M E T A C R E A T I O N

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Art and Artificial Life

METACREATION

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To Nicola and Thomas

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"Breeding Aesthetic Objects: Art and Artificial Evolution," in *Creative Evolutionary Systems,* ed. Peter Bentley and David Corne (San Diego: Morgan Kaufmann, 2001), 129–144.

"Morphogenetics: Generative Processes in the Work of Driessens and Verstappen," *Digital Creativity* 14, no. 1 (2003): 43–53.

M E T A C R E A T I O N

An image is projected on a screen: it is abstract and intricately, impossibly detailed; luminous and smooth, its filigreed structures recede toward computer-graphic horizons. On another screen, a moving image is projected; a dense grove of synthetic foliage conceals a group of what appear to be insects. The viewer's image, mirrored within this artificial environment, causes the insects to recoil and retreat. On yet another screen, an animation shows an intricate, geometric flower unfurling, extending snaky tendrils into a digital void; it spins and writhes, filling the frame. In a gallery space a group of intricate white sculptures stand on a table, forms made up of masses of tiny cubes, three-dimensional pixels. On a nearby computer monitor, similar forms appear in an ever-changing series. An artists' statement describes how these forms arise as a cubic volume

1 INTRODUCTION

differentiates itself, splitting like a living cell but at ever finer scales. Elsewhere a bicycle-wheeled robot rolls around a room in a nervous interactive dance with the people gathered there: it advances and retreats, spindly body rocking back and forth. Another room is filled with loud, skeletal machines that shriek and flail, seemingly attacking each other, menacing passersby with blinding lights and horrendous noises. In yet another, quieter space, three arms made from grape vines and wire twist and pivot from the ceiling, "singing" to each other in telephone touch-tones.

These are strange objects, embodying a series of contradictions and ambiguities. They are technological objects, this much is clear; made from the glowing points of light on computer screens, or from metal, motors, and electronics. Yet unlike the technological objects we routinely encounter, they are unpredictable and apparently autonomous; something in their movement, their reactions, their structure, reminds us — is clearly intended to remind us — of living things. They are art objects; we find them in galleries, at symposia and conferences, among other art objects made of computer code and electronics. Yet some of them are hardly objects at all; they refuse to sit still and be observed, but hide from us, play with us, or invite us into their own virtual worlds. Clearly, these things are made — they are the works of artists or others working artfully — but the signs of the will of a creator are sometimes less palpable in these objects than the manifestation of a "will" of their own. And while these works can be found in galleries and festivals, under the banner of art, they might also appear with their creators at conferences of another stripe, alongside elaborate computer simulations of cellular biology and crawling, multilegged robots, the technological objects of the science of artificial life.

Artificial life, or a-life, is a young, interdisciplinary scientific field concerned with the creation and study of artificial systems that mimic or manifest the properties of living systems. It is a strange object in itself; its Promethean project to create new forms of life arouses scepticism, fascination, and alarm in equal measures. Having turned (in part) away from the task of analyzing nature and toward its synthesis, a-life seems unlike a science in the conventional sense. However, the objects just described are, if anything, stranger still. While they apply the techniques and ideas of artificial life in a variety of ways, they present themselves as art objects rather than as scientific artifacts. They are manifestations of a kind of transdisciplinary dissemination of artificial life, the results of its recent propagation through cyberculture and popular science writing. They arise where artificial life meets contemporary practice in the new media arts.

This meeting point provides the location for this project, and these strange objects, their makers, and the thought and writing around them are the objects of its attention. This complex is interesting and significant for a number of reasons. Most immediately, the artwork itself is striking. It evolves, responds, mutates, and forms complex, supple systems and cryptic alien artifacts. It offers engaging experiences, interactions with complex looking-glass worlds and embodied agencies, encounters with weird aesthetic objects. Beyond the immediate experience, these works tend to become more difficult, though no less interesting. The elegance of the engineering — the beguiling way these systems operate — counterpoints a sense of suspicion at the lines of metaphor and association they draw. How is this lifelike exactly? At times, this practice entails an expansive, godlike creative sweep, bringing whole worlds into being, populating them with virtual creatures. Ingenious, certainly, but is this also an extreme form of artistic hubris? At the same time, conventions of creative agency are stretched to breaking point: much of the work is made in such a way that it makes itself — it is somehow autonomous. Is this an abdication of creative will or its ultimate fulfillment?

More generally, this work is important in that the mapping around which it pivots, between living things and technological systems, is provocative, problematic, and highly current. Western culture is in the midst of an explosive development in the technologies of life and the living: the modeling, simulation, decomposition, engineering, and manipulation of biological life. Contemporary culture is slowly coming to grips with radical changes in its notions of life as medical and biological technologies reveal living matter as increasingly plastic and susceptible to engineering. Stem cells — unspecialized protocells, a kind of basic living material — are isolated and cultured. Reproduction, conventionally a unique and definitive capacity of the living organism, is ever more readily engineered and decomposed. Large mammals are cloned, and some strive to clone human beings, raising ethical rather than technological questions. Proprietary life forms, genetically manipulated species, are grown as food crops. Distinctions between natural and artificial, born and made, become unsupportable. Technoscience seems to have an ever-increasing command of living matter, and in an era of global capital, life is reshaped according to logics that are principally commercial.

However, at the same time, life itself continues to escape and evade technological control; it remains active, retains an agency. In fact, technological interventions seem to create unforeseen opportunities for living things. During the late 1990s, outbreaks of bovine Creutzfeldt-Jakob disease ("mad cow disease") demonstrated how even the most primitive organism can work through, and ultimately against, a technological network. The gruesome efficiency of industrial agriculture forms a feedback cycle; the protein-folding prion, barely even alive, crosses species barriers and infects the human consumers at the top of the food chain; entire industry sectors close down. Elsewhere, genetically modified crops escape their fenced-off testing grounds to compete and possibly interbreed with the surrounding biota. Antibiotic-resistant bacteria thrive in hospital wards.

The tangled counterpoints of biology and technology are ubiquitous. Computer viruses proliferate, with an impact as real as the biological variety — or in a technocentric business culture, more so. The industrial networks that host the technologization of life are simultaneously engaged in the decimation of biodiversity and the destruction of habitat. In April 2002 a Japanese institute launched the Earth Simulator, currently the most powerful supercomputer in existence; it runs massively detailed climatic and seismic simulations. If successful, it will improve weather prediction and warn of impending earthquakes; in the words of one of the scientists involved, the project aims to "keep a good relationship between nature and mankind, a symbiotic relationship. . . ."[1] A large-scale digital simulation seems to act here as a benign intermediary; yet at the same time the accelerated currents of digital media tend to pull us away from the difficult, polluted, outside space of the physical world and toward the clean, controllable "inside" of mediated experience and synthetic immersion. Life and technology, biology and information, hang in a tense articulation.

Against this background, a cultural practice that is engaged with both technological culture and biological science is in a particularly interesting position. New media art, the primary context for this practice, is already deeply enmeshed in a wider technoculture; its standard practice is to take up the products of the technology industries — focused recently on personal and networked computing — and apply them to its own diverse ends, in a cultural domain. It draws on these technical resources but also characteristically reflects on and critiques them. New media art self-consciously reworks technology into culture, and rereads technology as culture. What's more, it does so in a concrete, applied way; it manipulates the technology itself, with a nonindustrial latitude that admits misapplication and adaptation, rewiring and hacking, pseudofunctionality and accident. New media art also fractures that technocultural material into millions of heterogeneous interests and agendas, specific investigations, aesthetics, approaches, and projects.

When this practice begins adopting and adapting the technoscience of artificial life, it comes to grips with a troublesome constellation. A-life crystallizes the conjunction of biological life and technology into a handful of bold claims and images. The computer in this context seems to contain not only organisms but whole living systems in detailed articulation. Evolution, an idea that has become the most powerful organizing narrative of contemporary culture, appears to unfold on a screen. A-life proposes not a slavish imitation of this or that living thing but, at its strongest, an abstract distillation of aliveness, life itself, reembodied in voltage and silicon.

In appropriating (and altering) artificial life, the artists considered in this book are engaged in a crucial task: that of working through the implications of its concepts and techniques, testing their potential, deforming and transforming them. These operations are only partly technical; they are primarily and most importantly cultural. New media art provides a venue for the transformation and translation of the technical and conceptual artifacts of artificial life into cultural objects — conglomerates of rhetoric, metaphor, and aesthetics. Such translations are important in general because of the terms they articulate; at a time of rapid and dramatic technological change, the process of assimilating, debating, contesting, and reflecting on that change within cultural domains is crucial. The interface of artificial life and cultural practice is particularly significant for all these reasons; it opens a space for creative experimentation and debate around the increasing technologization of living matter as well as broader issues of life and autonomy, agency and evolution, genetics, code and matter. This work explores a practice in which we are all increasingly required to participate: the art of technologized life.

ARTIFICIAL LIFE

Artificial life is a field of scientific research devoted to the simulation and synthesis of living things. It was founded in 1987 with a workshop at the Los Alamos National Laboratory, New Mexico. In subsequent years, interest in the field has grown: the artificial life workshops have become an ongoing international series, and the field has spawned dozens of other conferences; 1993 saw the publication of a journal dedicated to its work. The handful of scientists involved in the initial workshop has grown into a small international community.

Of course, efforts toward the simulation or synthesis of life are far older than this field. What distinguishes a-life from earlier work, and what unifies it currently, is a specific approach to this task. A-life begins with a notion of life that is wholly materialistic, involving no soul, vital force, or essence. In the words of the convenor of the first artificial life workshop, Christopher Langton, "Living organisms are nothing more than complex biochemical machines."[2] Langton contends that rather than being any special substance or force, life is "a property of the organization of matter."[3] Further, this organization is not simply a complex structure but a dynamic structure, a system active in time: for a-life, life is most importantly manifest in behavior. If, then, the "universal features" of life are in its abstract dynamic processes rather than inherent to a biological medium, we can consider the creation of such structures in another, artificial medium. Artificial life sets about creating such dynamic structures, almost always involving the most flexible, dynamic, and tightly controllable artificial medium at its disposal, computation.

It is this sense of living things as complex dynamic systems that informs the methodologies of artificial life. A-life's focus on the synthesis of such systems leads it to adopt the "bottom-up" approach that is one of the field's tenets. Influenced by theories of complex systems, a-life regards the complex dynamics of living things across all scales as phenomena that arise from the interaction of multitudes of smaller elements. Langton asserts that "natural life emerges out of the organized interactions of a great number of nonliving molecules, with no global controller responsible for the behavior of every part." Similarly,

> Artificial life starts at the bottom, viewing an organism as a large population of simple machines, and works upwards synthetically from there — constructing large aggregates of simple, rule-governed objects which interact with one another nonlinearly in the support of life-like, global dynamics.[4]

The process, known as emergence, by which these simple components interact to produce complex, lifelike results is another central concept in artificial life. Just as artificial life proposes that the complex behaviors of a living thing emerge from its nonliving parts, it seeks to recreate this process in artificial systems, so that an ensemble of simple computational parts interacts to spontaneously produce lifelike dynamic structures.

A useful way to briefly provide a sense of a-life's approach and its particular innovations is to examine the way it distinguishes itself from artificial intelligence (AI). It does so frequently, and tends to present itself as succeeding in its aims where AI has failed. Langton explains that in focusing on intelligence — the underlying mechanisms of which were (and are) poorly understood — AI was left without a model to follow and resorted to "serial computer programming," a methodology that "bore no demonstrable relationship to the method by which intelligence is generated in natural systems." Conventional AI strove without much success to make computer programs that could think; its approach was centralized, or "top-down," and focused on cognition. A-life, in contrast, deals with behavior that emerges from the bottom up. Langton describes a-life as remaining "true to natural life," following the "key insight" that "nature is fundamentally parallel" — that is, natural systems tend to be complex aggregates of parts, each of which has its own "behavioral repertoire"; behavior arises out of the parallel operation of these parts.

A-life has developed and adopted a repertoire of formal structures and techniques that apply this philosophy. While this repertoire is not fixed or static, there are a handful of key techniques, which bear introduction here.

Genetic algorithms, a central technique, roughly simulate biological genetics in digital computation. A genetic algorithm involves a "genotype," which is a string of code specifying a "phenotype." The phenotype can be any digital artifact: an artificial organism, a three-dimensional form, or a piece of software. By simulating the genetic variations caused by sexual reproduction and mutation, a genetic algorithm alters the genotype and the phenotype; and since this process is computational rather than biological, breeding is rapid and prolific. Wide ranges of possible phenotypes can be generated, which are often automatically evaluated for their "fitness," based on some formally specified criteria. In functional applications, an accelerated process of artificial evolution is applied to find a solution to a complex problem by searching within a large range of possible outcomes.

Agent-based systems often also apply artificial genetics. These systems model individuals interacting in an artificial world; their behaviors may be as basic as breeding and eating or as sophisticated as "communicating" or cooperating. Population dynamics may emerge, such as fluctuating predator/prey balances; with artificial genetics, agents' attributes may evolve, so that phenomena such as speciation, interbreeding, symbiosis, and coevolution become possible. Some simple agent-based systems involve no genetics yet exhibit a-life's characteristic bottom-up dynamics: in *flocks* agents follow simple rules for moving through space; each individual seeks to maintain a certain distance from the others while moving forward.[5] The result is the spontaneous formation of a flock of agents, with a supple coherence that resembles that of real-life flocks or shoals.

This architecture of decentralized control has also been applied in robotics: in *bottom-up robotics* multiple sensorimotor processes operate in parallel, in the absence of a controlling "brain", or an internal representation of the sensed world. As the work of Rodney Brooks and the MIT Robot Lab has shown, this architecture can generate simple, computationally efficient robots with surprisingly robust behaviors.[6]

Finally, *cellular automata* manifest this local-global transition in a purely formal domain. In these systems, an array of logical units or cells is computed with a set of simple rules for how each cell's future state is affected by the current states of its neighbors. In the best-known cellular automaton, the Game of Life, a two-dimensional array of one-bit, on/off cells and a handful of simple transition rules give rise to what seems to be a clockwork nanobestiary: cell formations blossom and disintegrate; oscillating, mobile formations crawl across the array.[7] This striking emergence of complexity from simplicity, and lifelike dynamics from formal rules, is frequently invoked in arguments for the merits of the a-life approach.

A-Life Art

Shortly after artificial life's self-declared inception in 1987, artists began to apply its techniques. Its earliest adopters were artists with interdisciplinary interests, followers of the biological and computational sciences who had the technical and conceptual means to begin experimenting with artificial life. William Latham and Karl Sims were prominent among these; their work was shown in major cultural institutions and on the new media festival circuit in the early 1990s. It demonstrated the viability and some of the potential of the conjunction of a-life and art making, and sparked the interest of other artists working in digital media. Since then increasing numbers of artists have taken up a-life concepts and techniques. While in terms of contemporary culture, or even contemporary art practice, a-life art remains a "fringe" activity, it has come to be recognized as an active area within new media practice. Publications such as *Leonardo* and festivals including Ars Electronica have devoted space to a-life art; in 1999 an annual competition for a-life art was inaugurated with *Life 2.0*.[8]

In a process mirroring the expansion and diversification of artificial life science, a-life art has come to encompass work in a wide range of forms, reflecting diverse intentions and perspectives. The early works in the field focused on a single key process — artificial evolution — and its application in generating aesthetic objects. In the following decade, artists began to draw on other elements and forms: ecosystem simulations, cellular automata, and behavioral robotics. These techniques are applied across the gamut of "new media" forms: digital image, animation, interactive installation and CD-ROM, on- and off-line virtual environments, and static, robotic and biological-robotic sculpture. Less obvious, though perhaps more important, is a corresponding diversity of conceptual approaches. Some artists endorse and play out a-life's aims for the synthesis of living systems; they reflect some of the progressive, futurist tendencies of a-life and the cultural discourses it has inspired. Others approach a-life critically, questioning the assumptions that underpin its techniques as they turn those techniques to creative ends. Still others draw on the technical resources of a-life only to alter them, reconfigure and reengineer them to serve particular aesthetic and conceptual concerns.

Contemporary new media artists use a-life in a variety of contexts, to a variety of ends: some works pursue an absolute, self-sufficient autonomy; others use an appearance of autonomy to provoke empathy or raise questions about human agency. Many of the artists using a-life strive for a supple, engaging form of interactivity and a work that draws the audience into an active relationship; others present aesthetic artifacts that arise through their own intense engagement with a-life processes. Some of the works considered in this book set about creating whole artificial worlds, and others seek out a complex, dynamic relationship with the physical "outside" world. In many works, the familiar appearances and behaviors of nature are imported and reproduced; the natural world is redrawn within computational space. In others, the process of rendering biology as computation comes under question; in still others, the familiar image of nature gives way to something else: a raw, blank sense of potential, of the unknown and of what could be.

Defining or delimiting a-life art is problematic, of course, though it is necessary for a review such as this. We can situate the field within a wider area of art practice that engages and applies technoscience in its form, content, and technique; Stephen Wilson has named this area "information arts" and made a comprehensive survey of it.[9] There is a range of work here that approaches a-life art in various ways, with related concerns, techniques, and approaches. Artists are working with biotechnology, another science of technologized life, though one that operates in the "wetware" of living tissue. Many other artists draw on artificial intelligence, which while it shares some of a-life's interests in autonomous agency, emphasizes mind and thought over behavior and life. A host of other tech-art forms touch on artificial life: work with robotics, avatars, or artificial agencies; generative processes or simulated worlds; and work addressing that central articulation of the natural and the technological. This work is very often concerned with a notion of artificial life in the broadest sense. Some of it may even resemble or seem to manifest artificial life forms. However, in this book, in the interest of clarity and focus, a-life art is defined quite strictly as work that specifically and deliberately takes up the techniques and processes of a-life science.

Precursors to A-Life Art

This definition gives the survey a very specific historical compass and a year zero, 1987, linked to the self-declared inception of artificial life. Yet in terms of developing an understanding of the field, it is essential to take a wider and longer view. As Lev Manovich has shown, the new media are not entirely new but have been anticipated and prefigured by old media practices and forms.[10] Such media prehistories enrich our knowledge of contemporary forms and guard against the technofuturistic rush that often characterizes new media culture. Similarly, in the interest of grounding a consideration of contemporary practice, it is useful to consider some precursors to a-life art practice. Yet how can we trace a-life art prior to a-life itself? Simply by suspending that definition momentarily and considering parallels in practice and theory. In contemporary work, artists apply and manipulate a-life's formal techniques for modeling (and perhaps instantiating) living systems. Broadly, art here seeks to mimic and apply the dynamic formal structures of life; and this book looks back to work that predates both a-life and a-life art.

The formal analogy that likens a work of art to a living organism is ancient, traceable to Plato and Aristotle, who use the body as a model of organization and coherence in discussions of rhetoric and drama.[11] That analogy reappears in the work of the German romantic poet and scholar Johann Wolfgang von Goethe around the turn of the nineteenth century. In fact Goethe's philosophy of nature parallels that of a-life in emphasizing an appreciation of the dynamic living whole over the constituent parts while also proposing a common underlying formal structure. This is exemplified in Goethe's notion of the *Urpflanze,* or "ur-plant," the archetype or template that underpins all real plant forms. Rather than a fixed template or Platonic ideal, the *Urpflanze* was, as one contemporary commentator remarks, "a vision of a dynamic pattern."[12] Goethe regarded the study of nature — based on an "intuitive awareness" of the organic whole — as a communion with the divine and the ultimate goal of art: "The highest demand made on an artist is this: that he be true to nature, that he study her, imitate her, and produce something that resembles her phenomena."[13] This resemblance is more than an image, however; it is procedural. In art "we can in the end rival nature only when we have learned, at least in part, her method of procedure in the creation of her works."

These ideas are echoed by Goethe's contemporaries and in a lineage of major nineteenth-century figures. Around 1800, August Wilhelm von Schlegel writes that art "must form living works, which are first set in motion, not by an outside mechanism, like a pendulum, but by an indwelling power."[14] Later, Samuel Taylor Coleridge developed this notion in his critical writing on Shakespeare; for Coleridge, the true work of art is organic, and organic form, unlike the arbitrary imposition of "mechanical" form, "is innate; it shapes as it develops itself from within."[15] This is the idealist and Romantic core of a line of organicist thinking that manifests itself across the arts, in literary criticism, architecture, and musical analysis. In the visual arts these ideas are taken up in the European and Russian avant-gardes during the early decades of the twentieth century.

It is clear that a-life art is engaged, in a very general way, with the underlying forms of living things; however, it is also engaged in the translation of those dynamic forms into technological media, into structures of code and engineering, into explicit and formal rules and processes. The clearest predecessors for a-life art practice, then, are those that combine these organic ideals with a tendency towards rigor and systematisation, where creative organisms arise not through the transfer of an ineffable vital essence but from the interactions of formal elements in a medium deliberately abstracted from nature.

The work of Paul Klee provides a rich example of exactly this combination of organic idealism with formalist thought. Klee's work expresses a Goethean sense of nature but manifests it in refined, considered abstraction. Once again, Klee begins with the study of nature and an understanding that moves from surface to dynamic formal structure. The artist's intuition "can transform outward impression into functional penetration. . . . Anatomy becomes physiology."[16] Here, too, this intimate, structural understanding enables the artist to "form free abstract structures which surpass schematic intention and achieve a new naturalness, the naturalness of the work." Examples of this process can be found in Klee's notebooks. In one 1923 lecture, Klee makes a graphic analysis of plant forms that abstracts them into general principles and "forces"; the leaf stem is an energetic vector that exhausts itself as it branches, and at its endpoint is contour, the outline of the leaf.[17] Beginning in the observation of nature, this becomes a lesson in the rules of an abstract, graphic cosmos, and in the relation of line to contour and plane. Klee set a creative exercise demonstrating the final, synthetic, or creative stage of his methodology: it was entitled "Imaginary leaves on the basis of the foregoing insight into basic rules."[18] The notebooks show Klee's own example: an artificial leaf made up of stem vectors and outline contours. While here inner dynamics crystallize into form, Klee cautions that "form is the end, death. Form-giving is movement, action. Form-giving is life."[19] The organic artwork must ultimately be alive: "Our work is given form in order that it may function, in order that it may be a functioning organism."[20]

Some of Klee's contemporaries in the Russian avant-garde pursued a similar vision of the organic artwork, though with more emphasis on the role of technology. In particular, Kasimir Malevich, founder of Suprematism, produced an expansive utopian discourse of the artwork as an autonomous organic machine. While Suprematism is widely known for its pursuit of abstract purity, emblematized by Malevich's black square, Malevich, like Klee, writes of abstract form as an approach to nature's underlying dynamics and forces. In "On New Systems in Art" (1919), the artist, observing a natural landscape, "stands and exults in the flow of forces and their harmony."[21] When these dynamics are transferred into the artwork, we find not a copy or a tracing, but "pure" or "absolute" creation, and "a work of pure, living art."[22] In "Infinity . . ." (1919), Malevich writes that the "highest and purest artistic, creative structure . . . does not possess a single form of the existent. It consists of elements of nature and forms an island, appearing anew."[23] While their exact constitution remains vague, it is clear that these autonomous islands are at once organic and technological: Malevich imagines the Suprematist machine as a spacecraft, propelled "not by means of engines, . . . but through the smooth harnessing of form to natural processes, through some magnetic interrelations within a single form."[24] These forms are so refined, so perfect, that they cleave away from the mundane

Earth and become new, autonomous, artificial worlds: "All technical organisms are nothing but small satellites, a whole living world ready to fly away into space and take up a particular position. Indeed, every such satellite is in fact equipped with reason and prepared to live out its own personal life."

If the details of Malevich's vision are indistinct, it must be partly because of limitations in its raw material; it was based primarily in the mechanical paradigm that defined the technology of his time. With the rise of electronics some fifty years later came a form of technology that miniaturized and internalized the dynamics of the machine. It was this technological shift that made it possible for the Soviet Union, in 1957, to fulfill one element of Malevich's vision, sending a tiny ball of electronic circuitry into orbit around the Earth. Meanwhile, during the preceding decade, a new scientific field had been emerging in the United States, through the Macy conferences on "Circular Causal and Feedback Mechanisms in Biological and Social Systems." This was cybernetics, named by Norbert Wiener in 1948.[25] A predecessor of contemporary complex systems science, and thus artificial life, cybernetics set out to address problems across living and nonliving systems by considering both in terms of abstract causal dynamics, inputs and outputs, and feedback loops. Moreover, like a-life, cybernetics was taken up in cultural as well as scientific practices: during the 1950s, artists began to encounter and apply cybernetics. Throughout the 1960s, as interest in electronic and kinetic art forms grew, it was taken up more widely and also began to appear in critical and theoretical art discourse. This period throws up some striking precursors for contemporary a-life art.

Among the early adopters of cybernetic techniques was Hungarian-born artist Nicholas Schöffer, who gained wide attention during the 1950s and 1960s with his kinetic and cybernetic sculptures. His 1956 *CYSP I* was an articulated tower that responded to sound and colored light by moving itself and its rotating metal vanes. Schöffer describes this work as "the first sculpture to have a human-like self-determined behavior."[26] The critic Jack Burnham writes that in *CYSP I* "ambiguous stimuli . . . produce the unpredictability of an organism."[27] For Schöffer, cybernetic techniques serve an aim of "nonredundancy," enabling art to keep pace with the perpetual novelties of the mass, electronic media. Moreover, Schöffer asserts, this is metacreation: "We are no longer creating a work, we are creating creation. . . . We are able to bring forth . . . results . . . which go beyond the intentions of their originators, and this in infinite number."

These ideas are echoed by James Seawright, a prominent American cyborg sculptor. He says of his works *Watcher* (1965–1966), *Searcher* (1966), and *Scanner* (1966), "My aim is not to 'program' them but to produce a kind of patterned personality. Just as a person you know very well can surprise you, so can these machines. That's the crux of what I want to happen."[28] All Seawright's works were cybernetic systems responding to environmental inputs; some, such as *Searcher* and *Scanner,* use feedback to dynamically modify their own programs. When grouped together, the works communicate among themselves: "The pieces interact and provide a continually varying pattern of independent and collective activity."

Artists in this cybernetic era also experimented with composite systems linking biological life with electronics in various ways. Anticipating Christa Sommerer and Laurent Mignonneau's *Interactive Plant Growing* (see chapter 3), Thomas Shannon and John Lifton experimented in the mid-1960s with living plants acting as electric pickups for robotic and sonic systems. A rare example of a warm-blooded composite is Nicholas Negroponte's *Seek* (1970), in which a robot arm transports and stacks two-inch cubes that form the "built environment" for a group of gerbils: the arm attempts to adaptively alter the structure to satisfy the desires of its rodent population.

With related work by Edward Ihnatowicz, Tsai Wen-Ying, and cybernetician Gordon Pask, and the animist kinetics of Robert Breer and Jean Tinguely, this period produced a strain of cyborg art that was very much concerned with the shared circuits within and between the living and the technological. A line of cyborg art theory also emerged during the late 1960s, and here again some striking premonitions of a-life art can be found. Writers including Jonathan Benthall and Gene Youngblood drew on cybernetics and cybernetic art, Benthall in his 1972 survey *Science and Technology in Art Today,* and Youngblood in *Expanded Cinema* (1970).[29] The most substantial contributor, however, was the American critic and theorist Jack Burnham. Burnham's *Beyond Modern Sculpture* (1968) builds cybernetic art into an expansive theory that centers on art's drive to imitate and ultimately reproduce life.[30]

Burnham begins at a point of artistic crisis: sculpture after World War II was apparently obliterating itself, abandoning traditional sculptural concerns for a dematerialized dynamism. This is a transition from object to system, Burnham argues, evident in forms such as kinetics, light art, cybernetic art, and environment art (13). With the rise of industrial capitalism, and the progress of science and technology, the modern environment is a sophisticated, interlocking artificial system, and this is reflected in art practice. This artificial system is, moreover, evolving; Burnham broadly invokes negentropy, or self-organization: it is "a common effect linking social, technical and biological evolution"; "each . . . moves towards a higher life form" (14). Art is inescapably involved: "sculpture . . . in a technological society must be regarded as a tiny microcosm of the entire . . . evolution." So, ultimately, if both art and technology are negentropic, then their common destiny is the creation of life. Burnham projects its arrival into the near future (our present): "The logical outcome of technology's influence on art before the end of the century should be a series of art forms that manifest true intelligence . . . with a capacity for reciprocal relationships with human beings" (15). This drive is at the core of *Beyond Modern Sculpture:* it organizes Burnham's historical account of modern sculpture, and the cybernetic art of the 1950s and 1960s is held out as its most complete realization. Twin art-historical threads of organicism and vitalism — for Burnham, the quest to convey life's metaphysical essence — converge: "[V]italism is a transitional step in this process from inanimate object to system" (76), and "the meaning of organicism . . . has already begun to converge toward a single end result — the understanding of living matter through its creation" (51).

What we find in cybernetic art, in Burnham, and in Klee and Malevich, suggests that a-life art is only the most recent addition to a modern creative tradition that seeks to imitate not only the appearance of nature but its functional structures, and that applies (or imagines) technological means to do so. More striking, though, is the Modernist-organicist drive that runs through this history, where artificial life is the very destiny of art making. This rearranges the terms of the present investigation: instead of art following technoscience and importing its techniques, a-life itself is an artistic project, even *the* artistic project. Can we understand contemporary a-life art as a continuation of this drive? Does it finally fulfill Burnham's vision of a living, cyborg art form? As it happens, Burnham later renounced his predictions in the wake of his experience as curator of the ambitious but troubled 1970 tech-art exhibition *Software.* Writing in 1974, he denounces the "archetypal desires" of science to create artificial intelligence as "Faustian myths of the highest order."[31] Later, he writes of *Beyond Modern Sculpture* that it "erred gravely . . . in its tendency to anthropomorphize the goals of technology."[32] He dismisses the cybernetic art of the 1950s and 1960s as "little more than a trivial fiasco," and the results of AI research (circa 1980) as "pale imitations." In this dramatic about-face is another possible reading of a-life art: that it, too, is replaying Faustian myths as well as myths of technological, evolutionary, and artistic progression, and that it, too, will come to be seen as a "trivial fiasco."

However this practice may be judged and rejudged in the future, it is highly significant in the present, for all the reasons outlined. Moreover, in terms of the field's development, the present moment is one where a critical examination of a-life art practice has become both possible and worthwhile. Artists have been using artificial life for around a decade, a short span in art history though a longer one in the accelerated time scale of new media practice. For most of that time, new media art has adopted a-life techniques experimentally, in scattered, initial encounters. However, activity in the field has increased in recent years, and at the same time experimentation has given way (in part) to more self-conscious, strategic engagements with artificial life. The field has developed to a point where a wide analytical account can be valuable. While a number of writers have made isolated forays, a-life art as a whole has received limited critical attention. So, my aim here is to simply provide that critical account of the field — the work itself and the conceptual and discursive structures that surround it. This book makes no claim to be an exhaustive catalog of a-life art, but it does aim to represent the range of practice in the field. Further, while the field will continue to change, and the work presented here will inevitably date, the intention is to address the broader themes and drives that it manifests and so to give an account that will remain useful even as its details age.

Chapters 2–5 deal with the primary material, the work itself. Here, a-life art practice is presented through a simple typology based on four of its prominent techniques and tendencies. The first of these, Breeders, focuses on processes of artificial evolution — a group that includes the earliest works of a-life art. The second, Cybernatures, expands the scope of the simulation: many of these works are interactive computational systems that mimic the tangled interrelations of organic life; all address the tension between organic life, or "nature," and its technological double. Chapter 4, Hardware, considers work that centers on a physical manifestation; as well as interactive robotic systems, this category includes biorobotic composites that involve a coupling between biological life forms and electromechanical systems. In chapter 5, Abstract Machines, the "life" in a-life recedes momentarily, in works in which the analogy implicit in these techniques is less important than their formal, generative properties.

Throughout these chapters the exposition of the work feeds directly into critical response and analysis. What is the work attempting? What does it achieve? What does it evoke or invoke? What does it exploit, critique, endorse, celebrate, or mourn? What are its implications? What does it suggest? This analysis also begins to abstract from individual instances, revealing commonalities and questions that bear on the field as a whole.

Chapter 6 pulls back to consider theoretical contexts for a-life art practice, which is not, of course, the only manifestation of artificial life in cultural thought. A-life has drawn the attention of some in fields such as cultural studies and anthropology, and their work makes some important contributions to an understanding of a-life art practice. Closer to that practice, there is a small cluster of writing addressing a-life art directly: artists and critics set out a range of aspirations, explanations, manifestos, proposals, and critiques. Reading these closely and analytically gives a sense of the variety of ways in which a-life art is being defined, justified, contextualized, and interrogated, and of the range of conceptual projects it contains.

Finally, Chapter 7 focuses on an elusive concept, emergence, which is at the core of both a-life science and a-life art practice. Emergence is the process by which complex systems seem to acquire new properties from one level of scale to another; centrally, how the complex interactions of inert matter at the microlevel give rise to life at the macrolevel. Emergence is central to a-life science's interests and its claims to be lifelike; a-life art, too, it will be argued, aspires to a state of emergence and to the surprise, the excess, the "something more" which that entails. Chapter 7 sets out to explore the concept of emergence in some detail, investigating its provenance and history, the claims for its manifestations in a-life and a-life art, and the forces and structures that act to limit and condition its operation.

Emergence is such a beguiling idea that it might not be too pat to apply it reflexively here. In fact, that might be essential if we are to take a-life's connectionist underpinnings seriously and regard culture itself as a system characterized by an interwoven and processual causality, by complex dynamics that are continuous with those not only of living systems but of their material substrate. While a text such as this is frozen, a static block, its aspirations must extend outward into those ongoing cultural dynamics, especially in a case where the subject matter is itself in flux. That is, this book is not intended to "cover" a-life art, to summarize the field once and for all. On the contrary, it is a starting point, an element to be taken up in wider systems, as the field's complex future unfolds.

2

Figure 2.1 Karl Sims, evolved image (1991).

B R E E D E R S

In his book *The Blind Watchmaker* (1986), Richard Dawkins recounts his experiments with Biomorph Land, a homemade computer program in which the user can guide the "evolution" of generations of graphic stick figures.[1] Dawkins uses this Biomorph breeder to argue for the creative capacity of cumulative selection in biological evolution; he aims to show that the accumulation of small random changes in an organism over time can lead to complex nonrandom results. While in this case it demonstrates Darwinian theory, the Biomorph system also suggests an important series of links and mappings between biology, aesthetics, and computation. First, it suggests that something like biological genetics can occur in computation, inside the computer. It also implies that something like evolution can occur in this domain: a form of evolution guided not by some nebulous force of natural selection but by the clear, deliberate choices of a human operator. Finally it shows that these processes, which couple artificial genetics with artificial evolution, can give rise to complex aesthetic objects. Although Dawkins was concerned primarily with making a point about evolution, others saw that artificial evolution could be used as a generative technique. Extending and altering Dawkins's template, they constructed new breeders, of complex images and elaborate virtual forms. Over the course of a decade Dawkins's initial experiment has itself evolved into something it was never intended to be: a technique for the creation of electronic art.

This is a simple sketch of the origin of contemporary a-life art: William Latham and Karl Sims, the artists inspired by Dawkins's Biomorph breeder, were the first to identify their creative work with the techniques, terminology, and metaphorical structures of artificial life. Yet as well as marking a historical point, this story describes an intersection, a crossing point, signaling the mixture of languages and metaphors at work in this field. An example designed by a popular evolutionary theorist has given rise to a body of artworks using artificial evolutionary and genetic processes: a complex set of intersections springs up between art practice, creativity, evolutionary biology, and computation; a set of mappings and associations arises between computation and genetics, creativity and evolution.

The breeder is introduced here through the work of Sims and Latham, which sets out the conceptual and figurative hallmarks of the form. These first-generation artists have inspired others to follow: Steven Rooke and Nik Gaffney provide contrasting examples of the form's more recent development. Later in this chapter, a closer examination of Dawkins's Biomorph breeder prompts questions about the basic analogy made between computational and biological processes: these questions carry across into the works themselves and their relationship to that analogy. As well, such breeders are considered from their discursive flip side, in terms of creation, agency, and aesthetics, through the language of art. Rather than simply writing these works into such a terminology, I set out to reveal the tensions and divergences involved in these works, the ways in which they pull away from conventional notions of artist and artwork. My intention is to follow the conceptual structures intrinsic to the works rather than to evaluate them against a ready-made critical frame. This path leads the analysis away from a simple critical resolution and returns it instead to the complex compound structures of the works themselves, and the desires and imaginations they embody.

KARL SIMS

Karl Sims's *Genetic Images* is one of the important early manifestations of a-life in electronic art. Shown at Ars Electronica in 1993 and

at the Pompidou Center in Paris the same year, *Genetic Images* is a lavish installation: a prominently displayed supercomputer — a black cube shimmering with tiny lights — sits beside a wide arc of sixteen video screens. The screens display colorful abstract images, which are replaced every thirty seconds or so with a slightly different set. Over successive cycles of variation, there are changes, both rapid and gradual, in the overall appearance of the images. When initialized, the installation shows simple planar figures; they steadily become more complex. Over many cycles of variation, the images acquire abstract detail; colors change, new compositional elements spontaneously appear. This process involves a limited but crucial element of interactivity: in front of each screen is a pressure-sensitive mat, which allows visitors to select which images will form the basis of the next iteration. Stand back from the arc of screens and survey the displayed images, then step forward to choose one or two: these images remain as the rest are replaced by a new set of variations. Step back, examine the results, and choose again. Over successive cycles these choices exert a steady influence on the aesthetic character of the generated images; visitors steer the process through cycle after cycle of graphic variation.

At a technical level the process is mathematical: each image is the product of a complex equation, evaluated and displayed by the installation's computer. When an image is selected by a visitor, its equation is randomly altered fifteen times to produce a new set of equations and a new set of images. But metaphorically this is an image breeder, and its process is founded on analogies with genetics and evolution. The image's equation is analogous to the genotype or genetic code, and the image itself corresponds to the phenotype or organism. In *Genetic Images* an image's equation might be altered randomly as it "reproduces," just as in living things rare variations in the replication of genetic material produce mutations. When two images in a set are selected, their equations are spliced together in a process analogous to sexual reproduction: the following generation of "children" contain various mixtures of the "parent" images' equations.

In natural selection, according to Darwinian orthodoxy, living things are the cumulative results of innumerable cycles of variation and selection, variations in organisms arise through mutation and sexual reproduction, and the organisms best adapted to their environment flourish. Sims presents "computer-simulated evolution," where images evolve according to human aesthetic selection.[2] Many generations of this process produce remarkable cumulative results: complex abstract images with mathematical "genes" so complicated that, in Sims's words, they "would be quite difficult for any human to design or even understand."[3] The image in figure 2.1, the result of Sims's breeding over thousands of generations, illustrates some of the graphic potential of the system, though not its variety.

Genetic Images sets out the basic breeder structure very clearly: a mutable digital genotype codes for a phenotypic form, which evolves through successive cycles of aesthetic selection and mutation. It also hints at the promise that makes these works so interesting: we could stand at *Genetic Images* all day, making selection after selection, watching wave after wave of images pass by, endlessly calling up new variants. Initial aesthetic goals are swamped in the flow; unexplored evolutionary sidetracks constantly beckon; strange, striking mutants appear almost without warning. This cycle of selection and variation is potentially endless: the variety of possible images seems infinite.

How can we come to grips with this endlessness? Sims presents it in terms of an abstract space, a "search space" or "parameter space."[4] A parameter space is simply a way to imagine a range of possible outcomes for a system with several variables, or parameters. In a system with two parameters, every possibility lies on an imaginary two-dimensional plane; in a system with three dimensions, that space is cubic; but a system may have many more variables and therefore a parameter space that is far harder to visualize, with four, ten, or a hundred dimensions. In the case of *Genetic Images,* each image represents one point in a parameter space, one combination of values, but that space has as many dimensions as there are variables in the simulated genome.

For Sims, *Genetic Images* is a way of easily exploring this very large multidimensional parameter space, an immense space of possible images. He talks about users navigating paths through this space with each successive generation.[5] This figurative space helps to anchor the sense of boundless potential that interaction with *Genetic Images* conveys. However, what is most interesting about this work is that the genome has no predetermined number of genes; the code for any given image might have one, thirty, or a hundred variables. The genomes are assembled from a library of mathematical functions including simple arithmetic, trigonometric functions, noise generators, and image-processing operations. While some mutations in this system simply alter the values of existing variables, others can add new elements — numerical variables or functions — to an existing genome and so effectively increase the space of possible images its parameters define.[6] Sims describes this as a genetic hyperspace, a space with a variable number of dimensions.[7] This feature makes visualizing the space even more difficult, but it accounts for the remarkable complexity Sims's system has produced: the field in which it operates is complex, dynamic, open-ended, and difficult to predict.

As well as introducing this spatial figure, Sims uses another, parallel metaphorical mode to describe this work, one that fits more intuitively with the language of genes, mutations, mating, and evolution. "I think of them as life-forms, in a way," he confides.[8] Sims investigates artificial (aesthetic) life more explicitly in several sophisticated computer animations from around the same time as *Genetic Images.* *Panspermia* (1990) uses procedural modeling and animation to render a sci-fi world of burgeoning vegetation: in a rush of artificial growth ferns uncurl, plants spring from the ground, and a dense thicket forms in seconds. The animation describes a fantastic cycle of growth and reproduction: it opens with a biomorphic pod traveling through space to land on a bare planet, where it explodes in a shower of seeds. As the new plants grow, they develop bulging trumpetlike flowers, which in the final seconds of the piece fire off their own seed pods into interplanetary space. Some of the plantlike forms in this animation were evolved in a process similar to that used in *Genetic Images;* the forms generated using this technique, and the narrative that those forms furnished, match the metaphorical content of the process.

Sims's later research, which has been widely hailed within the a-life science community, explores the evolution and coevolution of mobile artificial creatures in a simulated physical environment. Artificial organisms evolve automatically, based on their aptitude at carrying out certain well-defined "tasks" within this environment. Some of the most remarkable results of this work show how these artificial creatures — articulated assemblages of simple blocks — evolved various solutions to the problem of locomotion.[9] Some of the same techniques for the evolution of three-dimensional forms appear in Sims's most recent artwork, *Galapagos* (1997). Essentially, *Galapagos* uses the same form and process as *Genetic Images* but changes the nature of the evolved aesthetic objects. In this case, they are complex, mobile three-dimensional forms, ranging from the clearly biomorphic — with pods, tentacles, and spotted "skin" — to more abstract, geometric structures (figure 2.2). Just as in *Genetic Images,* these shapes are defined by an open-ended string of code written in a formal language. Here, too, a shape's code can be altered by mutation or combined with other codes in a simulation of sexual reproduction, and these transformations are guided by the selections made by visitors to the installation. As the work's title indicates, the most striking difference between *Genetic Images* and *Galapagos* is the shift toward biomorphic a-life. In *Genetic Images* the evolved

Figure 2.2 Karl Sims, evolved forms from *Galapagos* (1997).

results are highly abstract, a-referential forms, and this is reflected in the tone of Sims's discussion of the work; there is a sense of the images as life forms, but it is qualified. By contrast, the dynamic three-dimensional forms of *Galapagos* are clearly presented as artificial organisms.[10]

Sims's work presents the basic technical structure of the breeder: an artificial genome, an artificial phenotype, and an iterative, interactive selection process. It also illustrates two of the fundamental metaphors at work in this genre. From one perspective, these evolved forms are snapshots from an algorithmic hyperspace, artifacts indicating the selector's journey through that space, found objects brought back from a realm that promises an unimaginable, inexhaustible supply. From another perspective, they are life forms, the progeny of a process of accelerated, user-guided evolution.

