed. Mario Biagioli (New York: Routledge, 1999), 110–23, at 113.

8. Lorraine Daston, ed., *Biographies of Scientific Objects* (Chicago: University of Chicago Press, 2000).

9. Michel Foucault, *The Archaeology of Knowledge and the Discourse on Language*, trans. A. M. Sheridan Smith (New York: Pantheon, 1972), 138; first published in French in 1969.

10. Brian Cantwell Smith, *On the Origin of Objects* (Cambridge, MA: MIT Press, 1996).

11. Mary Poovey, *A History of the Modern Fact: Problems of Knowledge in the Sciences of Wealth and Society* (Chicago: University of Chicago Press, 1998), 17.

12. Foucault, *Archaeology*, 140.

13. Nadia Abu El-Haj, *Facts on the Ground: Archaeological Practice and Territorial Self-Fashioning in Israeli Society* (Chicago: University of Chicago Press, 2001).

14. David A. Mindell and Katherine Croff, "Deep Water, Archaeology and Technology Development," *MTS Journal* 36, no. 3 (2002): 13–20.

15. Claus Emmeche, *The Garden in the Machine: The Emerging Science of Artificial Life*, trans. Steven Sampson (Princeton, NJ: Princeton University Press, 1994). He also of course plays on Leo Marx's *The Machine in the Garden* (New York: Oxford University Press, 1964), a discussion of how technology has both disturbed and remodeled pastoral ideals in U.S. literature and culture.

16. Peter Galison, "Computer Simulations and the Trading Zone," in *The Disunity of Science: Boundaries, Contexts, and Power*, ed. P. Galison and D. J. Stump (Stanford, CA: Stanford University Press, 1996), 118–57, at 142–43.

17. Ibid., 144.

18. Ibid., 156–57. See also my argument in "The Word for World Is Computer: Simulating Second Natures in Artificial Life," in *Growing Explanations: Historical Perspectives on the Sciences of Complexity*, ed. Norton Wise (Durham, NC: Duke University Press, 2004), 275–300.

19. See Richard Doyle, *On Beyond Living: Rhetorical Transformations in the Life Sciences* (Stanford, CA: Stanford University Press, 1997), for an argument about the "rhetorical software" such imagery has constituted.

20. Demetri Terzopoulos, Xiaoyuan Tu, and Radek Grzeszczuk, "Artificial Fishes with Autonomous Locomotion, Perception, Behavior, and Learning in a Simulated Physical World," in *Artificial Life IV*, ed. R. Brooks and P. Maes (Cambridge, MA: MIT Press, 1994), 17–27.

21. Paul Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America* (Cambridge, MA: MIT Press, 1996).

22. On time in cinema and simulation, see Christopher Kelty and Hannah Landecker, "A Theory of Animation: Cells, L-Systems, and Film," *Grey Room* 17 (2004): 30–63.

23. Karl Sims, "Evolving 3D Morphology and Behavior by Competition," *Artificial Life* 1, no. 4 (1994): 353–72.

24. Elliott Sober, "Learning from Functionalism: Prospects for Strong Artificial Life," in Langton, Taylor, Farmer, and Rasmussen, *Artificial Life II*, 749–65; and Brian Keeley, "Against the Global Replacement: On the Application of the Philosophy of Artificial Intelligence to Artificial Life," in *Artificial Life III*, ed. Christopher G. Langton (Redwood City, CA: Addison-Wesley, 1994), 569–87.

25. Daniel Dennett, "Where Am I?" in *Brainstorms: Philosophical Essays on Mind and Psychology* (Montgomery, VT: Bradford Books, 1978), 310–23.

26. Ibid., 312.

27. John Lilly, "A Feeling of Weirdness," in *Mind in the Waters: A Book to Celebrate the Consciousness of Whales and Dolphins*, ed. Joan McIntyre (New York: Scribner's Sons and Sierra Club Books, 1974), 71–77, at 71.

28. Ibid., 71.

29. Richard Doyle, *Wetwares: Experiments in Postvital Living* (Minneapolis: University of Minnesota Press, 2003), 186. According to Doyle, The Online Hacker Jargon File defines "wetware" as "Human beings (programmers, operators, administrators) attached to a computer system, as opposed to the system's hardware or software." Doyle offers the following: "'Taint software, 'taint hardware" (181), and "Wetwares are inconceivable not because they sublimely exceed any reduction or representation but because they quite simply cannot be modeled in advance" (186).

30. See, for example, N. Katherine Hayles, "Simulated Nature and Natural Simulations: Rethinking the Relation between the Beholder and the World," in *Uncommon Ground: Toward the Reinvention of Nature*, ed. W. Cronin (New York: W. W. Norton, 1995), 409–25.

31. Jessica Riskin, "Eighteenth-Century Wetware," *Representations* 83 (2003): 97–125.

32. Riskin, "Defecating Duck," 606.

33. Christopher G. Langton, "Toward Artificial Life," *Whole Earth Review* 58 (1988): 74–79, at 74.

34. Mario Biagioli, "Confabulating Jurassic Science," in *Late Editions 2: Technoscientific Imaginaries: Conversations, Profiles, and Memoirs*, ed. George E. Marcus (Chicago: University of Chicago Press), 399–431.

35. Valentine Worth, quoted in Biagioli, "Confabulating," 409.

36. Biagioli, "Confabulating," 426.