WILLIAM LATHAM

During the late 1980s and early 1990s, William Latham, in collaboration with programmer Stephen Todd, created software for synthesizing, mutating, and evolving three-dimensional forms — what Latham calls "ghosts of sculptures."[11] During the same period Latham exhibited these "ghosts" as large prints and video animations: they show complex spiraling forms, coils of segmented tentacles and horns; they look like alien crustaceans or poisonous seashells rendered with the synthetic textures and smooth, shiny surface of early 1990s computer graphics.[12] Each still image depicts a single sculptural entity, like a museum specimen, suspended in darkness or sitting on a receding plane. In later animations these forms unravel and transform; spinning arrays of spheres form rows of spiraling segmented tentacles around a writhing starfishlike nucleus; shifting organic composites are formed from the intersection of dozens of globular strands as they coil, grow, and shrink.[13] These virtual forms strongly recall living things, yet they remain unsettlingly cold, dead, and artificial.

Like Sims's images, these virtual sculptures have been bred in a computational process that models itself on genetics and evolution. However, where Sims's genetic code is a mutable mathematical equation, Latham's artificial genome is a geometrical procedure, a recipe for a virtual form. Following an interest in natural systems and morphogenesis, and influenced by approaches to formal synthesis in the visual arts, particularly Constructivism, Latham initially devised a framework for selectively evolving geometric forms by hand. This system, known as FormSynth (1989), entailed a simple set of rules describing transformations of an existing form. A form might be altered by adding a cone, a sphere, or a cubic element, by duplicating an existing formal element, by subtracting an element (for example, scooping out a spherical hole), or by combining elements across forms. Applying these rules, Latham produced huge hand-drawn evolutionary "trees" in which geometric primitives become complex constructions in branching sequences of simple transformations and combinations. Todd and Latham recount that "[s]imple as the rules of FormSynth were, they seemed to have a creative power of their own. . . . As the drawings grew larger . . . [Latham] realized that the FormSynth system defined an infinite world of predetermined forms, which the artist explored to reveal only a selected few."[14]

The software developed by Todd and Latham uses the same methods as FormSynth; a set of primitives (a "grammar") is used to build up complex forms. In software, repeated accumulations and transformations produce "fans" and "stacks" of these simple elements; a sphere replicated and scaled along an axis becomes a "horn"; a sphere squashed, stacked, and twisted produces a "tentacle." Todd and Latham's FormGrow system uses a modular syntax of these predefined generative elements; horn and tentacle transformations can combine into more complex "web" and "ribcage" forms.[15] A form's description is simply the coded instructions for how to build it — a set of elements, transformations, and numerical parameters that for evolutionary purposes is the genetic code. These formal descriptions can be combined like genes by being spliced into each other in a process analogous to sexual reproduction and can be mutated by alteration of their parameters or grammatical structure. Todd and Latham's Mutator software implements these processes; like Sims's *Genetic Images* it presents the user with a set of mutated forms to be selected for further evolution — this is Latham's breeder.

Like Sims, Latham and Todd describe Mutator as a metaphorical navigator through a space of potential forms, a "form space" or "gene space" with some thirty dimensions.[16] In fact, the software attempts to extrapolate the user's trajectory through form space in order to anticipate the desired results of a mutation. Latham's later animations of these forms are generated using "genetic interpolation," where one evolved form is transformed into another by gradually changing the values of the form's procedural parameters; essentially, this technique animates a movement through form space. In *Mutations* (1991) this technique is extended to produce animations that Latham and Todd call life cycles, where forms grow and spawn "children" before disintegrating.

This form space is very different, however, from that in Sims's *Genetic Images.* Latham's genome is more tightly defined, less mutable: because the genome has a finite number of variables, the procedural forms they code for occupy a genetic space that, while large, has clear boundaries. Sims's algorithmic genome has a fine structure that produces unpredictable phenotypic results; its mathematical terms interact with each other in complex ways. Latham's genome has a more obvious relation to the form it defines because far more of the phenotypic structure is already present in the grammar of the genome, in predefined procedural units. Latham's innovation is to use the computer's number-crunching power, in the form of simulated mutation and evolution, to test the aesthetic bounds of this high-level procedural grammar.

The elemental quality of this grammar and the tightly constrained structures it generates tally with Latham's Constructivist influence. However, Latham also cites the influence of British zoologist D'Arcy Thompson, a link suggesting a slightly different understanding of this work. Thompson's *On Growth and Form* develops a detailed formal (and mathematical) analysis of living structures, describing the influence of physical forces such as surface tension on organic morphologies.[17] As Philip Ritterbush comments, Thompson's work is above all concerned with "demonstrating the orderliness of virtually every realm of organic form."[18] It is clear that Latham's work begins with a notion of organic form informed by this sense of order, in which formal elements exist in rule-driven relationships. Perhaps Latham's work can be understood as a synthetic experiment based on this sense of organic order — an evocation of the fantastic forms that arise when real morphogenetic processes are abstracted into computational rules.

STEVEN ROOKE

If Latham's work is a kind of formal exhaustion of an orderly organic grammar, the work of the American artist Steven Rooke aspires to be almost the opposite: an exploration of the mysterious, boundless expanses of algorithmic image hyperspace. Rooke describes himself as an image breeder "in a tradition inspired by evolutionary art pioneer Karl Sims."[19] Like Sims, Rooke uses a genome constructed from a grammar of mathematical functions; once again, variation is induced through random variation (mutation) or the combination of two existing genomes (sexual reproduction). The only significant technical differences between Sims's *Genetic Images* and Rooke's work are in Rooke's larger library of mathematical functions, including some that generate fractals. These functions are visible in Rooke's images, many of which resemble fantastic landscapes, with the familiar swirls and filigrees of Julia and Mandelbrot fractals sweeping into the distance, as in *In the Beginning* and *Skaters.*[20] In Rooke's later work, he has opened the fractal functions themselves to genetic variation, resulting in images with a less familiar signature but even more intricate visual forms; the most striking example is his *Hyperspace Embryo* (1999) (figure 2.3).

The expansive image titles begin to hint at what makes Rooke's work remarkable and more than a simple extension of Sims's image-breeding technique. The difference is in the importance invested in the images themselves: whereas Sims's evolved images are examples demonstrating a range of aesthetic potential, Rooke's images are personal creations, explorations of a distinct style. Whereas Sims is interested in communicating a sense of evolutionary process with the open interactivity of *Genetic Images* and *Galapagos,* Rooke's practice is solitary, focused on the resulting image. It is the personal nature of Rooke's approach that distinguishes him from others in this field. Rather than a calm aesthetic exploration, Rooke's search is a passionate process, strongly linked to a mystical or metaphysical vision:

> Images evolve that look like places I see in my dreams, sometimes complex landscapes I can fly through, sometimes evocative forms that seem familiar, just beyond the edge of recognition. . . . I have seen these shapes and places before, in dreams, in altered states, in rocks, landforms, forests, arthropod shells, galaxies, in microscopes.[21]

Rooke frequently describes his process in terms of familiarity and its own urgent momentum:

> I can't stop. There is something compelling about this process. It feels as though the images are trying to break out of their

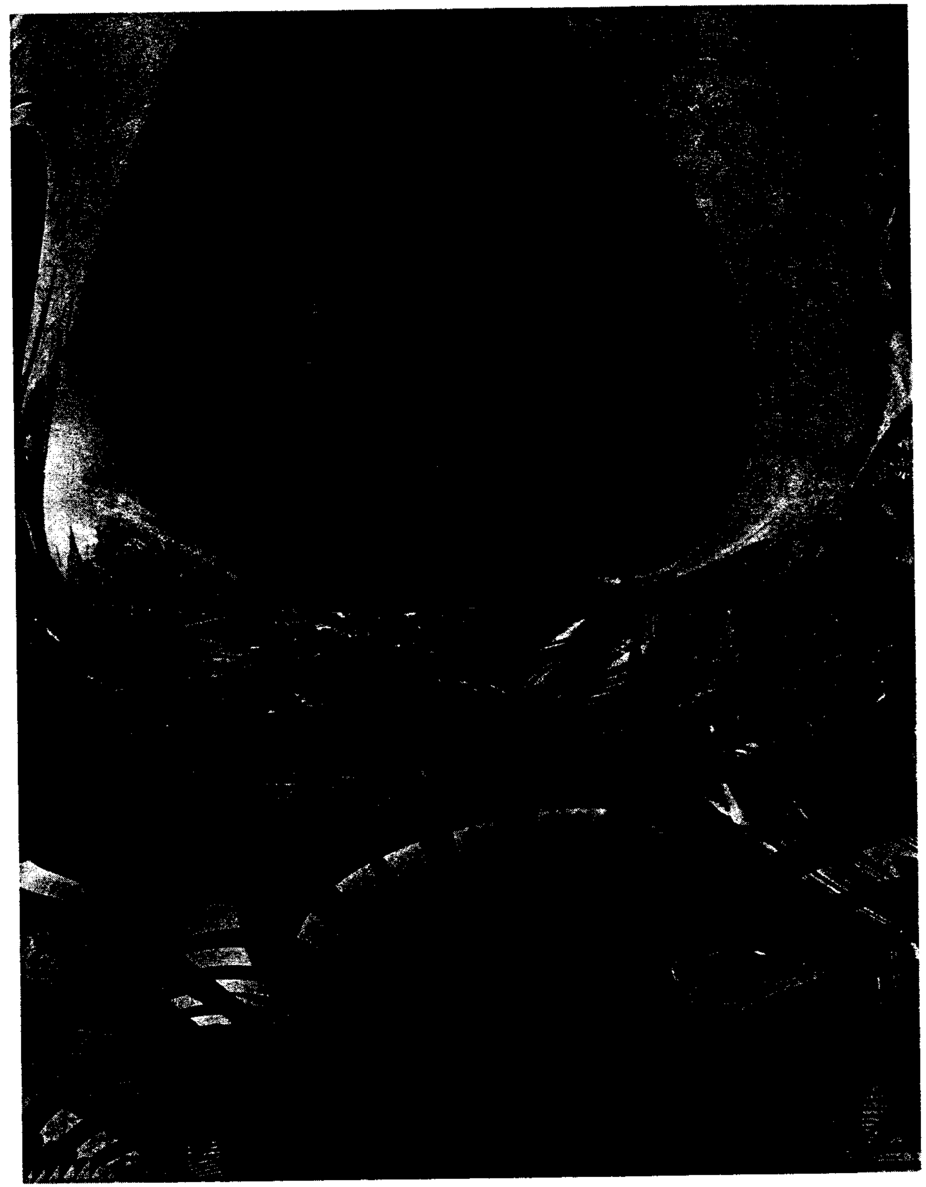

Figure 2.3 Steven Rooke, *Hyperspace Embryo* (1999).

> hyperspace into the physical world. Sometimes I'll be two or three days into a run — dozens of generations with one or two hundred individuals in the population — when Wham! there's something familiar staring back at me from out of the computer screen, demanding to be made real.

As this quotation shows, Rooke is open about his personal investment in this process, and this brings us close to what is most striking about this work. The interest lies not in the techniques, which are already familiar, but in the network of imagery, metaphor, cultural influence, and personal value in which Rooke embeds his practice. Rooke shows that the processes Latham and Sims pioneered are never simply computational but are elements in a discursive complex.

This is clear in the way Rooke draws out correspondences with terrestrial biology and paleontology. Rather than start the evolutionary process from primordial scratch for each image, Rooke begins with "digital amber," genomes already evolved to a certain degree of complexity and stored for future use.[22] (Rooke refers to the preservation of ancient insects and their genetic material in the solidified resin that forms amber.) This involves a reduction in the diversity of possible images that the process can access but limits the exploration to a smaller region that Rooke has preselected as aesthetically interesting. He likens this honing-down of genetic diversity to the evolutionary shakeout that reduced biological diversity after the proliferation of the Cambrian period. So, metaphorically, Rooke is locating his work within a strongly progressive evolutionary flow: rather than the fast, cheap diversity of an initial evolutionary boom, this is about the long haul, the slow evolution of higher orders of complexity. The sheer scale of this evolutionary process — the number of generations an image embodies — has its own appeal: it projects a personal creative process into the expanses of geological time.

Rooke's Web site gives a generous list of acknowledgments that flesh out the personal and cultural context for his work. Aldous Huxley, Rupert Sheldrake, and Terence McKenna stand out from the more familiar artificial life and computer graphics crowd.[23] Rooke describes Huxley's influence as profound and credits his own remission from rheumatoid arthritis to the use of the psychoactive "entheogens" Huxley advocated in his later life. Rooke lists Sheldrake as a personal friend, and he plans to experiment with Sheldrake's suggestion that the inclusion of a "realtime random number generator" in Rooke's software might reveal evidence of morphic resonance.[24] McKenna is influential in his "ideas about the non-physical reality of imagery — a hyperspace where thoughts and souls dwell or visit (his 'invisible landscape') — and their relation to entheogenic states." In fact, Rooke hints that his work actually depicts McKenna's "invisible landscape"; the artist describes the images as psychedelic and reports having "seen these shapes and places before, . . . in altered states." Equally revealing is the work's involvement in a wider psychedelic and New Age culture. Rooke has shown his work in slide form at New Age institutions such as the Telluride Mushroom Festival and the Esalen Institute.

As the combination of Sheldrake and McKenna suggests, there is also a Jungian notion of the archetype at work in Rooke's creative philosophy. This is most apparent as Rooke discusses the possibility of an automated image selector, a software system that evaluates and selects candidates for further evolution, replacing human aesthetic judgment in the image-breeding process. Of course, given a fixed set of criteria for evolution, the process will stop when an image meeting those criteria is generated. However, Rooke proposes that the criteria of the system could actually coevolve with the images, resulting in shifting evolutionary goals. Dawkins proposes this idea in *The Blind Watchmaker,* citing the coevolution of flowering plants and pollinating insects, a process that has led to highly evolved and aesthetically rich structures.[25] Of course, in an automated form, this coevolutionary process is radically accelerated: it could continue, Rooke says, for "zillions" of generations:

> I maintain that no one knows what this process might reveal, or how far it might go. In principle . . . it could lead to the evolution of quite powerful, perhaps universal shapes or forms. Coupled with a realtime source of random numbers from Nature, . . . might it be our first chance at an 'archetype camera'?[26]

This system might also be realized in a system that dissolves the human-machine interface involved in artificial evolution. Live biosensors would link either voluntary body motions such as eye movement or involuntary responses such as changes in skin temperature, brain activity, or heart rate to the selection of images. Rooke speculates that "something like this should lead eventually to . . . a much more fluid, interactive, richer way to pull images out of [people's heads | image hyperspace]."[27]

Rooke's work involves an extraordinary development of the spatial metaphors of Sims and Latham. Their relatively mild notions of form and parameter space are transformed in Rooke's work into an "image hyperspace" that involves a rich mixture of other spaces: it is a computational space of infinite potential (located behind the screen), an inner space of unconsciousness ("people's heads"), a space of psychedelic visions, and a reservoir of natural archetypes. There is a strong sense that this space has an independent or preexisting reality: the space is not generated by the computational process; rather it is *accessed;* the "archetype camera" and the invisible landscape suggest that the images are preexisting forms, found rather than made. Rooke's plans for systems that bypass and accelerate the conscious selection process, through complete automation or an intimate biointerface, feed into the same metaphorical structure and suggest that under the right conditions archetypal images will simply emerge from their inner hyperspace.

NIK GAFFNEY (*MUTAGEN*)

Nik Gaffney's *Mutagen* presents a cryptic surface: a black screen shows a frame and an assortment of glyphlike buttons. With the artist at the controls, the frame fills with a grey, polygonal form, a kind of digital origami, rotating slowly. It is soon replaced by a slightly different form, a complex mass of intersecting facets (figure 2.4). While its aesthetic results have none of the vibrant color or overt organicism of other breeders, and its interface surface gives little away, *Mutagen* pursues a number of interesting conceptual and technical developments.

First, it takes a different approach to the construction of an artificial genome, with a more complex and dynamic genetic structure. In *Mutagen* the genome is a string of hexadecimal numbers, where values in different ranges code for different genotypic properties; some values specify coordinate points, others specify structural relationships, still others influence methods of reproduction. This generates a structure where some genetic elements depend on others for their effects, so that the influence of a particular numerical value on the phenotype will depend on its context within the genome string; codependent genes are grouped together into "chromosomes." This structure is a kind of hybrid of Sims's fine-grained, algorithmic genetic structure (in which elements can influence each other in a similar way) and Latham's procedural-geometric genome, which also codes for three-dimensional structures.

Mutagen also introduces an extra layer of complexity in the process of expression: the translation of the genotype into the phenotypic image or form. In Sims's and Latham's systems, expression is a straightforward mapping or rendering process. Sims's (and Rooke's)

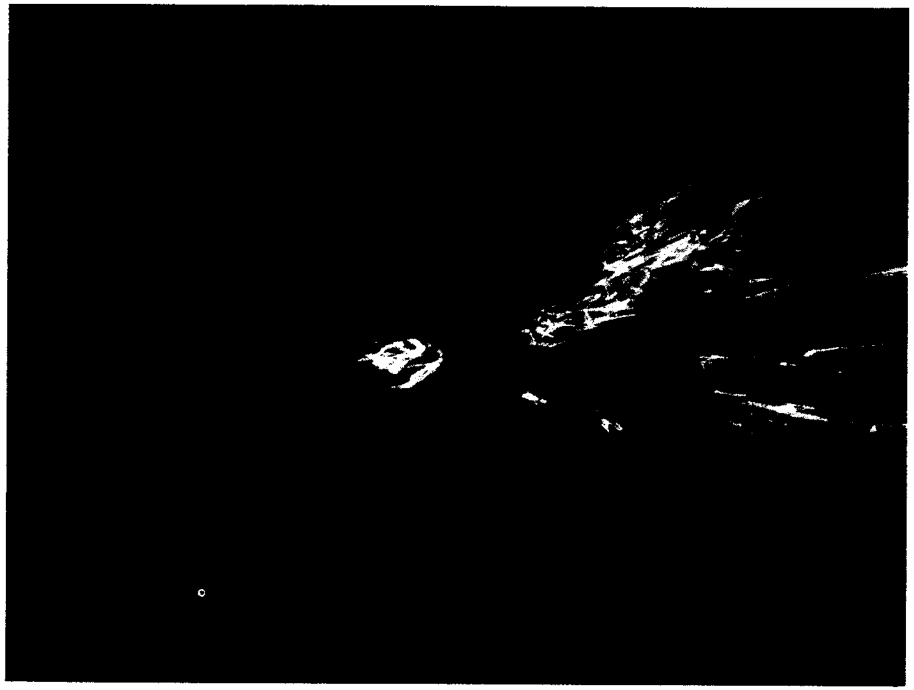

Figure 2.4 Nik Gaffney, *Mutagen* (1997–).

genotype is the equation evaluated to give the image; in Latham's system the genetic material is a procedural description of the phenotype's geometry. *Mutagen* inserts a third formal layer between the genotype and its phenotypic form: the genotype is interpreted to produce a "structure record," a means of encoding a three-dimensional form in a data structure called a directed graph. This data structure draws on the coordinate information specified in the genome but also specifies a hierarchical relationship of those points. What's more, the location of each point is determined not in relation to an absolute grid but in relation to its "parent" in the hierarchy, so each coordinate is in fact a three-dimensional offset, or interval. In a final twist — one that adds significantly to the richness of the forms — this hierarchy can be recursive, such that a point may have one of the "ancestor" nodes above it as a "child." This creates a recursive loop in the structure record, resulting in a portion of the phenotypic form's being duplicated and offset.

Mutagen also diverges from the breeder template in a more basic way: as well as enabling the user to breed forms by aesthetic selection, entities in *Mutagen* can reproduce themselves sexually. Each form applies its own encoded selection criteria to the structure record of a potential mate: open-ended coevolution can occur as attractiveness criteria and phenotypic forms mutate. Of course, Rooke speculates on the potential of exactly this process but with an interest in its acceleration. In *Mutagen* this coevolution occurs at a human time scale and is open to the user's intervention at any point.

However, *Mutagen* resists the user-centered, utilitarian approach taken by other breeders and does so both formally and conceptually. Sims, Latham, and others set out to breed aesthetic objects: the formal templates of painting and sculpture inform the products and processes. *Mutagen* is less concerned with producing aesthetic results than with its own internal processes of aesthetic selection: it sets up a computational space that declines to turn itself toward the user as explicitly as other breeders. Instead, it turns inward: Gaffney describes *Mutagen* as a "basic attempt at finding an aesthetic that is more natural to the simulated environment."[28] He links this approach to Tom Ray's work on evolution "native" to a computational environment, an approach exemplified in Ray's Tierra system.[29] The simulated space in *Mutagen* is counterintuitive, non-Cartesian:

> 3D Cartesian space has been discarded as . . . a simplification that is perhaps irrelevant to the n(on)-space of a simulation. *Mutagen* occurs in a series of Reimann spaces which are based on the form of the individual creatures . . . communication between spaces occupied by the creatures occurs at a speed determined by the relative number of living creatures rather than the distance between them.[30]

A Reimann space is one that, as Gaffney says, is "continuous but not necessarily uniform"; in *Mutagen* the temporal distance between two creatures increases as the population of creatures increases, simply because the computer slows down as its computational load increases. Once again, while this space is counterintuitive, its properties are a product of its computational medium. Where Sims's *Genetic Images* installs the user as a god directing aesthetic evolution, *Mutagen* tends to place the user outside the evolutionary space. It allows a view in through the graphic rendering of the evolved form, and allows a certain amount of intervention, but retains a sense of an autonomous, "other" space that remains inaccessible.

CYBERCULTURE, BREEDING

Rooke and Gaffney aren't alone in following Dawkins, Sims, and Latham into form and image breeding; in fact, a kind of breeder microculture has appeared and flourished in which these processes are taken up in a variety of contexts, not always that of art practice. Much of the other work in this area occupies an interesting fringe zone. Some of these breeders are downloadable freeware, others are commercial products sold as creative tools or graphic ornaments (such as screen-savers). Some of these artifacts are presented as personal experiments, some as computer science research, others as slick multimedia products, others as toys, games, or novelties. In general, they can be neatly divided along the lines of the techniques they adopt. Projects following Latham's use of procedural constructive geometry include Andrew Rowbottom's FORM software — a freeware breeder of virtual sculptures — and Cybertation and DancerDNA, commercial products by (the now defunct) British company Notting Hill Publishing.[31] Others including the algorithmic artist and graphics programmer Ken Musgrave, the Dutch AI researcher Peter Kleiweg, the Japanese AI researcher Tatsuo Unemi, and the American computer scientist John Mount, have all pursued Sims's techniques.[32] Unemi has programmed SBART, an image breeder that runs on a personal computer and provides a useful sense of the nature of the process. John Mount's long-running International Interactive Genetic Art project offers an on-line version of Sims's *Genetic Images* installation, allowing Web users to act collectively as aesthetic selectors. Jeffrey Ventrella programmed a similar project for a Web site spin-off of Kevin Kelly's book *Out of Control,* hosted by Absolut Vodka. Ventrella's Absolut Kelly breeder was designed to produce variants on Absolut's characteristic bottle ads — the bottle shape is hard-coded into the system's genes[33] (figure 2.5).

In an indication of the profile of this genre in popular cyberculture, Ventrella is joined by Sims and Rooke in a little cluster of breeders around Kelly and the pop-cyberculture masthead for which he was once executive editor — *Wired* magazine. Kelly himself reviewed Sims's *Genetic Images* in *Wired* 2.09 (September 1994), and *Galapagos* was featured in *Wired* 6.10 (October 1998).[34] Rooke's work was featured in a double-page pictorial in *Wired* 3.12 (December 1995);[35] Rooke also joined such digital art stars as Kai Krause and Jim Ludtke in producing his own Absolut Vodka commercial,

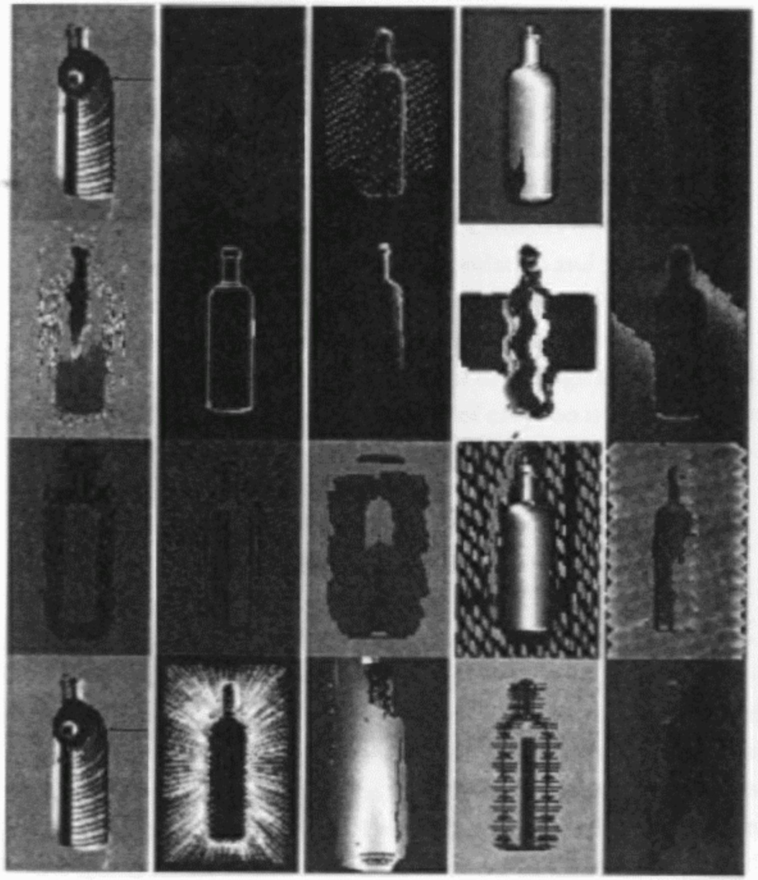

Figure 2.5 Evolved vodka bottles from Jeffrey Ventrella's *Absolut Kelly* breeder.

printed on the back cover of *Wired* 4.04 and 4.11 (April and November 1996). It is tempting to see Kelly and *Wired* at the center of the breeders' cultural territory: *Wired* has clearly been important in popularizing this work within mainstream cyberculture, and its brightly colored cyberaesthetic and technoevolutionary tendencies fit well with the work of Sims and Rooke. Such an identification doesn't account for the field as a whole, however, as the divergent aesthetics of Latham or Gaffney demonstrate.

What the breeders grouped around *Wired* do illustrate is the genre's partial commercialization and the absorption of algorithmic cyberdelia and evolutionary proliferation into the graphic language of advertising. Notting Hill once promoted software called DancerDNA, which promised to "enable you to evolve infinitely varied, organic creations which dance to music."[36] The company generated a cultural identity around the product by linking it to the U.K. dance music scene; DancerDNA is used to generate live animated visuals in clubs. Remarkably, Notting Hill also promoted the software as a digital advertising medium in this context: "a superb new tool for delivering corporate brands . . . to the youth market at clubs and live events."[37] Some of the more prominent figures in this field are also bringing their software to market: Latham's company, Computer Artworks, offers Organic Art, a software package based on Latham's earlier evolved work, with a screen-saver "continually creating new mutations" automatically and a "fully interactive . . . unique Evolutionary Generator."[38] Computer Artworks has subsequently become a games developer: its titles include *Evolva*, "a tactical shoot-em-up" where both alien creatures and Genohunters, the player's proxies in this world, use artificial evolution.[39]

As these examples show, the breeder now exists as a generic form not only within media art practice but in cyberculture at large. As well as providing a sense of cultural context, these commercialized breeders are useful in evoking a critical response. Of course, the commercialization of artificial evolutionary processes is unremarkable in itself; what is striking is the way in which the process is sold. Analogies with life and evolution are central: what could be more appealing than "creating a world where life evolves," generating "infinitely varied organic creations"?

Driven by the imperative of advertising, a certain promise crystallizes: a promise of endlessness, novelty, even life itself. This promise, which is very significant for a-life art in general, is taken up in chapter 7, Emergence. More immediately, a critical approach to this work can begin by considering the two dominant figures underlying this promise: biology and creative agency. Latham's claim for his Organic Art screen-saver makes a neat encapsulation and prompts some questions: If these works are largely about "continually creating new mutations," what does *mutation* mean here? More generally, what kind of resemblance do these systems bear to biological genetics and evolutionary processes? Also, what kind of creation is this? How do these works operate in terms of creative agency and in relation to familiar categories of artist and artwork?

Biomorphs

As mentioned earlier, the breeders of Sims and Latham share a common ancestor. Both artists refer explicitly to Richard Dawkins's Biomorph system; and its influence is clear.[40] In Dawkins' system the user selects two-dimensional line drawings for reproduction; the genes of these biomorphs are, as with Latham's forms, parameters describing structural features. Before Sims and Latham, Dawkins used spatial terms to describe the genesis of these forms: he argued that although the process of guided selection feels creative, "what you are really doing is *finding* the creature, for it is, in a mathematical sense, already sitting in its own place in Biomorph Land."[41]

Given its importance in the development of the genre, Dawkins's system merits some attention; in particular, it offers a way to address the analogy at the core of this genre, between computational and biological evolution. Dawkins presents the biomorphs in support of an argument for the capacity of evolution; specifically, "the power of . . . cumulative selection," where accumulated small changes produce complex, statistically "improbable" results.[42] Cumulative selection is Dawkins's answer to the argument that living things are too complex or well-adapted to have come about by chance, and the biomorphs provide an example that supports this case: Dawkins shows a long sequence of biomorph mutants, each slightly different from the last, beginning with a protean dot and ending with an elaborate insectlike form.[43] Step by small step, we can see the evolution of complex form occurring.

When considering the technical details, however, the biological resemblance wavers: every level of this simulation contains a drastic simplification of biological genetics. Here, both genotype and phenotype are static entities, fixed patterns of digital information. The genotype is a concrete recipe, a formal procedure for making the phenotype: genotype becomes phenotype in an instantaneous, deterministic process of expression. In "wet" embryogenesis (which Dawkins links explicitly with the biomorphs[44]) genetic expression occurs not once but millions of times, as each cell divides, and each expression is context-sensitive, producing different cells in different structures. The path from genotype to phenotype is riddled with complex loops; genes form regulatory networks that, in tandem with environmental influences, dynamically alter the process of expression. The phenotype and genotype, entirely separate in Dawkins's system, operate in biological life embedded in the same material and temporal stratum, components in a dynamic physical system that is continuous with the organism's environment. The only sense of environment for Dawkins is the most rudimentary imaginable, that embodied by the process of user-driven selection.

Of course rendering life's most powerful complexities in the formal logic of computation demands some kind of simplification, and

Dawkins would surely acknowledge that the biomorph model is particularly simplistic. But still, a variety of complex stick figures do evolve; some kind of morphogenesis is occurring. Dawkins carefully couches that morphogenesis in terms of biological evolution; in the example involving a long sequence of biomorphs, the initial shape is "a dot, like a bacterium in the primeval slime."[45] The impression is that these forms evolve from primitive scratch: in fact, Dawkins has, in setting up the procedural structure of the genotype, already provided a fixed genotypic language corresponding to a specific set of possible phenotypic forms (branching lines). While any genetic simulation must set up some such structure, it seems there is no such high-level grammar in biological genetics. Without installing an omniscient programmer to supply metastructures for biology, or some imperceptible morphic field, we must believe that life has formed itself out of the immanence of matter in time, at every scale from the molecule to the ecosystem. The macrostructures we see in living things are not predetermined elements but have themselves coevolved. Dawkins's genotypic grammar is effective *for its designed purpose* — to allow the rendering of a variety of forms from a single procedural structure with variable parameters — yet this effectiveness in itself is not an indication of any link with biology. As Stuart Kauffman has said of Dawkins's Biomorph breeder,

> There's less there than meets the eye. . . . It's clear you can generate varieties of morphologies, if you have something called a genotype that makes something called a morphology. . . . The part I tend to dislike in what he's done is that there's nothing natural or self-organized or robust about the development mechanisms and morphologies that Richard posits. He simply has computer programs arbitrarily draw stick figures or whatever. That's not how real development works.[46]

Spaces of potential — form space, parameter space, image hyperspace — feature prominently in the explanatory discourses of Sims, Latham, and Rooke. So, too, in Dawkins's writing, the concept of genetic space is introduced as "a way to understand evolution as a gradual, cumulative process."[47] A single mutation in Dawkins's simulation is an incremental change in a single parameter, a single step in a nine-dimensional genetic space. As a parameter space this is a useful way to imagine the range of variation of a set of variables, but analogized as gene space and later as animal space, it is more troublesome. Dawkins transfers the genetic space of Biomorph Land easily across into biological evolution: "There is another mathematical space filled, not with nine-gened biomorphs but with flesh and blood animals . . . each containing tens of thousands of genes. This is not biomorph space but real genetic space."[48] For Dawkins, this space is traversed by the evolutionary trajectories that have produced all real organisms, past and present; areas outside these trajectories are inhabited by "theoretical animals that *could* exist" and hypothetical "impossible monsters." As a figure, this animal space is useful, Dawkins argues, as a way to think about evolutionary change moving through small mutations across a wide range of forms. However, it retains the character of its origins as a formal parameter space: by smoothly importing the spatial metaphor from a *simulation* of evolution, Dawkins implies that biological evolution has a parallel structure. When Dawkins says that extinct species are "lurking there forever in their private corners of that huge genetic hypervolume, waiting to be *found,*" he can't help but imply that evolution somehow realizes preexisting permutations of a genetic code that wait in some vast timeless vault. Absent in this figure is any sense that genetic space itself can change, or has changed, as variations in the amount of genetic material across species suggest. Also absent, although not inherently contradicted by this figure, is any sense of evolution as a cooperative process, one involving interactions between organisms. In Dawkins's computer model it is the singular phenotype, the lone organism that is selected; the evolutionary trajectories he discusses are heterogeneous lineages through genetic space, paths one organism wide. In a coevolutionary model, species' interactions mutually alter their evolutionary potential; the Platonic reservoir of animal space becomes dynamic and recursive, opening and closing its own trajectories from the inside.

The character of the animal space image, and its basic tendency to equate biological evolution with a formal process, aligns more broadly with the kind of evolutionary theory Dawkins has helped popularize. In this ultra-Darwinism the diversity of the biosphere can be described solely in terms of natural selection operating at the level of genetics. Its focus on the codelike qualities of DNA seems at least partly inspired by developments in computer science; the use Dawkins makes of the biomorphs indicates his willingness to draw comparisons across these fields. He makes an even more explicit analogy between DNA and digital memory in *The Blind Watchmaker.*[49] Within biology and evolutionary science and within wider culture, Dawkins's work is both influential and controversial. While the simplicity and apparent efficacy of ultra-Darwinism is appealing for some, it has encountered considerable resistance among a wide circle of biologists, including for example, Stephen Jay Gould, Lynn Margulis, and Stuart Kauffman, who argue for more complex and materially entangled models of selection and evolution.

Breeders and the Biological Analogy

Given the close links between Dawkins's biomorphs and the breeders of Latham and Sims, what is the significance of Dawkins's computational model for the artistic work it has inspired? In particular, what relevance does Dawkins's tendency to genocentric oversimplification have to the creative aims of artists using systems derived from his biomorphs? The answer is linked to the relative significance of this biological analogy in the construction of each artist's work.

In Latham's case, the centrality of the biological analogy is clear; from his initial interest in natural formal grammars and their manual

realization to his engineering of reproductive cycles for his animated forms, his work shows a continued interest in the formal structures of life and the (artificial) syntheses they enable. Formal structures are prominently displayed in Latham's *Mutations* installation; text from the genetic code of the forms appears alongside images of their rendered phenotypes. This expository style is also evident in the titles of the exhibitions themselves: *Mutations, The Conquest of Form.* Sean Cubitt, in a powerful analysis of Latham's work, recognizes in it an organicist aesthetic of "wholeness and ordered alteration."[50] This work is less about pretty virtual sculptures than about the processes of morphogenesis and evolution themselves and Latham's formal/grammatical reconstruction of these processes.

However, it is notable that the language Latham uses to describe the relation between his work and the biological processes it models is ambiguous, if not completely negative. The works "use and abuse for artistic ends the current scientific theories of life, and can be viewed as a comment on later twentieth-century genetic engineering"; the artist also describes them as using "a parody of genetic engineering" and commenting on "the wanton destruction of the natural world."[51] If Latham's virtual sculpture works of the early 1990s have an edge of the grotesque or monstrous, perhaps this equivocation explains why; this is not a benign flourishing garden of elegant formal essences; it is a fabrication, a coopting of nature's mechanisms spawning a litter of ugly digital crustaceans. Perhaps Latham's work parodies Dawkins-style genocentrism in the same way it parodies genetic engineering; if so, it is simultaneously critical of its own formal basis.

Sims seems more clearly sympathetic with Dawkins's ideas: in one discussion he aligns *Genetic Images* with Dawkins's central argument for the creative capacity of evolution. Sims hopes that *Genetic Images* will "provoke an awareness of the power of the evolutionary process in general — in simulation, as well as . . . in the world around us."[52] However much of Sims's work has complicated the simple genetic model Dawkins uses. Even in *Genetic Images,* the complex mutability of the genome and the corresponding openness of the image space it defines are in dramatic contrast to the fixed structure and parameter space of Dawkins's procedural model. Sims's later work on the evolution of locomotion in a virtual physics uses a genetic structure that is still more complex and dynamic. Sims has also done work on coevolution and competition in artificial creatures, aspects of evolution that Dawkins all but ignores in *The Blind Watchmaker.*

In fact, Sims seems well aware of the relative simplicity of the kind of simulations used in *Genetic Images;* it is with this in mind that he draws our attention to the surprisingly rich results of the process. The work doesn't rest on claims to be a perfect simulation of biological genetics; instead, it is interested in the results that emerge from a specific, limited application of evolutionary and genetic structures. Gaffney's *Mutagen* is similar: while it goes to some trouble in constructing a system that mimics biological genetics, using a chromosomal model where genetic expression is context-sensitive, *Mutagen's* model is, in Gaffney's words, "extremely simplified."[53] Again, biological accuracy is not a measure of the validity of the work. Gaffney is concerned, as we have seen, with a process that is in some sense native to the computer, a process that draws its models from evolution but absorbs and exploits the peculiarities of its digital implementation. The biological figures remain as descriptive terms and analogies, but the focus of the work is on synthesis rather than simulation. It begins to part company from its biological referents and turns inward.

Steven Rooke's work follows this pattern. While the biological analogy permeates Rooke's accounts of his own process, the veracity of this analogy is less important than the potential of the computational process it has inspired. Rooke talks about breeding, mass extinctions, "virtual genes," and "digital amber" by way of explanation, but he is principally engaged by the process itself, by its expansive aesthetic potential and its mystical or archetypal implications. The compulsive pull Rooke describes, and the sense of dreamlike or natural-mystical familiarity he reports, suggests that like Gaffney, Rooke's process has peeled away from its biological analogy and begun to acquire its own self-sufficient dynamics.

Perhaps this genre can be described as a sort of transverse movement; Dawkins's biomorphs have been adopted sideways into art practice, where their biological referent works as a convenient analogy that resonates strongly with existing organic metaphors for art and art making, but where the generative potential of the process, its promise of excess, acquires its own momentum, independent of any strict biological correspondence.

BREEDING ART

This practice refers to, adopts, and adapts biological models of genetics and evolution but does not identify with them in any straightforward way. Pursuing its other dominant figure, creation, reveals similarly complex relationships, involving both the discourse around the works and the forms of creative agency suggested by the works' own processes.

In Latham and Rooke, that agency seems initially to operate in a straightforward way. Both identify themselves as artists; both make and sell objects identified as artworks. Here artificial aesthetic evolution is the process, and the aesthetic result, a digital artifact, is the product. However, details in the writing of both artists suggest a more complex relation of process, agency, and artist status. Todd and Latham discuss the way their evolutionism "changes the role of the artist in creating an art work."[54] That role is twofold, involving "the creation of generative systems and structures" on one level and "the selection of specific forms and animations" on the other. While the authors anticipate that these roles might be performed by different people such that the artist's role becomes "less clear," they vigorously distance themselves from any such confusion. They declare that "for Latham's works there is no ambiguity . . . Latham is clearly the artist." This assertion is extended: "[Latham] invented the evolutionism style. . . . [He] will remain creator of the style in the same way that Picasso is the father of Cubism and Haydn of the string quartet" (210). They even claim that any future work using aesthetic evolution will be the "joint creation of Latham" and the artist-breeder.

Latham and Todd introduce an analogy linked to this twofold artistic role that suggests another important side to the constructions of agency operating in these systems. "The artist first creates the systems of the virtual world . . . then becomes a gardener within this world he has created" (12). The authors frequently refer to these roles simply as artist-creator and artist-gardener. Kevin Kelly makes the implicit explicit when he concludes an article on Sims by announcing, "The artist becomes a god, creating an Eden in which surprising things will grow."[55] To one reviewer, Latham's work suggests "anxiety . . . in the face of a pervasive god-like omnipotent fantasy, provoked by the possession and control of powerful technical equipment."[56] Latham's depiction of himself as the creator of a virtual world replete with organic form certainly suggests such an "omnipotent fantasy." Equally revealing, however, is the psychology of the shift from creator to gardener. In formal terms this switch in roles implies a shift in frame of reference: the systems that were explicit constructions for the creator become implicit for the gardener, expressed in the particularities of form they allow. The joy of the gardener comes from being surprised in the garden, confronted with the autonomy of the evolved form, but the creator at once recognizes it as one of his own, a manifestation of the structures already set down. Being lost in the artificial garden is to be both surprised, overwhelmed, or exceeded, and at once safe within the formal enclosures of a computational space.

Steven Rooke reflects something like this desire for selflessness or surrender in the way he constructs his own position as an artist.

Rooke's background is in geology, programming, and image analysis; he acknowledges his outsider status, but it only serves to return him to the images: "I cannot speak the language of a traditional artist, as I have no such background. Instead I must rely on what the images themselves are telling me, and the process that produces them."[57] Rooke adopts a familiar position: the artist as lone mystic, driven deeper into his work by solitude. In his accounts of the image-breeding process he depicts himself being swept away by its autonomous momentum, dictated to once again by images "demanding to be made real." Relying on "what the images themselves are telling me," Rooke attributes the primary agency to the aesthetic object and constructs himself in a position that is both servile or interpretive and mystically intimate; it is, after all, a kind of inner vision that drives the image selection. However, Rooke's work is also shaped by the aesthetic responses of others: criticism in mid-1996 that his images lacked depth and were too "textury, undimensional" triggered a search resulting in the discovery of a key landscapelike image that provided a genetic seed for the artist's subsequent evolved images.[58]

In more expansive speculation along the same lines, Rooke suggests that the response to his work in the marketplace will influence its evolution. Rooke implies that offering evolved art for sale (as he currently does) is a way of coupling its long-term evolution to another complex system: the market.[59] Where the aesthetic objects are able to adapt to the market's whims, the artist plays the role of a conduit, an agent, giving people what they really (archetypally) want in a spiral of desire and fulfillment. So, while Rooke is deeply engaged in the technical development of his breeder in a quest for more transparent access to ever richer image spaces, he repeatedly sets his own creative agency aside: as with Latham, any self-consciousness about the artist's role in constructing and constraining the evolutionary process seems less attractive than the experience of being lost in, overwhelmed, or even spoken to by that process.

In Sims's and Gaffney's breeders, control of the process is willingly relinquished: Sims and Gaffney stay in the creator role, defining the structures underlying an aesthetic space that others explore. The composite or collaborative agency this suggests, the same complex agency that threatened Latham's sense of his own status, is something Sims explores with more enthusiasm: this is "an unusual collaboration between humans and machine" that "permits the creation of results that neither of the two could produce alone."[60] He also asks what kind of creation this is:

> Can this interactive evolution of images be considered a creative process? . . . A designer seems absent in this process, and yet very complex and interesting results can still arise. If enough selections are made by the user and the number of possibilities is large enough, is the user actually being creative?

Sims ultimately identifies *Genetic Images* with evolution's paradoxical designer-free creativity, a creativity of accident rather than good. He further implies that the creativity here lies not with the user as an individual but with the whole evolutionary process — a process that accounts not only for biological diversity, Sims suggests, but for "scientific theories, religious beliefs, or even artistic styles."

Sims's appeals to a generalized evolutionary creativity begin to dissolve the role of the individual user or selector, just as in *Genetic Images,* an individual's sequence of preferences might be absorbed by a longer-term, more collective process of evolution. The importance of the subjective process of breeding aesthetic objects cannot be neglected, however. Its compulsive grip on Rooke is clear, but the response of a normally staid Dawkins is even more remarkable: "I cannot conceal from you my feeling of exultation as I first watched these exquisite creatures emerging before my eyes. . . . I couldn't eat, and that night 'my' insects swarmed behind my eyelids as I tried to sleep."[61]

The moment of alteration is crucial to this engagement: as Sims explains, creative variation is "succinctly executed by the computer" in the form of a random mutation. This computational mutation is the key to an understanding of the creative agency at work in these breeders, one that operates through preference and selection rather than active construction. The passive position of the artist/user is particularly important: the computer tirelessly, "succinctly" varies the aesthetic object and can do so quickly, easily, and endlessly. Propelled at speed through generation after generation, the artist enjoys an exhilarating excess of choice, as new objects/creatures appear and are left behind. With the effortlessness of mutation comes an accelerated loop of change and selection that can continue indefinitely; one can transform the object endlessly, following the slightest whim of preference, the tiniest margin of desire. The creative process is extended into an endless deferral of its object. An analogy can be made with the psychology of shopping, an activity that in affluent cultures offers not material necessities but sheer desire, the endless promise of more. Similarly, the psychology of breeding aesthetic objects is caught up with the process more than the object, a spiral of variation, desire, and selection without apparent limits. Perhaps the strength of the desiring loop these works set up explains the intensity of the processual engagement expressed by Rooke and Dawkins.

As this rush of "accelerated evolution" feeds itself, it risks rendering its aesthetic objects meaningless. In this overflow of image material, how can one mutant claim more significance than another? When evolution is this fast and this easy, how do we interpret its results? Moreover, as visual artifacts, these evolved images are strangely and completely empty. The formal-procedural grammar that underpins them is a-scalar; a single image is an arbitrary, infinitely detailed window in an infinitely large coordinate plane. A rendering of an image at a certain resolution might produce something resembling a kind of decorative abstraction, though without the materiality or the gestural quality, the index of human agency, of a painting: like a fractal, it recedes forever within the frame and extends indefinitely outside it. These products of aesthetic selection represent a strange coupling, as Sims suggests, between an a-scalar, a-human generative process and a human aesthetic perception.

Kelly describes Sims's images as "mirages . . . of an alien beauty"; however, often the beauty that these artists breed moves away from the inherent strangeness of its underlying generative language and toward more conventional modes of representation.[62] In one article, Sims presents an image evolved to resemble a face, suggesting an urge to find an image of the human, a mirror, in these vast abstract fields.[63] In one sense, Rooke's account of his move towards more illusionistic landscapelike images shows a similar desire to find a familiar pictorial language. Images such as *In the Beginning* and *Skaters* illustrate the tension between formal generative elements (the distinctive fractal curls, flattened and stretched throughout the images) and representational convention (the horizon line, the sense of illusionistic depth).

Rooke's work also shows very clearly how the metaphors attached to the breeding process inform its products. The increasingly spatial nature of Rooke's images resonates strongly with the other linked spaces he discusses: the image hyperspace, McKenna's "invisible landscape," the Jungian archetypal reservoir. It seems Rooke is trying to depict in his images the very space he imagines them to inhabit; but, as well, the images operate literally as spaces, spaces in themselves. A vast, high-resolution print of the image swallows the viewer up:

> I suppose I am known as something of a fanatic about image resolution, or detail. For me, there is never enough. I want to print these images at the largest size, with the finest resolution and quality available. . . . Picture seeing a large mural from a hundred feet away. As you walk closer to it, you see increasing detail — right up to the limit of your vision 12 inches away.[64]

The same sense is evoked as Rooke projects slides of his works onto the bodies of dancers: "When people enter the images, sometimes a phenomenon happens where the dancer feels like they're snapping into and out of the image ('Am I in the image, or is it in me?')."[65] Rooke refers to this technique as "slide immersion."[66]

Finally, the strange emptiness of these aesthetic objects is filled by the metaphorical constructs operating around the process itself. In the case of Sims and Latham, those constructs are largely self-referential, Dawkins-inspired evocations of the power of evolution and the unstoppable (if accidental) emergence of form, richness, or beauty. In Rooke's work those constructs are more diverse and multilayered; his personal mythology of image hyperspaces, Jungian archetypes, and immersive selflessness both feeds and is fed by the image-breeding process.

This analysis began with an unpacking of a phrase of Latham's advertising a commercial breeder/screen-saver "continually creating new mutations." The complex operations of creation and mutation have been set out, but perhaps the other two terms in that phrase are equally important in suggesting an account of the operation of these works. Both creation and mutation (and the genetic substrate they rely on) are primarily concerned with the continually new. While these artists use biology as a metaphorical staple, they ultimately uncouple themselves from biological simulation to pursue the abstract potential of their own artificial hyperspaces. The forms of agency these works set up suggest that what drives them is an internal a-referential feedback loop of desire, inspired by the sense of synthetic potential offered by artificial evolution — the combination of godlike control over underlying structure and its nearly effortless and endlessly various realization.

Figure 3.1 *Interactive Plant Growing*, © 1992 Christa Sommerer and Laurent Mignonneau. Interactive computer installation. Collection of the Mediamuseum at the ZKM Karlsruhe.

Breeders involve a coupling of human agency with a computational process of variation; recall Latham's notion of the artist as a gardener participating in an artificial ecology, acting as a selector on the evolution of forms. The garden here is generally a blank, passive entity, a process of combination and random variation. However, works such as Gaffney's *Mutagen* already suggest a more complex and autonomous system, one where human agency operates alongside artificial agencies; where Latham's garden of static forms springs into computational life.

A-life science has engineered a variety of artificial ecosystems, computational systems that model (or perhaps instantiate) aspects of the dynamics and behavior of biological ecosystems. These are con-

tained artificial worlds: landscapes inhabited by entities with artificial genetics, entities that interact with each other and their "environment," "eating" and being eaten, "mating," being "born," and "dying." Whereas the breeders operate at the microlevel of genetic code, these systems present a more dynamic macroscale: whole artificial organisms, in artificial spaces, living artificial lives.

Artists have followed a-life science in building artificial ecosystems, but whereas scientists have been primarily concerned with replicating the dynamics of biological systems, artists have often approached them as virtual environments, contexts for human experience and interaction.[1] Breeders involve the audience (by proxy through the artist or directly) in a stepwise process of creation, where each result is a frozen formal entity, but an artificial ecosystem offers something more: involvement in a real-time, dynamic system made up of multitudes of autonomous entities. Artificial swarms swirl around us, pixelated plants grow underfoot; virtual jellyfish throb in an interactive pond, each chasing another in search of a meal or a mate. Whereas the breeders are organized around a drive for aesthetic variation, these artificial ecosystems are more concerned with dynamics of interaction and the construction of a whole, living space.

A remarkable synthesis seems to occur in this space; out of a system made from expensive computers and video projectors comes something that looks and responds like a living natural system. Technology takes on the behaviors and appearances of nature, often setting itself aside in the process: this is cybernature, a construction that is central to the work considered in this chapter. Like the biological analogy discussed in chapter 2, this is a troublesome, awkward figure; in the following discussion it sits, with those works that adopt it, at the focus of critical attention. Not all of these works endorse that construction; instead, some take it as a critical object, examining the tension between the natural and the informational that the cybernatural glosses over. Others pursue alternative approaches, drawing attention to the entanglement or separation of a natural outside and a computational inside. As a group, these works deal directly with a basic tense articulation (which underpins a-life art and a-life in general) between the made and the born, computation and life, artifice and nature. What makes them interesting, though, is that they never split neatly into these established binaries; nature and technology are fused, confused, and transposed, indistinguishable in the thickets of pixelated foliage.

Christa Sommerer and Laurent Mignonneau

Christa Sommerer and Laurent Mignonneau are two of the most prominent creators of interactive cybernatures. Their *Interactive Plant Growing* (1993) (figure 3.1) is an important early work in this area, something of a classic in interactive art in general and a-life art in particular. In *Plant Growing* five potted plants — ferns and a small cactus — stand illuminated on waist-high plinths in front of a large video projection screen. Initially the screen is blank, but brush or touch one of the plants and a moving image appears. It is a computer-graphic plant, a detailed, three-dimensional fernlike thing, rapidly growing frond by frond; continue to brush the fronds of the real fern on its pedestal and the artificial ferns proliferate on the screen. Others may join in, ruffling the other plants and generating different artificial species: vines, trees, and mosses. Members of each species are similar but not identical; in fact, their shape is influenced by the visitor's interaction with the real plants, which are fitted with small electrodes. The high-end computer running the installation senses tiny changes in the electric potential of the plant caused by the visitor's interaction, and these changing voltages influence shape parameters in the virtual plants: their size, color, and orientation. Over time the virtual plants accumulate on the screen, overlapping to form a dense tangled jungle; touching the small potted cactus triggers a "killer plant," which dissolves the screen back to its original black, clearing the virtual garden bed for a new crop.

As the broken symmetry of potted plants and virtual plants suggests, the articulation of the virtual and the real is central here. A living physical system forms a supple interface to control a virtual generative process, which in turn mirrors that living system. The use of real plants as sensing entities adds a "natural" complexity because the voltage fluctuations vary with the individual size and shape of the real plant. The real-time influences on the growth of the virtual plants are left to the visitor to discover, so that learning to control the virtual plants involves establishing a gestural and tactile relationship with a real plant. The artists go slightly further, claiming that "[s]ince it takes some time for the viewer to discover the different levels for modulating and building the virtual plants, he will develop a higher sensitivity and awareness for real plants."[2] As well as connecting plant and person in an interface pair, the work allows up to five people to collaborate in growing a virtual jungle; the loop of human-plant-computer interaction extends to include multiple participants.

Sommerer and Mignonneau's later works develop various aspects of *Plant Growing*, but all share a concern with intuitive physical interfaces — the artists call them natural interfaces — which enable real-time interaction with virtual ecologies. In *A-Volve*, first shown at Ars Electronica in 1994, the artists create a virtual pond: in a darkened room, a video-projected image is reflected onto the underside of a shallow glass tray filled with water (figure 3.2). In this pond, strange virtual creatures seem to swim; a variety of textured abstract forms pulse like jellyfish, moving slowly around. At the pond's edge, visitors gather and dip their hands: the creatures may recoil or approach, and the slower ones can be easily caught, encircled by a pair of hands. Of course, these creatures are more than playthings for the human visitors: they have artificial lives to live and are busy avoiding being eaten by faster creatures in the pool, seeking out mates, and reproducing before their limited life spans expire. These abstract jellyfish constitute an artificial ecosystem.

In fact, *A-Volve* is a virtual ecosystem of some complexity; the system models the creatures' jellyfish-style locomotion as well as rudimentary vision, and builds in a range of behaviors including collision avoidance, predation, mating, and parental protectiveness.[3] An artificial genome codes for each creature's shape, color, and texture; when two creatures mate, their genomes combine in the single offspring, which will have a form that is some combination of its parents' forms. Crucially, this variation is also functional: in *A-Volve* each creature swims by way of a muscular pulse, which travels along the axis of its form. Because the system models physical dynamics, some radial forms will be better swimmers — generate more forward motion — than others, and in this pond, where creatures are competing for food and mates, swimming speed is important.

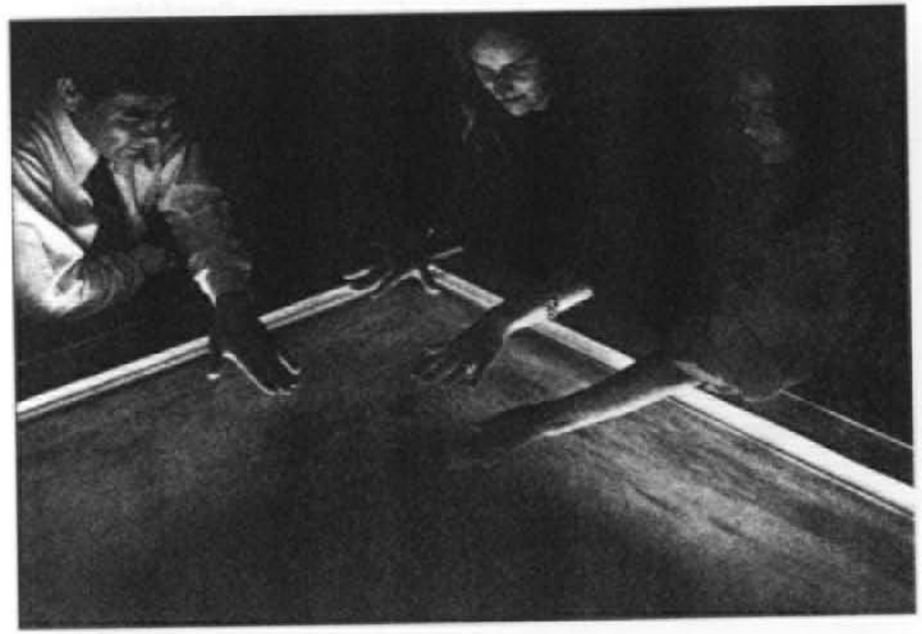

Figure 3.2 *A-volve*, © 1994 Christa Sommerer and Laurent Mignonneau. Interactive computer installation. Supported by NTT ICC, Japan, and NCSA, USA.

Better swimmers will eat more and have the energy to reproduce more often; their genes will proliferate. This artificial ecosystem is artificially evolving.

The artists' innovation here is to open the system to human influences, so that visitors are involved in the life of the ecosystem; in fact, they are a complex selection mechanism in themselves.[4] Most directly, visitors can create new creatures in the pond by drawing on a pressure-sensitive tablet at one side of the installation. The drawn profile is spun (as if on a virtual lathe) to create the new creature's radial three-dimensional form. Because form is so closely linked to swimming ability (and thus fitness), these interventions might introduce to the pond a new deadly predator or hapless slow-moving prey for the existing population. Visitors can also influence this system in a more open interactive way: a shape- and motion-tracking element in the installation detects visitors' movements over the pond, fusing the projected virtual space of the artificial creatures with the physical space of the installation. This mechanism allows the virtual creatures to respond to a real hand dipped in the pond. This physical interaction allows for some significant interventions: a visitor might prevent a creature from being eaten by restraining the predator or protecting the prey. Two creatures can be encouraged to reproduce by herding them toward each other. Allowing visitors to create new creatures for the pool adds an element of personal identification that motivates this intervention; a visitor might protect her "own" creature, select its mates, or even catch its food. As with *Plant Growing,* the artists suggest that this identification with the virtual environment feeds back into the real space of the installation, fostering communication and interaction between the visitors.

This enmeshing of the real and the virtual is further developed in *Trans Plant* and *Intro Act,* both first shown in 1995. These works use a patented 3D video key, a system that embeds a real-time video image of a single visitor within an artificial 3D space. In these works, motion tracking interprets the visitor's movement in order to influence the growth of the surrounding 3D forms. In *Trans Plant* these forms are highly detailed and realistically plantlike, and sprout following the visitor, whose size, speed of movement, and distance from the screen influence the virtual plants' size, shape, and species. As in *Plant Growing,* the visitor generates a burgeoning virtual jungle; the visitor's image is inserted seamlessly into that virtual space, and the jungle literally springs up at her heels; the visitor's body is endowed with the power to generate life in tangling, green, 3D abundance. In *Intro Act* the generated forms are more abstract: wormlike tendrils grow and are destroyed in response to particular detected gestures; the visitor is cocooned in a tangle of vines that grow not from a ground but from beyond the edges of an empty virtual space. Here it is not simply nature that is called up, but something more expansive: the visitor shapes an entire world: "he defines it, creates it, destroys it and explores it"; for the artists, the piece "represents a universe of unexplored organic forms that react and interact with human beings."[5] The artists emphasize the personal nature of the interaction in both pieces. In *Trans Plant* each visitor "will bring up his/her own virtual forest, that is an expression of his personal attention and feeling for the virtual space."[6] Similarly, *Intro Act* aims to "create a personal environment, where visitors find themselves freely interacting with the virtual space, become part of it and essentially create this space by themselves."[7]

Later work by these artists combines the simulated ecosystems of *A-Volve* with the video key immersion of *Trans Plant* and *Intro Act* and also adds on-line interaction. *Life Spacies* (1997) involves two physically separate but networked projection spaces, where participants see themselves inside the same virtual space, a thicket of virtual vegetation crawling with virtual creatures (figure 3.3).[8] As in *A-Volve,* these creatures react to human presence and can be caught; when a lone participant catches a creature, it immediately clones itself; two participants can cause two of the creatures to mate by catching them

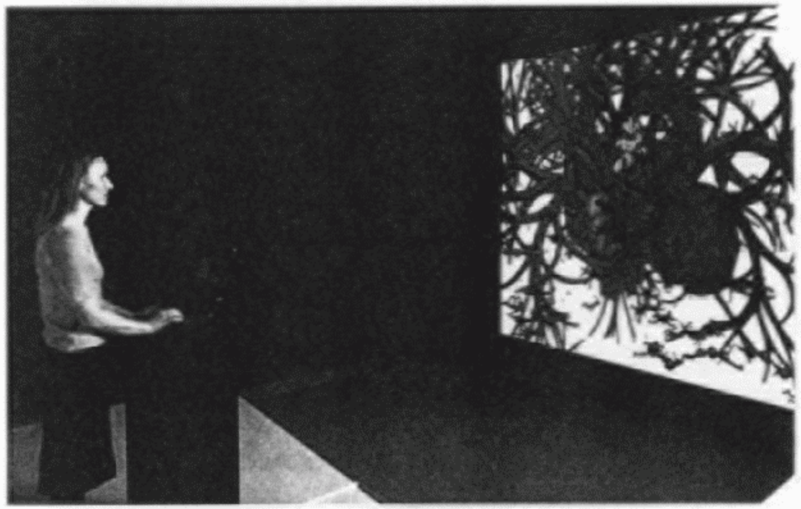

Figure 3.3 *Life Spacies*, © 1997–1999 Christa Sommerer and Laurent Mignonneau. On-line artificial life environment. Collection of the NTT ICC Museum, Japan.

simultaneously. As in *A-Volve*, the resulting child will inherit a mixture of its parents' genetic material. In a twist developed further in *Life Spacies II* (1999), new creatures and new genetic material can enter the system through its on-line interface. At the *Life Spacies* Web site, anyone can generate a creature simply by sending e-mail to the system. The textual content of the e-mail is interpreted as the genome for a new creature; the longer the message, the more properties are defined and the more complex the resulting creature. Thus, as with *A-Volve*, humans act as creators and selectors in an immersive artificial ecosystem. Whereas *A-Volve* carefully embeds the ecosystem in a single simulated space, the projected pool, the *Life Spacies* works make a point of dispersing it through a shared, networked space. The next stage in this process is suggested by the artists' proposed IKI-IKI Phone system, where users would nurture, share, and breed artificial pets through their mobile phones, creating a new wireless cybernature.[9]

TechnoSphere

Virtual space is a central and by now familiar new media form. At one time the exotic touchstone of the discourse of virtual reality, it is now ubiquitous in computer animation and games, and on-line, where the imaginary locus of cyberspace is now often virtually realized. In proprietary virtual environments such as ActiveWorlds and Everquest, thousands of people join to game and socialize.[10] For some, however, on-line virtual environments promise a space that is more than a meeting place for human avatars: they can be a habitat for artificial life. As the a-life programmer and artist Jeffrey Ventrella writes,

> Virtual reality doesn't have to be a lonely place. Many of us who are building computer-based media have an agenda: to invent and then populate virtual realities with interacting, adaptive, quasi-intelligent entities. The human participant can

> become one member of an ecological system, not merely a lone wandering self in a space of Euclidean objects.[11]

These systems mark a merger of two imaginary spaces: the collective imagination of cyberspace — the spatialization of interactive electronic communication — joins with a-life's own imaginary inner space, the simulation or model world. As a-life ecosystems move on-line, the simulated system expands to accommodate multiple users and huge populations of virtual creatures. It makes an imaginary shift from the "in there" of a stand-alone simulation to the "out there" of collective, distributed on-line space.

One of the earliest instances of an on-line cybernature is *Techno-Sphere,* a system created by the British artists Jane Prophet, Gordon Selley, Rycharde Hawkes, Julian Saunderson, and Andrew Kind.[12] Like Sommerer and Mignonneau's *Plant Growing,* this work has had a long life; after going on-line in September 1995, it has undergone three major revisions and is still being developed. *TechnoSphere* presents a simple promise: on-line visitors can construct an artificial creature that will join thousands of others roaming through a virtual terrain, the TechnoSphere. A creature's creator receives regular e-mail updates from the system about the creature's life, which in rudimentary a-life style consists entirely of foraging, eating, looking for a mate, mating, giving birth, being eaten, or dying of old age. In its on-line form, *TechnoSphere* does not offer an immersive point of view or detailed interaction but relies for its interest on the user's identifying with a creature in the system and following its progress. The Web site interface allows users to examine their critter's current status: its state of health, the amount of food it has consumed, the distance it has traveled, and the number of children it has borne. A separate page gives statistics on the current state of the Techno-Sphere, such as the age of the current simulation (the world may be restarted periodically in the event of a crash) and its population (both living and dead). In an element borrowed from the genre of on-line gaming and chat environments, the page also includes a "hall of fame" documenting the world's longest-lived, most fecund, and most bloodthirsty creatures.

The a-life mechanics of *TechnoSphere* are straightforward. Creatures come in predefined families — herbivore or carnivore — and are constructed from predefined parts: head, eyes, a body, and wheels drawn from a library of cartoonish 3D shapes. After constructing a creature, the user enters an e-mail address and releases his freakish-looking jumble into the TechnoSphere, a tract of fractally generated virtual terrain complete with hills, valleys, and trees. There, the creature's life is its own: it forages for food, eats, mates, and sleeps according to fluctuations in its parameters for hunger, energy, and so on. The creature's viability — its ability to eat enough, see and escape predators, or move fast enough to catch its prey — is determined by its combination of body parts. Through trial and error or by copying the world's most successful creatures, a user can create the perfect predator from the right combination of fast wheels, savage mouth, and keen eyes. However, some creatures are born rather than made; pairs sharing the same torso may mate, and in this gender-free world the creature that initiates the sexual encounter will invest a portion of its energy in bearing a child. The new creature inherits a mixture of the parents' body parts and hence their behavioral attributes. With this simple genetic/reproductive mechanism, and the competitive pressures of predation and resource competition, a degree of evolution takes place: over time, creatures become better adapted to their environment. Populations of carnivores and herbivores fluctuate, while the continual influx of newly made creatures prevents evolutionary stasis.

Taken at face value, *TechnoSphere* seems to be a straightforward, light-hearted experiment in on-line artificial life, a toy ecosystem of cartoonlike critters. However, in Jane Prophet's characterization of the work, a-life technique is less important than the networks of interaction which that technique motivates.[13] The site's designers and users are involved in what Prophet characterizes as a bottom-up collaborative process.[14] Indeed, it is the users of *TechnoSphere,* rather than its artificial life forms, who continue to attract Prophet's interest: she comments on the continued popularity of the site (it reportedly receives 70,000 to 80,000 "hits" per day) and remarks that "[p]robably the most interesting thing about the project is its anthropological [and] sociological elements."[15] Prophet had earlier observed that "users often identify with the creatures that they have made" to the extent that they see them at times as autonomous avatars or representatives of themselves. In fact, this on-line art project has spawned an on-line fan culture: a Web search on "technosphere" turns up a host of sites where users document their pet creatures, linking back to *TechnoSphere* itself so that visitors can check on their well-being. Prophet discusses developing the social aspects of *TechnoSphere,* adding chat spaces where users can establish connections through the interactions of their artificial creatures. As the fan sites also indicate, these contacts are already occurring through other channels; Prophet reports that some users "have even met one another for sex, and discussion of their [a-life] progeny."[16]

So, *TechnoSphere* operates not only as an a-life experiment but as a virtual space where anthropomorphic emotional investment is cultivated. Here users are linked to a virtual world that manifests itself through Web pages and e-mail communication, forms that, while they only imply the presence and activity of this virtual world, are increasingly accepted as signs of a "real life" — of commercial transactions, events, institutions, and individuals — that is beyond the reach of everyday physical existence. If we can correspond with unknown, unseen individuals in distant countries, or order books from some giant far-off warehouse and have them faithfully materialize at the doorstep, then why doubt *TechnoSphere's* reports of the health of our virtual progeny or the scrupulously detailed accounts of an artificial existence the site supplies?

ROBB LOVELL AND JOHN MITCHELL (*EIDEA*)

TechnoSphere is a cybernature founded in the virtual place of on-line communication. By contrast, Robb Lovell and John Mitchell's *EIDEA* ("Environment for the Interactive Design of Emergent Art") is an artificial ecosystem that links itself to the real place in which it is located. Installed at Deep Creek School, near Telluride, Colorado, in 1995, the work is described by the artists as "a direct response to [the] challenge" of how to respond to the surrounding natural environment.[17] *EIDEA's* ecosystem structure is straightforward. Three species interact and evolve: trees, birds, and wolves. The trees bear fruit, which is eaten by both wolves and birds; the birds in turn may be eaten by the wolves. The behavior of each individual is coded in an artificial genome, so here, too, species compete with and adapt to each other over time. This system is visualized in two ways: a simple wire frame 3D view (figure 3.4) and an electronic "sand painting," projected on the floor, which shows accumulated traces of the movement within the world.

The most striking feature of *EIDEA* is its generation of an artificial world that retains a connection with its own physical environment. The work uses a digital weather station to gather data on barometric pressure, air temperature, relative humidity, and wind speed, and each of these factors influences events in the artificial ecosystem. High winds interfere with the birds' flight, blowing them around. As in terrestrial biology, air temperature influences the creatures' metabolisms and mating rates; they hunt and eat more during warm weather and breed when the weather is cold. Weather data including temperature and barometric pressure influence the installation's generated soundtrack. The fluctuating sound of Deep Creek itself is linked to the measured humidity; as the humidity increases, typically with nightfall, the sound of the creek becomes more prominent. The sound generation software also gathers and "sonifies"

Figure 3.4 Robb Lovell and John Mitchell, *EIDEA* (1995). Detail.

statistical information about the artificial ecosystem, including population sizes and birth and death rates. In the artists' words, the audio component acts as "an intermediary or crossing point between cyber reality and the natural or outside world."

Whereas for Sommerer and Mignonneau this crossing point is the ideally natural transparent interface between participant and computational system, for Lovell and Mitchell it is itself a surface for contemplation. *EIDEA* is a graphic and sonic rendering of the intersections of natural and virtual systems, a linkage that operates to simultaneously connect and differentiate these spaces, at once implying a resemblance between the simulation and its original, and highlighting their disjunction. As Lovell says, the work explores notions of "inside" and "outside":

> It seemed natural to talk about what came from outside the system and what was generated from within the system. Ultimately, everything starts outside, but at some point the stuff inside is "let go" to determine its own destiny. Yet that destiny was influenced by "computer sensed" data coming from outside the system.[18]

As with all artificial ecosystems, "everything starts outside." A portion of the outside world begins to turn itself inward; representational and computational boundaries are constructed, and a bounded set of dynamic relationships is set up between the entities represented within the system. The outside is, of course, ever-present in the form of physical infrastructure, but it is most often deemphasized; the reliance of these internal artificial worlds on a wider outside is downplayed. *EIDEA* is interesting in that it draws attention to this relationship, breaking the customary membrane around these cybernatures. The notion of the autonomy of the artificial life forms and their inner space remains — Lovell reports his enjoyment of "the creativity of making a new little world" — but this autonomy retains a certain connection with the outside world.

Constructing Cybernatures

This play of inside and outside, and of nature and its simulation, is basic to all the works considered so far. Artificial plants flourish; a flock of wire frame birds wheels around; another screen displays an image of a misty tree-dotted fractal terrain. This is the basic cybernatural disjunction: images that unequivocally evoke nature appear in a computational medium — a medium that represents our culture's most sophisticated artifice. These elements — technology and nature, medium and content — are brought together in an analogical relationship. While plainly, self-evidently artificial, these works refer to a natural original: in Sommerer and Mignonneau's *Plant Growing,* we understand the generated images as computer-graphic plants. They resemble real plants, certainly, but these images are thoroughly marked by their medium, in the pixelated grain of the video projection and the dynamic geometry of their accelerated growth. An analogy is conveyed: this work announces itself as a computational process that is plantlike. In other works, the same analogy is extended: these computational systems liken themselves to natural ecosystems.

This analogy is induced through an interlocking set of correspondences. Visual cues are the most immediate, but there are also behavioral resemblances in the movement of those forms and their responsive interactions. Most basically, we are shown familiar structures, a familiar spatiality, a ground, a sky. Together, these structures provide a context within which the entities and events in these artificial worlds are understood. Our cultural familiarity with screen-based representation and the ubiquity of this form (essentially a view of a landscape) leave us well equipped to take up these cues, however scarce or marginal, and construct a stable analogy. Once this artificial landscape is established, we read the represented events, however crude, according to the same analogy. When two computer-graphic blobs meet, and a third, smaller blob appears, we understand that a birth has occurred. When two forms meet and one vanishes, we see a predator and its prey.

In general terms, this analogy is familiar; it is evident in the breeders discussed in chapter 2, where it centers on the genetic code, the phenotypic form, and the evolutionary process. There it gains its credibility from the popular orthodoxies of evolutionary theory. Here the analogy is more stable and more readily formed because it draws on a more basic reservoir of personal experience and cultural knowledge. Few of us have bred pets or livestock, let alone experimented with genetic engineering; many more of us have watched fish in a pond, insects in the grass, birds in the trees. While the breeders hinge on a genetic mechanism, an isolated formal device, these works are distinguished by their presentation of familiar *wholes:* active landscapes, dynamic networks of artificial entities, entire cycles of life, reproduction, and death. More, these wholes appear seemingly intact, or at least recognizable, inside a computational space. These works assert, in that basic analogical structure, the computer's capacity to reproduce the complex dynamics of a natural system.

That assertion is supported by our willingness to take up the representational slack, with the consequence that any gaps, cracks, or inconsistencies in this computational reproduction go unnoticed. Not that the artifice involved in these works is effaced; rather it is openly displayed. It is the constitution of that artifice — its construction, its framework — that remains unstated. At one level, that artifice involves a set of maps and models, a set of abstractions and approximations required in order to make the transition from biology to computation. As already argued, this transition cannot be taken for granted; the systems considered here take on the same mapping of genome to code used in the breeders but add to it a set of higher-level constructions. The genotype and phenotype become code, but so do the actions, responses, and behaviors that form an entire artificial life, and, beyond that, the rules and constraints that constitute an artificial world. That process of encoding and the mediation it implies go unremarked in these works.

At a second level, the natural analogy involved in these works actually reinforces the representational structures that underpin their artificial spaces. Under that analogy, space is a kind of prerequisite: life, as we understand it, implies space, and artificial life seems equally to demand an artificial space. Of course, the simulated space inhabited by the artificial ecology is as constructed as the ecology itself, formed from a set of specific computational and representational mechanisms, rules for perspective, rendering, and shading. The spaces vary slightly, but their construction is always taken for granted; our identification with the life in these systems pulls us past the question of the space itself. This phenomenon can be seen particularly in *TechnoSphere,* where the habitat is primarily presented as statistical information, automated e-mail reports, or a simple periodic snapshot; this is an imaginary space reconstructed from the barest signs of life.

Moreover, almost all the spaces invite and incorporate the presence and action of those viewing or visiting the work. What might it mean to interact with these cybernatures? Or, to rephrase the question, what might it mean that these cybernatures are interactive? In the rhetoric around these works, interactivity is highly prized; it signifies an active engagement of the individual and, in works such as *A-volve,* a form of collective participation. However, if these works are understood as artificial natures, this celebration of interactive engagement acquires a twist. In the works of Sommerer and Mignonneau, in particular, interactivity is central. As technical and computational structures, these systems are built around the visitor: motion is detected and interpreted, video images are composited. Of course, we should expect nothing else from interactive art, but the careful construction of an "ecosystem" around the participant's agency and experience can't help but suggest a particular relationship between human and nature. If these spaces are meant in some way to signify or recall natural spaces, then many of them, such as *Plant Growing* and *Trans Plant,* signify a nature organized around human presence and agency.

At worst, these systems evoke a questionable analogy between biological and computational structures and, in the process, reinforce an anthropocentric notion of nature, not intentionally but as a consequence of their representational forms. They adopt the artificial ecosystem as a device through which to pursue interactivity or investigate on-line sociology; however, to a large extent they adopt it uncritically. The a-life form is taken on for what it *can* do — provide a complex interactive artificial environment — rather than interrogated for what it omits or implies.

So, we can ask, What is left out in the process of rendering natural systems as computational artifacts? If computation can reproduce nature, what becomes of its biological original? And what if, rather than seeking to reproduce familiar natural forms, these computational systems were addressed on their own terms? Works such as *EIDEA* begin to draw attention to the tension involved in this cybernatural binary. The works considered in the remainder of this chapter continue this process and, in doing so, lead us to address some of these questions. Rather than pulling us easily through the analogy between nature and computer, these works pay more explicit attention to the implications of that transition.

TROY INNOCENT (*ICONICA*)

That transition and that binary can be recast as concerning matter and code. A cybernature is a coded construction, a mass of interlinked symbols and variables, a complex formation of predetermined elements in a programming language. Sommerer and Mignonneau allude to this in *Life Spacies*, where e-mail text becomes genome. However, that work stops short of the more challenging notion that the work's entire artificial environment, its behavioral rules, its graphics software, its network protocols are all textual constructions. Cybernatures are, in one sense, worlds made from language.

The Australian artist Troy Innocent has a long-standing interest in the creation of virtual spaces and in the investigation of their native languages and inhabitants. His interactive *<Idea-ON!>* (1992–1994) is a set of synthetic worlds and entities made from a shiny digital vernacular of pop-graphic logos and icons.[19] While these icon entities are a kind of imaginary a-life, Innocent's *Iconica* (1999) adopts a-life as a computational technique. The result is a complex interactive space that makes no attempt to appear natural: *Iconica* forms an active artificial world out of the raw material of computation: code. The work's fabric is an idiosyncratic system of iconic signs, a kind of semiotic biochemistry that forms space, landscape, form, genotype, phenotype, and ultimately language (figure 3.5).

The system begins with six elementary categories: real, synthetic, coded, abstract, subconscious (or psyche), and metaphysical (or meta). Four additional symbols — natural, constructed, chaotic, and ideal — inflect these elements to form complex descriptors, so that a form or entity might be natural coded, chaotic synthetic, ideal metaphysical, or constructed real. The six elements also form the species of *Iconica:* real and synthetic humanoids, translucent cubic code beings, quadrupedal psyche animals, and abstract and meta 3D icons. These species are mutable though: as interbreeding and mutation occur, elements and body parts will begin to mix, so that entities in later generations may have, for example, a synthetic body, a metaphysical head, and a code spirit.[20] The digital genome here is a string hundreds of characters long made up of the six elementary units, and an entity's constitution is determined by which of those elements is dominant.

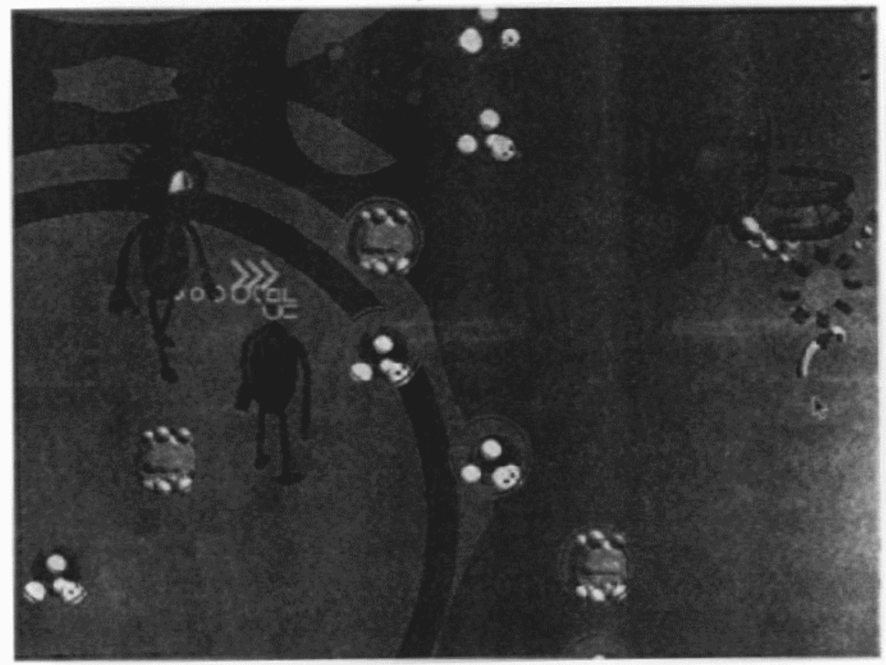

Figure 3.5 Troy Innocent, *Iconica* (1999). Screen shot.

In *Iconica's* most complex layer, this iconic system is elaborated into a language that entities use to communicate with each other and the human user. With some sixty recombinant elements, the language includes syntactical modifiers, personal pronouns, and objects ("I," "we," and "you") as well as the foundational elements and their modifiers. Engage an entity in conversation and form a simple query — something like, "You?" — and it will reply with an iconic construction: "I am moving toward a head form made from synthetic reality" or "I am attacking an energy form made from constructed code" (figure 3.6). Each linguistic element has a matching sound component, which is varied according to the six foundational elements, so that each utterance is also a distinctive sonic compound. Viewed from above their two-dimensional world, the entities flash icons and emit sounds, which indicate their actions. Their internal actions are visible and audible: we see and hear them looking, moving, attacking, and crying for help in this alien language.

For the visitor, *Iconica* is initially a completely bewildering experience; bizarre iconic entities spin, walk, twitch, flash unfamiliar glyphs, emit strange noises. Are they pursuing something, attacking something? What is it they want? Faced with learning a new language, the visitor resorts to simple questions, trying to glean clues about both the world and the language that forms it. The linguistic and ecological structures become gradually more familiar; learning occurs through testing these structures and through simple play: What happens if I drop this food form onto this entity? if I ask it what it is made of? The work offers various interfaces for viewing and interacting with the world; the user can generate new forms, including food and head forms, and offer them to the entities. As in *A-Volve,* this interaction can alter the evolutionary dynamics of the system if it favors one individual or group other another.

As an a-life system, *Iconica* achieves a quite remarkable richness. While it uses the standard devices of artificial genetics, mutation,

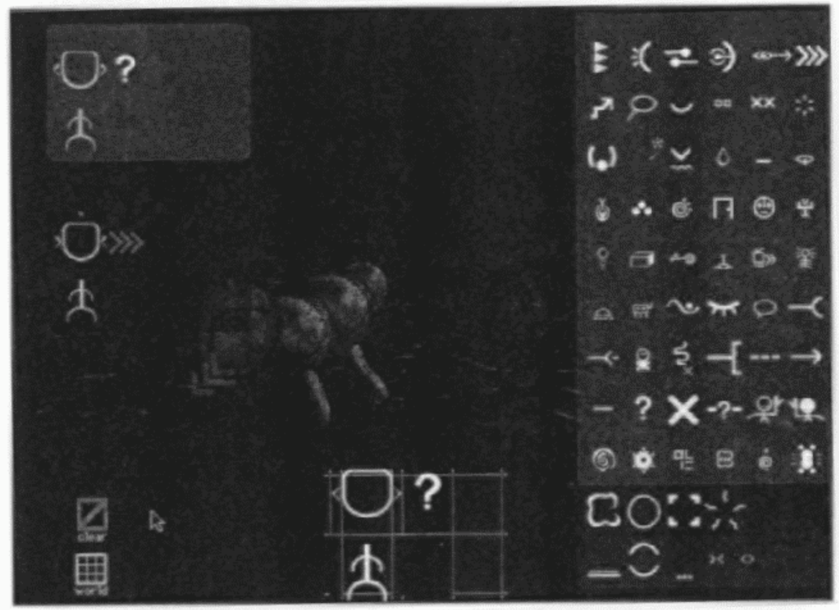

Figure 3.6 The *Iconica* conversation interface. User: "You?" Iconic Entity: "I am going."

and reproduction, it allows for a wide range of complex interactions and behavior, culminating in its iconic language. While Innocent expresses an interest in developing *Iconica* as a more sophisticated experiment in a-life techniques, he also makes it clear that this is not the main concern of the current work. *Iconica* is a clear continuation of Innocent's earlier explorations and deformations of the native aesthetic language of computer culture. Innocent explains his approach as an enquiry into the qualities of computational spaces: "What forms are endemic to the space? What structures? Is there a unique language or aesthetic for electronic space?"[21] Virtual worlds, Innocent recognizes, are fundamentally "data, pure information"; spaces defined by an "explicit description . . . the basic elements, the rules for combining and sequencing elements, deep structures, surface structures." *Iconica's* artificial language makes this point clear: the code is genotype and phenotype, language, behavior, and space. It is literally a world made of language, seeking to "capture the idea of a language of electronic space which is a kind of natural state for the medium."[22] In this sense, *Iconica* is a kind of inversion of the cybernatures discussed earlier: instead of linking computational artifice with biological nature, it attempts to come to grips with the computer's own natural state, with the inherent properties of computational space. Living matter and lived space have no special primacy here; the real and the natural are drawn into an artificial cosmology alongside the abstract, the coded, and the metaphysical.

JON McCORMACK

Innocent's *Iconica* leaves nature and material reality aside for a world of code. The Australian artist Jon McCormack considers the interface of these worlds, combining virtuosic applications of a-life techniques with a poetic stance that reflects on the meaning of those techniques. Despite their often lavish aesthetics, McCormack's cybernatures do not celebrate an artificial nature; even as they mine its riches, they convey an ambivalence and unease about its implications.

McCormack's earlier work illustrates this tension clearly and gives a sense of his approach to a-life techniques. His work is a sophisticated exploration of procedural techniques for computer graphics: *Flux* (1992) uses cellular automata and L-systems to generate rich elaborate forms in an abstract investigation of natural patterns of flow. There is no trace of biomorphic artificial life here, although the generative methodology is familiar. McCormack writes, "I wanted to extract the essential logical rules of these phenomena and represent them visually in an abstracted sense."[23] Just as in a-life, the "behaviors and motions that result from these techniques could not be predicted before the simulation is run. The complexity emerges." Other works such as *Four Imaginary Walls* (1991) and *Wild* (1994) move beyond the pure interior of formal generative systems and, like Lovell and Mitchell's *EIDEA*, address the articulation of computational space and the world outside. Environmental inputs such as temperature are mapped onto real-time generative procedures; as McCormack writes of *Four Imaginary Walls*, the work addresses "notions of containment and the increasingly blurred relation between nature and machine."[24]

These interests come together in spectacular fashion in McCormack's 1995 work *Turbulence*. In its installation form, the visitor enters *Turbulence* through a corridor lined with illuminated specimen jars. A fan of filigreed coral, the coiling tangled limbs of a starfish, the tapered curve of a small octopus; these things are recognizably natural objects yet have an alien visual quality that anticipates the work proper and resonates with its subtitle, "A Museum of Unnatural History." Inside the darkened projection space, a small touch screen allows the visitor to navigate that museum, a library of computer animations stored on videodisc. These sequences are the aesthetic core of *Turbulence*, rich, dense depictions of fantastic dynamic forms and teeming virtual spaces. Filed under "organisms" is a scene of burgeoning, writhing vegetation with galloping skeletal centipedes and urchinlike tumbleweeds. Bizarre flowers grow; a vigorous, angry-looking thing produces a bloom whose translucent bubble contains another wriggling life form; in the sound track it screeches like a sci-fi monster. A second flower erupts like a double-storied sunflower, two spiraled discs of yellow surrounded by more waving tendrils (figure 3.7). As in Sims's *Panspermia*, vegetative time is accelerated; these plants rush out of the planar ground in seconds, booming with artificial vitality. In a section labeled "the realm of phantoms" is a "submarine garden," another flowerlike form but a more gentle, ordered, mobile constellation of rotating geometric elements, undulating and pulsing. At its base, an array of pearls sends out coiling red tendrils in a riotous mass, as if engaged in some urgent process of spawning or feeding.

In a 1997 review, Annemarie Jonson aptly describes *Turbulence* as "breathtakingly beautiful, in a semi-psychedelic, lava-lamp kind of way"; it is lushly patterned, constantly mobile, brightly colored — an almost orgiastic play of forms.[25] Jonson also likens the work, insightfully, to the "world is born" sequence in Disney's 1940 *Fantasia*. *Turbulence* is characterized by just such a moment of birth; its life is never quiescent but always coming into being, flowering, growing. The musical accompaniment to the video is all portentous chords and cosmic booms and crashes, gestures at a scale matching the eternally receding expanses of virtual space that this life colonizes. This is a lavish drama, life unfolding grandly inside the machine.

Turbulence sounds like a prime example of that genre of computer animation where technical and graphic virtuosity outweigh subject matter.[26] In fact, this lush aesthetic is informed by the artist's reflections on nature, technology, and simulation. In the work's catalog essay, McCormack borrows from nineteenth-century poet Gerard Manley Hopkins the term *inscape*, "a name for that 'individually distinctive' form which constitutes the rich and revealing 'oneness' of the natural object."[27] For McCormack, *Turbulence* addresses the reforming of this oneness as a code artifact, a digital genome, or a set

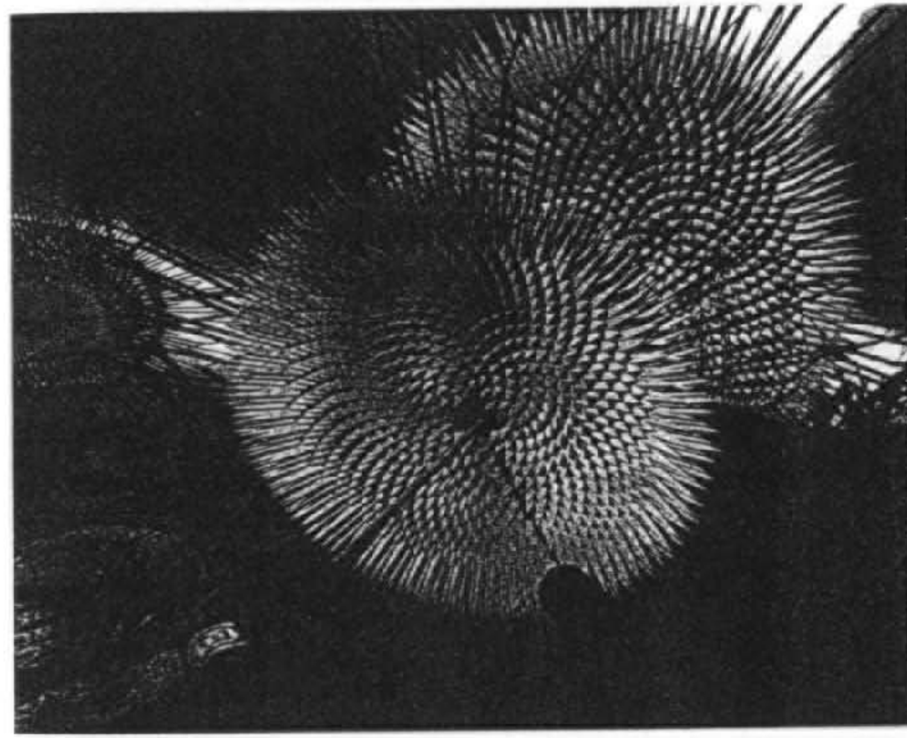

Figure 3.7 Jon McCormack, *Turbulence* (1995). Detail.

of procedural elements that blossom into a synthetic nature. On one hand, McCormack celebrates the transformative potential of this shift, hailing "a new evolutionary landscape . . . a digital *poesis*"; on the other, he evokes through Hopkins a lament for the loss of biological nature, for the destruction of a natural landscape that is a psychic, emotional, and even aesthetic necessity. *Turbulence*, then, is both "a lament for things now gone" and "a celebration of the beauty to come." McCormack is far from easy with the replacement this seems to entail, however; he acknowledges that "our first-world society is rapidly turning inward to the comfortable synthesis of the computer screen (or VR display) in order to hide from the uncomfortable reality that we have created around us." He leaves unanswered the question of how adequate this replacement might be, whether "the beauty to be" will equal "the beauty been."

In McCormack's more recent work, this tension is less prominent though still implicit. *Eden* (2000–2001) is an interactive ecosystem with a minimal, abstract graphic surface; the aesthetic emphasis is on the sound track, a dense synthetic texture built up from the calls of *Eden*'s agents. *Eden* follows most of the technical conventions for artificial ecosystems: a set of rules, or artificial genome, codes for the agents' behaviors, which evolve over time. However, agents can prioritize their built-in rules according to their usefulness, and those priorities are passed on to the agents' offspring, so that evolution here is Lamarckian rather than Darwinian. At the sonic layer of the system, agents can hear sound and locate its source, and they can sing. As an action, singing has no built-in logic or significance for the agents, whose initial behavior rules are a random set of connections between sensation and action. However, in some runs of *Eden*, sonic behaviors acquire a survival value: McCormack reports observing creatures "calling" others to share an abundance of food and other creatures exploiting this altruism by "calling" in order to lure their neighbors to be killed and eaten.[28] Agents' hearing is sensitive in three distinct frequency bands; some groups will communicate using only a particular frequency band; others will use different bands in conjunction with particular behaviors (such as eating and mating).

McCormack credits the inspiration of the work to a holiday spent in the northern Australian wilderness in a visually sparse landscape that manifests its life in slowly changing sonic textures. Similarly, in *Eden*, the sounds change gradually and fluctuate across multiple time scales with the artificial world's seasons, population fluctuations, and long-term mutations in sonic behavior. While *Eden*'s time scale is certainly accelerated (a "year" lasts a couple of minutes), evolutionary change only becomes apparent over long periods of attention. In a later version, *Eden* was installed in a Melbourne bar as a generative, immersive audiovisual stream. Proximity and motion sensors were linked to the simulated world, altering mutation rates and energy levels in order to reward creatures for attracting and engaging human attention. The audience's (possibly unintentional) responses steered the system's evolution, resulting in the world's making more sound and evolving more diverse sonic behaviors.[29]

McCormack's proposed *Future Garden* project continues this articulation of physical and informational life, although here these roles are reversed as a-life moves out into the open. *Future Garden* takes the form of three large raised "beds" topped with arrays of multicolored LEDs.[30] The arrays display complex shifting patterns and behaviors driven by cellular automata rule sets; as well, they will respond locally to touch and globally to environmental conditions such as temperature and light levels. This project returns McCormack squarely to his speculations on the shifting status of nature as concept and experience. The artist asks, "What would a garden that takes into account new ideas about nature and life be like?" Of course, the garden is an ancient figure for the human control and organization of nature; gardens are always inherently artificial in that sense. So, this might be the "perfect" garden, either in its final rationalization and abstraction of nature or in its openness about that very process, its total abandonment of any familiar image of the natural.

Yet this garden also reflects new ideas about a more process-oriented concept of natural systems. If it seems to present an artificial surface, it may be that, as in the organicism of Goethe and Klee, it reflects nature at a structural level. Perhaps, as McCormack suggests in an earlier essay, this cybernatural synthesis can offer some kind of insight:

> You might expect that my ideas about the world are introverted around the machine, in fact the opposite is true. The computer has shown me things about the world that I could not have known, understood or seen any other way. I see and appreciate nature in a fundamentally different way than before.[31]

McCormack's words are echoed and amplified by another Australian artist, Rodney Berry, himself a creator of an artificial ecosystem, *Feeping Creatures* (1997):

> I see that this work fosters an interest in an aesthetic of systems and processes, rather than objects and images . . . and I think that that is important to me in how we perceive the world, that we don't see things just as objects, that they are interrelated, that they have their own separate existence but they also have an incorporated existence with other things. And I think that . . . people developing an aesthetic of looking at the flow of things, procedures, algorithms in the artificial world feeds back into their appreciation of the natural world.[32]

Artificial ecosystems can easily be criticized for their turn toward simulation and away from uncomfortable realities; McCormack and Berry suggest an alternative position. These artificial systems might function as illustrations of the dynamic structures of the material world, reminders of the systems underlying the simple surface of objects and images. The computer, rather than creating an impoverished replacement for natural space, functions as a tool for understanding real processes, making them explicit by denaturalizing them, pulling them out of the immanence of the material.

NATALIE JEREMIJENKO (*ONETREES*)

This notion of the computer as a tool or an instrument begins to complicate any opposition between computation and the natural. However, even if artificial ecosystems may work as diagrammatic or illustrative models that enhance our awareness of natural systems, that very process of modeling, the conversion of material forms and their interactions into informational units and their relations, is never addressed in these works. We certainly recognize these systems as mediated abstractions of natural processes, but that point of mediation goes unremarked.

In the work of the American-based artist Natalie Jeremijenko, that mediation between nature and computation is central. Jeremijenko's *OneTrees* project is a complex work-in-progress that considers the tensions between biological nature and its informational representations and simulations.[33] The one tree of the project's title is a real biological tree, a hybrid variety of Californian Black Walnut known (appropriately) as Paradox. Using juvenile tissue from a single tree, Jeremijenko had some six thousand identical individual "plantlets" cloned. In the first phase of the work's exhibition, in November 1998, one hundred of these plantlets were shown, together with an outline of the subsequent stages of the project (figure 3.8).[34] As planned, the work will see several hundred more cloned trees planted on street fronts throughout San Francisco. Attached to each of the growing trees will be a small battery of sensors detecting temperature, humidity, and chemical changes, and a small digital camera providing an image of the tree. This information will be relayed to

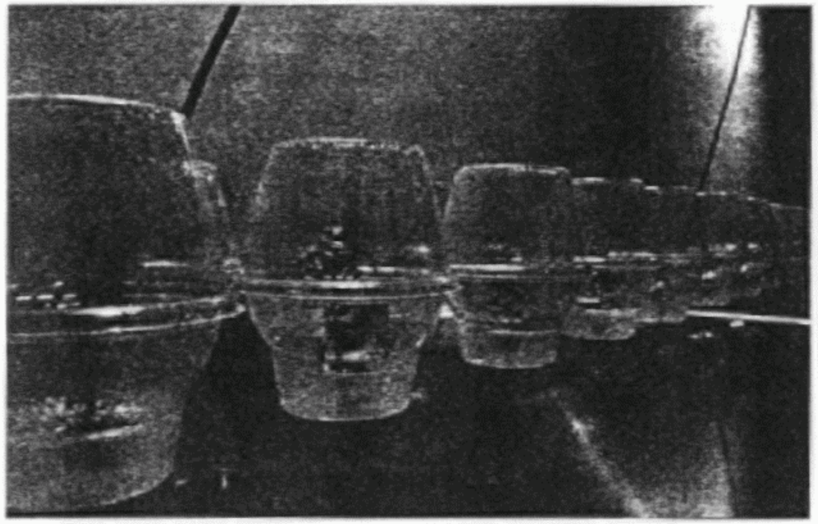

Figure 3.8 Natalie Jeremijenko, *OneTrees* (1998–). Exhibit showing cloned plants.

a central on-line database; a large distributed population will be readable as a rich swathe of data points. Moreover, this population will be genetically uniform, so the database will show how, even with matching genetic codes, each tree is shaped by local material and environmental conditions. In fixing the genetic variable in the complex process of growth and development, the other variables involved become more accessible. Thus, the trees are actually a measuring device; Jeremijenko refers to them as "a biologically manipulated instrument that, when distributed, will be a document of environmental and social difference."[35]

OneTrees will also involve a virtual population mirroring this real one: a program distributed on CD-ROM will grow a virtual tree that resembles the Black Walnut hybrids. In an inspired twist, these virtual trees will be programmed to grow only as fast as their real counterparts, over years rather than seconds. Instead of a dynamic, animated rush, they will undergo an imperceptibly slow transformation — an injection of an embodied biological time scale into the digital arena, where speed is an ever-present imperative. This software will also interface with a carbon dioxide sensor so that the local CO_2 level influences the growth of each individual artificial tree; so, once again, local and environmental variation will modulate a population of identical individuals. As Jeremijenko says, CO_2 is an "interesting metric"; while it is an environmentally negative sign, implying fossil fuel consumption and global warming, trees actually grow faster, up to a point, with increased levels of the gas.[36]

This aspect of the project draws the physical environment of the computer user into the inner space of the computer itself. In a final symmetrical pun, *OneTrees* will also draw attention to the way that the computer user's actions extend outward into that environment. When installed, the artificial tree software will insert a "virus" into the system-level printing software of the host machine. This small background routine will simply count pages sent to the printer until, after about a tree's worth of paper has been used, it will print out a page of its own, showing a cross-sectional slice of tree. As tree after tree flows through the printer, slice after slice is printed: "You can actually build up a stump of the forest that your printer has consumed." Jeremijenko refers to this as the "stump" or "stumped" component of the project, an informational marker that seeks to reconnect the sheltered personal computing environment with the largely intangible material processes on which it feeds. The stump is a memorial, an emblem for the pulped forest, but it also literally "stumps" us; it puzzles us or leaves us at a loss, frozen at the intersection of personal utility and its environmental consequences.

As envisaged, *OneTrees* forms a complex network that oscillates between the biological and the informational: an array of uniformly coded life forms shows up the contingencies of real life, in real time, and reinscribes them as on-line information. A simple program counts pages and reconstitutes a reminder of the material and biologic of personal consumption. At one level, *OneTrees* raises a familiar set of environmental concerns, as in the "stump" virus. At another, it addresses issues central to the field of artificial life, questioning the simplification involved in mapping between genetic code and computer code, between a material system and an informational system. The work enables a comparison of the material trees with their idealized informational doubles, testing that mapping in one direction. It also opens up a comparison of the material trees with each other, an experiment allowing us to observe the local material complications of a single inner code. In their variations, this array of trees will form a subtle refutation of genetic determinism and the popular notion of clones as identical copies. In public, too: the trees will be on street fronts and at trolley and bus stops. Jeremijenko refers to the trees as "a material demonstration, a long, quiet and persisting spectacle of the Bay Area's diverse environment."[37] *Environment* here refers to more than a set of abstract material parameters, temperatures, and gas levels; it is an urban, social, and economic space, a space of traffic flows, vandals, power lines, drainpipes, and real estate.

A-life plays an interesting, ambiguous mixture of roles in this work. A-life is used in a negative sense, in that the artificial trees operate as one pole in the juxtaposition of nature and its informational double; they are the true coded clones against which the variegated lives of the real trees can be thrown into relief. However, the a-life trees are also used in a way that subverts the conventions of the field: their carbon dioxide sensors act, as Jeremijenko says, to "puncture" the separation between the virtual and the actual that normally characterizes such systems. They become environmentally contingent themselves, though only (of course) through the datafication of a single physical variable. The slow growth of the artificial trees is a subtle but even more pointed act of subversion: by simply fixing one parameter in the computational model, its implications shift completely. Hypertrophic vegetation is almost a cliché in these works: it flourishes in the interactives of Sommerer and Mignonneau and in McCormack's animations. It springs up under the feet, or the fingers, of interactors, or writhes and screams monstrously. This acceleration represents a strange anthropomorphization of plant life: it compresses growth into human-friendly durations, so that it occurs at the same time scale as human motion. As well, particularly in Sommerer and Mignonneau, it brings the triggering (and re- and retriggering) of virtual growth under interactive control. Plant life can be conjured and erased in seconds.

The slow-growing plants of *OneTrees* are quite different; they are not only realistically slow but noninteractive. Their time parameter is linked to the system clock of the host computer; they cannot be restarted but will continue to grow even when their software is inactive, even when the host computer is shut down. Short of manually resetting the system clock, or its battery running down, the trees will stay stuck in real time. As a result, they are no longer animated spectacles: as Frances Dyson puns, watching these trees will be "about as exciting as watching grass grow."[38] Instead, they will be checked from time to time, or forgotten and rediscovered. The computer desktop is an environment that undergoes near-constant change and renovation. System updates, Internet downloads, new tools and toys appear and disappear. However, provided with a modicum of environmental stability (a functional hard drive), these trees will work against that accelerated pace as rare, unhurried (and unhurriable) presences.

CYBER/NATURE

Jon McCormack raises an awkward irony that sits at the core of this field. While Western industrial culture is steadily demolishing its biological environment, it is becoming increasingly adept at simulating living systems. The causal links between these processes are nebulous, yet the symmetry has a grim appeal: as human civilization voraciously consumes natural resources (individuals, species, whole ecosystems and habitats), a pristine new nature begins to form in a remote inner chamber. Supported by expensive sophisticated technology, this nature offers several advantages over the rapidly unraveling original. It is enormously malleable; it might resemble the "old" nature or some fantastic environment of our own imagination. Being immaterial, it is entirely benign; it won't eat, poison, flood, or otherwise disturb its human inhabitants. Rather, it can be truly Edenic, the ultimate garden, in fact, finally under complete control (even though it may appear otherwise). The fallacy of nature as pure other — as distinct from and opposed to culture — is less sustainable than ever at a time of global warming and genetic engineering. Yet in reconstituting living environments as computational systems, some cybernatures also reconstitute them as pure nature, autonomous, self-referential, and impervious to human pollution.

This is a caricature of a situation that is far more complex, but it pinpoints the tension that makes these works both interesting and problematic. It is clear that in their direct invitation of a correspondence between a simulated space and a natural space, works such as *A-volve* can be seen to be complicit in the formation of a benign, controllable, anthropocentric cybernature. Even when the agenda of the work moves in another direction, as in *TechnoSphere,* or begins to destabilize the closure of the artificial world, as in *EIDEA,* this formation persists. It need not obscure the virtues of these works — each is a sophisticated creative experiment — but it persists.

The work of an artist such as McCormack offers one option for addressing this tension, where generative riches are offset by a critical reflexivity. McCormack is open about the status of these works as artifactual views from a specific cultural location: this is "nature as seen by someone from a very First World environment."[39] Troy Innocent pursues a different tangent, creating a world that leaves nature — in fact, even matter — entirely behind. More than any of the other works here, *Iconica* pursues a "hard a-life" agenda, a process exploring "life as it could be" in a strictly symbolic form. However, unlike other such experiments, the result is wonderfully idiosyncratic: a personal iconography that becomes an animated cosmology: "life as I write it."

The hope that Rodney Berry articulates, that these artificial systems may enrich our awareness of biological systems, is also evident in Jeremijenko's proposals for *OneTrees.* These artists offer an approach that complicates or perhaps circumvents the binary of the cyber/natural. Jeremijenko's work is fundamentally concerned with the engagement of these poles, with the presence of nature (or, at least, of signs of natural systems) in the technological and informational systems that contemporary culture favors. In fact, Jeremijenko goes further than the other artists considered here in destabilizing the idea of the natural. In the cybernatures of Sommerer and Mignonneau, in *TechnoSphere* and even *EIDEA*, artificial environments model and mirror an idealized nature. They project an image of a nature that is a seamless, intact whole, a set of stable behaviors and rules, a well-defined environment. They present a nature formed from the materials of Western technoculture but in which culture and civilization are utterly absent. The interactive subject is returned to a precivilized native state, offered a kind of raw experience of a reconstructed nature. In work such as McCormack's the purity and artifice of this cybernature is used reflectively, to draw attention to its culturally grounded process of computational renovation. The natural remains central, however, as an aesthetic necessity or an object of poetic reverie. In *OneTrees*, nature as such is substantially unraveled. The real trees — icons of the natural — are engineered clones, technological organisms. Already part of a larger techno-scientific-artistic instrument, their lives are to be closely intertwined with the social and institutional structures surrounding them.

Beyond the engaging awkwardness of the cyber/natural, these works further illustrate the diversity of creative practice using a-life techniques. Applications range from the credulous to the critical; a-life's representational templates are both endorsed and interrogated, its forms celebrated, reflected, personalized, and strategically deployed. The creative rewards that a-life techniques offer — subtle interactivity, complex dynamic artificial environments, and a lavish procedural aesthetic — are widely apparent. At the same time, these works show that the representational and computational structures on which those rewards conventionally depend can themselves be altered and contested.

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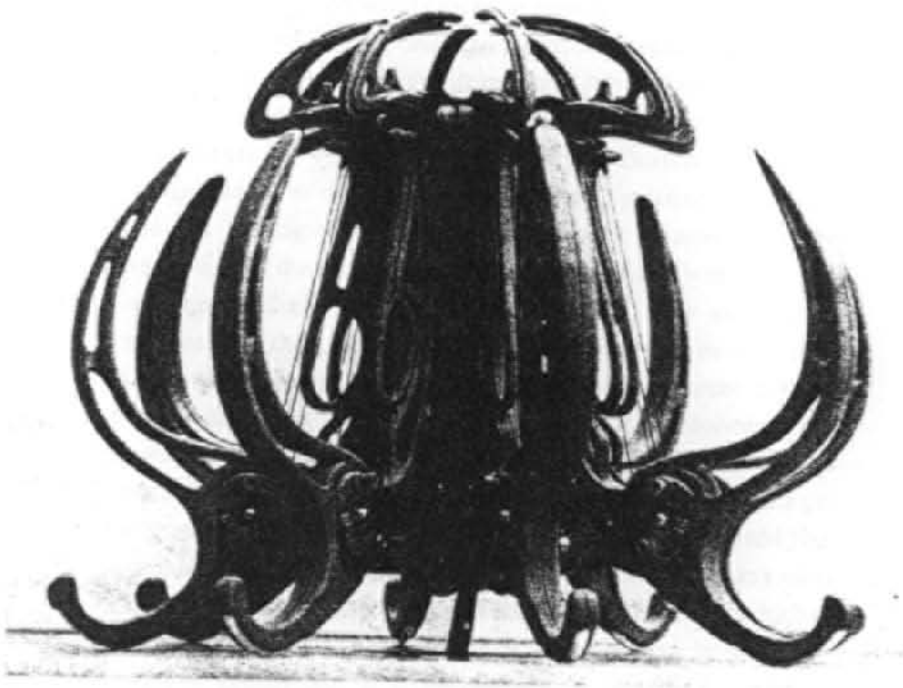

Figure 4.1 Yves Amu Klein, *Octofungi* (1996).

This chapter completes a progression that is implicit in the previous two chapters: a movement of artistic focus from inner to outer worlds. Breeders operate in a coded computational interior, open only to limited interactions, and although they draw extensively on biological metaphors, the artifacts they generate often seem to belong more to that coded inner space than to the outer world. In cybernatures, that computational space begins to open outward in both form and content; the outside is drawn in through the user's interactive involvement and mirrored, awkwardly, in these toy worlds. This chapter, considers works that pull away from the inner window provided by the computer screen and consciously occupy physical space. These artists build a variety of physical systems: interactive robotic creatures, technological and biological composites, installed

HARDWARE

robotic "ecosystems" and "communities." They take a deliberate and difficult step into embodiment: a-life is most easily implemented in computation, where it remains malleable, portable, and immaterial; the development, construction, and maintenance of complex electromechanical devices is far more demanding. However, the rewards this transition brings are considerable: the embodied work has a palpable presence; it becomes more richly available to experience. In placing their works in the room with us rather than in the "elsewhere" of a virtual or simulated space, these artists are able to explore an open, transparent form of interactivity that in a sense requires no interface. The weight and presence of a "body" brings with it an immediacy that screen-based work often lacks.

This sense of "being with us" is at the core of the concerns articulated by these artists. In particular, they pursue not a simple sculptural presence or a passive being but an active, responsive, autonomous presence; to a varying extent their works are in fact *beings* with us. These works embody and provoke questions of autonomous agency, interaction, and subjectivity; they address the line between object and being, between inert artifact and active self-sufficient other.

As such, they approach in various ways the figure of the automaton, the artificial autonomous being, and its long history. From Egyptian articulated statues and water clocks to elaborate nineteenth-century clockwork automata and Vaucanson's famous mechanical duck, this history, when linked with the progressive drive of technology, describes the gradually increasing autonomy of its objects.[1] As mentioned earlier, the cybernetic art theorist Jack Burnham considered the implications of this progression for artistic practice, declaring in 1968 that "the logical outcome of technology's influence on art before the end of the century should be a series of art forms that manifest true intelligence."[2] Burnham's vision of truly autonomous sculpture, and the coupled drive of technology and modernist art making that it articulates, is echoed in the work of some contemporary a-life artists. The ensemble of techniques and concepts these artists apply is strongly contemporary, however. The work of the roboticist Rodney Brooks is particularly influential, providing the primary reference point for a-life artists' models of agency and their approach to synthesizing autonomy. In considering Brooks's work, it becomes apparent that the quest for absolute autonomy, which remains at the core of his work, yields an interesting by-product: a model of agency that is decentralized and embodied, where the single entity is in fact a collection of interacting processes linked closely with their environment. The notion of agency's arising from a single, coherent center of consciousness, conventionally identified with the mind and rational thought, is complicated. The following discussion treats Brooks's work in detail and explores ways in which these artists play, in a quite concrete way, with the implications of Brooksian models of agency and subjectivity. While the urge for artificial autonomy is ever-present in these works, it is often less important and less interesting than their reflexive investigations of agency, interaction, subjectivity, and sociality. These artificial, engineered agencies operate like strangely articulated mirrors; we recognize something familiar and identify with their responsiveness, their actions and interactions. We see some flicker of our own autonomy reflected in their electromechanical forms and come to reflect on the nature of that autonomy (ours and theirs) and on the engineering of its operation.

YVES AMU KLEIN

Yves Amu Klein is one of the few artists considered here whose work aims unambiguously for living autonomy. The son of the painter and performance artist who shares his name, Klein groups his recent work under the banner "living sculpture," "a series of works that attempts to bring emotional intelligence and awareness to sculptured life forms."[3]

Octofungi (1996) is an eight-legged radial construction, about 30 centimeters high, a vaguely mushroom-shaped octopus made from moulded polyurethane (figure 4.1). Its construction is highly sophisticated, integrating sensors and electronics into a light compact form; it uses a shape-memory alloy wire, or muscle wire, to flex the eight legs, avoiding the need for heavy, noisy motors. *Octofungi's* eight light sensors, mounted around the top of the structure, are connected to a brain in the form of a simulated neural network. This network is able to adjust to its input over time, with the result that *Octofungi* will be still or, as Klein says, relax when its environment is static. When a change is detected, often as a result of movement in the surrounding space, the sculpture responds, flexing its eight curvilinear legs in order to approach or recoil from the detected change. The resulting interactive motion is subtle and smooth, a product of the work's eight-way geometry and the lifelike behavior of the muscle wire.

Klein likens *Octofungi's* behavior to that of a moth or a snail, saying its awareness is purely instinctual and its actions are reflexive.[4] However, the planned implementation of an overseer brain will allow recognition and response over time; Klein claims the work will "recognize sequences of movements and reply with sequences"[5] as well as be able to learn new sequences. Klein has developed a software environment designed to breed new neural network brains for *Octofungi* using genetic algorithm techniques; here brains are selected based on the behavior they produce in a software simulation of the hardware *Octofungi*. The neural net model that this software evolves is particularly complex; it includes simulations of hormonal flows over time intended to achieve a sense of emotional change, inflecting the brain's response. It also mimics the neural background noise found in biological neural structures. Klein is optimistic that such a system will produce brains whose behavior is "more flexible and 'fuzzy' than conventional neural networks."[6]

Klein's investment in "emotional" software is complemented by a sculptural approach to the hardware bodies of his creations. He strives for "a sense of biological design," a form that is intricate and considered, where inner and outer systems are tightly integrated and every detail significant. "[H]ardly any of the details in my sculptures are simply for aesthetic purposes," he says. "Each line and curve should have a significant effect on the functionality and aesthetics of the piece in order to survive the design process. In a sense, I apply some of the principles of natural selection to a sculpture in progress." Further, Klein distances himself from the rough bricolage approach characteristic of some other artists in the field, such as the robotic performance group Survival Research Laboratories.[7] "Every thing I build starts from scratch. . . . I do not use . . . found parts. I build things keeping in mind reliability, safety, and durability."[8] Klein's overriding concern in both hardware and software is with organic unity: "What I really thrive on is to find ways to integrate all of those parts into a harmoniously unified living sculpture."

Klein's later work includes *Lili-Pods,* a set of small floating solar-powered sculptures that communicate over electromagnetic and infrared and use artificial evolution to adapt to each other over time. As well, Klein's plans for "living jewelry" have begun to materialize with *Bella,* a small handheld object that glows, vibrates, and shimmers through its perforated gold and silver casing (figure 4.2). *Bella* is densely packed with sensors for light, infrared, and stereo sound; its behavior adapts using an evolvable neural network. Klein likens *Bella* to a fetish or talisman, a precious companion object that develops an emotional connection with its owner.

Other works in progress include *Lumabloom,* a squat eight-legged pod with an articulated electromechanical flower; and *Trila,* a large sculpture with three unfurling leaves whose arrays of LEDs will display shifting, emotionally modulated images based on real-time scans of the sculpture's surroundings.[9] Klein has also outlined plans for "symbiotic sculpture," the construction of composite systems involving biological life, where a technological system acts as an ecological mediator, joining "species that would normally kill one another into a sculpture in such a way that all three would interact in a friendly and co-operative way."[10] In the proposed *Robo-Ant* project, an ant colony and a robot sculpture would be sustainably integrated, forming a composite entity with emergent interactive behaviors. Such a peaceful symbiosis has wider significance, of course: "This type of relationship gives a glimpse of what the future will hold for us and our natural environment as our advances in science and technology slowly converge with the laws of nature for the benefit — or the desolation — of all."[11]

Most recently, Klein has outlined plans for *Lumadusa,* a tiny six-legged robot only 4 millimeters in diameter, which lives in a water-filled pendant. It will make use of sophisticated "smart" materials, electronically active polymer filaments that serve as muscles, folding the silicon wafer that is the sculpture's body. This project marks an

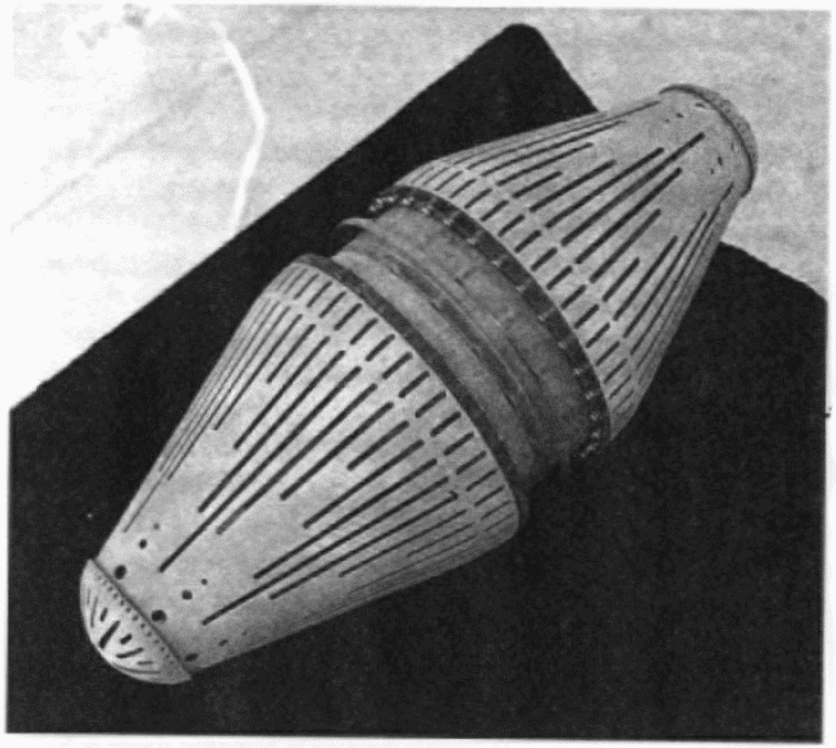

Figure 4.2 Yves Amu Klein, *Bella* (2001).

interesting move away from macroscale electromechanics toward nanoscale molecular engineering, which for Klein paves the way for artificial creatures that can grow, develop, and heal themselves (like even the simplest organic life forms).[12] Klein also anticipates investigations of artificial metabolisms and digestive systems, such as using distillation to convert organic matter into alcoholic fuel, and self-replicating sculptures imbued with artificial genetics and based on "a multitude of self-contained robotic cells." These plans for emotional, metabolizing, self-reproducing systems suggest that the phrase "living sculpture" is applied quite seriously here: an entity with these abilities would meet many of the hallmarks for aliveness and approach the ultimate goal of so-called hard artificial life. At one point, Klein describes living sculpture as "a body of ongoing projects that endeavors to forge an evolving autonomous art."[13]

However, despite these aspirations, Klein steps back from making a strong claim for the aliveness of the works: "It doesn't mean that the sculptures are alive per se." Rather, they "incorporate some of our understanding of the principles that govern life" in an effort to become "more life like" and thus to "increase the intensity and the complexity of the relationship between viewer and sculpture." Art rather than life remains central here. This point is reinforced as Klein places his work in the context of traditional sculpture, which he understands as "grabbing the essence" of its subjects; in the same way, Klein sets out to capture the essential qualities of living organisms and to reintegrate those qualities in an artificial medium. At a certain level of complexity, or at a point where those essential qualities are accurately captured, the work may become so lifelike that it is effectively alive; once again, this point recalls Jack Burnham's Modernist, systems organicism.

KENNETH RINALDO

Kenneth Rinaldo shares some of Klein's aspirations for emergent autonomous sculpture, eagerly anticipating "the day when my artwork greets me 'good morning' when it has not been programmed to do so."[14] However, Rinaldo also shares Klein's interest in symbiotic (or at least benign) interactions between technological and living systems. In fact, this interaction or intersection outweighs emergent autonomy to become the central theme in Rinaldo's work.

Rinaldo's best-known work is *The Flock,* a collaboration with the electronic engineer Mark Grossman first shown at Siggraph in 1993 (figure 4.3). *The Flock* is an installation comprising three delicately articulated robotic arms suspended from the ceiling. *Robotic* here is a technical rather than an aesthetic description: the arms are made largely from sections of rough grapevine, delicately joined with pine and held in tension with steel wire. Within the sinuous organic lines of the vine framework are finer inorganic tendrils of electric cable and the cords and pulleys that pull the arms into motion. Each arm consists of four jointed segments and tapers to a point as it approaches the floor of the space; toward the tip of each arm is a small speaker that emits telephone touch-tones. Video documentation shows the arms moving in response to the presence of a human figure in the installation space: they sway slowly but irregularly, arching a sensor tip upward and pulling back as the visitor moves forward.[15] Around 3 meters in length, the arms have a strong physical presence; they extend well overhead and move over a large radius. Rinaldo writes of the importance of scale in the work: "Anything bigger than we are is the master of our universe and suddenly we encounter it on a different level."[16] Because of the space it occupies, *The Flock* is not so much observed as entered: visitors move with and within the piece rather than around it.

The Flock's graceful, responsive mobility is the product of a complex technical infrastructure. Mounted at the top of each arm, where it is anchored to the ceiling, is a battery of sensors: three infrared proximity sensors are used to track motion within the space, and an array of four microphones allows sound to be detected and localized.

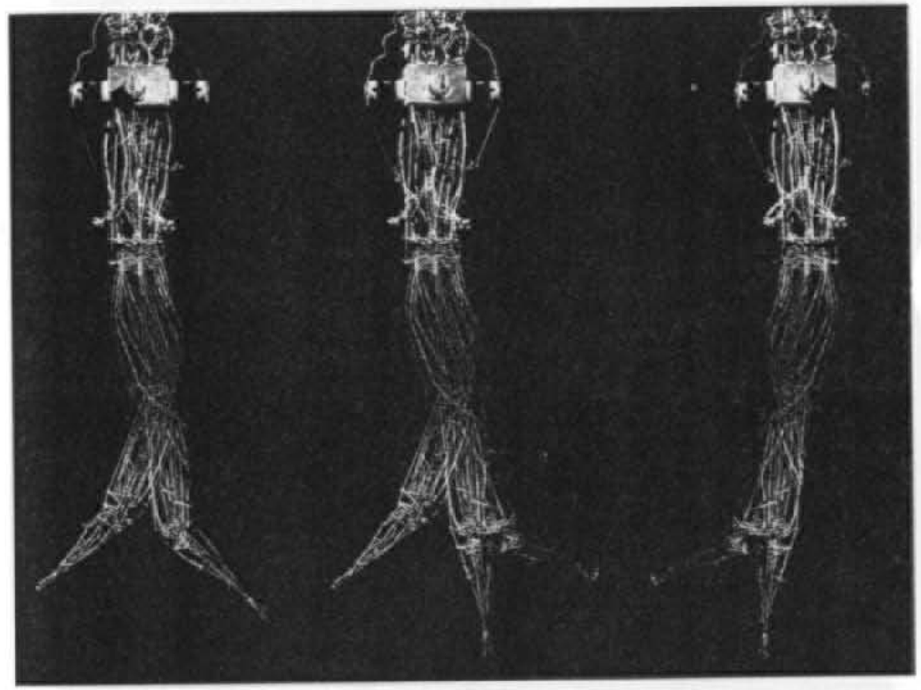

Figure 4.3 Kenneth Rinaldo and Mark Grossman, *The Flock* (1995). Time lapse image.

An additional infrared sensor at the tip of each arm detects motion at a smaller scale, allowing the arms to negotiate closer interactions. Data from these sensors are used in what Rinaldo describes as "a collection of co-operating real-time processes," which interact to generate the flock's complex behavior; these processes share some data with each other but follow no central controller.[17] At the simplest level of this architecture is a "self-preservation" process, in which each arm uses the upper infrared sensors to detect the presence of visitors or other arms and avoids colliding with them. At a second level, the sound-tracking process causes the arms to move toward a sound source (typically, a human voice) but recoil if the sound is louder than a given threshold. In a more complex layer, the arms are programmed to be able to communicate with each other using their emitted telephone touch-tones. The tonal qualities of these signals make them easy for the arms to recognize and distinguish them from the typical sounds of human speech. Visitors can hear the arms singing to each other, but their song operates as a kind of private language. Its melodic strings are in fact coded spatial information, a set of coordinates describing the position of a detected motion source. When an arm "hears" this information, it will move toward that position. It is this real-time intercommunication between the arms that allows coordinated flocking movements to arise.

Autopoiesis (2000) develops and extends *The Flock:* here fifteen 2-meter grapevine arms occupy a whole room (figure 4.4). They are sensitive and responsive, delicately approaching visitors and singing them touch-tones as well as communicating privately among themselves over a digital network. Here, too, there is a complex articulation of local and global behaviors: the group's choreography is modulated by locally sensed motion, and that global movement is broken in turn by the arms' local reactions. Also, two of the arms carry tiny video cameras at their tips, which feed projections on the wall of the installation space. This simple device strengthens the

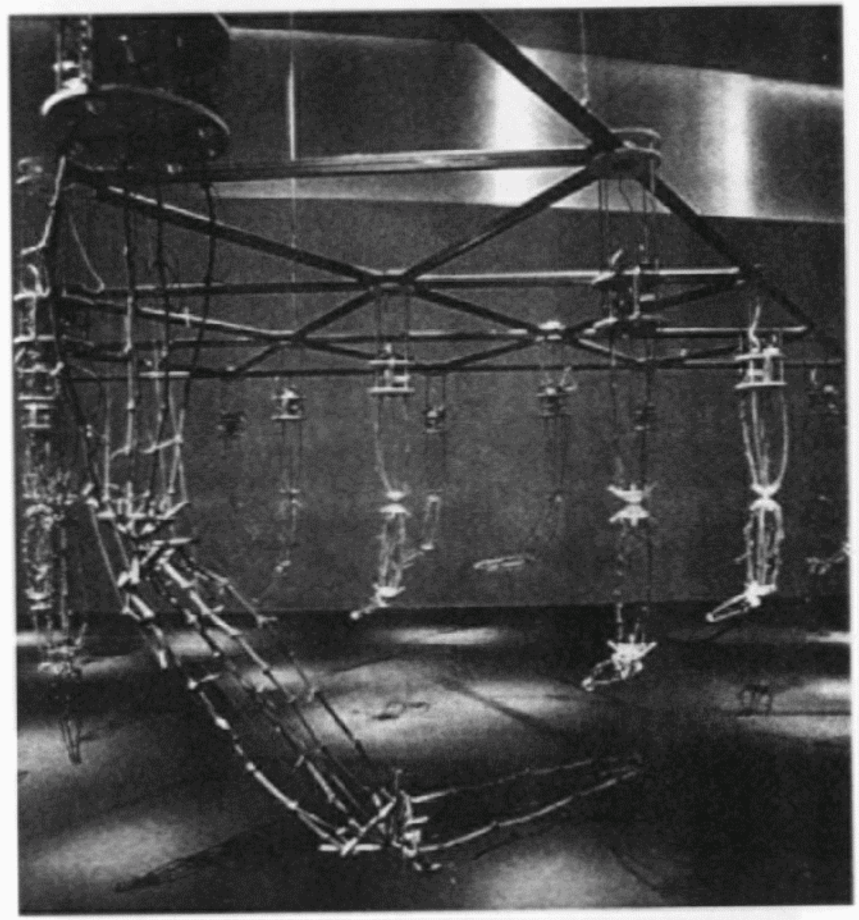

Figure 4.4 Kenneth Rinaldo, *Autopoiesis* (2000). Exhibited in *Alien Intelligence* (2000), Museum of Contemporary Art Kiasma and Central Art Archives. Photo by Yehia Eweis.

work's sense of autonomous agency: we can see both that it is watching us and that its point of view is spatially and dynamically very different from our own. The scale of the array also alters the experience significantly, providing an immersive, responsive physical environment, a dynamic hanging forest.

The intertwining of technological and natural materials in *Autopoiesis* and *The Flock* reflects Rinaldo's underlying interest in, and optimistic engineering of, the articulation of natural and technological systems. This articulation is evident in works such as *Technology Recapitulates Phylogeny* (1994); here a living colony of tubifex worms is housed in a shallow dish, illuminated in response to detected motion. The worms form a variety of complex macrostructures, musclelike masses that twitch and recoil when touched, expanding branching tree-structures, and independent anemone-like clusters. Mounted on the wall alongside, a circuit board and two slides containing human brain cells reinforce the association alluded to in the work's title. The juxtaposition of biological and technological systems points to a shared form: the tree structure. Such structures are, Rinaldo asserts, "super-efficient matter- , energy- and information-distributing networks" evident "in organic and now inorganic systems."[18] Rinaldo argues in this work, and more generally in his writing, that technological systems are gradually taking on naturally occurring models, recapitulating the development of living systems.

Works such as *Delicate Balance* (1995) move beyond this structural isomorphism to explore an active dynamic symbiosis between the organic and the inorganic (figure 4.5). In this work, a Siamese fighting fish swims in a small heated bubblelike tank balanced on a cable stretched between grapevine pylons. As the fish swims in front of movement sensors mounted on either side of the tank, the tank moves slowly to and fro along the cable. Using a simple electromechanical interface, Rinaldo extends the mobility of the fish beyond

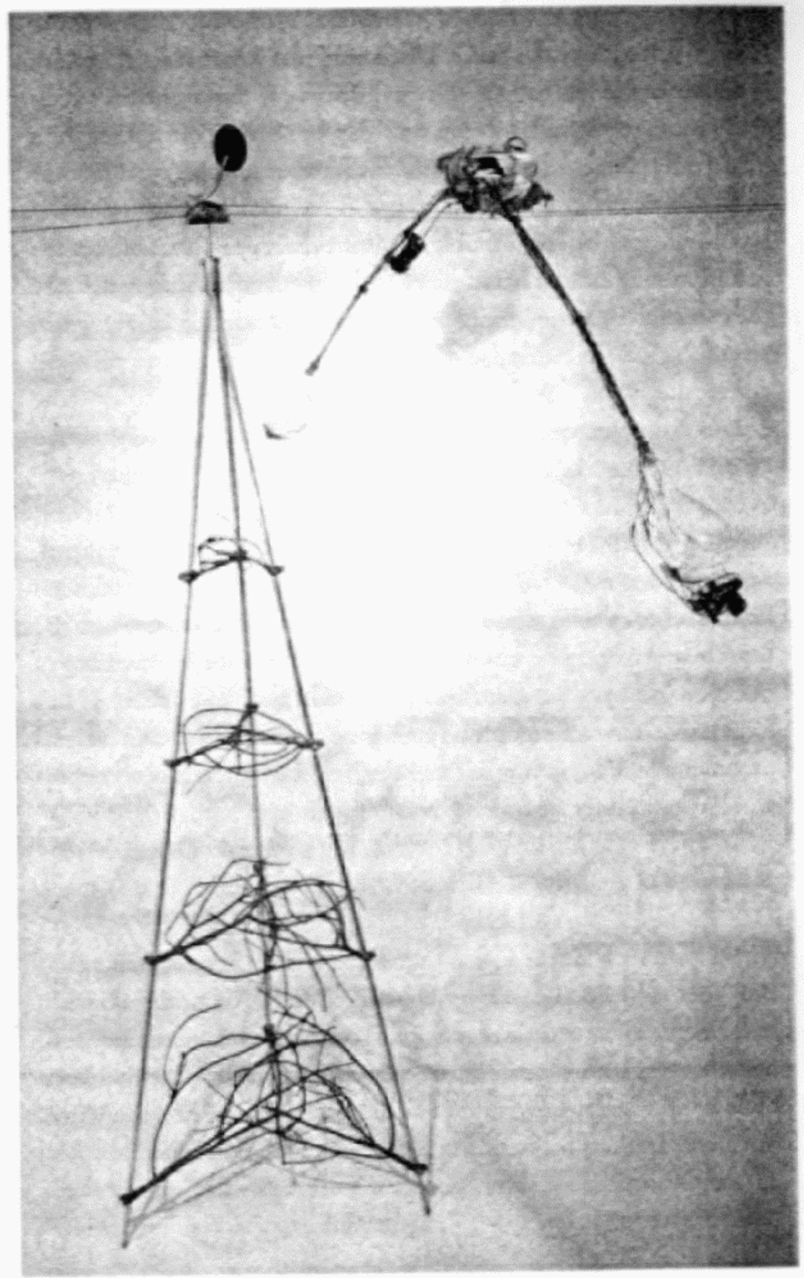

Figure 4.5 Kenneth Rinaldo, *Delicate Balance* (1995).

the normally static confines of its small tank, drawing its habitat out along the length of the cable. Discussing this work in an interview, Rinaldo says it was triggered by the discovery that fish have excellent vision, so fish in tanks can only explore a small portion of their visual environment: "The question was, what if you gave a fish the ability to determine where it went? . . . Would the fish use it and would the fish be comfortable?"[19] Rinaldo reports that in fact the fish in mobile tanks lived longer than others, "interestingly because they seem to be having more fun moving back and forth." As well as an ethological (and ethical) experiment, this technological-biological composite is for Rinaldo a metaphor for the degradation of the oceans, complex organic systems being exploited and constrained along human axes.

As this last point indicates, the confluence of biology and technology that Rinaldo pursues is motivated by ecological concerns; it attempts to exemplify a smooth integration of technology into the biosphere. Rinaldo expresses his hope "for a sustainable melding of our biological environment and the technotope" and declares, "It is imperative that technological systems be modeled on the principles of general living systems, so that they will inherently fuse to permit an emergent, interdependent earth."[20]

Bill Vorn and Louis-Philippe Demers

There is no such idealism in the robotic installation environments of Bill Vorn and Louis-Philippe Demers. While Klein and Rinaldo make benign, harmonious systems, Vorn and Demers make loud, nasty, violent ones; where Rinaldo smoothes the boundary between biology and technology, and between the audience and the work, Vorn and Demers make this interface threatening, playing fear and anthropomorphic empathy against each other in what becomes a robotic theater of affect.

Demers and Vorn describe their works broadly as "robotic ecosystems"; robot-sculptural components are installed in a space with various sensors, dynamic lighting, and sound projection.[21] The entire complex is controlled by one or more central computers, which deal with incoming sensor data and trigger movement, light, and sound in the installation. The individual robotic components are dumb, that is, they have no discrete processing power, but the computer system uses artificial life techniques to imbue them with degrees of behavioral independence; they interact with human visitors or with other robotic entities and exhibit collective behaviors such as flocking.

Espace Vectoriel (1994) is a monoculture, a population of identical steel tubes 1.2 meters long and 7.5 centimeters in diameter mounted on pivoting, rotating bases (figure 4.6). At the base of each tube is a halogen light and a small speaker, both aimed toward the tube's open mouth; around the eight clustered individual tubes are eight ultrasound sensors arranged to cover the perimeter of the space, occupied by the audience. In action, the open pipes emitting bursts of light and sound read anthropomorphically as eyestalks or mouth tubes, and their motion, triggered by the presence and location of observers, is stiffly inquisitive. Pivoting in a dim foggy space, their lights extend the line of each tube, forming a mobile vector space that extends beyond the installation's physical bounds. The behavior of *Espace Vectoriel* has several distinct modalities; in the "organic" mode each tube makes slow random changes in its pan and tilt, producing an overall undulation. If a tube senses a viewer within a certain radius, it will recoil and react with a distinctive responsive routine. In another mode the tubes fan out, each tube emitting sharp sound and light pulses at a tempo influenced by the concentration of viewers in the space. The group of tubes can also flock, pointing toward the most crowded part of the space and entering into a feedback dance with the viewers as they move away from the intense sound and light bombardment.

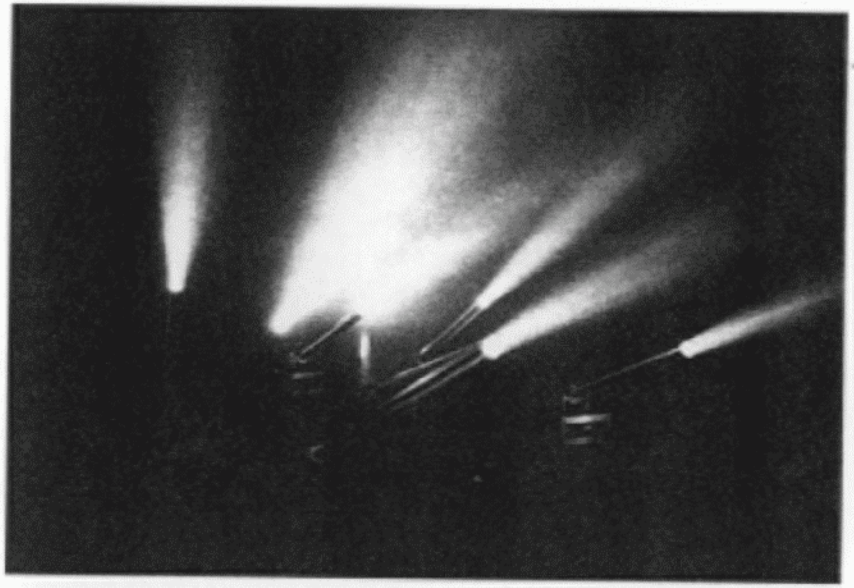

Figure 4.6 Bill Vorn and Louis-Philippe Demers, *Espace Vectoriel* (1994).

The Frenchman Lake (1995) is another population of identical units that follows many of these technical and behavioral forms. The units in this case are small transparent hemispheres, about 30 centimeters in diameter, each housing a halogen light and a speaker, and mounted on a pneumatic piston actuator that can raise or lower the dome through a range of about 1 meter. These are aquatic robots, installed either in a large basin or sixteen individual 44-gallon drums (figure 4.7). In the latter configuration, the units bob twitchily up and down in their tiny individual lakes, which are perhaps more like drums of toxic waste: the installation is named after a nuclear test site in Nevada that remains radioactive. "Even under a calm and serene appearance, the valley drizzles with invisible 'life'."[22] As with *Espace Vectoriel,* this group has behaviors that allow individual articulation; the units respond to viewers' proximity and disturb their neighbors. The total result suggests an industrial noise dungeon or a waste dump inhabited by furiously twitching hermit-robots.

No Man's Land (1996) and *La Cour des Miracles* (1997) are robot ecosystems with greater diversity; both these works are large installations involving numerous different types of robot individuals intended to interact in particular ways. *No Man's Land* has Scavengers, simple robots fighting over a lump of metallic carrion, which slides itself around a metal tray; Parasites, small solenoid-driven beaks that peck at the bodies of their host robots; and Captives, four-limbed frames that thrash helplessly on the floor, tethered by their own cables. In correspondence, Vorn says of *La Cour:* "Our intent is to show the 'misery' of the machines. We hope that people will 'feel' something for these poor robots by normal empathic reactions and anthropomorphism."[23] This latest work includes the most openly humanoid robots Demers and Vorn have made, including The Heretic Machine, a two-limbed torso that grips the wire mesh of its cage and shakes furiously as a viewer approaches, and The Convulsive Machine, a four-limbed figure pinned twitching to the floor

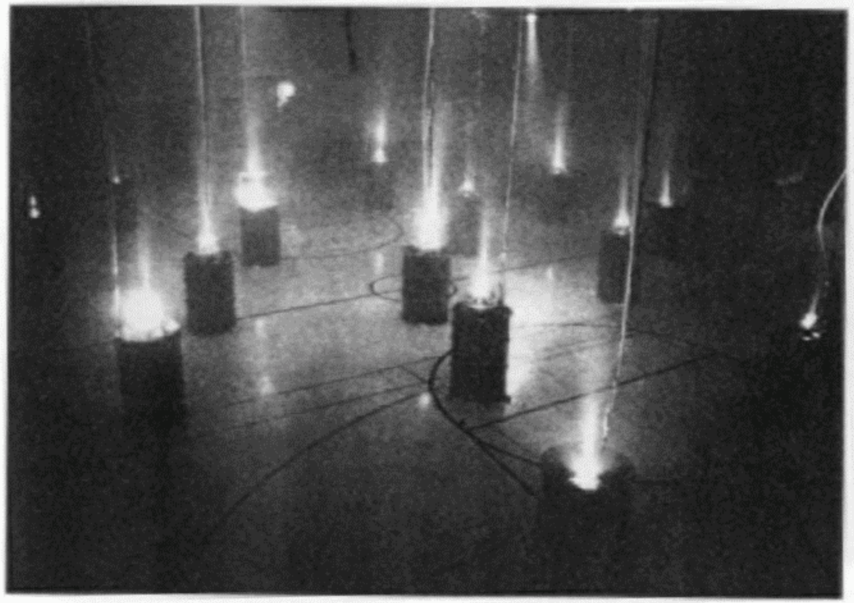

Figure 4.7 Bill Vorn and Louis-Philippe Demers, *The Frenchman Lake* (1995).

(figure 4.8). Other robotic developments include a Begging Machine with a single suction-equipped arm and a Harassing Machine, which taunts onlookers with bunches of latex tubes animated by bursts of compressed air.

Demers and Vorn's work presents an interesting contrast with most applications of a-life in new media art. If one characteristic of this field is a cool attentiveness to systemic properties of the work, as in Lovell and Mitchell's *EIDEA*, then the work of Demers and Vorn represents an opposite pole, far less concerned with the system as a system than as theater, an immersive, affective environment. As in human theater, affect is channeled through characterization and identification. Where this analogy begins to break down is also where it is most interesting; these aren't characters at all, but cybernetic systems, simple automata. However, they are not so much crude as carefully focused, each trapped in a single affective gesture, a single theatrical moment. Rather than follow the path of developing flexible, autonomous artificial subjects, Demers and Vorn produce part-subjects, fragmented affective machines (literally). The ontological status of these machines is not at issue; Demers and Vorn describe these installations as constructing a fictitious society: "immersed in this simulated world, the audience is more convinced of the simulacra."[24] This evocation occurs through a perceptual displacement: "These installations are about displacement of existing artifacts and expected life-like behaviors. [They impose] our own perception of natural behaviors upon a society of mechanical, audio and visual elements." The artists seem most interested in how much apparent life they can evoke with "an abstract, . . . bare inorganic skeleton"; this is artificial life as a carefully evoked anthropomorphic projection, encased in an environment that displaces its human audience, where "viewers are both visitors and intruders."[25]

Interestingly, the theatrical and anthropomorphic aspects of Demers and Vorn's work seem to be growing in importance. While *Espace*

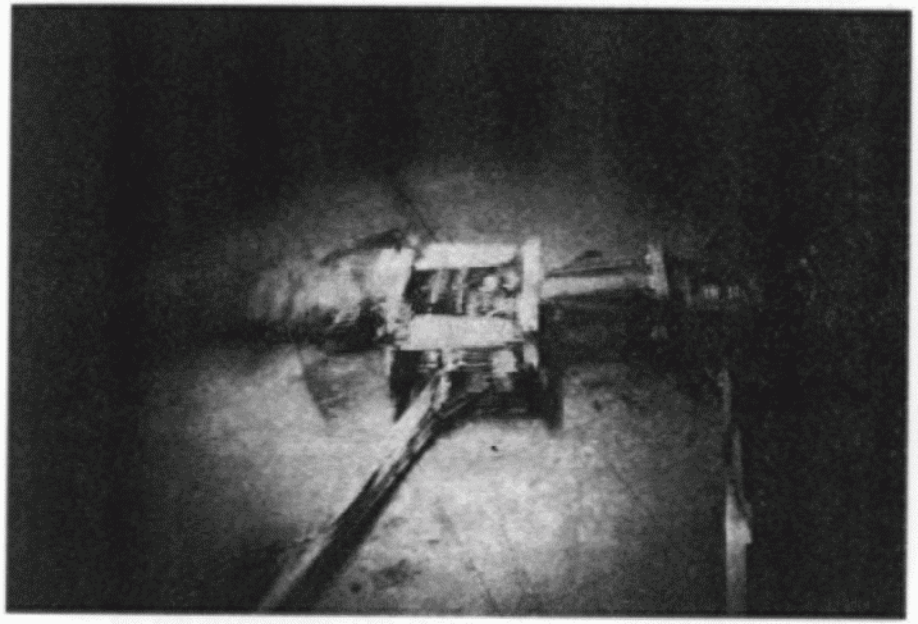

Figure 4.8 Bill Vorn and Louis-Philippe Demers, The Convulsive Machine, in *La Cour des Miracles* (1997).

Vectoriel and *The Frenchman Lake* are clearly focused on collective behavior in a homogeneous group of simple robots, with behavioral flexibility and organic interaction, later works become more theatrical and the robots more humanoid and affect-driven. This tendency moves a step further in their 1999 work *Le Procès — The Trial*. Named for the Kafka novel, this project is billed as "a multimedia performance staging a world populated exclusively by robotic actors."[26] This is a "reflexive tribunal," a reciprocal trial of humans by machines and machines by humans: it focuses and ritualizes the mechanical antagonism underlying their later installations.

Demers and Vorn's work could be aligned with that of other violent roboticists such as Mark Pauline's San Francisco-based Survival Research Laboratories (SRL); there is a certain similarity in the antihuman stance, the extreme demands placed on the audience, and the raw-robotic aesthetic of the machines. What sets their work apart is its extensive use of a-life programming, and the (relative) autonomy this brings, as well as its close ties with theater. Whereas in SRL performances the machines threaten to actually escape into the world or crush or incinerate an innocent bystander, in Demers and Vorn's work the robots are carefully restrained, tethered, chained, or bolted to the floor; they are like marionettes, controlled and restrained by the cables linking them to the computer. The installations create an internal immersive space, threatening for its visitors but ultimately contained: Vorn likens the installations to a Jurassic Park for machines, suggesting simultaneously a sanctuary and a theme park, a natural space and a space of affect.[27]

The central tension that emerges in considering this work is between two discursive strands running through Demers and Vorn's writing and implicit in the works. On one hand, the theatricality of the environments is clearly constructed: sensory and interactive immersion produces the illusion of machine life for the viewer. On the other, there are hints of an interest in the real autonomy of machines. The artists write, "We regard machines as distinct entities from us, as much as we consider ourselves distinct from nature."[28] While Vorn denies any Frankenstein impulse to create life, he allows that "we do believe that machines are part of life and evolution."[29] Neither of these quotes argues for a simple autonomy; this is far from a hard a-life perspective; rather it is a more moderate machinism, informed more by an awareness of the interdependence of human and machine, and the machine's role as a mirror or projection of the human, than by a desire to create mechanical life. The machinic otherness that Demers and Vorn present is a romance, a drama — Vorn describes it as "some sort of dramatic post-industrial poetry" — that uses all the tricks of a-life. In one sense, this work uses these devices as tricks, smoke-and-mirrors devices to provoke reflection on the edges of humanity and machine life. In another sense, it plays self-consciously with the point where these theatrical devices reach such a level of sophistication and sensitivity that they begin to attain independence.

SIMON PENNY

Simon Penny's work is similarly concerned with the space of interaction, the behavioral or affective space between the machine and the human observer. An artist building complex robotic and immersive systems, Penny also writes critically on the problematics of art and technology. This reciprocity is conveyed in his writing, which presents the position of the artist working with technology, and in his artwork, which embodies a fusion of engineering experimentalism and critical perspective, and persistently intermingles the cultural and the technological. Penny describes his work as investigating "the aesthetics of real-space interaction"; rather than a technologically mediated representational space, Penny's robotics are consciously situated in physical space.[30] "I am particularly interested in interaction which takes place in the space of the body, in which kinaesthetic intelligences . . . play a major part." This focus on embodiment is also at the core of Penny's critical writing. Articles such as "The Virtualization of Art Practice" continue a critique of the "engineering worldview" — reductionist scientific rationality — for its perpetuation of a Cartesian split.[31] In this article Penny discusses the influence that this worldview has on the practice of artists working with technology, the process of disembodiment, or bodily "deskilling," involved in the convergence of diverse practices into the "bodily monoculture" of computer operation. Fundamental to Penny's thinking is a notion of bodily intelligence running against a body/mind duality. Penny declares, "I want in all seriousness to argue that I 'know' with my arms and with my stomach."[32] He cites recent neurological research to support this argument. Coupled with this critical interest in embodiment is an engagement with artificial life, both in practice and theory. In "The Darwin Machine: Artificial Life and Interactive Art," Penny expresses a guarded optimism about the potential for a-life techniques in artistic practice; in particular, he sees in emergent order a possible alternative to deterministic interaction, where interactivity is merely "pre-set responses to user navigation through an ossified database."[33] Penny contrasts the dualistic top-down style of conventional computing with the holistic bottom-up approach more characteristic of artificial life.

The close links between Penny's critical writing and his robotic works are demonstrated in *Petit Mal*, an autonomous robot sculpture first shown in 1995 (figure 4.9). *Petit Mal* stands about 1.2 meters high, a spindly counterweighted column topped with a cluster of infrared sensors and perched between two large bicycle wheels. As *Petit Mal* detects a warm object (usually human), it approaches the object and stops, backing off if the object comes closer. It is an ambiguous figure, seeming fragile as its doubly pivoted frame sways precariously back and forth, but purposeful or even aggressive as it accelerates toward a target. Those interacting with *Petit Mal* pace

Figure 4.9 Simon Penny, *Petit Mal* (1995).

warily around it, face it in a delicate standoff, or flee as it seems to pursue them. As Penny says,

> The robot presents somebody with the impression of a non-human, non-animal sentience, which then has to be dealt with in some way. If they run away, it will chase them. If they want to play, it will play. If they are aggressive and advance, it will back off. At some point, if you're boring, it gets bored and goes away.[34]

Petit Mal presents a critique of the conventions of robotics in a number of ways. Its name refers to a type of seizure or fit involving a momentary loss of consciousness: Penny's intention here was "to have a robot that was not entirely in control, that would have these momentary lapses in consciousness — but still be able to survive." Where a more conventional autonomous robot would diligently maintain its artificial awareness, tracking the space and activity around it, *Petit Mal* is forever passing out, forgetting itself. The work also addresses the Cartesian dualism that Penny criticizes in his writing. *Petit Mal* is concerned with a "holistic approach to the hardware/software duality," and its form is a product not so much of design as of the "brutally expedient exploitation of minimal hardware"; form emerges from the functional requirements of locomotion and sensing.[35] The minimal sensor array includes a "rudimentary proprioceptive sensor" that provides the robot with a degree of awareness of its own body. Penny says he "wanted the software to 'emerge' from the hardware"; he links the conventional hardware/software duality in computer science and robotics with "the privileging of abstract over concrete" and describes *Petit Mal* as an attempt to implement an alternative structure.

As much as an illustration of embodied robotics, *Petit Mal* is intended as an interactive agent onto which viewers project motivations and subjective traits; as well, this is "an agent whose function is self-reflexive, to engage the public in a consideration of agency itself."[36] For Penny here, the engineering of an autonomous entity is less a question of the entity's internal representations or its design as a system than of its capacity to provoke projections of subjectivity in the humans with which it interacts. Penny says, "One of the foci of my work over recent years has been to pragmatically explore 'how much can be left out' in the construction of an agent, and still give the impression of sentience." For the artist, *Petit Mal* investigates the "social and cultural aspects" of this question, "concentrating on the dynamics of projection and representation." With *Caucus*, a proposed work involving mobile autonomous agents capable of a kind of linguistic communication, this engineering of social dynamics is tackled more explicitly. Penny hopes that *Caucus* will demonstrate an "emergent sociality, without recourse to preprogrammed roles, hierarchies or social behaviors."

The two *Sympathetic Sentience* works, made in collaboration with Jamieson Schulte, are simpler examples of Penny's work with emergent behavior and collectivity. *Sympathetic Sentience I* (1995–1996) consists of a group of small electronic devices fixed to the walls of a space, with tiny speakers emitting rhythmic electronic chirps (figure 4.10). These devices communicate with each other using infrared beams, forming a data stream that loops through the entire group.[37] The rhythm emitted by each unit is passed on to the next in the stream, with some possible alteration — a simple electronic game of Chinese Whispers. *Sympathetic Sentience II* (1996–1997) is a similar group that adds pitch variation; while the first version of the piece suggests crickets or frogs, in the second, the resulting texture sounds like a swarm of tiny techno-riffing analog synths. What makes these pieces more than random blip generators is their subtle occupation of the installation space: the invisible infrared beams that weave through the room are interrupted by visitors, causing dead spots in the data stream that continue to orbit the group. A persistent

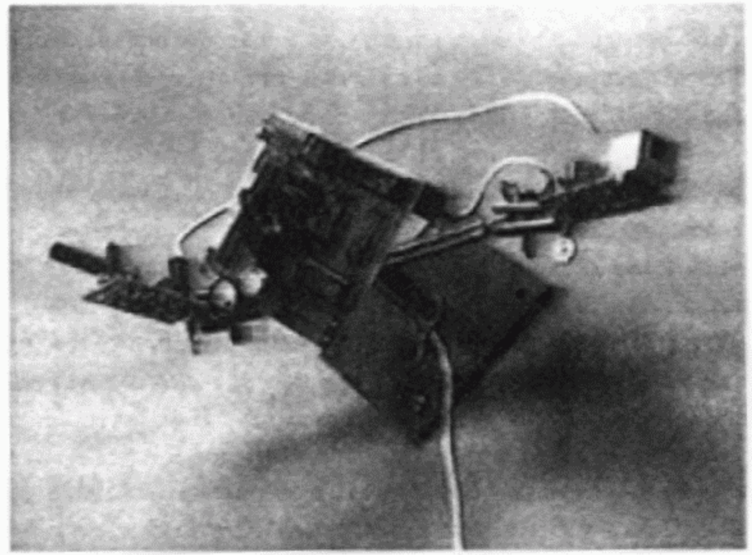

Figure 4.10 Simon Penny with Jamieson Schulte, *Sympathetic Sentience I* (1995–1996). Detail. The unit's infrared emitter and receiver are visible at the left and right of this image.

interruption will silence the whole system, and a new rhythm will accumulate from chance additions when communication is restored. These pieces are parenthetically subtitled *Two Communities,* suggesting that this group of simple chirping robots is in some sense a mirror of the human community interacting with it. Like *Petit Mal,* this robotic system is embedded in a social environment in a way that links interaction with reflection: the chattering crowd at the exhibition opening meets this other chattering crowd, and the two negotiate their overlapping communicative spaces.

Penny's later works continue to investigate interactive autonomy and a-life technique, although they describe shifts away from hardware and toward the interface between embodiment and mediated representation. In *Fugitive* (1995–1997) a video image slides around an enclosing circular screen, running away from the user; a machine vision system interprets the dynamics of the user's motion and drives the projected image in response. *Traces* (2000) uses a high-tech CAVE virtual reality platform and experiments with alternatives to the virtual reality paradigm, which Penny has powerfully criticized. In *Traces* there is no represented world, only a dynamic pseudo-autonomous avatar that mirrors a visitor's body, reconstructing it from chunky, cubic voxels (volume pixels). The avatar retains fading traces of the body's motion; the visitor "'dances' a 'sculpture' into existence."[38] Moreover, this sculpture begins to take on a life of its own: at one stage the virtual traces begin to persist and flicker, or propagate; the work uses a three-dimensional cellular automaton to allow the voxel traces to interact with each other. Finally, the visitor is able to throw off autonomous traces with a flick of the hand or foot. These traces are swarming spheres that flock around each other and the visitor's avatar. These techniques for autonomy are familiar, but here they have an interesting critical leverage; acting partly as aesthetic generators, they primarily trigger an awareness of the otherness of the avatar, the nonidentity of avatar and visitor.

ERWIN DRIESSENS AND MARIA VERSTAPPEN (*TICKLE*)

Although the Dutch artists Erwin Driessens and Maria Verstappen work largely with software and generative processes, as discussed in chapter 5, their *Tickle* project is very much hardware. In fact, as in Penny's work, embodied human experience is central here, although there is a new ingredient: pleasure. As part of a practice that systematically seeks out the generative pleasures of unknown forms and aesthetics, the artists have been working on automatic tickling systems for some thirteen years. Tickling is, of course, a challenging and delicate sensory/spatial task; as Verstappen says, "An important aspect of good tickling is that it has to be unpredictable."[39] *Tickle* (1995–1996) is a small autonomous robot: a blank stainless steel box about the size of a cigarette packet, it is fitted with a pair of nubbed rubber caterpillar tracks (figure 4.11). With simple mechanical sensors and a motor powered by rechargeable batteries, it crawls over a reclining body, reversing and pivoting to avoid falling off and tracing a wandering, unpredictable, and apparently pleasurable path.

From its context and documentation, we can infer that *Tickle* is an art object; at the same time, Driessens and Verstappen allow it to be interpreted as a purely utilitarian object, an autonomous robot masseur, perhaps even a vaguely erotic plaything. Their Web site discusses the prospect of limited commercial production, an idea that only arose, Verstappen says, in response to the interest generated by on-line documentation of the work. Other solutions in the artists' experiments with automatic ticklers include a motorized blade of grass suspended over the ticklee's back. In their wonderful prototype *TickleSalon* (2002), they update this structure radically: a ceiling-mounted robot gently drags a soft brush over the prone body.[40] It uses tension sensors to maintain delicate contact and at the same time maps the coordinates of the body surface, displaying them on

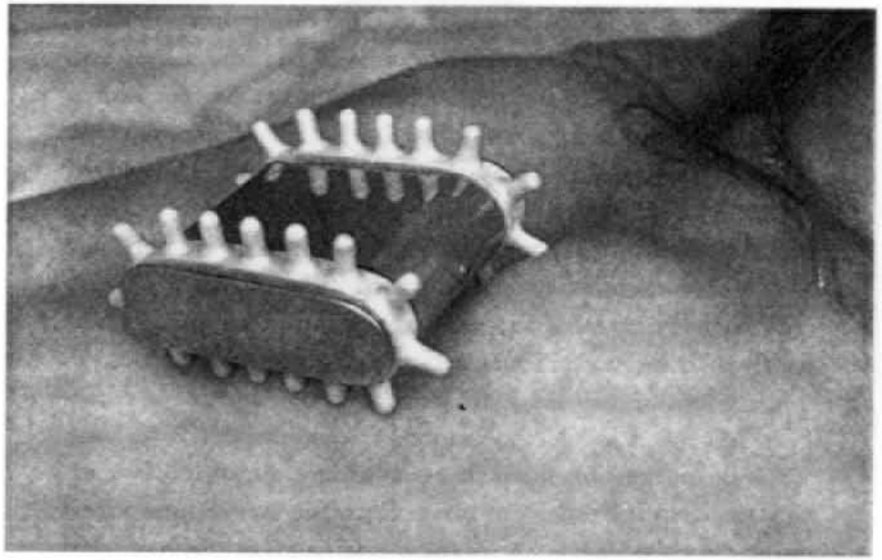

Figure 4.11 Erwin Driessens and Maria Verstappen, *Tickle* (1995–1996).

a computer monitor; this information in turn shapes the robot's path in its quest for the formal hallmarks of tickling pleasure: "variation, unpredictability, and smoothness."

ULRIKE GABRIEL

The *Tickle* robots invite us into a physically intimate relationship that challenges and titillates our corporeal sensibilities as well as questioning relationships between autonomy, servility, and pleasure. Ulrike Gabriel's interactive robotics take an equally intimate position, though their connection is mental. Gabriel's works have included virtual reality environments, collective on-line spaces, community projects, and interactive robotic installations. Three works in the last category, *Terrain_01*, *Terrain_02*, and *Barriere*, are most relevant here.

In *Terrain_01* (1993) a small group of roachlike solar-powered robots moves around a shallow circular dish (figure 4.12). The robots have simple sensors allowing them to move around without colliding; because they are solar-powered, their overall level of activity depends on the amount of light striking their photovoltaic cells. Gabriel links a brain wave sensor to the installation's lighting so that the light level increases with the level of alpha waves detected. Alpha waves occur in deep relaxation and meditation, so as the participant switches off, the robots switch on; the more excited or agitated the participant, the dimmer the lights and the more sluggish the robot population. *Barriere* increases the robot population to thirty and adds a second human participant. The two sit on chairs facing each other; between them the robots move around a 5-meter-long cigar-shaped tray on the floor, illuminated by a long bank of lights overhead (figure 4.13). In this case, the frequency spectra of the participants' brain waves are analyzed and compared, and each frequency band linked to one light in the bank. Rather than being linked simply to amplitude, as in *Terrain_01*, the light level here is linked to the degree of similarity

Figure 4.12 Ulrike Gabriel, *Terrain_01* (1993). Detail.

Figure 4.13 Ulrike Gabriel, *Barriere*.

between the two measured spectra; the more similar the spectra in a particular band, the brighter the corresponding light. A couple with identical spectra will illuminate the entire tray, and the robots will move freely along its length; more often, a partial correlation results in light and dark patches and a different energetic surface for the robots to negotiate.

In *Terrain_02* the robots' environment becomes more complex still; the surface of the small tray, situated between the two participants at table level, is illuminated from below as well as from above; differing correspondences between brain wave levels create different illuminated terrains, patterns of light and dark. The behavior of the robots can be altered by the variable electromagnetic fields emitted by the panels in the tray's surface; differing levels (which correspond to the levels of illumination) produce specific single behavior states such as "panic" — forward and backward oscillation — or "avoidance" — the robot avoids obstacles until blocked. At high levels of illumination, the robots are switched into an autonomous state in which they can alter their own behavior using any of these single states. Gabriel claims that "the more closely the brain wave frequencies of the users resemble each other, the more homogeneously the robot population moves, attaining a fluidity of motion and behavior over the entire robot terrain."[41]

Michael Klein, in a statement on *Terrain_01,* writes of the progressive erosion of the idea of a detached, objective observer in physics through relativity, quantum theory, and chaos.[42] This subjective embeddedness is framed and amplified in the *Terrain* works, as the subject is inescapably involved in a process shaping the bounded environment of the autonomous robots. Klein frames *Terrain_01* as an artificial world that allows us to take "both an internal as well as an external stance"; *Terrain_02* and *Barriere* also focus on this duality, adding a second subject to create complex loops of observation, awareness, reflexivity, and behavior.

Gabriel's use of complex systems and emergent order is unusual; whereas most applications focus on the emergent result, an autonomous being or "excess," Gabriel uses the autonomous behavior of the robot population as a device for imparting the sense of separateness or otherness that forms one pole of the fundamental dynamic of these works. Like chessboards, the robot trays in these works function as toy worlds, indicative of the will and consciousness around them, but with an extra degree of autonomy or independent life. Although it goes unstated by the artists, there is an element of animism here, too, or artificial animism. It is as if the participant's internal mental activity is off-loaded onto the robot population; the robots serve as a collective vehicle for, or manifestation of, the inner state of the participant, an outboard hive-mind. In *Terrain_02* and *Barriere* the robots reflect the consonance or dissonance of the two minds attached; Gabriel says the patterns of their movement reflect the users' synergy, "embodying subliminal tendencies."[43]

Brooksian Robotics and the Emergent Subject

These works form a diverse and unruly robotic mass, with dispositions ranging from placid to sociopathic and aesthetics from happily biomorphic to harsh and metallic. However, underneath this range of styles and aesthetics are a handful of important commonalities: concerns with interaction and emergent agency, with robotic flocks, ecosystems, and communities. More specifically, the ways in which these works set about engineering robotic autonomy is heavily informed by the work of Rodney Brooks, a prominent researcher in a-life robotics. An examination of Brooks's approach and the philosophical underpinnings of his work provides the framework for a general analysis of this robotic subspecies of a-life art.

Since the mid-1980s, Rodney Brooks has worked at the MIT Artificial Intelligence Laboratory, where he is currently director. During that time Brooks has taken a radical approach to artificial intelligence research, building simple mobile autonomous robots that owe more to work in artificial life than the cognitive, mind-centric tradition of artificial intelligence research. Brooks's work is motivated by a belief that the goals of conventional artificial intelligence are too lofty and based on inadequate knowledge, and that what he calls human-level intelligence is too poorly understood to be decomposed into its components and artificially remade.[44] He is critical of AI's recent tendency to retreat into working on the components of intelligence in isolation, for vision research, language processing, and knowledge representation (for example) to be pursued separately. Instead, Brooks proposes an incremental approach to artificial intelligence: building very simple systems, but simple systems that are whole and wholly embodied. "We should build complete intelligent systems that we let loose in the real world with real sensing and real action," he says. "Anything less provides a candidate with which we can delude ourselves."

However, it is the way in which Brooks has achieved this goal that is most interesting. A traditional AI approach would engineer an autonomous robot around a central processor, or brain, that gathers data from sensors and controls the robot's actions. Rather than break intelligence down along these functional lines (perception, thought, action), Brooks's tactic is to decompose it into distinct "activity producing subsystems" or layers. According to this model, a simple intelligence might comprise a number of parallel layers, each of which produces a certain activity, "a pattern of interactions with the world."[45] In one example Brooks gives, the base layer moves the robot forward while avoiding obstacles; another layer causes the robot to change direction randomly, or wander; and a third layer causes it to seek out distant places and move toward them. These layers interact, the higher layers suppressing and modifying the action of lower layers; for example, the robot will continue to head for the distant location it has detected while avoiding obstacles. Out of the interaction of very simple components, each of which corresponds to a single behavior, a robust agency emerges. There is no central brain and no attempt to build up an internal representation of the robot's environment; no "inside" is constituted, only a group of processes all linked directly to the "outside" through the robot's sensors and effectors.

Artificial creatures built using this layered approach, which Brooks calls "subsumption architecture," include Ghengis, a six-legged, cockroachlike robot some 30 centimeters in length. In Ghengis the processes controlling each leg operate in parallel and interact to produce an emergent scuttling gait; they allow the robot to negotiate difficult terrain by feeling its way one foot at a time. Bottom-up subsumption architectures deliver behavioral robustness and complexity with very limited computational resources — a result traditional representation-based AI approaches have been unable to achieve. However, as Brooks writes, there was some doubt among proponents of traditional AI that this approach would scale well: although robots such as Ghengis might exhibit an insectlike intelligence, it is not clear that a more complex humanlike agency can be achieved using the same techniques.[46] In an attempt to answer such questions, the MIT group is currently working on Cog, an ambitious project to build a humanoid robot according to the behavior-based, embodied approach developed in simpler robots. The robot's humanoid form is based not on outward resemblance to a human model but on the theory that for humanlike intelligence to emerge, a humanlike body is necessary. "In order for the humanoid to be able to participate in the same sorts of body metaphors as are used by humans, it needs to have a symmetric human-like torso."[47] It also has videocamera eyes that can move rapidly, like human eyes, and a complex articulated neck. The language used to describe the Cog project is striking: Cog "will learn to 'think' by building on its bodily experiences to accomplish progressively more abstract tasks." Cog's realtime reactions and human scale "allows us to design the robot to learn new behaviors under human feedback such as human manual guidance and vocal approval." Cog is, in fact, an attempt to build an artificial infant, a collection of complex embodied sensing and acting processes which is socialized into subjectivity through its interaction with human beings.

Whether or not Brooks succeeds in creating embodied artificial intelligence, his work reflects an important philosophical shift, both in the methodology of artificial intelligence research and more broadly in models of agency and subjectivity. The singular transcendent subject is unpacked into a network of interacting microagencies; consciousness appears not as an ineffable essence of subjectivity but as an epiphenomenon, another emergent property of evolution's engineering; the body here is not simply a vehicle for the self but forms the self in its interactions with the world and other bodies.

Bottom-Up Robotics and A-Life Art

The influence of Brooks's work on robotic a-life art can be shown in several ways. Ken Rinaldo, Vorn and Demers, and Simon Penny acknowledge Brooks explicitly. Rinaldo adopts (and credits) Brooks's subsumption architecture for *The Flock,* a system that like Brooks's own robots involves a number of distinct behavioral processes operating in parallel.[48] Similarly, Vorn and Demers cite Brooks's work in relation to their distributed robot ecosystems, where control software operates "in a local and contextual manner." They offer an example where "a behavior might be ruling the overall system while some isolated triggered behaviors might supersede some global actions."[49] Simon Penny addresses Brooks's work and demonstrates its influence most clearly. He says of his "embodied cultural agent" *Petit Mal,* "My project owes a great deal, of course, to Brooks' iconoclastic proposals."[50] Penny's critiques of the engineering worldview and his interest in embodiment and the potential of bottom-up structures and emergent interactivity align clearly with a Brooksian approach. As well, Klein, Driessens and Verstappen, and Gabriel all clearly employ distributed bottom-up architectures and their emergent agencies.

So Brooks's work and the concepts it involves can provide a standpoint from which to consider the robotic agencies constructed by a-life artists. These works direct us towards a Brooksian sense of agency, one that is multiplicitous, dynamic, embodied, and tightly linked to its environment (including its human audience). These works are more than artistic translations of bottom-up robotics, however; they explore this approach to artificial agency without regard for the goals of AI or a-life; they implement it in different ways and to different ends and incorporate it into their own distinctive conceptual and metaphorical mixtures.

One of the most obvious ways in which these works vary Brooks's robotics is through multiplication: individual entities proliferate into robotic flocks and swarms, arrays of simple units that interact to form a dynamic macroscale structure. Penny's *Sympathetic Sentience* works, Demers and Vorn's ecosystems, Gabriel's solar-powered swarms, and Rinaldo's *The Flock* and *Autopoiesis* are clear examples of this tendency. Although these multiples remain thoroughly bottom-up constructions, they mark an interesting shift in emphasis. They manifest a kind of externalized, exposed subsumption architecture; they turn the inner articulations of a single Brooksian agent outward into a more explicit multiplicity. From an AI perspective, the benefit of a bottom-up architecture lies in its robust manifestation of autonomy, its ability to deal efficiently with an unpredictable environment. A-life art, on the other hand, seems often to be more interested in the inherent multiplicity of the bottom-up approach. All these multiples demonstrate a degree of autonomous behavior, but they are less concerned with outright autonomy than with simply presenting their own complex articulations and interrelations of part with part, and part with whole.

These complex articulations form the focus of the aesthetic experiences these works offer. Many are spatially distributed in a way that allows visitors to be literally surrounded; all use interactivity to draw participants in, involve them, and include them in the robot swarm. In Demers and Vorn's *The Frenchman Lake,* Rinaldo's *Autopoiesis,* and Penny's *Sympathetic Sentience* works, the installation space is filled with the calls of artificial entities, calls corresponding to (or, in Rinaldo's works, actually constituting) lines of communication between the entities. Visitors are immersed in an active communicative network that recalls naturally occurring networks of bird and insect calls; we can adopt a familiar perceptual routine, enjoying the interplay of micro and macro, now observing a single chirping bug, now another, now hearing the whole complex texture. (The prominence of sound as an index of agency in each of these works is striking.) At the same time, in these works we are shown very clearly that the entities involved are not birds or crickets but bare circuit boards, skeletons of wood and wire, or bobbing Perspex domes in steel drums. A dynamic, communicative, or even organic multiplicity — but a multiplicitous whole — emerges from a transparently technological structure.

Where the multiplicity of the bottom-up approach is contained, as in Brooks's robots, in a single mobile agent, these works operate quite differently. In Penny's *Petit Mal,* in particular, the concrete multiplicity of sensors, motors, structural components, and software is fused very deliberately into a form that is interpreted as a single agent, a single autonomous will. In the same way, Klein's *Octofungi* subsumes the parallelism of its internal architecture within a biomorphic form. Interaction here is focused; the robot entity becomes a curiosity, a specimen to be kinaesthetically tested, an agency to be apprehended. Penny's work in particular engages with this interactive standoff and with the anthropomorphic projections of agency that it evokes; the robot is an experiment in the aesthetics of interactivity and anthropomorphism "in the space of the body." As in the flocks and multiples, the electromechanical workings of *Petit Mal* are expressed rather than concealed; we are presented with the tension between a technical multiplicity (a mobile assemblage of mechanical and electronic elements) and a unified, apparently coherent artificial agency.

Whether they are multiplying the individual robot into a swarm or flock, or engineering humans (and other biological life forms) into the operation of artificial agencies, these works take up the dynamic multiplicity of the bottom-up approach and expand it. The emphasis remains squarely on emergent phenomena and complex interactions, but these often occur outside the robot agencies and include human subjective, physiological, and cultural elements — corporeal sensations, anthropomorphic projections, involuntary brain states, representational conventions — or nonhuman biological components such as the fish in Rinaldo's *Delicate Balance.* Artists use the bottom-up paradigm to simultaneously span the engineered interiors of artificial agents, their emergent interactions with each other, and their interactions with a wider social, subjective, and biological milieu. In computer-based interactive works, interaction often becomes synonymous with operation, manipulation, or control. Here artists aim for a form of interaction that draws the participants into the system, where they act together with artificial agencies. Vorn and Demers describe their works as reactive rather than interactive: "In the reactive model . . . the viewers do not gain control at their leisure and will over the self-steering system but, instead, influence the unfolding of high level events."[51] "In many ways," they observe, "this communication scheme seems closer to the relationship between living organisms and their environment compared to the usual interactive model." So, the quality of relationality that characterizes the bottom-up model continues outward into the engineering of social and subjective interactive spaces; individual agency is not only decomposed into an embodied population of microagents but recomposed into an extensive embodied network, where it participates in macroagencies of ecology and sociality.

Of course the macrostructures these works present are in a sense both simplistic and idealistic, even compared to the cybernatural systems considered in the chapter 3. These hardware ecologies are largely clean and stable, free even from death, sex, or predation: the active forms of interaction are generally benign, communicative, sculptural, and disconnected from the biological imperatives of survival and reproduction. On the other hand, none of the works makes a claim to be ecological: like those computational ecologies discussed earlier, they can be seen as toys set in motion, devices for playing with notions of ecosystem, agency, and community in concrete ways. Whereas a harmonious ecological idealism is pervasive in Rinaldo and Klein, Vorn and Demers and to some extent Penny balance the wholesome appeal of emergent behavior with a wry dystopian edge. Vorn and Demers's ecosystems are, at least in a performative sense, rife with parasitism, predation, territorial disputes, and abject misery; their collectives of frantic robotic part-subjects might be dense with emergent behavior, but they are far from harmonious or happy. Interestingly, these works are also the only multiples to introduce notions of power and inequality. Read along social and political rather than ecological lines, other works show a kind of homogeneity, a flat power structure, that is (to say the least) at odds with general experience. Perhaps there is a certain idealism at work here, too, a vision of a utopian collective, a happily anarchic emergent politics, a harmonious and egalitarian democracy. While these collectives direct us to phenomena of emergent order and complexity, they are not yet complex enough to show the higher-order behaviors of such systems, specifically the ways in which emergent phenomena give rise to dominant self-perpetuating structures, and the ways in which these macroscale structures condition the action of individuals.

The emphasis on multiplicity and connectivity in these works makes an interesting contrast with the figure of the automaton raised at the opening of this chapter. Historically, automata have manifested apparently self-motivated, spontaneous action; the clockwork figure emerges, all by itself, to chime the hour. The clock's inner workings and its mechanical causality are hidden from view: its reliance on human energy and intent is downplayed in order to support a show of autonomy.

As the hopes of Klein and Rinaldo show, the notion of a wholly autonomous artwork remains an active if distant goal in the contemporary context. More interesting, however, are the changes in the way in which that goal is pursued. Klein and Rinaldo are less concerned with making a show of autonomy than with its final functional realization via the systems engineering approach of artificial life. In taking up that approach, moreover, the very notion of what constitutes autonomy becomes more complex.

Rather than absolute autonomy, otherness, or separation, these works largely present agencies entangled in connective webs of environmental and interactive influence; rather than self-contained individuals, these systems constitute robotic ecologies or collectives. Even where individual agents are presented, their autonomy is defined according to the quality of their environmental responses, their reactivity; they operate as actors in a wider game of social and cultural interaction. In a neat complementarity, our contemporary sense of autonomy and otherness seems inextricably linked with qualities of connectivity and responsiveness.

5

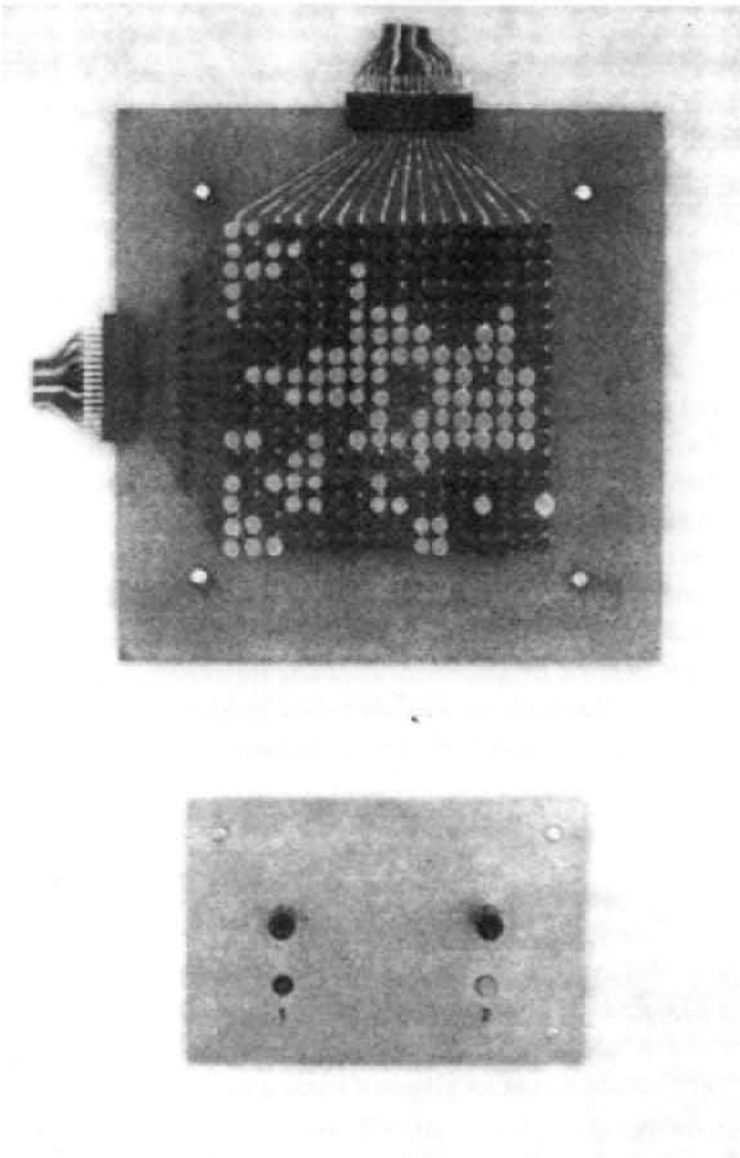

Figure 5.1 Paul Brown, *Cellular Automaton* (1979).

As the previous chapters have shown, a-life art teems with creatures, a whole varied zoo of artificial entities in software, hardware, and virtual environments. These performances of life play out easily for an audience primed by biophilia, an affinity for life as we know it, and a cultural affinity for certain forms of representation. As Vorn and Demers recognized, we are only too happy to find life in the crudest signs of autonomous agency and to project ourselves anthropomorphically back on to it. This practice also draws heavily on a set of concepts around and within biomorphic life: world or environment, genetics, and evolution. In the work considered so far, that biological reference, whether as outright mimesis, analogical play, or reflexive interrogation, is inescapable.

ABSTRACT MACHINES

Yet, at one level, a-life techniques are purely formal structures, templates for computation, patterns of rules, even as a-life science relies, as theorists such as Katherine Hayles have argued, on stories of life to frame the interpretation of its artifacts (see chapter 6). Prising these two layers apart, the machinic and the figurative, is an interesting prospect. If a-life techniques were not bound to reproduce lifelike forms, structures, images, and behaviors, what else might they produce? What figures and referents might in turn come into play? Is there a glimpse here of Langton's "life as it could be," something other that might arise from a-life's architectures?

The works considered in this chapter illustrate and explore in a variety of ways the creative potential of this unhinging of figure and mechanism. These works use a-life techniques but focus on their formal morphogenetic properties rather than on their lifelikeness.

Familiar tropes of endless novelty and metacreation reappear; often the works are somehow autonomous; once made, they make themselves. Also, there is a new heightened attentiveness to form in itself and to processes of growth and transformation; where in so much a-life art morphogenesis is dry and instantaneous, here it is richer and more articulated. There is a corresponding emphasis on temporality and, in particular, on the generative capacity of history, the ways in which past and present shape future forms and states. This contrasts with a-life art's wider tendencies to accelerate and compress developmental time.

The most important outcome of this uncoupling of a-life's central analogy is in fact a creative and critical reconfiguration of a-life in both figure and mechanism. These works show that new media art is not simply adopting a-life but adapting and transforming it. Abstraction opens a space here for templates and forms to be rewired, hybridized, rethought. In toying with basic mechanisms, these artists produce some remarkable artifacts and processes; they often make those processes richer and more interesting. In doing so, they illustrate that the rules of a-life technique are thoroughly malleable, as are the values and assumptions that those rules encode.

Paul Brown

Cellular automata (CAs) have been central to the work of Paul Brown, an artist who is one of the unheralded pioneers of a-life art. In fact, Brown's practice predates artificial life as a field by many years; his work with CAs dates to around 1973, whereas Langton coined artificial life in the mid-1980s. As well as for its historical significance Brown's practice is notable for its rich adaptation of CA techniques as tools for image making.

During the late 1960s, as a student, Brown became interested in making images using simple tiling systems, with arrays of rotated elements generating macroscale patterns. He recalls his interest at the time in "removing myself from the work and objectifying the art making process."[1] Brown was also fascinated by the I Ching, in which permutations of binary elements unfold into the myriad creatures of the sixty-four hexagrams. In October 1970, Martin Gardner's Mathematical Games column in *Scientific American* presented a new game, devised by the Cambridge mathematician John Conway: the Game of Life. Brown was intrigued and spent months running the Game manually on graph paper before setting it aside. Finally, after enrolling at Liverpool Polytechnic in 1974, Brown began programming computers to generate tile-based image generators. Dissatisfied with the results of random number generation to drive the array, he recalled the Game of Life and began programming two-dimensional cellular automata.

Over the following decades, Brown worked with two-dimensional CAs to produce still images — single frames from an automaton — and automata that ran in real time. Early still work such as *Lifegame* (1979) was output directly to a pen plotter. Brown's real-time work dates to 1976: in the *North West Export Award* a sculpture housing custom digital electronics generates a three-cell CA creature roaming over a pyramid-shaped, illuminated array. *Cellular Automaton* (1979) used a hard-coded digital processor driving an array of red LEDs and ran two different selectable rule sets: a slightly randomized version of Conway's Life and a "builder-eater" in which two concurrent processes competed (figure 5.1). For later still image works Brown used a variety of commercial software to manipulate and process the raw CA material, generating rhythmic surfaces that play with pattern, depth, and figure/ground relationships.

The key synthesis in Brown's practice occurs in his adaptation of the CA as a logical rather than a visual engine. Instead of mapping the cells of the automaton directly onto the image surface, Brown introduces an intermediate stage, the tile, which can have a graphic structure of its own. Brown's characteristic strategy has been to use simple tile sets with carefully designed edge relationships, so that individual tiles merge into a larger patterned whole. The simplest works use two cell states, like the Game of Life; each cell's state can be described by a single binary bit: 1 or 0, on or off. Brown assigns the two cell states to patterned tiles or to two rotations of the same tile.

With such systems, graphic variety is linked to the number of different cell states. This suggests a CA with greater depth, where each cell can have eight, twenty, or one hundred states at any point in time. However, Brown has arrived at a solution that not only increases the number of cell states but alters the temporal dynamics of the automaton. He uses simple one-bit automata but integrates a series of cell states over time; in the time-based work *Sandlines* (2000) and images such as *The Deluge* (figure 5.2), two time steps are combined and mapped onto a set of four tiles. Here the tiles represent transitions in the underlying automaton rather than the cell states themselves. Instead of simply "alive" and "dead" we see types of change and stasis: being born, dying, being alive, being dead. In *Sandlines*, Brown continues this temporal smoothing process by animating the transitions between cell states so that, rather than switching and flickering, the surface slides and twists.

Brown's works in progress *Chromos* and *Where's the Red Wedge* (both 2000) appear to be explorations along similar lines, using animated tiling systems. *Chromos* uses an eight-tile set of curling, looping lines that link and unlink in a polymorphous cellular network. However, while these works use Brown's characteristic tiling systems, they signal a change in direction: rather than CAs, they are driven by simple neural networks. During 2000, Brown was artist-in-residence at the Centre for Computational Neuroscience and Robotics at the University of Sussex, where he was struck by the rich generative capacity of the simple neural nets used in the Centre's experiments in

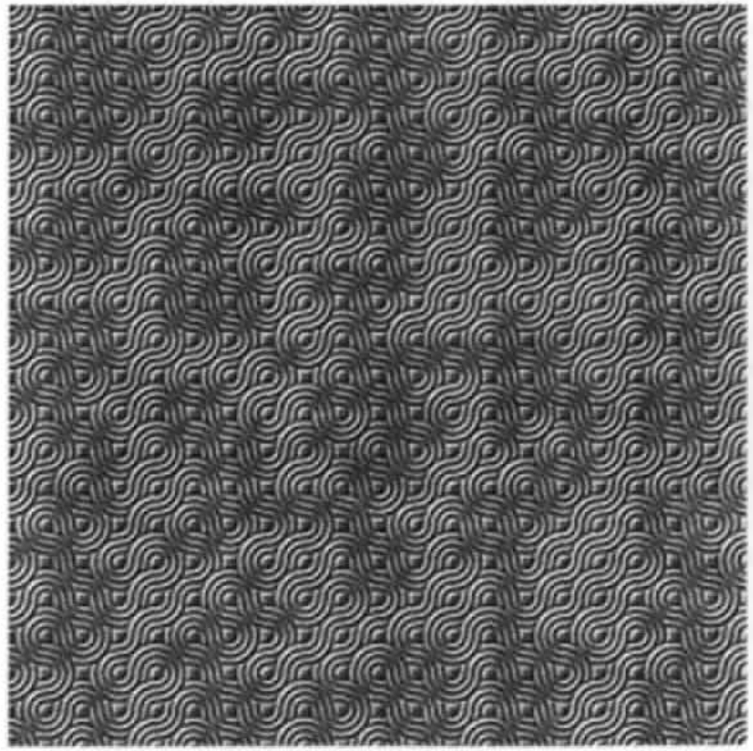

Figure 5.2 Paul Brown, *The Deluge (After Leonardo)* (1995).

evolutionary robotics.[2] Following these initial experiments with neural nets, Brown plans a more radical departure, in collaboration with the Centre's Phil Husbands: a move into hardware. Following the Sussex Centre's emphasis on evolution in the real world rather than in simulated environments, Brown and Husbands plan to create a group of simple drawing robots with evolvable neural net brains. A host of issues arise: evolvability, fitness criteria, the possibility of evolving group interactions. Yet the ultimate aim, for Brown, is unchanged: it is raw metacreation, the desire to make works of art that "make themselves."[3]

Scott Draves

Brown's practice is very much concerned with art making and with the Modernist project of investigating the limits and boundaries of that practice, testing and questioning its definition. The drive for a generativity that transcends and supersedes the individual artist clearly situates this work in the same lineage as the generative techno-organicism of Malevich and the Russian avant-garde and of Jack Burnham's notion of an ultimately autonomous cyborg art. The agenda here is focused on Western visual art and the larger question of art itself.

By contrast, Scott Draves, who like Brown works with cellular automata and other abstract generative machines, writes, "I've never taken a course in art and only recently, in face of overwhelming evidence, have dared to call myself an artist. So 'art' is not my context. I am an outsider in the art world."[4] The overwhelming evidence here is the recognition that Draves's work has received within new media art in general and a-life art in particular. His *Electric Sheep* (2001) shared first prize in the 2001 *Life 4.0* competition; *Bomb* (1995–1997) won third prize and the Prix du Public in *Life 2.0* (1999). Yet Draves still describes his primary role as that of a computer programmer and, in his words, "metaprogrammer." The dichotomy here is striking, partly because it indicates two characteristic approaches to a-life art — we could loosely call them the modern and the postmodern — but also because, despite their radically different contexts, artists such as Brown and Draves share techniques and some fundamental aims.

Developed between 1995 and 1997, *Bomb* is a generator of animated graphics, or "visual music." It uses a combination of complex or chaotic algorithms and an open library of preexisting graphics to turn out a dense digital-psychedelic stream of visual stimulus. *Bomb* can be aligned with the growing genre of software systems for generating real-time graphics, or just visuals, in conjunction with music; this software has arisen out of the cultures of electronic dance music, where visuals are a staple sensory ingredient. Draves uses *Bomb* and his other graphics software in live performance and cites the rave scene as a contextual influence, along with hallucinogenic and dissociative drugs. Like much of Draves's other work, *Bomb* is "eye candy," though in a quite serious sense: it is a magnet for visual attention, something that in Draves's words "makes you stare." It succeeds in that: boiling, flickering forms, spreading waves of color and texture, streams and sprays of pixels; the visual surface is fundamentally unstable. Iconic images appear and are dissolved or submerged; colors, speeds, and patterns shift abruptly. There is nothing biomorphic here, nothing that resembles life; rather the overall impression is of complex dynamics and patterns, flows, accretions, and erosions. Not life as we imagine it, but perhaps something more protean.

Technically, the a-life in *Bomb* resides at the level of the graphics algorithms, most of which are cellular automata. Draves uses a handful of preexisting rule sets, including "brain," a more active variant on Conway's Game of Life, and "rug," a rule based on an averaging of cell neighborhoods. (Incidentally, "brain" and "rug" were invented by CA explorer, sci-fi author, and noted cyberpunk Rudy Rucker.) Draves's important innovation here is in how these rule sets interact with each other in time and space. Rather than as an isolated world, Draves treats the CA as a real-time dynamic filter, feeding image information into it from a background layer. That information might be static, such as a still image; or dynamic, driven by the computer's audio input; or complex and chaotic, generated by a second cellular automaton or another iterated system. In one of *Bomb*'s modes the background automaton is the Game of Life, although it is rarely recognizable; its characteristic patterns are smeared and elaborated by a dynamic foreground layer running the "rug" rule. As well as this spatial coupling, CAs in *Bomb* are linked through time. Whether under user control or on autopilot, the system constantly shifts through rule sets and parameters. There is no playing out of any single CA world; instead each new algorithm begins with the remains of the last, and each passes on a visual residue to the next. In both spatial and temporal axes, Draves works against the determinism of the CA or any idea of the CA as a formal world; instead they are contingent elements in an unstable visual soup.

Conceptually, for Draves at least, *Bomb* manifests artificial life in a broader and more expansive sense. He describes *Bomb* as a whole system, as a "form of artificial life," and as "living software."[5] Most tellingly, it is a "visual parasite": it modifies itself and propagates by engaging the attention and energy of human users and programmers. It is open source (and has been since before the concept was popularized by Linux); anyone can copy and modify its source code, compile the program for different platforms, and build interfaces with other systems. Thus while, like any other formal generative system, any single instance of *Bomb* may fall short of what Draves recognizes as the ongoing novelty and "creative expansion" of living things, *Bomb* as an ongoing process is more difficult to delimit.

This expanded composite notion of creative artificial life is taken much further in Draves's latest project, *Electric Sheep*.[6] *Electric Sheep* is a distributed screen-saver that "realizes the collective dream of sleeping computers from all over the Internet." The architecture of the system was inspired by SETI@home, a popular experiment in distributed computing that uses the spare processor power of thousands of Internet-connected computers to scour radio telescope data for messages from extraterrestrial life. In *Electric Sheep,* client machines compute frames in abstract, algorithmically generated animations, the sheep of the title. When a client computer goes to sleep, it begins displaying ("dreaming") sheep already downloaded and stored locally; at the same time it contacts the server and joins in the computation of new sheep, rendering frames and uploading them back to the central server. Periodically, a new sheep is completed and distributed to the clients. Hundreds of clients might participate in this shared "dream" at any one time.

All of which would be for nothing, of course, except for the beauty of the sheep themselves, which are what Draves calls "fractal flames," forms generated by the nonlinear mathematics of iterated function systems (figure 5.3). On the screen they are luminous, twisting, elastic shapes, abstract tangles and loops of glowing filaments. Their motion is generated through smooth changes in the parameters of the flame algorithms; each individual sheep is a seamless loop, generated by plotting a circular path through that parameter space. The system also generates transitions between sheep in the same way, so that in the screen-saver the individuals merge into a continuous graphic flow, a path through a network of linked collective dreams.

As in *Bomb,* the most interesting engagement with a-life here is not in the technical details of the system. In fact, *Electric Sheep* currently makes only the barest use of artificial life techniques, by labeling the parameter set a genotype and the graphic output a phenotype. While Draves plans to introduce artificial evolution, the system currently generates new sheep at random; users can, however, vote for favorite sheep, thus increasing their longevity in the flock. Once again, the striking feature here is Draves's creation of an open system that feeds

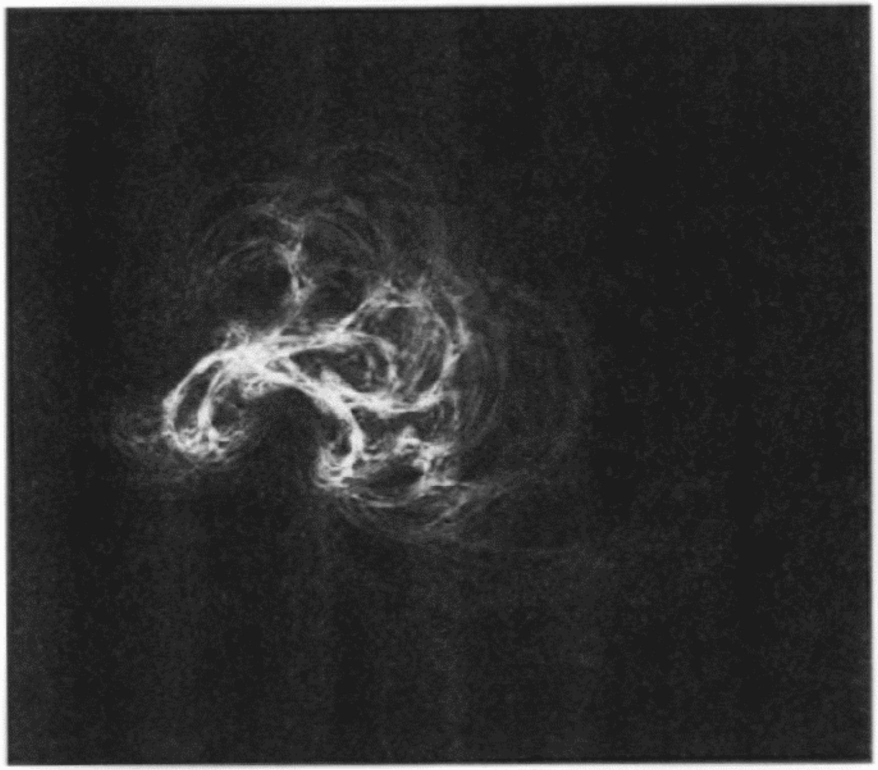

Figure 5.3 Scott Draves, fractal flame (1993).

on human participation and energy; he calls it an "attention vortex."[7] The contributions of individual clients are identified on the central server, developing a sense of a personal stake in the system. A bulletin board system fosters communication among communities of users and developers; the project is open source, so clients appear on new platforms, increasing the user base and the life of the system. Draves imagines the totality as "an evolving ecology of agents, codes and protocols."

Erwin Driessens and Maria Verstappen

In Draves's work morphological novelty and variety compose the basic currency of attention and serve as the engine for generating subjective engagement. The work of the Dutch collaborators Erwin Driessens and Maria Verstappen centers on the same tropes of novelty but for different reasons. Working in the European visual arts scene in the early 1990s, the artists reflected on the art system's insatiable appetite for new work:

> At that time we felt ourselves so much confronted with [the social-political] reality of the art practice, that we had to deal with it in a very direct way. Then we thought, if all these [gallery] spaces have necessarily to be filled up with art each month again and again, we can think of [how to] automate this production. Somehow very nihilistic in its approach we started to make our first attempts to make automatic artificial art. But very quickly we understood this was not an easy job, and then it became really interesting, an exciting adventure.[8]

Thus what began as an attempt to satirize the art world's endless desire for novelty became an engaged investigation of the generative processes that might supply such novelty. Verstappen positions the artists' practice as post-Duchamp, post-ready-made; she observes that even after Duchamp's work opened the way for "an aesthetic interpretation of everything," subsequent creative practice has dealt only with limited segments of this unimaginable everything — "somehow they all end up defining rules [for] how to interpret reality." This everything becomes the object of the artists' practice:

> We see a challenge in the question "how can we express the longing for an activity that explores the unseen, the unthought and the unknown?" Not influenced by taste, style and meaning but also avoiding complete unpredictability.[9]

The artists respond to this challenge through a set of carefully engineered frameworks, systems of constraints that constitute morphogenetic processes, and in turn forms and images that inhabit specific slices of this space, "the unseen, the unthought and the unknown." Artificial life techniques are prominent in their systems, although the usual biological analogies are absent and the techniques operate as abstract formal engines. This abstraction creates a space in this practice in which the artists are able to rework and reconfigure a-life techniques in some remarkable and instructive ways.

Breed (1995–1997) is a project spanning process and product, consisting of form-generating software, the resulting virtual three-dimensional forms, and physical fabrications of those forms (figure 5.4). As the name suggests, this is a kind of breeder, though a very different kind than those considered in chapter 2. In fact, it hybridizes two basic a-life forms, the genetic algorithm and the cellular automaton, reengineering both in the process. *Breed* generates intricate three-dimensional forms through a stepwise process of spatial differentiation. We begin with a solid, cubic volume, a single cell. When the cell divides, its volume is partitioned into eight smaller cubic cells, units of space that may be either solid or empty; so the space occupied by the initial cube is coarsely differentiated; a chunky, blocky assemblage is formed. The same process continues

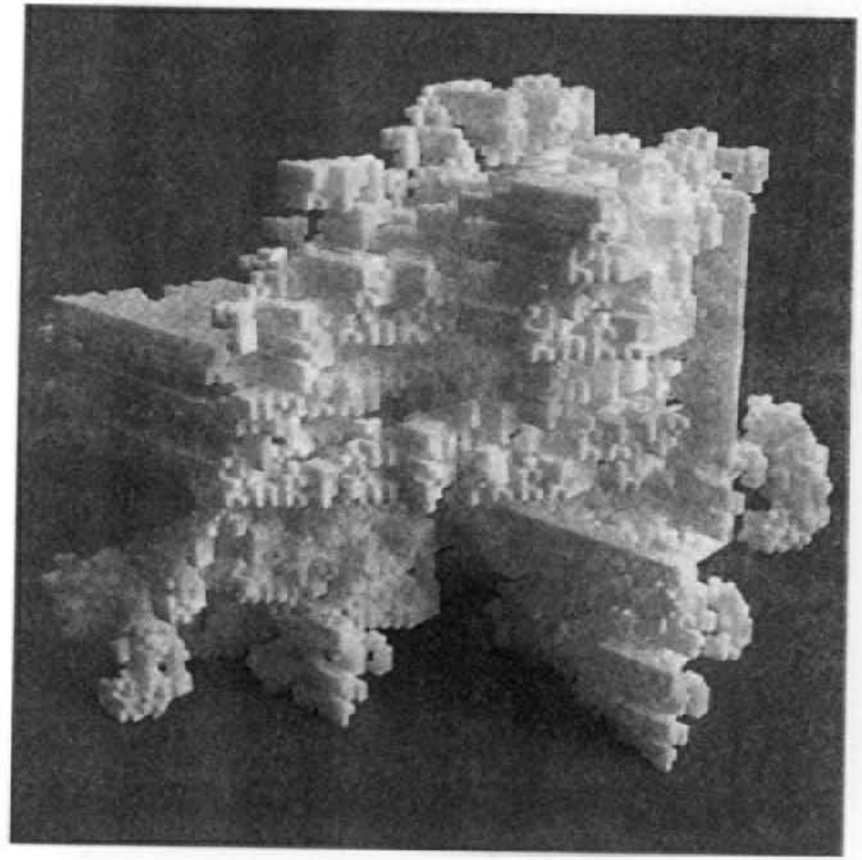

Figure 5.4 Erwin Driessens and Maria Verstappen, *Breed* (1999). Detail.

for each of the eight new cellular units, which divide in turn into eight, and the resultant form is again more detailed and differentiated. This process continues, being applied to rapidly increasing numbers of smaller and smaller cells. Viewed as an animated process, the initial cube carves itself away in ever-finer cellular chunks, finally resembling a complex sculpture assembled from cubic Lego blocks, a pixelated mass perforated with irregular hollows and voids.

This morphogenetic process is controlled by a set of parameters that, following the pattern of the breeder, are treated as the form's genome. These parameters are in fact simple rules governing the process of cellular differentiation. At each step in the process, a cell's subsequent differentiation is controlled by the presence (or absence) of neighboring cells; the morphogenetic rules simply dictate how every possible combination of present or absent neighbors influences the next split. So, in this very elegant form of artificial genetics, a simple compact genome generates a complex form recursively, at ever-finer scales, rather than through a high-level or global specification. Of course, the genetic parameters still completely determine the resulting form — any given genome will generate the same form every time — but the process of expression, the transition from code to form, is tightly bound to the phenotypic context of the virtual form. The formation of a certain void or bump at a certain level of detail depends not on an explicit representation encoded in the genome but on the genetically specified interaction of neighboring units of volume. In an architecture that follows a-life's bottom-up maxim, a set of simple microscale rules gives rise to a complex macroscale result.

The evolutionary process in *Breed* occurs as a form generated by a random genome is evaluated for "fitness" according to a set of spatial criteria. An automatic measurement is made of a set of properties: volume, surface area, and connectivity. The form's genome is tweaked, a new form is generated, and its fitness values compared with the initial form: if the new form is fitter, it is retained as the basis for the following mutation; if not, the new form is discarded and the initial form is mutated again. Through repetition of this simple automatic loop, a form will eventually be generated that has maximal fitness according to those predetermined formal criteria. This process gives the impression of a highly linear, progressive drive toward an optimal ideal, but this is not the case; the relatively open nature of the criteria (volume, surface area, and connectivity) means that they can be met by many different forms. In another elegant twist, the structure of the evolutionary process mirrors the morphogenetic process; rather than searching for a single absolute goal, this simple stepwise evolution uses only a local comparison. As it forms a sequence of incrementally fitter forms, the process paints itself into a corner; the final optimal form is in fact only the most optimal form that the specific sequence of random alterations has produced.

This is an interesting inversion of an important a-life convention. In the jargon of artificial evolution, a range of possible forms for a given system is sometimes described in terms of a fitness landscape, imagined initially as a flat two-dimensional plane. Different areas can be assigned a height that corresponds to the fitness of the forms at that point. In conventional applications of genetic algorithms, the central aim is to breed a solution with maximal fitness, one that occupies the highest peak on that hilly landscape. One of the key problems for such systems is that without exhaustively searching the space of possible forms — such spaces are often very large — it may be impossible to tell whether a certain solution sits on the highest peak or only on a medium-sized hill. The random mutations of artificial evolution can be thought of as exploring the area around a certain solution — its locality in this imaginary landscape. If a process searching for ever-better solutions, like the one in *Breed,* finds itself on a local fitness maximum — the highest hill in the immediate neighborhood — it will stop. Mutations will only result in forms with a lower fitness value, and since the process cannot "climb down," it will stay stuck on that hilltop. In utilitarian applications of genetic algorithms, this phenomenon of evolution's halting at a local maximum is a problem.[10] In *Breed,* Driessens and Verstappen turn this problem into a virtue, for it is in finding local maxima, and backing itself inexorably up the nearest hill, that this automated evolutionary process can produce a variety of forms that meet these open spatial criteria. Rather than defining a fixed formal or aesthetic optimum, the artists frame the fitness criteria in a way that achieves a kind of loose control over the results, where the details of the evolved forms are unguided even as global attributes, such as volume and surface area, are firmly specified.

Driessens and Verstappen have brought this project to a sculptural conclusion by fabricating a selection of the evolved forms. Originally they used plywood, which was hand-cut and assembled into forms with thirty-two 0.5-centimeter voxels per side. More recently, they have used a computer-controlled rapid prototyping process (selective laser sintering) to generate more delicate and intricate forms comprising 10-centimeter cubes with sixty-four voxels per side. Even here, the resolution of the forms is limited by the physical realization; Verstappen writes, "It would be nice if you could hardly see the voxel elements, to see that some parts really get an organic structure like coral or broccoli."[11]

Another experiment in computational morphogenesis and a similar transition from the immaterial to the material occurs in the artists' more recent *Tuboid* sculptures (1998–1999). Here the spatial template is a tube rather than a cube but, as in *Breed,* it is a form that shapes its own development through space and time using a simple artificial evolutionary process. A wormlike shape is formed from a sequence of cross-sections (two-dimensional slices), which accumulate over time. In the generative process, these slices are derived from a complex internal structure of pivoting articulated spokes; a genome specifies the spoke segment lengths and rotation speeds. As each new slice is generated, its parameters are altered slightly, and it is tested to check that the outline does not intersect itself, that the slice encloses a single two-dimensional form. A sequence of profiles is projected through a third dimension to define a single smooth organomorphic tube. The architecture of articulated spokes and the encoding of rotational speed in the genome combine with a simple spatial constraint to generate tuboid forms that are highly coherent, with smoothly undulating bulges and ridges. As in *Breed,* these forms are not specified by any single genome but emerge from the playing out of a self-constraining morphological process.

Tuboid exists in both virtual and physical manifestations. In virtual form, these tubes can be viewed either from the outside as solid extrusions or from within, generated in real time as enfolding, continuously unfolding tunnels. Driessens and Verstappen have fabricated a selection of these forms as physical objects, in this case somewhat eerie shiny white towers about 1 meter high (figure 5.5). These are built up from 4-millimeter slices of fiberboard, hand-smoothed, and sprayed with glossy automotive lacquer. They resemble stalagmites cast in plastic, but with their bulbous protrusions and rippling ridges they also have more bodily connotations, like tapering sections of intestinal tract.

Morphological history is a key concern in *Breed* and *Tuboid,* although in both of those systems it moves toward an endpoint, closing itself down. By contrast, *Ima Traveller* (1996–1998) is an endless generative process, a continuous unfolding of visual form. *Ima Traveller* is an image machine that, like *Breed,* is an elegant variation on a cellular automaton. Initially a single cell — a pixel at the center of the screen — births new cells, neighbors. These split in turn, and the reproductive cycle continues until the screen is quickly filled with proliferating masses of pixels. As in *Breed,* a set of rules controls the way in which each cell reproduces, and here too those rules draw on each cell's own state and its current environment, its neighbors. In

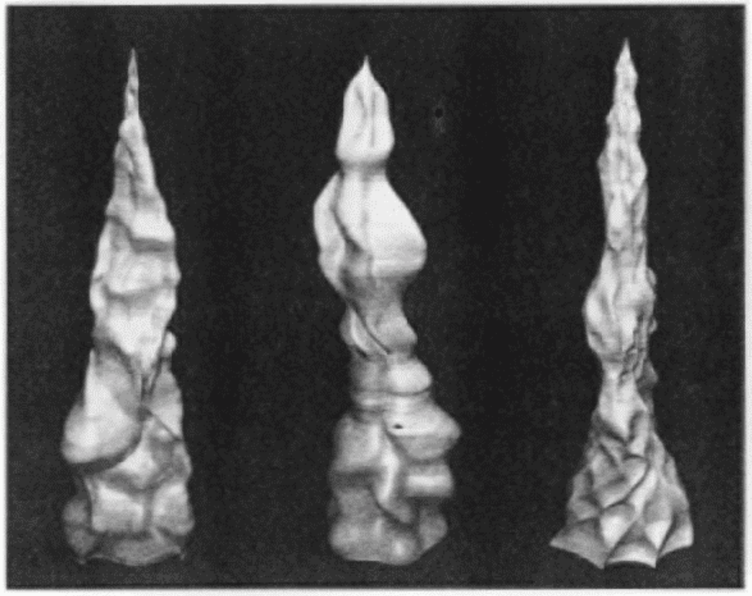

Figure 5.5 Erwin Driessens and Maria Verstappen, *Tuboid* (1998–1999). Composite image showing three physical models.

Ima Traveller each cell is a pixel, a point of color, and it can have one of hundreds of possible color states. In *Breed* the process of cellular differentiation works inward, refining the original volume in ever-finer detail; here the cellular space itself grows, expanding beyond the edge of the display; cells crowd each other out in an ever-spreading pixelated mass. The artists have engineered the splitting rules so that the dividing cells form blossoming masses of color that differentiate endlessly, opening up into ever-greater detail; the visual effect is of a relentless zoom, a sense of diving into a continuously unfolding picture plane.

The nearest visual analogy is with a "fractal zoom," the computer graphics cliché that tunnels into the filigreed coastlines of a Mandelbrot set image, revealing ever-smaller coastlines and curling filaments. However, *Traveller* is less slick, more pointillistic, suggesting colored clouds or variegated mats of lichen (figure 5.6). The software interface also allows this diving zoom to be steered with a mouse so that a path can be woven through the most interesting zones. The simple interactive pleasure of this process is in the way these zones continually explode, expand, differentiate, and refine themselves. An apparently uniform patch of sky-blue is soon peppered with darker specks, one of which opens into an inky void, which in turn lightens to a cloudy grey mass, which in turn sprouts islands of green. Jon McCormack and Alan Dorin have used this work to exemplify what they call the "computational sublime," a sense of generative vastness inducing both pleasure and fear.[12] Emanuelle Lequeux, writing in a catalog essay, responds lyrically: "Images give birth to other images, pixels to other pixels, without end. At each tremble of the mouse another universe is born."[13]

RICHARD BROWN (*BIOTICA*)

Another universe is born: hovering at a strange portal, arms outstretched, we see a group of wobbling luminous spheres hanging in a

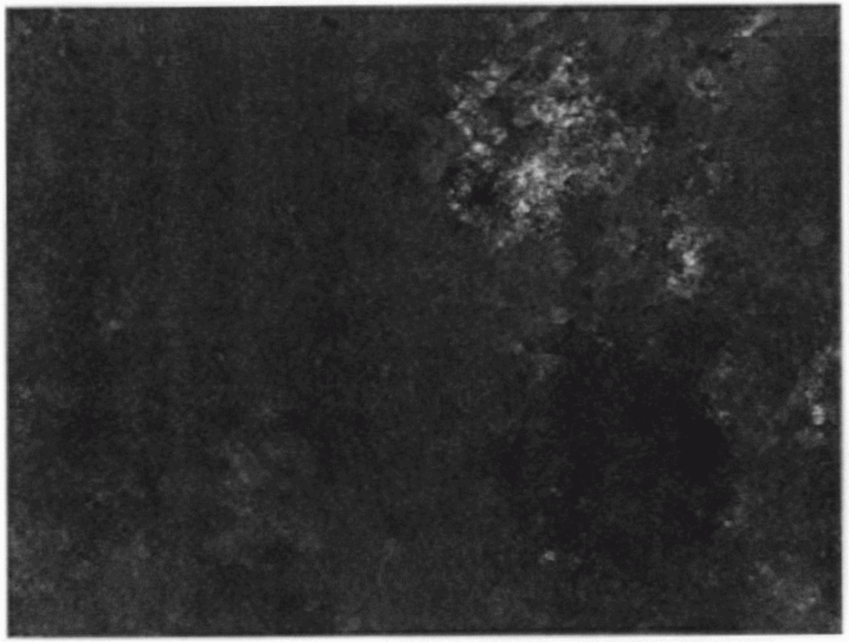

Figure 5.6 Erwin Driessens and Maria Verstappen, *Ima Traveller* (1996–1998). Detail.

void. They seem to be model molecules until they begin pirouetting around each other, drawing closer and joining in interlocking clusters; new spheres flicker and appear, colors shifting. Over time more complex clusters appear, Platonic microbes with spinning spherical appendages, oscillating geometric networks. This is *Biotica* (1999), an installation by the British artist Richard Brown, which promises "an immersive experience of artificial life."[14] This is a familiar enough promise; what makes this work interesting is its approach to that aim. Brown's previous work *Alembic* (1997) draws on modern computational models of matter as well as on the ancient protoscience of alchemy; a video projection creates a crucible containing a shifting mass of elemental virtual matter.[15] *Biotica* then attempts an ambitious leap, from digital physics and alchemy to virtual chemistry and biology.[16] Working with Jonathan Mackenzie and Gavin Baily, Brown began with a molecular chemistry model in which charged atoms spontaneously arranged themselves into complex, higher-level forms. Recasting these atoms as virtual cells ("bions"), the developers added sensors, springlike muscles, signaling networks, and cellular reproduction. Their goal was an "emergent soup," a virtual biochemistry in which complex, lifelike, self-replicating structures would form spontaneously, replaying that mythic moment, the formation of protean life from nonliving molecules.[17]

The most interesting aspect of *Biotica* is in fact how and why it fails to meet this goal, which is reported with unusual candor in the book documenting the project. This artificial biochemistry entailed a massive space of possibility: endless permutations of interconnecting rules and relationships, most of which would produce only chaos. The chances of stumbling across the rules for life, or at least lifelikeness, seemed remote. Automated artificial evolution was considered and abandoned; as Brown writes, "Could we devise a fitness function that would filter out the interesting from the chaotic?"[18] Instead, the developers turned to a simpler rule-based system for specifying bion relationships that could be hand-programmed. This finally allowed them to seed the simulation with bion creatures that would develop, reproduce, and interact in complex ways. In the final installation, this system is further scripted, providing what Brown terms "thematic content." The world begins with a single primal sphere, which splits to form two new two-bion creatures (colored red and blue, for male and female). "Logical evolution" proceeds as three, four, five, six, and twelve-bion creatures follow; each new generation appears after its predecessors have attained a certain population. Reproduction depends on the proximity of the hovering user, so the conclusion of *Biotica* is a reward for sustained attention.

Brown's reflections on the project make clear that the system was a compromise generated by a conflict between the emergence-focused research project and the interactive art project. Users found the experience too abstract; the work failed to communicate a sense of aliveness, and the user's own role in the world was unclear. Brown's subsequent work *Mimetic Starfish* (2000) clearly addresses these perceived failings.[19] *Starfish* is a virtual creature with a realistic form, a transparent collective interface (similar to Sommerer and Mignonneau's *A-Volve*), and lively reactive behavior. Its tentacles stretch and recoil; it takes fright or reaches out with apparent curiosity: it was a popular success when exhibited at the London Millennium Dome.

Yet *Biotica,* despite its failings, is a far richer and more interesting system. *Starfish* is a cybernature in the most conservative mould: interactive digital nature. In its raw architecture, *Biotica* succeeds in showing us something stranger, more abstract, and more honestly artifactual. Like some of Driessens and Verstappen's work, it is unusually attentive to materiality and bottom-up morphogenesis; its original aims for an emergent digital soup are wildly ambitious but engaging. The limitations here are mainly in notions of the role and function of the artwork.

In the organic-creative philosophy of Paul Klee, the graphic surface becomes a new cosmos, a two-dimensional world with a cosmogeny in parallel with nature. This is a world in which lines, famously, gain some kind of independence from the artist and "go for a walk." Beginning with the most basic graphic elements, surface and line, Mauro Annunziato and his collaborator Piero Pierucci have created a series of abstract machines that are in one sense realizations of Klee's generative two-dimensional cosmos. This is a simpler world than *Biotica,* yet that simplicity brings some powerful benefits. One of the key problems for the creators of *Biotica* was the system's openness, its lack of constraints. Annunziato and Pierucci offer an insightful solution: let the world constrain itself.

Annunziato's a-life work begins with *Artificial Societies* (1998–1999), a series of digital images generated using a multiagent a-life system that is a kind of ecology, or for Annunziato a society, of lines. Here an individual agent is a graphic point, a virtual stylus, with a set of behavioral properties encoded in a digital genome. While their manifestation is strictly graphic, Annunziato makes the metaphor clear in labeling the parameter types: character, energy, irrationality, fecundity, and mortality.[20] Character determines movement, which may be more or less unforeseeable (random) or may tend toward a fixed or steadily changing curvature. Energy regulates reproduction, which is more or less probable according to fecundity. Reproduction is asexual; when a line reproduces it splits, like a tree branch, into two thinner lines. Irrationality determines the overall randomness of the agent's movement, and a global environmental parameter, freedom, affects the agents' self-determination; low freedom values compel the agents to move in straight lines. One more basic rule of interaction completes this formal flatland: when an agent meets the trail of another agent, it dies.

The system as such is straightforward, and this makes the graphic results all the more remarkable. The *Artificial Societies* images are immediately striking for their simple graphic language: their monochrome calligraphy suggests both the act and the genre of drawing.[21] These are, however, hypertrophic, massively intricate, extraordinary drawings that are the traces of thousands of individual interactions across spatial (and by implication temporal) scales (figures 5.7 and 5.8). Each image displays a particular graphic quality, a different occupation of the picture plane, corresponding to its initial parameter settings and the contingent interactions of the drawing agents. The images suggest a variety of organic and inorganic structures: plant branches and tendrils, hair, crystal lattices, aerial landscapes, and street maps. Annunziato reinforces these references in some titles — *Microorganism of Memory* (1998); *Neuro-Society* (1998) — while arguing that in fact what is manifest here are "primitive (archetypal) patterns which represent similar growth dynamics for completely different phenomena."[22]

Growth, and by implication time, is crucial here. This is best illustrated by Annunziato's subsequent work with Piero Pierucci, *Relazioni Emergenti* (Emergent Relations) (2000). In this interactive installation the generative system just described is run in real time, linked to both video and sound output and opened to human interaction. Documentation of the installation shows how the structures evident in the still images — ranged clusters of filaments and recursive divisions and infillings of space — arise through the interaction and evolution of the drawing agents. The logics and constraints, which Annunziato clearly analyzes, are simple but powerfully productive. There are a handful of key characteristics: in the early stages of growth, filaments with a low curvature live longest and so have a better chance of reproducing; so the plane is often divided, early in the process, into large segments. This creates new constraints for subsequent generations, when more curved and more fecund filaments are favored. Again, the beauty here, formally and aesthetically,

Figure 5.7 Mauro Annunziato, *Contaminazione* (1999).

Figure 5.8 Mauro Annunziato, *Contaminazione* (1999). Detail.

is in the self-constraining nature of the system; it shapes its own evolutionary conditions and selection pressures throughout its life. The processes of collective adaptation are clearly visible as the surface is gradually saturated. An initial slowly expanding mat of spirals spawns straighter lines, which move quickly into empty territory, branching themselves and giving rise in turn to groups with different spatial strategies: clusters of linear hatching, recursive fernlike fingers, dense fine squiggles. As the available space closes down, the last surviving agents are densely packed, highly curved, and fast-breeding, literally filling in the niches carved out by their more spatially extravagant predecessors.

In the *Relazioni Emergenti* installation, visitors approach the growing filaments on the video projection, hands outstretched. The installation uses a machine vision system that detects proximity to the screen surface, then maps proximity to a local increase in the environmental energy parameter. A-life flourishes in response to human touch; with more energy the filaments breed and move more rapidly. Annunziato observes visitors using their hands as "a sort of life brush," encouraging different clusters and forms in what the artists speculate is an innate appreciation of the "aesthetics of biodiversity."[23] In Annunziato's conceptual framework, this interactivity is a platform for an expansive investigation of communication and "hybrid intercontamination" between human and artificial beings and societies. For the artists, the generative visual system is only the surface of a metaphorical mirror in which human cultural and social dynamics are crystallized and reflected but also set out as complex, contingent, bottom-up dynamic systems.

(Artificial) Life as It Could Be

The British artist and writer Matthew Fuller inverts this mirror and returns us to the cellular automaton in a final example of a-life's creative reconfiguration. The *Human Cellular Automaton* was a group action initiated by Fuller at gatherings in London (2000) and Berlin (2001).[24] Drawing, as Fuller says, on the instruction pieces of Fluxus and Vito Aconci, the *Human Cellular Automation* is simply a script for a crowd to follow in order to run Conway's Game of Life; each person represents a cell that who consults its neighbors, and each person raises or lowers a sheet of paper for the "on" and "off" states. This is a human computer, as Fuller says, "the slowest, most high-energy processor for miles." It's a game — "distributed fun processing" — though one with serious implications. Like a Fluxus piece, it allows for a suspension of normal thought and action, a testing out of other potentials; like free software, the code can easily be distributed and the process extended; and like a modern political demonstration, Fuller suggests, it operates by keeping the crowd "networked, communicating and aware of itself." So, this simple appropriation generates a whole set of critical short circuits: when computation is (once again) a human operation, it is opened to the flows of experience and social space. At the same time, performing this formal rule set — playing at being a computer — is an exercise in human connectivity, group awareness, and emergent dynamics. The abstraction of the Game of Life is a tool for reconsidering the resolutely unabstract activity of ordinary life.

Human Cellular Automaton is a radical example of the adaptation and transformation of a-life techniques that occurs throughout the works considered in this chapter. In particular, it reworks the cellular automaton, one of the most widely used forms in these abstract machines. As they are conventionally deployed in a-life and its popular rhetoric, CAs are understood as extensive matrices, spatial grids that define an artificial universe. In the Game of Life, coherent formations within the lattice of cells are characterized as autonomous living entities.[25] Gliders, for example, are formations that traverse this grid on diagonal paths, continuing endlessly unless they collide with another group of cells. A host of other characteristic formations, native life forms, have been identified, such as the blinker, a small symmetrical oscillating structure, and the rock, a stable block of four cells. Thus the Game, a deterministic grid that gives rise to characteristic temporal and spatial patterns, is figured as a terrain for life.

Of course, CAs are, underneath their a-life metaphors, completely abstract formal systems. Paul Brown and Draves both adapt and apply CAs at this formal level, treating them as image engines, machines for visual novelty and variation. Cellular automata present a basic problem when used for this purpose: they are closed deterministic systems, which almost always settle into stasis. These artists both bypass this problem by prodding the grid, adding noise (in Brown's *Sandlines*) or other shifting layers of input (in *Bomb*). Rather than closed and internally consistent worlds, these collections of automata are open dynamic visual surfaces. Especially in *Bomb*, they are used as recombinant algorithmic filters, melting images down into psychedelic turbulence. In *Bomb* this layering also acts to conceal the recognizable life of Conway's rule set; Brown, who makes more use of the Game of Life rules, buries them elaborately. His tiling systems break down the visual identity of the underlying cells, merging them into a wider tesselation; the recognizable figures of the Game's bestiary (such as gliders) disappear into patterns where figure and ground are interchangeable. The integration of cell states over time distances the original automaton still further.

Driessens and Verstappen push this reconfiguration of cellular automata much further. In fact, they overturn a basic premise and rupture the continuity and constancy of the cellular grid itself: they take the cellular aspect of the CA literally and treat the cells as entities that, while formally discrete, are dynamic and divisible. In *Breed* and *Ima Traveller*, cells continually divide, refining their locality, and the patterns that arise are marks of an ongoing morphogenetic process rather than metaphorical life forms. In a sense, Driessens and Verstappen turn the cellular automaton inside out (or rather, outside in): in a conventional CA the emergent life forms exist inside the fixed cellular grid. The plastic differentiating cellular grids in *Breed* and *Ima Traveller* only exist inside their resultant forms. This change fits with the artists' leanings toward the material: conventionally the emergent forms are mere epiphenomena, patterns of activation traveling over a static array of formal elements. In the theories of Edward Fredkin this property of CAs is expanded into a speculative cosmological theory called "Finite Nature."[26] Under this hypothesis, the cosmos is itself a gigantic CA: our three-dimensional universe of matter, space, and time is an emergent pattern generated by a formal array with a higher dimensionality. Matter and life are thus ultimately manifestations of an underlying process of computation, an immanent logical substrate. Driessens and Verstappen, by contrast, use CAs in a way that puts matter and morphogenesis ahead of the logical array. In a process such as *Breed,* there is no given array, only a certain level of detail, a certain number of cellular subdivisions. In *Ima Traveller* the same process is at work, though here the array sprawls outward endlessly, growing like a puddle of bacteria. In each case there is no absolute or underlying granularity: space continues to open up. Here a radically analog, continuous cosmology unfolds, made possible, ironically, enough, by the discrete digital medium of computation.

Along with Richard Brown's *Biotica,* these works also present a rethinking of one of a-life's most problematic conventions: the relationship between code (or genotype) and form (or phenotype). In *Breed* and *Tuboid,* and in *Biotica,* the action of the genotype is linked tightly to an ongoing morphological process. Rather than the gene's specifying the form, the gene specifies the form's ongoing interactions with itself. The importance of developmental sequence and context in these works — what we might call morphogenetic time — contrasts sharply with the instantaneous expressive processes of Latham- and Sims-style breeders. Moreover, where expression in those systems occurs once, in a single act of translation that specifies the entire phenotype, these works adopt a model where expression occurs repeatedly and locally, and where the artificial genome is not a blueprint but one element in a more complex system. Driessens and Verstappen bend the breeder model further in *Tuboid,* where the resultant form is not so much a phenotype as a three-dimensional temporal record of a self-constraining evolutionary process. Rather than springing fully formed from a single inner code, these blobby towers are accretions of slices in a sequence of mutated individuals, something like a colony organism such as a coral reef or stromatolite. In fact, these works answer, to a limited extent, Stuart Kauffman's critique of Dawkins's Biomorph breeder (see chapter 2) and show that digital morphogenesis can be robust and self-organized. Certainly the simplistic a-temporal notions of genetic expression that a-life generally adopts are here thoroughly complicated, as is the conventional correspondence of code with genome and form with individual organism.

Breed is also a manifestation of evolutionary self-constraint, and the contrast with other implementations of genetic algorithms is striking. In general, breeders emphasize a wide generative potential — the vastness of image or creature space — far more than the constraints inherent in the language that allows access to that space. The constitutive structures of each grammar are largely ignored in the rhetoric around these works; instead, the dominant language of Darwinian evolution gives them an air of grand totality. As we have seen, the presence and agency of a human aesthetic selector is a crucial element in that rhetoric. Here, on the other hand, artificial evolutionary processes act primarily to constrain morphological outcomes in a balance between unpredictable novelty and spatial coherence. The automated evolution in *Breed* uses a simple self-limiting technique that, with successive runs, gives a variety of results for a given set of criteria. Rather than a desire-driven amplification of creative agency, the artists deliver a "blind" process, a quietly automated factory for novel forms that meet a set of specific criteria. Other breeders tend to figure evolution as akin to a manned spacecraft, a propulsive process steered by human aesthetic will, which traces sweeping arcs through a vast hyperspace. Here, by contrast, evolution is set up to self-organize, to coalesce and converge.

Annunziato and Pierucci's work can be read in a similar way; it, too, places particular emphasis on developmental history, literally drawing that history into the agents' environment to create a richly self-organizing system. Most immediately these works make a strong point about the beauty of the collective and especially of collective history. Articulated collectives abound in a-life and a-life art in the form of flocks, though these are always instantaneous forms; the emphasis is on their swarming momentary interactions. Such flocks are generally composed of identical individuals, without evolutionary or developmental histories. Artificial ecosystems are also collectives, of course, though once again the emphasis is largely on the present and often on the ongoing interactions of identifiable and biomorphic individuals (as in *TechnoSphere,* for example). Moreover, linked dynamics of individual behavior and evolutionary change exist in all such systems; Annunziato and Pierucci's first step is to plot these dynamics through time, revealing the patterns that are the systems' most telling emergent phenomena. (This is unusual but not unique; Lovell and Mitchell also trace the paths of agents in the sand paintings of their *EIDEA* installation.) Crucially, here those patterns are not only traced but inscribed into the world of the simulation; they alter the environment and thus shape the ongoing development of the system.

This is a simple but striking innovation and another point of contrast with the conventions of a-life and a-life art. In general, the environment in agent-based systems is a blank static space, an inert ground on which the interactions of the agents (the biomorphic focus) are played out. In some systems the world is nonhomogeneous, with zones (as in *Iconica*) or landscape features (rocks or mountains, as in *Eden* or *TechnoSphere*) that constrain the agents in various ways.

The environment is never so open and changeable as it is here, however. In perhaps the simplest imaginable way, Annunziato and Pierucci illustrate a process that is manifest in biological life and other complex systems (societies, cultures): their continual transformation of the conditions shaping their own present. If these works are read, as the artists intend, as metaphors for social and cultural structures, it is this interplay of self-constraint and generative self-transformation, and the richness of the resultant forms, that is most suggestive for ideas of social and cultural agency. In the context of a-life and a-life art, they can also be read more critically, to show that a complex reciprocity between agent and environment can be rendered in a computational model: the convention of a static, inert, impervious environment is a product of conceptual rather than technical constraints.

The image of familiar life recedes in this work: no biomorphic creatures or virtual vegetation. Yet it seems that the generative processes unfolding here come closer to the rich dynamics of biological and material systems than their more lifelike counterparts. For, of course, life is "as we know it," and we know it through conventional categories, cultural constructs, and narratives; we know not only its image but its elementary building blocks: genome, organism, environment. As a number of theorists argue in chapter 6, conventional a-life techniques reinforce particular models of these categories. When those techniques are unpinned from the life we know, it is more susceptible to being reconfigured, hybridized, and rewired; as conventional delineations break down, this work suggests a dynamic generative continuum, which might be significant not only for life as it could be but for the more ubiquitous strangeness of life as it is.

The creative work that forms the core of this investigation is one manifestation of the cultural presence of artificial life, but it is not the only one. In the decade or so since its inception, a-life science has attracted considerable attention. Its striking rhetoric, its lofty aims, and the wide implications of its rethinking of life itself have drawn writers of popular science to the field.[1] Partly through their retellings, the ideas of a-life have come to circulate within Western technoculture. A-life has begun to permeate the literature of cultural thought, where it is both an object of critique and a rhetorical resource. The interface of a-life and cultural thought is crucial here, for obvious reasons: a-life art as a cultural practice is located at exactly this juncture.

THEORIZING A-LIFE, ART, AND CULTURE

As well, a body of theory has recently begun to emerge around art and artificial life. This work is engaged in two related but distinct tasks: most broadly, it addresses the basic conjunction between art practice and the field of artificial life. All the works considered here manifest that relationship in a concrete way, but how might we think about that relationship in general? What are its terms? Why should these practices come together, what do they have in common, and what do they offer each other?

More specifically, there is a slender line of thinking that turns to the practice of a-life art itself, offering explanations, anticipations, and rhetorical supports. A-life artists are the main contributors to a discourse that is in its early stages yet is important in proposing creative agendas and art-historical contexts for a-life art practice. It addresses some of the basic questions implicit in this investigation: Why are artists adopting a-life techniques? and What is it they believe their work is doing?

This survey provides a sense of cultural and discursive context for a-life art practice, a sense of the rhetorics, ideals, and critiques that surround it. It also provides an impetus for this book's own contribution to that discourse. In the body of contemporary thought around a-life, art, and culture, where are the gaps, silences, inconsistencies, and zones of inarticulation? This chapter identifies one crucial gap, around the concept of emergence.

Connections and Convergences

The disciplinary boundaries that traverse this field are often indistinct: artists publish papers in a-life conference proceedings; those who represent themselves as artists within this field often come from scientific or transdisciplinary backgrounds. While a-life science and art practice can be identified as separate practices through their institutional structures, each field is open to the other: individuals and ideas flow between the two with relative ease. Boundaries shift with the individual's perspective: Edward Shanken observes that despite the fact that the roboticist Rodney Brooks and the a-life artist Ken Rinaldo attended the same Ars Electronica symposium in 1994, Brooks "recognizes little in common between his work and art" whereas Rinaldo "understands Brooks' robots as continuous with his own artwork and would readily embrace them as art."[2] Tom Ray collaborated with Christa Sommerer and Laurent Mignonneau on their work *A-Volve,* and he published, in an anthology edited by the artists, a paper entitled "Evolution as Artist," which discusses the potential of artificial evolutionary techniques for artists and engineers.[3] Jonathan Mackenzie describes a-life systems such as Ray's Tierra and Conway's Game of Life, and Richard Brown's artwork *Biotica,* as occupying a new territory that transcends the distinction between art and science.[4] Elsewhere, there is some evidence that a-life science is regarded by its practitioners as something of an artistic activity. Stefan Helmreich reports on one researcher who readily acknowledged the influence of science fiction literature on his work and described himself as a storyteller; following a conversation about his work at a party, others remarked that "he was more of an artist than a scientist."[5] Helmreich also quotes an "older U.S. biologist" who remarked on a-life's disciplinary haziness: "the boundary between what's science, what is experimental mathematics, what is interesting games and what's an art form has gotten to be very unclear."[6] The sense of some possible continuity between a-life and art provokes unease or suspicion for this scientist for territorial reasons: the boundaries of science appear unstable.

Of course, while this instability is unsettling for some, many others, particularly in the art domain, relish it. The theorist and artist Nell Tenhaaf takes up the case for an alignment between a-life and art: in particular, she sees artlike features within the modes and methods of a-life science. She points out that a-life science is centrally concerned with representation; "its foundational features . . . are driven by the pull of analogy and the power of metaphor."[7] A-life science parallels the most primal task of art making, "to develop a symbolic logic and representational system that teases out some kind of order and meaning from a chaotic surround." Tenhaaf also argues that the ways in which a-life science forms its symbolic logic are less informed by scientific verity than by shared metaphorical languages and representational conventions, methods conventionally identified with art practice. She also contends that "because its modelling parameters arise more from computational ingenuity than from methods of observation of natural phenomena, a-life is a fundamentally creative platform."[8] Both a-life and art, then,

> in their preoccupation with philosophical and theoretical questions regarding the nature of life, . . . are focussed on the creation of means for life's representation. Each is of necessity

> concerned with how the mode of development of representational apparatuses or technologies affects the very kinds of representations that can be made. Interpretation of the representations is dependent on the material, lived context of the interpreter.

Further, Tenhaaf suggests, a-life and art "share some basic concerns with modelling narratives of life in its social sense." While a-life simulations may rest on computational algorithms, they also "carry rich associative connotations"; they are in fact "inextricable from the fabulous narratives about accelerated evolution that circulate in technoculture." Rather than read a-life critically through these narratives, Tenhaaf suggests that they offer in themselves a potentially invigorating critique of mainstream science. She argues that a-life "takes up biology as a 'readymade'"; just as Duchamp's urinal drew attention to conventional understandings of the category "artwork," a-life simulations "place quotation marks around a segment of nature and make explicit . . . its encoding within a particular set of technoscientific practices, which are thereby revealed as representational practices." Just as Dadaism and other varieties of "anti-art" triggered a reconsideration of the relationship between art and nonart, Tenhaaf suggests, a-life can be considered an anti-science or "parascientific practice," the basis of a critique "calling attention to the sociopolitical imbrications of science." Such a critique is necessary and empowering, she argues, in that it raises our awareness of the construction of nature through the representational frameworks of science and technology.

Tenhaaf links a-life and art making through their shared basis in representation; both activities construct coherent stories from their "chaotic surround." Elsewhere, Roy Ascott's writing develops a rhetoric that intertwines a-life with art practice with the same shared basis in mind. However, where Tenhaaf leaves us with a critical perspective, Ascott's project centers on an expansive vision, calling for artists to take up artificial life and bring about a creative reconstruction of life and nature.

Ascott, an artist and writer who has worked with telecommunications technology since the 1970s, was one of the pioneers of telematic art, the precursor to contemporary Internet art. Telematic art typically involved events connecting collaborators across the globe in real-time text and image exchanges. Ascott has developed a provocative utopian rhetoric around telematic art, which during the 1990s began to draw on artificial life. In 1984, inspired by collaborative telecommunication projects such as *La Plissure du Texte* (1983), Ascott sets out the basis for a theory of telematic art.[9] It mixes the wholism of David Bohm with Roland Barthes' theories of textual pleasure, and adds elements of cybernetics and liberal amounts of McLuhan and Fuller's utopian globalism. Ascott discusses an art of networked collaborative text involving an "interweaving of imaginations,"[10] a distributed authorship. Telematic art inhabits telematic space, a "non-localized, timeless," "aetheric, electronic" space that Ascott also calls the "information matrix." Invoking Teilhard de Chardin's noosphere and Peter Russell's theory of the planetary brain, Ascott suggests the emergence (in an a-life sense) of a collective consciousness enabled by telematic connectivity.

Ascott's more recent introduction of a-life into this discursive mixture can be seen in his paper "Homo Telematicus in the Garden of A-Life."[11] The rhetorical tone is similar — the article is a celebration of telematic art and the cultural transformations it might provoke — but the metaphorical language shifts as Ascott makes a series of correlations between a-life science, telematics, and art practice. He initially argues that the "bottom-up, distributed, local determination of behavior" that characterizes a-life also describes "the art of homo telematicus . . . of art in the telematic culture." This art is distributed, connective, and collaborative, "emergent from a multiplicity of interactions in electronic space." For Ascott, art emerges from telematic interaction the way artificial life forms emerge from their computational substrate.

The second correlation Ascott makes is prepared by the introduction of a radical constructivist worldview, whereby the works of artists and scientists are equivalent (both are basically metaphorical) and "what we call reality is constructed by us, within our cognitive/corporeal limitations." This position is linked to a "post-modern, post-structuralist" world model with multiple, nonhierarchical layers, also described as an "explosion of meaning" with a "swirling infinity of fragments." Rather than inducing a relativistic malaise or a loss of meaning, Ascott hopes, the aftermath of this explosion will "lead eventually perhaps to a semantic reseeding of the planet." The agents of this reseeding are artists, "working between layers of meaning, across varieties of perceptual modes," engaging with the kind of phenomena characteristic of a-life: "growth, spontaneously generated levels of order, and self-organization constitute the dynamic aspects of our practice. We think that our work anticipates new language and new behavior and will contribute to the evolution of new environments, even new realities."

Ascott's deployment of nature is striking; when he declares that "we connectivists feel we are much closer to life, to living systems," he seems to be naturalizing the technocultural practice of telematic art. Yet, if nature is a cultural construction, then a-life offers a more authentic relationship:

> It is in Artificial Life that we may yet encounter living nature. That is to say we shall only be in touch with nature when we end our futile attempt to dominate it, or to be above it, withdrawn from it, viewing it . . . in the middle distance, at a cultural remove. Artificial life by contrast is the attempt to collaborate with life, interact with it, to see ourselves as part of an infinite network of connectivity, in which neither nature nor ourselves are separate or independent.

Adopting radical constructivism, everything is artificial, nothing is given, everything is personally and provisionally constructed and can be equally reconstructed. A-life promises a reconstruction of nature and life itself, as Ascott enthuses: "Now we are going to arrange it from the inside-out, from the bottom-up, from the very atoms, molecules, and genes onward."[12] Elsewhere, he argues strongly for the involvement of artists in this radical reconstruction:

> With the demise of artifice, the death of art's staged and constrained representations of life and nature, we anticipate the emergence of a cultural connectivity in which we artists can participate fully with scientists in the creation of Life as it could be.[13]

For Ascott, then, art and a-life are allied in a particular way, within a particular context: after radical constructivism dissolves or explodes the certainty of meaning, artists and scientists remake the world and are connected more closely with it through the bottom-up techniques of a-life.

Ascott's constructivist/connectivist position is echoed in the writing of the theorist Sadie Plant, in particular in her 1996 paper "The Virtual Complexity of Culture." Plant opens with a question from Kevin Kelly: "What alchemical transformation occurs when you connect everything to everything?"[14] Her answer, in brief, is a new kind of thinking, "an emergent connectionist thinking" which involves a host of far-reaching transformations. It sees a sweeping convergence of the natural and the artificial, the collapse of disciplinary categorizations of knowledge, the unification of theory and praxis, and it prompts corresponding changes in thinking "the social, the human and the cultural." Plant draws on complex systems science and connectionist artificial intelligence (which centers on the use of simulated neural networks) to propose an idea of culture as a dynamic complex system — not an autonomous system but one involved in a greater complex spanning technological, biological, and social systems, all supporting adaptive, emergent, self-organizing phenomena. While Plant does not deal explicitly with a-life, the connection is clear; this is a theory of "artificial culture," where the complex dynamics so central to a-life are manifest more widely. As in Ascott, this theorization results in a widespread collapse of distinctions: nature/culture, human/machine, art/science; all dissolve into a connectionist network.

In both Plant and Ascott, notions of emergence and self-organization support an expansive and positive form of futurism, a set towards change and transformation. Ascott looks to the future, eagerly anticipating "new language . . . new behavior . . . new environment . . . new realities"; he borrows Langton's catchphrase for a-life, "life as it could be," for its sense of the possible, of things to come. Ascott uses the same phrase to advocate an art that is "visionary, polemical, propositional"; these words apply equally well to his own writing.

While Ascott projects the fusion of a-life with art practice into a connectivist future, the Japanese media art theorist Machiko Kusahara seeks to support the same conjunction using historical evidence. Kusahara frames a discussion of a-life art by drawing historical parallels between shifts in scientific and creative thinking, locating a-life art at a particular historical convergence of science and art. She sketches a history of twentieth-century art whereby the art object and its relation to the viewer undergo a series of transformations; film dematerializes art, shifting it into the realm of optical illusion; Dada and then Fluxus undermine the conventional nature of the object and propose a new, more active inclusion of the viewer. "In other words, art would become an environment that viewers can step into and interact with."[15] Meanwhile, in molecular biology, life is first of all described in terms of "physics, chemistry and information science," and in a contemporary approach, determinism and mechanism are superseded by an interest in "chaos, complexity and emergence" (99, 110). With the discovery that "information is the key element that supports the diversity of life," the involvement of artists in information-based media, and the wide cultural influence of notions such as evolution, DNA, and ecology, Kusahara suggests, "life has achieved a role . . . as a medium of art and communication."

Kusahara's enthusiasm for the merger of art with artificial life centers on a familiar trope, "life as it could be." Given the vague conditions for defining what constitutes life, "there is room for artificial systems . . . to be thought of as a form of life. This allows a vast possibility for an artistic approach to life" (103). A-life "is a search for life using approaches which are not necessarily bound to reality. Here is the key to the necessity of the involvement of art in this new field of research" (105). She observes that viewers sometimes complain that the artificial organisms in an a-life work are unconvincing, lacking in visual reality. They miss the point, she suggests, that "life can be a more abstract entity. This is a point that art and A-life share" (104).

Here, once again, the sense of possibility inherent in the rhetoric of artificial life becomes associated with the sense of potential involved in artistic creation. Through a linkage at this single point, through the category of creativity, a wider congruence is suggested. The same linkage is at work in the writing of the a-life artists Christa Sommerer and Laurent Mignonneau. In their 1999 manifesto "Art as a Living System," the languages and histories of art and science are once again interwoven. Sommerer and Mignonneau plot a progression in the sciences, away from a Newtonian, Cartesian, mechanist view of nature and toward the quantum-mechanical interconnectedness propounded by the physicists Niels Bohr and David Bohm and the systems perspective of Gregory Bateson. The artists present their work as exploring the creative implications of the insight that this perspective supplies: "That interaction itself and the interrelation between entities are the driving forces behind the structures of life."[16] Specifically, they "investigate interaction and the creative process itself." In this paradigm,

> Creation is no longer understood as expression of the artist's inner creativity or "ingenium" (according to Hegel) but becomes itself an intrinsically dynamic process that represents the interaction between the human observer, his/her consciousness and the evolutionary dynamic and complex image processes of the works ('Art as a Living System').

Sommerer and Mignonneau also supply an art history that parallels this scientific paradigm shift. They invoke Duchamp, who demonstrated and exploited the involvement of the observer; John Cage is cited for teaching that "consciousness is not a thing but a process, that art must entail the random, indeterminate and chance aspects of nature and culture"[17]; Fluxus and Allan Kaprow are credited once again with "integrating the audience into the art process." A-life enters this constellation in the service of these interests in the creative process; Sommerer and Mignonneau are "fascinated by the ideas of creation through evolution, not understood as a scientific simulation or mimicry of nature but as an investigation into the creative process itself."[18] While the terms of nature and life become important elements in this discursive framework, here a-life is presented simply as a creative technique "[s]imilar to John Cage's use of chance procedures."

Sommerer and Mignonneau clearly imply a general correlation between a-life and the creative process. However, their notions of artwork and artist draw on questions raised by late Modernism, in particular shifting creation away from individual will and toward autonomous and interactive processes. Likening themselves to Cage, they "intentionally replace themselves" with artificial evolution and audience interaction; in the tradition of Fluxus they describe themselves as "blurring the border between life and art."[19] Thus, a-life and art come to a productive union in this discourse, but they do so only as art's conventional structures are undermined.

The conjunctions proposed by Tenhaaf, Ascott, Kusahara, and Sommerer and Mignonneau give a sense of the rhetoric and values involved with the thinking-together of a-life and art. There are differences in rhetorical style and argument but also some important commonalities. All agree on a positive affinity between artistic practice and artificial life, based on common materials (constructed representations), common properties (such as emergence and connectivity), and a common orientation toward the prospective, toward what could be. Ascott and Plant also suggest a stronger argument, for if culture is, like nature, complex, connected, and emergent, then a-life art is an emblematic practice, a practical project in artificial culture.

A-LIFE ART THEORY

While a-life art is certainly undertheorized, a number of writers, particularly artists, have begun to consider what the significance of that practice might be. Although some of this material is linked to specific work or specific artists, it is presented here for the general points it makes, the sense in which it sets out particular theoretical, philosophical, and critical contexts for a-life art.

Ken Rinaldo's 1998 paper "Technology Recapitulates Phylogeny" is a case in point. While it is clearly aligned with the artist's approach, it moves beyond his work to describe an agenda and a context for a-life art practice in general. Central here is a sweeping version of emergence, which is not only a systemic property but a macrohistorical tendency, an all-encompassing movement toward synthesis and integration. This "new paradigm for . . . global change" is already evident, Rinaldo argues, in the increasing interdisciplinarity of science and art practice. Like Ascott and others, Rinaldo heralds a "merging of the cultures of art and science" that may even be "the next cultural evolutionary step in the ascent of man in the cosmos"; enabled by the connectivity of the Web, an emergent mixture of knowledge forms the "primordial soup" for artificial life.[20] Within this overarching emergence, Rinaldo locates a-life art practice at the nexus of biology, culture, and technology. He argues for the continuity of evolution across technological and biological forms (as the title of the paper indicates); like Kevin Kelly, he understands the development of technology in the marketplace as analogous to the evolution of life. Moreover, technology, operating at the heightened pace of cultural evolution, is destined to reenact the evolutionary solutions already manifest in biological life. Biology and technology both reflect "what seems to be an inevitable and overall evolution toward intelligent systems."[21]

Rinaldo's specific argument for the merits of a-life art rests on the notion of interactivity. A-life techniques promise a richer mode of interactivity than the "hackneyed replicable paths" of conventional multimedia, Rinaldo suggests, offering instead "a real poetry of interactive form and content," "[a] cybernetic ballet of experience" where a-life systems "evolve relationships with each viewer individually."[22] Rinaldo anticipates the point where interactivity crosses over into living agency, declaring, "I for one look forward to the day when my artwork greets me 'good morning' when it has not been programmed to do so." The coevolution of biology and technology is fulfilled as technology attains life, and through its continued adoption of biological models — its recapitulation of phylogeny — merges easily with the biosphere.

Where Sommerer and Mignonneau address a-life art practice, they do so along similar lines. With the notion of "Art as a Living System" they hold that "the art work . . . is no longer a static object or pre-defined multiple choice interaction but has become a process-like living system. . . . The art work is characterized by complex interrelations and interactions of real and virtual entities."[23] This also entails, as we have seen, a particular self-marginalization on the part of the artist. More importantly, for the artists, the work embodies certain universal qualities, manifesting dynamics of interrelation and interconnection that "are the driving forces behind the structures of life" (148). Just as the "cosmic web" is alive, such works "could be considered alive as they are processes of continuous change, adaptation and evolution" (159). As in Ascott's constructivist connectionism, the artificiality of a-life evaporates here; Sommerer and Mignonneau make no distinction between "processes of nature or artificial nature"; as shown in the earlier discussion of their work, the virtuality involved in these interactive systems is seen as unproblematic or transparent (160).

At their core these characterizations of a-life art carry a familiar selection of connectionist tenets: interactivity, telematic connection, progressive evolution, and the unity of the organic and the technological. As in other forms of connectionist rhetoric, however, these writers leave aside any sense of how the relationship between technology and nature might be conditioned, or of how the communicative connectivity which enables interaction might be mediated. They also leave aside the basic processes of construction that are involved in the fabrication of a lifelike system.

Critical Perspectives

We are developing a detailed sense of the related ways in which a-life art is theorized both as a concept or prospect and as a practice. At a certain point, however, what is unsaid here becomes more urgent: How might we begin to approach a-life art critically? Can we find vantage points outside the somewhat nebulous networks of connectionist thinking? While the analyses in the preceding chapters begin to suggest critical approaches, there is more to be said. In particular, we can draw not only on critiques of a-life art directly but on the richer literature around artificial life in cultural studies and related fields.

Edward Shanken's writing is useful in bringing a certain clarity to the discussion. His analysis centers on a question of ontology and the claim of life; in particular, he points out that a-life operates not with living matter but with explanations and theories of life. This produces an "inherent circularity": "Take a biological theory or law L, model it on a computer, and lo and behold, behavior resembling that of biological organisms described by law L emerges."[24] Thus he proposes "synthetic biology" as a more accurate descriptor for a-life, one that acknowledges its basis in an epistemology rather than in an ontology of life. This distinction also applies, he argues, to artists applying a-life, who are "not creating life but are creating art that is informed by . . . [or] emulates . . . biological theory." While Shanken remains open to the value of a-life art, and in fact shows that it can address these ontological and epistemological issues, he cautions that such value "cannot be attributed to the life it purports to embody."

Similarly, Simon Penny balances a sense of the creative promise of a-life techniques with a strong critical analysis. Like Rinaldo, Penny has a practical interest in a-life techniques that centers on emergence and interactivity. He suggests that the "emergent order" of a-life "offers an alternative to the current all too deterministic paradigm," which is described as "pre-set responses to user navigation through an ossified database."[25] Penny calls emergent interactive behavior a "new paradigm of interactivity," which questions conventional modes and makes their inherent deterministic top-down ideologies more apparent. He suggests that a-life may offer "tools for an aesthetic interactive practice," a suggestion clearly taken up in his own works.

Penny also joins the connectionists in observing that a-life and the complexity sciences pose critical challenges to mainstream science (62). Concepts from chaos theory such as sensitive dependence on initial conditions (better known as "the butterfly effect") reveal the narrow view of conventional physics, the necessarily constrained and simplified causalities that it describes. Similarly, fractal geometry offers an alternative to the ideal abstractions of Euclidian geometry, emphasizing a complex ongoing process of formation. Self-organization undermines the nihilism of thermodynamic entropy, and the principle of emergence questions an entire scientific tradition based on reductive analysis, revealing the irreducibility of complex wholes.

Yet, Penny is ultimately cautious about the implications of artificial life. In particular, he questions a-life's rationalist assumption that the informational aspect of life can be extracted from the material, and attacks this implied division of matter and information as dualistic, "a narrative construction rooted in Enlightenment precepts" (61). The supposed importation of life's informational essence into the computer "induces the (quite wrong) assumption that modern computational techniques are structurally similar to the deep structure of biological life." Penny also unpacks some of a-life's tacit ideological formations. He locates a-life within a long Western tradition of natural exploitation; postindustrial a-life simply operates by "harnessing the mechanism of biodiversity" rather than its biological products. The purposes of this harnessing, Penny notes suspiciously, remain obscure. Finally, he warns artists using a-life "not to unconsciously and unquestioningly endorse the value systems and narratives hidden in scientific discourses, where they often lie hidden, disguised as axioms" (68).

Penny hints at a way to read artificial life critically, deconstructively, to read it for the values and ideologies it embodies and for the narratives it plays out. This approach has been taken up beyond the bounds of art practice, by cultural theorists considering artificial life. In these analyses science is shown to be grounded in society and culture:

science is treated as a cultural practice rather than as a neutral apparatus for determining the true nature of things; it is shown to construct its meanings in the same way meaning is constructed throughout cultural life, through narrative. Like all other cultural narratives, these are prone to analysis, which locates their basis in socially grounded values, ideologies, and common sense.

The anthropologist Stefan Helmreich presents a comprehensive cultural analysis of a-life science in his 1998 book *Silicon Second Nature.* Based on extensive fieldwork within the a-life community, primarily at the Santa Fe Institute in New Mexico, Helmreich's work sets out to uncover the cultural values embedded in the practices and discourses of a-life science. He locates this project within the sociology, anthropology, and cultural study of science, areas that consider the social and cultural production of scientific meaning as well as the cultural and political implications of scientific knowledge.

Although her background is in literary theory, Katherine Hayles approaches a-life science from a similar perspective. Less extensive in its aims than Helmreich's survey, her work focuses on the narrative constructions operating within a-life science. In her 1998 monograph *How We Became Posthuman,* Hayles positions her analysis of a-life's narrativity within a wider project addressing the interplay of material and informational bodies within science and literature.[26] Helmreich and Hayles are joined, in the following account, by a handful of other writers addressing a-life science from various cultural and critical perspectives.

Helmreich's central argument is that "Artificial Life scientists' computational models of 'possible biologies' are powerfully inflected by their cultural conceptions and lived understandings of gender, kinship, sexuality, race, economy and cosmology and by the social and political contexts in which these understandings take place."[27] Helmreich uses the field-based approach of anthropology to document the basis of a-life's scientific work in a specific institutional and cultural location. He also describes his project in terms of an interest in a-life's propagation of "'hegemonic' . . . stories; stories that find sustenance in pervasive, commonsensical, almost unconscious, dominant ways of understanding, experiencing, and acting in the world."[28] A similar interest in stories characterizes Hayles's investigation; a-life's claims for itself are best approached, she suggests, by "looking not only at the scientific content of the programs but at the stories told about and through them. These stories constitute a multilayered system of metaphoric and material relays through which 'life', 'nature' and the 'human' are being redefined."[29]

Hayles's 1996 article "Narratives of Artificial Life" makes the case for the importance of narrative constructions in a-life science. For Hayles, it is narrative that operates to translate the raw "binary operations" of computation into "biological analogues"; it transforms "changing electrical polarities on silicon into the high drama of a Darwinian struggle for survival and reproduction" (148). Hayles observes that Tom Ray's descriptions of his Tierra system are peppered with biological language, including references to mother and daughter cells, parasites and ancestors, and a primeval soup. However, she says, these biological analogies are more than interpretation after the fact; Ray is the system's designer, and Tierra has clearly been constructed as a biological analogy from the outset: "Ray's biomorphic namings and interpretations function not so much as an overlay, . . . as an explication of an intention that was there at the beginning. Analogy is not incidental or belated but central to the program's artifactual design" (150). Hence, like Tenhaaf, Hayles argues that "the program operates as much within the imagination as it does within the computer" (147). The core of Hayles's argument here is that the narrative constructions undertaken "are essential to the claim that the 'creatures' are in some meaningful sense alive." In other words, those making the strong claim for the aliveness of their creations do so with the support of stories that draw on familiar models and established conventions. These stories, furthermore, firmly link this vision of artificial life, "life as it could be," to very familiar notions of "life as it is."

This reiteration of cultural narratives of life can be seen as a form of feedback loop, and Hayles, Helmreich, and others draw attention to such feedback loops within a-life science. Hayles describes them as processes of "reinscription," where the established cultural categories involved in shaping artificial life are reproduced and reinforced through its own discursive processes. These loops are also central to Helmreich's analysis; he catalogs a set of normative cultural values that inform a-life science, including notions of gender, family, deity, the individual, and that, he argues, a-life reproduces, reinforces, and naturalizes. Hayles and Helmreich agree, however, that a-life science is also involved in the transformation of cultural values. Helmreich "tries to get at how new notions of life are being materialized,"[30] as well as how existing notions are reproduced; Hayles thinks of this mixture as a "seriated pattern of innovation and replication."[31]

Helmreich opens his analysis with an unraveling of one of the dominant figures in simulation-based a-life, the notion of the computer as a world or universe. He traces the constitution of this article of a-life "commonsense," showing that a range of scientific artifacts and theories, including cellular automata and theories of quantum mechanics, are used to support a notion that the physical universe is essentially rule-based and informational, and thus that it can be unproblematically recreated *in silico.* In the first of these reinscriptive loops, scientific assumptions about the nature of the world allow it to be rendered in computation without incurring any ontological damage. Helmreich quotes the a-life researcher Larry Yaeger: "Worlds and universes are complex processes, based on fixed, low-level principles. Computer simulations are complex processes, based on fixed, low-level principles."[32] Hayles notes that the notion of simple rules or immaterial forms underpinning reality has been central to the tradition of reductionistic science. While a-life has distanced itself from the reductionistic approach, focusing on complex systems and emergent results, Hayles argues that a-life uses reductionism in reverse:

> Instead of starting with a complex phenomenal world and reasoning back through chains of inference to what the fundamental elements must be, they start with the elements and complicate them through appropriately nonlinear processes so that the complex phenomenal world appears on its own.[33]

Thus, analysis has been replaced by synthesis, but a-life nonetheless "reinscribes . . . the mainstream assumption that simple rules and forms give rise to phenomenal complexity."

Helmreich also argues that the construction of computers as self-contained worlds is informed by, and in turn reinforces, certain cultural and social dynamics. In particular, he argues that Western theology "enables the thinking of Artificial Life in a deep way."[34] In an example of this, he suggests that a-life programmers' figurations of themselves as "a genus of god" allows them to position themselves as either transcendent, omnipotent manipulators of their world or as entirely separate, distant observers, as necessary.[35] Taking on the role of deity is a way for scientists to reinforce the constitution of the simulation as a world and at the same time, according to Helmreich, "to erase their own presence as the beings who gave their simulations meaning as worlds." This theme of erasure appears in other critiques. The cultural critic Tiziana Terranova points out that in a-life simulations the basic rules built into the system by its designer are "usually made invisible and naturalized."[36] She links this "erasure of . . . design" to a general "silence around issues of 'power' and 'responsibility'" in artificial life and the cybercultural rhetoric that it inspires.[37]

Within a-life science the notion of a computational world forms the substrate for computational life, life as an informational pattern, pure form, independent of its material substrate. The culture and ideology involved in this construction are treated widely in the critical literature. As Helmreich shows, the ground for this notion is prepared by evolutionary biology: he uses Tierra to exemplify the "implosion" of the embodied complexities of living organisms onto the cleanliness of the purely formal digital genome. He cites a-life scientists and their simulations to show the predominance of an identification of life with the genetic code. Helmreich places that identification in the context of the rise of molecular genetics in biology and links it more broadly to a Cartesianist mind-set favoring disembodied rationality over embodied materiality.[38]

Similarly, the theorist Richard Barbrook attacks the drive for disembodiment in the speculative writing of Marvin Minksy and Hans Moravec, both of whom have been prominent in forecasting radical advances in artificial intelligence and robotics. Barbrook denounces their visions as myths of "cyborg immortality" and "becoming pure spirit." These reiterate ancient beliefs, he argues, and reinforce longstanding dualities of mind and body, matter and spirit. Like their religious predecessors, Barbrook says, a-life's "grand narratives" "distract us from the practical problems of improving the years of life which we do have."[39]

Hayles also deals with Moravec, pointing out his affinity with traditional religious beliefs and his "perfect" reinscription of Cartesian dualisms.[40] She suggests that his notion of subjectivity as "pure form" is compatible with the formal organisms of a system such as Tierra, and presents Moravec's proposals for the "downloading" of human consciousness as an image of the implications of artificial life for human life, a move toward an informational, posthuman life form. As she points out, however, Moravec's position is not only ideologically outmoded but practically dubious; his "wishful" imagination is contradicted by "a large body of empirical evidence demonstrating the importance of embodiment to thought."[41]

A number of analysts observe that gender categories, along with associated notions of sexual reproduction and the family unit, are reproduced within a-life science. Helmreich's analysis of Tom Ray's Tierra system leads into a consideration of its gendered language of creation, of "seed," "soil," and what Helmreich terms "masculine monogenesis."[42] Helmreich agrees with Hayles in arguing that Tierra "symbolically mimics the story of creation in the Bible," where a single divine Word, uttered by a masculine-gendered God, brings forth all life.[43] Similarly, Richard Barbrook demolishes what he regards as a-life's myth of "men having babies." It is a reworking of the story of virgin birth, he suggests, and the cooption of mysterious female powers of creation by male scientists "gripped by womb envy."[44] Helmreich, too, links the "clean conception" of a-life with divine impregnation and presents some inconclusive evidence of male "birth envy." Terranova vents her frustration at "this incorrigible re-enactment of the masculinist act of erasure of the female body (among others) and its obsession with immaculate fatherhood."[45]

Even where "masculine monogenesis" gives way to artificial sexual reproduction, Helmreich argues, culturally dominant norms are reinscribed. Despite the strictly abstract mechanisms of crossover and replication within a genetic algorithm, reproduction is presented using normative imagery of family and "productive heterosex."[46] In the discourse of a-life scientists and in popular representations "monogamous heterosexual marriage" is applied as "a realistic template for natural processes of sexual coupling for reproduction" (147). In simulations where sex differences are built in, Helmreich argues, culturally dominant notions of gender categories as genetically determined and congruent with biological sex, and gender stereotypes of active males and passive females, are also built in. In a similar way Helmreich demonstrates how notions of family, kinship, race, and culture as biogenetically determined are reflected in, and naturalized by, the discourse of a-life simulation.

Helmreich also argues that the discourses of evolution within artificial life reflect culturally built-in notions of nature, that the genetic algorithm reflects a sense of nature as rational and evolution as progressive. Nature here is imagined as a designer searching for optimal solutions, an agency that, as he observes, "most closely resembles a person engaged in artificial selection" (143). Citing Stephen Jay Gould, Helmreich contrasts the neat genetic determinism of a-life with the messy developmental structure of real biology, wherein "it makes little sense to talk of particular traits being optimized."[47] Once again Helmreich locates a circular process of reinscription, though in this case there is an additional twist, as the particularities of the computational simulation — the instrumentalization of evolution to give an optimal solution, and the presence of an agency behind evolution — are projected back onto the natural processes that inspired it.

For Helmreich, a-life also involves narratives of agency and thus subjectivity. Agent-based systems such as John Holland's Echo platform reinscribe a particular culturally specific model of the subject, namely, the self-determining, competitive, "formally equal" individual formed by Western liberal political theory (166).[48] The only interactions between agents in Echo are trading, combat, and mating; Helmreich describes the model as "extraordinarily gendered" and the Echo agent as resembling "a masculine individual that masquerades as a universal organism" (168). Echo also leads Helmreich into a discussion of the interaction between a-life science at the Santa Fe Institute and economic theory. He points out the role of the institute in propagating biological models of economic activity, where, in the words of one SFI economist, the economy is seen as "evolving organically," "like an ecology" (173). Helmreich argues against this naturalization of economics, suggesting that these models are formed from a privileged (middle-class, male) economic position and informed by the interests of SFI's corporate sponsors. The biologically inspired corporate rhetoric of adaptation is linked, Helmreich observes, to the advent of post-Fordist production and globally mobile capital; the naturalization of these changes erases the social inequalities that such a system amplifies (177).

Tiziana Terranova argues along similar lines, although her target is one of the popular exponents of this new brand of economic theory: *Wired* editor-at-large Kevin Kelly. She cites Kelly's "rhetoric of abundance" but notes its omission of the less palatable aspects of Darwinian theory, such as competition, survival of the fittest, and resource scarcity. Just as Helmreich locates the subjective position implicit in Santa Fe economics, Terranova asserts that Kelly's rhetoric, suggesting "limitless expansion and exponential rates of growth," "could be born only inside the hyper-economy of electronic communication."[49] From this privileged position, she suggests, it "overlooks the limits set to evolution by power relations working through the 'natural' . . . rules of the status quo."[50]

The critique revealing a-life's grounding in cultural feedback loops brings us this far. A-life science, in this view, is an activity reproducing a whole range of suspect ideologies around gender, embodiment, and agency, and doing so from the shelter of the culturally and economically privileged sphere of technoscience. A-life claims to explore "life as it could be" and perhaps hints at "life as it will be"; as both Helmreich and Hayles observe, a-life discourse involves a rhetoric of artificial life forms seen as an evolutionary "next step," a move into a postbiological mode of evolution.[51] Yet, a-life's narratives are, for Helmreich, nostalgic fantasies, images of "life as it should be."[52] In arguing against a-life's reinscriptive loops, Helmreich and other critics resist the writing of a single, authorized life form (even lifestyle) into formal rules for life itself. In the midst of the technological reconstruction of life, this resistance is all the more urgent. Hayles warns, "As humans on the brink of what some see as an evolutionary threshold, we cannot afford to blind ourselves to . . . the narratives which produce artificial life, and are produced by it, [for they] affect us all."[53]

Between Critique and Connectionism

For some theorists and artists, as we have seen, the conjunction of art and artificial life is rich with potential: it signifies an emerging, evolving interconnectedness; a paradigmatic shift in art, culture and science; a positive, expansive creative potential. For others, the techniques and discourses of a-life reinscribe normative or even regressive cultural values in the guise of its computational structures and technological artifacts. What are we to make of the disjunction here? To a certain extent it must be expected, since these are not opposing sides of an argument but discourses that reflect quite distinct projects. For cultural critics, a-life is a value-laden technoscientific practice; for artists and connectionists, it is a technical and conceptual resource. One project is primarily critical, the other primarily creative.

Yet, of course, each has implications for the other. Cultural critiques of a-life can be readily applied to a-life art, especially where, against Simon Penny's advice, artists redeploy a-life techniques and forms and "unconsciously or unquestioningly endorse" its embedded narratives and values. This is not a total critique, though; while the previous chapters contain many examples of unquestioning endorsement, there are as many instances where artists have departed from a-life's cultural script, recasting its techniques and concepts or using them critically and reflexively. As Tenhaaf argues, a-life and art both deal in metaphors; artists often recognize a-life techniques as inherently figurative and use them as such.

Conversely, the connectionist rhetorics around art and artificial life illustrate the limits of these cultural critiques. In the writing of Ascott, Plant, Rinaldo, Sommerer and Mignonneau, and others, there is an emphasis on a-life's systemic tenets: connectivity, complex dynamics, emergence, evolution, and self-organization. These properties — not, explicitly, a technological takeover of "life itself" — are the engines for the connectionist rethinking of art and culture with artificial life. These generative aspects of a-life are not addressed, however, in the cultural critiques, which are in a sense themselves reductive; they take a-life science apart and deliver a powerful analysis of its constitutive narrative elements. Yet, they stop short of commenting on a-life's dynamic wholes and their behavior; they don't observe or engage with those systemic properties. Even while an a-life system embodies certain cultural values and reflects dubious assumptions on the nature of matter and information, does it not also manifest something striking of its own, something more than the playing out of familiar stories?

Connectionist thinking itself offers little to answer this question, however. While complex connectivity, self-organization, and emergence are frequently evoked, there is no detailed engagement here either; these notions are never unpacked, tested, or defined, but appear as articles of faith. If a-life processes do hold the promise of, in Ascott's words, "growth, spontaneously generated . . . order and self-organization," how is that promise realized? If a-life art is anything more than a refiguration of a-life metaphors and techniques, this question is crucial. How do real a-life systems, especially as used by artists, manifest emergence, and how might we think about exactly what that is, and what its potentials and limits might be?

Emergence is central to artificial life. It is the concept that explains the crucial leap it makes between nonlife and life. A-life science regards living systems as complex material systems whose microscale parts interact in such a way as to give rise to complex macroscale structures and behaviors. In attempting to model and synthesize living things, a-life reproduces this structure, creating complex computational systems composed of multitudes of simple parts interacting in complex ways, and observing the complex, sometimes surprising behavior of those systems. According to the bottom-up approach that distinguishes a-life, those complex lifelike behaviors are not directly controlled or specified; rather they arise spontaneously from microscale interactions. *Emergence* is the term and the concept used to account for those phenomena.

7 E M E R G E N C E

More broadly, emergence refers to something novel or unanticipated, something extra; what makes a-life systems striking is the fact that, made as they are from commonplace components, they yet manifest complex, subtle, unpredictable behavior. Put simply, they seem to deliver something more than the sum of their computational parts, and that something more may be in the form of a spatial pattern or form (as in Driessens and Verstappen's *Tuboids*), a specific behavior (such as the flocking of artificial entities in *EIDEA*), or a more general systemic tendency (as in the coevolution in *Iconica, A-Volve,* or *Eden*). Each of the systems mentioned here is grounded in a fixed set of computational rules and processes, but these rules are far less interesting than the rich, varied, complex, emergent outcomes they support. As the following discussion shows in detail, the something more of emergence is central to the interests and the appeal of a-life art.

As such, it warrants close investigation. Several questions arise: How do we come to grips with the concept itself — how can emergence be thought through as something more than a vague "something more"? How is it manifest in a-life art? How is it constrained, conditioned, or shaped by the technological structures supporting it? I will argue that emergence is not merely central to the mechanics of a-life art practice but represents its primary interest and its dominant drive, that emergence is to a significant extent the reward that draws artists to use a-life. In part, the discussion seeks to follow that drive for emergence, to consider the obstacles it faces, and to imagine the terms of its fulfillment. In the process, notions of what emergence is and where it might be located within creative practice begin to shift. If emergent phenomena are commonplace in art making, if they are, as some propose, an essential feature of any form of creative thought, what are we to make of a form of art practice that seeks to replicate those phenomena in the controlled abstract space of computation?

Emergent History

Part of the appeal of emergence as a concept is that it defies clear definition. Its function in a-life discourse often seems to be a form of antiexplanation, a vague answer blocking off further investigation. A historical overview of its various usages and contexts provides a more concrete sense of what emergence might be and also opens up a history of debate around the concept, a history that is useful in considering its significance in contemporary a-life art.

The first technical use of the term appears in the work of the English philosopher and literary critic George Henry Lewes in his *Problems of Life and Mind* (1875).[1] Lewes uses *emergent* to designate an effect involving several causes that cannot be reduced or traced back to those component causes. This definition arises as part of a discussion of causality, in particular, the problem of the "composition of causes" earlier addressed by the philosopher John Stuart Mill in *A System of Logic* (1843).[2] In fact, Mill's discussion is regarded as the first formal treatment of emergence, and although it does not use the term, it characterizes the concept very clearly. Like Lewes, Mill discusses cases where multiple causes produce a single effect, making a distinction between cases where the effect is a simple accumulation of multiple causes and cases where the effect is irreducible to those causes.

As an example of simple accumulation Mill gives the vectoral composition of force: an object moved a certain distance by a force will be moved the same distance by the successive application of the two or three vectoral components of that force. Irreducible effects, on the other hand, can be found in chemical compounds: the combination of certain chemical elements (for example, hydrogen and oxygen) gives an effect (water) which is in no sense a simple aggregate or summation of the components. Water is not simply hydrogen plus oxygen; it is a new substance with properties very different from those of its components. Lewes follows Mill, and he labels these properties *emergent*. Mill's discussion omits that term but anticipates issues that form the core of the debates around emergence for the following century. Prefiguring artificial life, Mill argues that no matter how thoroughly we might know the elements of the living body, "it is certain that no mere summing up of the separate actions of those elements will ever amount to the living body itself."[3] He also predicts the wider applicability of these "irreducible effects," suggesting that this complex causality "will be found equally true in the phenomena of mind; and even in social and political phenomena."[4] This accurately describes the field now known as complex systems science.

Achim Stephan, in a useful historical overview, characterizes the work of Mill and Lewes as the first phase of the history of emergence.[5] The second he identifies in English philosophy of the early

1920s, in particular, Samuel Alexander's *Space, Time and Deity* (1920), C. Lloyd Morgan's *Emergent Evolution* (1923), and C. D. Broad's *The Mind and Its Place in Nature* (1925).[6] These writers all apply concepts of emergence from Mill and Lewes to theories of evolution in an effort to provide alternatives to both mechanistic and vitalistic conceptions of life. In particular, their work involves an attempt to recenter humanity and mind in the cosmological order of things. The historian of science Peter Bowler describes the emergent evolution movement as "an effort to retain a faith in the values of human nature while admitting that man had been framed by evolution."[7] Alexander, Lloyd Morgan, and Broad share a vision of a unified universe, from Alexander's space-time matrix upwards through matter, life, mind, and finally (for Alexander and Lloyd Morgan, at least) deity. Each level of this hierarchy is emergent with respect to the previous one, that is, it results from interactions at the previous level but displays distinctive new properties. Thus life emerges from inert matter, mind emerges from life, and so on.

Discussion about this expansive form of emergence continued until the 1960s, when writers including Ernst Nagel revisited the concept on more skeptical and logical terms. Nagel's *The Structure of Science* (1961) contains a critique of "the doctrine of emergence" which argues that emergence is a kind of logical truism, such that

> statements about the properties of complex wholes can be deduced from statements about their constituents only if the premises contain a suitable *theory* concerning these constituents — one which makes it possible to analyze the behavior of such wholes as "resultants" of the assumed behaviors of the constituents.[8]

In other words, if a complex whole (such as a water molecule) displays properties that are unpredictable based on knowledge of its constituents, this is only because our theory concerning the constituents does not contain terms to describe these properties. Thus, Nagel writes,

> to say of a given property that it is an "emergent" is to attribute to it a character which the property may possess relative to one theory or body of assumptions, but may not possess relative to some other theory. Accordingly, the doctrine of emergence . . . must be understood as stating certain logical facts about formal relations between statements rather than any experimental or even "metaphysical" facts about some allegedly inherent traits of properties of objects.

Here Nagel introduces the idea of emergence as an epistemological phenomenon, involving the formation of theories and models of observed phenomena. Emergence as a special or irreducible ontological trait is argued away.

Meanwhile, the cosmology of emergence proposed by Lloyd Morgan, Alexander, and Broad had been overtaken by scientific developments. The new properties these theorists ascribed to each ontological level rested on claims for "downward causation," whereby a macrostructure can change the behavior of its microcomponents, implying that living matter behaves in a fundamentally different way than nonliving matter simply by virtue of its being involved in a living whole. This seemed to require new natural laws and forces specific to each level; emergent evolution invokes special "configurational forces" that are themselves emergent properties of complex wholes such as living organisms. As the philosopher of science Brian McLaughlin argues, advances in quantum mechanics and molecular genetics suggested that the complexities of organic matter and evolved life could be explained without resorting to these special forces; there is "not a scintilla of evidence that there is downward causation."[9]

In the wake of Nagel's critiques and the lack of scientific support for emergent evolution, emergence received little attention. Only during the 1980s and 1990s, with developments in complex systems science and artificial life, has the term regained some currency. It is central to the approach of artificial life, as Christopher Langton explains:

> The "key" concept in AL is *emergent behavior.* Natural life emerges out of the organized interactions of a great number of nonliving molecules, with no global controller responsible for the behavior of every part. Rather, every part is a behavior itself, and life is the behavior that emerges from out of all of the local interactions among individual behaviors. It is this bottom-up, distributed, local determination of behavior that AL employs in its primary methodological approach to the generation of lifelike behaviors.[10]

Steven Levy describes emergent behavior more succinctly as "the payoff of the bottom-up approach."[11] Here the issue is less the ascription of emergence as a property to a certain complex whole than the characterization of emergence as a process, an umbrella term for the results of a multitude of complex microinteractions; rather than on inherent properties of matter, the focus is on macroscopic behavior. A-life's continued pursuit of a bottom-up approach reflects its faith in this form of emergence, one with none of the mystical or ineffable overtones of emergent evolution but seen as the most appropriate way to effect the synthesis of life. No new physical laws are proposed, nor do they seem necessary; in the light of recent work on complex systems, it seems that many of the special properties of living matter that the emergent evolutionists sought to explain arise spontaneously in complex material systems.[12] The complexity sciences shift attention from static laws of matter to complex interactions over time; a-life science is directly informed by this approach.

Many of the artists working with artificial life invoke emergence explicitly in writing about their works; this is a crude but effective measure of the prominence of he idea. Lovell and Mitchell's *Environment for the Interactive Design of Emergent Art* refers to the "emergent phenomena of artificial life."[13] Jane Prophet writes of behavior emerging as a result of low-level interactions in *TechnoSphere.*[14] Jon McCormack describes his *Turbulence* as "an unimaginable digiscape that has emerged from . . . computation and logic."[15] Troy Innocent, in a statement on *Iconica,* quotes the a-life scientist John Holland discussing the emergence of "surprising complexity" from simple rules.[16] Scott Draves describes his creative practice in a paper titled "Metaprogramming Emergent Graphics."[17] Richard Brown's documentation of his *Biotica* project is subtitled "Art, Emergence and Artificial Life."[18] Mauro Annunziato and Piero Pierucci write of "The Art of Emergence."[19]

Emergence is central to the work of Ken Rinaldo; he has named his creative enterprise "Emergent Systems." Rhetorically, Rinaldo uses an expansive version of emergence; it is "the new paradigm for a global change," an interdisciplinary convergence fostered by increased connectivity.[20] In *The Flock* "the main concept . . . is emergence, the coming together of systems with no central controller guiding their behavior."[21] Simon Penny's writing treats emergence in some detail, and his conscious evocation of emergence in his interactive robotic systems is clear; *Sympathetic Sentience* (with Jamieson Schulte) "generates complex patterns of rhythmic sound through the phenomenon of 'emergent complexity'"; his plans for *Caucus,* a group of autonomous agents, focus on an "emergent sociality."[22] Vorn and Demers refer to emergent behavior in their robot ecosystems "derived from the dynamic and complex interactions between low-level task agents," evident in works such as *The Frenchman Lake.*[23]

So the term is everywhere, but what form of emergence is this? These artists have come to the concept through its use in artificial life and have used it to describe their own work. Emergence here matches Langton's definition, referring to the complex high-level consequences of low-level rule-based interactions; thus a-life artists identify emergence in their works in the same way that a-life scientists identify emergence in theirs. This is a beginning; what's more important and more difficult is coming to grips with the emergent phenomena that discourse announces. The stronger proposal here is that emergence *as a phenomenon* is not just ubiquitous but universal in a-life art.

This shared notion of emergence can be transcribed into a structural template made up of two levels: a local (computational) level, where complex interactions are driven by a set of formal rules; and a global level, where behaviors appear as patterns in time or space. Those behaviors are a result of low-level interactions but seem somehow to exceed them, to produce something more. When tested against this simple template, a-life art seems to be rife with emergence; as the artists' own words indicate, this structure is used almost universally. It applies very clearly to the artificial ecosystems of Sommerer and Mignonneau, Lovell and Mitchell, Prophet, and McCormack, where flocks fly, artificial entities interact and interbreed, populations fluctuate. While those phenomena are not exactly unexpected, neither are they coded specifically into the low-level computational structure of the system. Similarly, in robotic a-life art, simple processes operate in parallel in a way that gives rise to a more complex overall behavior; this occurs clearly, for example, in Penny's *Petit Mal* and in *Sympathetic Sentience* and in Rinaldo's *The Flock* and *Autopoiesis*.

While the forms of these works correspond precisely with the bottom-up schema that Langton describes, this two-tiered template can also be understood in a way that broadens the notion of emergence and extends its applicability to a-life art practice. The computational level can be thought of more generally as a technological substrate, a designed framework of software and hardware. Similarly, the global emergent level can be thought of as the phenomenal and behavioral product of that technological substrate. We can readily make a similar split in an everyday computer system between the hardware and software "machine" and its phenomenal products, the monitor display or amplified sound: one level supports and produces the other. The important distinction lies in the relationship between these two levels: in everyday utilitarian computing, the causality is straightforward and immediate: I type and (with any luck) letters appear on the screen. In a-life systems there is no simple correspondence between substrate and phenomenon but a complex entangled causality giving rise to artifacts and events that seem to constitute something new, something extra.

This broader binary of substrate and emergent phenomenon applies very clearly to a-life art, even to works with architectures that do not strictly match Langton's bottom-up template. In a breeder the software substrate consists of the programmed processes of mutation and replication, the artificial genome, and its rules of expression. The phenomenal results center on the evolved form or image. Whether the result of thousands of generations of careful aesthetic selection or an instant miraculous mutant, the results of these processes do exceed the simple causality of a typical computational experience. From out of the microscale computational actions of the artificial genome, its mutations and interbreedings, arises a result of a different order, an image or form that strikes us as novel, significant, beautiful, or surprising. The evolved form can be considered an emergent phenomenon, one that has somehow exceeded or pulled away from its mechanistic substrate. The nature of the breeders is such that they largely give a particular emphasis to their emergent result, because it manifests itself in a neat and culturally familiar package: the aesthetic object. However, this emphasis is not restricted to the breeders; as the preceding analyses have shown, *a-life art is defined by its constant evocation of an emergent result.*

Without exception the focus in the works considered here is on complex, reactive, rich, flexible, or unpredictable results arising from a designed technological substrate. In Yves Amu Klein's sculpture the lifelikeness and ultimately the life of the works is the central concern, manifest in complex behavior emergent from a complex composite of hardware and software. In the interactive environments of Sommerer and Mignonneau, human participants negotiate with the emergent behavior of artificial agents. In these works, as in other a-life robotics and immersive environments, emergence is behavioral and interactive. The breeders pursue emergence in the guise of form. The expansive sense of potential offered by such systems, the endless promise of variety, represents an extension of the single emergent result into an open-ended process of change. This process is also exemplified in the real-time unfoldings of Driessens and Verstappen's *Ima Traveller* and *Tuboid,* both of which entail a boundless process of variation arising from the complex interactions of simple rule-based morphological elements.

Not only are emergent phenomena the focus of a-life art but emergence can be seen to function as the focus of the field's collective desire. Simon Penny writes, "I'm charmed and fascinated by the possibilities of complexity theory and emergent order."[24] Asked if he pursued the "something extra" of emergence in his work, he replies, "Definitely. I work toward and hope for something extra." Robb Lovell writes of "going after creating something that gives me more than I expected."[25] Richard Brown's *Biotica* team pursued the "grand goal of emergent soup."[26] Moreover, just as the open process of a breeder extends and repeats the emergence of novel complex structures, many of the artists in this field share an interest in pursuing an extension or amplification of emergence. This is evident simply in the artists' plans or aims for future work. For example, Rinaldo anticipates that the future evolution of *The Flock* will involve a switch from a Brooksian subsumption-architecture approach to a genetic algorithm method that would "allow a new *Flock* to evolve its own behavior."[27] Stephen Rooke proposes a range of modifications to his image breeder, including an exploration of Lynn Margulis's notion of symbiogenesis through the implementation of a more open dynamic genetic structure; these modifications are intended to give rise to an increasingly excessive, autonomous, emergent result.[28]

Questioning Emergence

If emergence is at the core of this field, it is crucial to understand in greater depth what it is. If emergence delivers the important "something extra" in these systems, it is less apparent what the nature and extent of that "something" might be. One theorization of emergence within a-life provides a useful way of considering these limits and offers a structure for thinking about emergence in greater detail. In an important 1992 paper, Peter Cariani addresses exactly these questions with reference to the computational structures that characterize a-life systems (both art and science). Centrally, Cariani asks a challenging question — "whether purely computational devices are capable of fundamentally creative, truly emergent behavior."[29]

Cariani's approach recalls the critiques of Nagel in that he treats the question of emergence as one that is fundamentally epistemological, tied up with observation and expectation. Drawing on cybernetics and systems theory, Cariani sketches a definition of emergence labeled "emergence relative to a model"; under this definition, emergence is simply "the deviation of a physical system from an observer's model of it" (779). Cariani's most provocative conclusion is that under this definition, computational artificial life simulations must be nonemergent. He argues that "[a]ll computer simulations can be described in terms of finite-state automata, as networks of computational state transitions, as formal manipulation systems. As observer-programmers we can always find a frame which will make our simulation appear nonemergent" (789). In other words, the nature of computation is such that even with chaotic mathematics and pseudorandom numbers, any single initial state will always progress through the same succession of states and produce the same results. The key concept here is the idea of the observational frame, the point of view from which the observer forms a model of the system being considered. Cariani's point is that however difficult it might be to access practically, given a model of the computer as a closed deterministic symbol processor and complete knowledge of its (finite symbolic) states, the computer's activity will never deviate from what is predicted by that model. Cariani refers to the emergent properties exhibited by such simulations as instances of "computational emergence," where emergence is simply the production of diverse complex macroscale phenomena from a few simple microscale rules (777, table 1). This corresponds to the dominant usage of emergence within artificial life, as exemplified in Christopher Langton's statements quoted earlier.

Cariani sets out a typology of devices that clarifies the structure of systems that meet or fail to meet his epistemological definition of emergence (785–789). In this analysis, the key features of an emergence-capable device are openness to the environment — the ability to measure or effect changes in the outside world — and a capacity for adaptive self-alteration. Certain devices can alter the rules that define their internal computations; Cariani labels these "syntactically adaptive." He allows that, from a certain observational frame, processes involving techniques such as genetic algorithms can be syntactically adaptive, reprogramming themselves in response to fitness criteria. The second of Cariani's types can alter the mapping between environmental input and the internal symbolic representation; these he labels "semantically adaptive" because this mapping can be thought of as describing the meaning of the input. The exemplary semantic adaptation is the formation of a new sensory organ, where a new kind of information from the environment becomes available to the device's computational processes.

A device that is both syntactically and semantically emergent Cariani calls a "general evolutionary" device, capable of altering both the meaning of its environmental measurements and the internal symbolic operations it performs on them. Even these systems are ultimately guided by externally imposed fitness criteria that guide their adaptations, however. Cariani anticipates devices with even greater autonomy, capable of "constructing their own performance-measuring apparatuses" and hence becoming "motivationally autonomous." He muses that "[s]uch devices would not be useful for accomplishing our purposes as their evaluatory criteria might well diverge from our own over time." Of course, as Cariani remarks, this is a familiar problem, which we encounter in our dealings with other autonomous entities, human and animal.

Cariani's typology can be linked with the binary of substrate and emergent result discussed earlier. Computational emergence, which corresponds to a nonadaptive "fixed computational" device in his typology, involves a static (though complex) relationship between a computational substrate and its emergent complex phenomena. The initial state and simple rule-set constitute a deterministic seed that grows a complex plant, but the same plant will grow time and again from the same seed. There is a single moment of excess, a single jump from the microcomputational to the macrophenomenal level. The device types that Cariani describes as capable of emergent behavior under his definition involve an ongoing process of adaptation. Here the two levels, substrate and emergent result, are linked in a feedback loop: the result loops back to effect changes in the infrastructure, which in turn alters the emergent result. The device types are determined by which parts of the infrastructure are included in this loop.

Cariani's analysis provides a useful set of tools for deepening (and complicating) consideration of emergence in a-life art. It offers a clear structure through which a-life art's own claims of emergence can be teased out, and it poses a strong challenge to the status of some of those claims. Cariani's argument that macroscale computational phenomena are ultimately nonemergent is key here because much of what a-life art (and a-life science) treats as emergent phenomena fits this description. Nor are the macroscale behaviors in robotic works such as *Petit Mal* and *The Flock* truly emergent by Cariani's definition because the sensors and effectors used in these and other robotic works are nonadaptive. Works involving artificial evolutionary processes can be classified as syntactically adaptive systems, although that alteration is strictly confined to the artificial genome; the computations involved in interpreting the genome, mutating it, rendering the phenotype, or interpreting user interaction all remain untouched by the process of evolution. Thus, none of the works considered in this book could be considered semantically adaptive; none evolves new sensors, new perceptual categories, or new meanings, and thus none approaches the designation of general evolutionary device, let alone any more complete motivational autonomy.

Cariani's taxonomy of emergent systems is not invoked here in order to debunk emergence in a-life art. Rather than accepting his analysis as a definitive ruling on emergence, it can be taken as a tool for further inquiry because it brings into focus larger questions about the realization of the aims of artificial life and a-life art. It clarifies and formalizes the fulfillment of the desire for emergence that is so central in a-life art practice. Cariani's motivationally autonomous, general evolutionary device answers this quest for increased autonomy, increased emergent excess; it is the absolute endpoint of this drive. As such, Cariani's typology also reveals all the ways in which contemporary work falls short of its emergent desires — again, this is not a platform for critique but for analysis and extrapolation. How are we to explain this apparent disjunction between a-life art practice and its desire for emergence? What currently frustrates this urge for excess and autonomy, and what might a-life art be if it were met?

These questions can be addressed through a thought experiment, a series of imaginary modifications performed on familiar a-life art systems. Consider a breeder, like those of William Latham, that produces a virtual three-dimensional phenotype through simulated genetic processes. Breeders have a simple functional imperative, the exploration of an aesthetic space, and thus the generation of novel and appealing phenotypes. The underlying aim is to explore the widest possible fields of form, to be able to evolve any shape whatsoever, yet as already shown, existing systems fall short of this goal; they are constrained by the fixed code structures defining the genetic grammar and its phenotypic expression. These structures limit the outcomes in a way that produces a kind of familial style, as in Latham's forms. In an art world context this emergent style is readily accepted as the style of the individual artist, but from the perspective of an exploratory generative breeder these structures form a boundary, a limit.

Imagining a breeder that is emergent by Cariani's definition seems simple enough initially: instead of simply evolving phenotypes using a predetermined genotype grammar, allow variation and evolution in the grammar and the rules of expression that link it to the phenotype — mutant syntax, mutant rules, and metamutant phenotypes. A Lathamesque spiral-sphere tentacle-shell might become a string of cubes, then a lofted procedural skin will cover the cubes, which in turn will be interpolated with three-dimensional shape data imported from the Net. Then, the recursive structure that generated the initial spiral might be applied to transformations on vertices of the imported file, and that transformation linked to surface characteristics of the lofted skin. At each stage in this transformation, a new computation appears involving a transformation not only in the form but in the syntactical structure specifying that form.

The catch, of course, is that for syntactical changes such as these to come about, they must have been prepared in advance, anticipated by the system's designer. The ability to source form data from the Internet must have been built in; as with all the other syntactical mutations, the system must have been designed to accommodate them. Therefore, they are once again predictable permutations of a fixed syntactical repertoire. For these traits to be emergent, they must have arisen spontaneously from a general computational substructure, and this is where the difficulty lies. It is extremely unlikely that an evolved computer program would happen upon the necessary code to deal with a network protocol, let alone stumble across the single correct data structure for a file containing three-dimensional shape data. These are highly specific, arbitrary structures, infinitesimal needles in a gigantic haystack of meaningless permutations. To go a step further, if we withdraw all a priori knowledge about the computer's operating system (how to access memory or the hard drive, how to track the mouse or read the keyboard) and instead hope for a result that emerges from some fluid nanocomputational realm, it would be ludicrously optimistic to expect a form breeder, no matter how many cycles of guided evolution we subject it to. Other lines of mutation branch off everywhere; the breeder might become a virus or a network worm, an unreliable disk utility or a quixotic image processor. Each of these is nearly as unlikely as a functional breeder, though; most likely, the program would be an autistic system-crashing monster, unexecutable code that trips over its own computational infrastructure and expires.

This fantasy makes a serious point about the problems facing the realization of semantic emergence and motivational autonomy in a computational system. Mutant variability meets the formal brittleness of computational processes: to come into being, mutant code must fulfill the (static) requirements of the interpreting and executing formal system, and as such, its variation is always circumscribed by those requirements. An analogous problem faces robotic a-life; how can we imagine a robotic device that evolves sensors and effectors? Cariani gives a single example of a semantically adaptive robotic system, an electrochemical device built in the late 1950s by the cybernetician Gordon Pask.[30] It could grow iron filaments in a tank containing a solution of iron sulfide; these conductive filaments were tested for their functionality as sound sensors and with training were able to adapt in order to distinguish between sounds of two different frequencies. Pask's device shows how adaptation can occur in physical devices given a suitable substrate; in this case, it is literally fluid. More recently, Yves Amu Klein's plans for *Lumadusa* indicate a move toward "smart" materials and nanoscale artificial "groware" in recognition that "the lack of ability to grow brain/body systems greatly limits what we can do."[31] These limits are a factor of the coarse, rigid grammar of conventional electromechnical robotics. Imagine a robot attempting to modify itself by wandering the shelves of an electronics store, selecting components, and connecting them to itself at random; as in the computational system described earlier, any such variation is most likely to be nonfunctional or even self-destructive.

However even this coarse grammar of electronic componentry seems to offer a richer substrate for emergent phenomena than the symbolic registers of computation, because mutant hardware need not operate according to known conventions. This is the most exciting lesson in the work of Adrian Thompson, a researcher at the University of Sussex who uses artificial evolution to breed electronic circuits.[32] Technically, Thompson's system is relatively straightforward; a circuit diagram generated in a conventional software breeder is used to configure a special programmable integrated circuit (a Field Gate Programmable Array, or FGPA). The evolved circuit is tested and given a score based on how well it performs a particular task such as (in a replay of Pask's experiment) discriminating between tones of different frequencies. As in other breeders, large generations of circuits are bred and tested, and the fittest individuals are mated and mutated to generate the next generation.

It is perhaps unsurprising that after thousands of generations, Thompson's breeder delivers circuits that carry out their simple task effectively. More interesting is that the evolved circuits carry out that task in unforeseen and incomprehensible ways. As Thompson explains, conventional digital circuit design is based on a workable abstraction: the reduction of the complex electrophysical behavior of a circuit to flows of binary patterns and logical operations. Of course, circuits designed in this way are perfectly functional; Thompson simply argues that the conventional approach constrains the outcome in certain ways, in particular, it precludes the nonlinear complexities of feedback loops and structures time into discrete controlled units (clock cycles). Thompson uses artificial evolution to explore alternatives to this approach, designs that, unconstrained by binary abstraction, can make full use of the complex dynamics of their physical medium.

The results of Thompson's tone discriminator experiment exemplify this adaptive use of complex physical dynamics. After some four thousand generations of breeding, circuits appeared that distinguished between two frequencies accurately and consistently. When the final evolved circuit was examined, it was apparent that it functioned in an entirely unfamiliar way. After initial analysis, only sixteen of the one hundred cells in the programmable array were found to be involved in the circuit, and these units were connected in a tangled network. Further investigation delineated three linked feedback loops that appeared to make use of minuscule timing delays to convert the incoming signals into a simple on/off response. The exact mechanisms involved finally defied explanation; the result could not be reproduced in a simulation nor could the circuit be probed physically without disturbing its dynamics. Thompson and his colleagues describe the circuit as "bizarre, mysterious and unconventional."[33]

While this artifact resists analysis, its behavior offers some fascinating indications of the implications of mutant, emergent hardware.

When the evolved circuit design was transferred to another, "nominally identical" chip, its performance suffered; it seems that the design made use of highly specific physical qualities of the chip on which it had evolved. It had also evolved to operate accurately at a particular temperature; because of the physical properties the design relied on, its behavior changed at warmer or cooler temperatures. Thompson's subsequent work has involved breeding out this variability, extending the "operational envelope" of the evolved circuit designs and making them more suitable for functional applications. This technique may well result in improvements in the engineering of electronics, but what is most striking about these early experiments is their revelation of an adaptive, nonhuman engineering process lodged firmly in a material continuum rather than in the finite, discrete domain of computation.

Out of Bounds

Thompson and his colleagues describe their evolved circuit as bizarre and mysterious. As these systems offer indications of emergence in the physical domain, their creators' comments announce a corresponding transition from the known to the unknown, from the familiar to the strange. It seems that the most successful manifestations of emergence involve systems operating outside the technological and formal grammars of designed robotics and computation. At this point artificial life begins to peel away from design, intent, and human conceptual models, and becomes alien, or at least as alien as our own bodies and those of our fellow creatures. Biology entails an attempt to grasp these structures as stable knowledge, formal relations, causalities; yet despite that science's remarkable successes, those structures continue to slip away, to resist complete prediction or understanding. If a-life achieves its underlying aims for ongoing emergence, it will involve an inversion of the same relationship: the known, formal, designed, modeled structures of single-stage, computationally emergent systems will give way to autonomous, mysterious, open systems.

A-life as a scientific epistemological project relies, as Katherine Hayles says, on a kind of reverse reductionism, the creation of the mysterious, excessive, and ungraspable from its knowable components.[34] Instead of dissecting the frog, it tries to build one, although the goal, an enhanced knowledge of a living thing, is the same. Artists, by comparison, tend to embrace a-life with more synthetic, creative aims. As suggested earlier, the emphasis here is on the emergent result, the excess, rather than on a known or knowable relationship between the formal infrastructure and the emergent phenomenon. Inasmuch as it is driven by a desire for absolute emergence, endless excess, a-life art is a *metacreative* endeavor: it wants to create creation, variation, otherness. If a-life science is about knowing and understanding, a-life art is very basically about making and becoming, becoming-other, and becoming-unknown.

This orientation puts a-life art in a paradoxical position; currently making increasingly sophisticated a-life systems demands an increase in technical knowledge and in willed design, control, and intentionality, toward an end that hopes to exceed that very intentionality and knowledge. This approach leads to an a-life art that follows the explorations of scientific a-life, applying its techniques for cultural and aesthetic ends. If a-life art is to get what it wants, a becoming-other, an endless excess, it has to surrender its intentionality at some point in this process. The question is whether this point of surrender, the point of emergence, will arrive when technological and formal innovation reaches a certain crucial point, or appear in another domain, on another axis altogether.

The preceding discussion has focused on the prospects for the former — the conjuring of emergence from within a technological substrate. However, when Cariani's analysis is taken at its most general level, it becomes clear that the concept can be applied more widely. One of the key features of Cariani's version of emergence is its inclusion of an observer: here emergence is not so much a technical achievement or an ontological statement as a situated experience that occurs when a system's behavior deviates from an observer's model of that system. While it may be extremely difficult to fabricate artificial systems that supply us with that experience, the experience itself is everyday. The complexities of the world and its inhabitants are such that our internal models of those systems are subject to constant challenges and under constant renovation. Where artificial life deals in bounded systems, our everyday experience involves systems that are (for the purposes of the observer) open and unbounded. These quotidian systems can also be classed as emergent in the sense in which the term is more often used in artificial life, that is, they manifest global properties that are irreducible to their local dynamics.

Adopting a cultural connectionism such as that set out by Sadie Plant, one can regard art itself as an open system rife with emergence. A particular work is at one level concrete and material, paint, canvas, steel, electricity, plastic. That structure is open to its environment in rich and multiplex ways, however: it affects individuals in ways that we can anticipate (through the models of art and cultural theory) and in ways we cannot (the myriad particularities of an encounter or interpretation); in either case, its operation can never be predicted solely from the structure of its material substrate. Considered diachronically, art gives rise to emergent phenomena (culture, discourse) that inform the production of subsequent works in the feedback loop of ongoing emergence. Taken to an extreme, art could be figured as a self-reproducing cultural entity, an abstract life form traversing social, biological, psychological, and technological strata. This characterization is fraught with problems, yet what would it imply for a-life art? If art practice is involved in a complex cultural system that is emergent in both epistemological and ontological senses, then a-life art seems like a strange reflexive involution. A-life art seeks to formalize emergence, wrap it up in a finite technological system, where ironically it is bound to be circumscribed and conditioned by that very system. The cultural dynamics of art provide a far more suitable substrate for emergence, and thus it is as art objects rather than a-life systems that these works become open, emergent, and unpredictable. Cariani makes a similar argument regarding computational emergence in a-life simulations: "The interesting emergent events that involve artificial life simulations reside not in the simulations themselves, but in the ways that they change the way we think and interact with the world."[35]

From this perspective, the urge for emergent excess and autonomy implicit in so much a-life art leads finally to a point of dissolution. Any system capable of autonomous ongoing emergence could move outside the bounds of its host system, across domains. A work of a-life art that succeeds might be conceptual or cultural as much as robotic or computational; it might be imperceptible, subsisting within and across existing structures but changing, adapting itself and them. There is no reason why it should stay in the gallery or in the computer. If the coevolutionary processes observed in biological life are any indication, emergent a-life would sustain itself in processes that span strata of media, culture, technology, and biology. It would become continuous with those cultural processes that, in Plant's connectionism, are already emergent and evolving. Thus if a-life art were to fulfill its desire for excess, it would cease to be identifiable (and functional) as art. It would be unbounded and unintentional, an adaptive pattern indistinguishable from the wider dynamics of its environment.

"Creative" Emergence

From another angle, emergence might be located more specifically, inside one of the microprocesses constituting the cultural complex system around art. *Creativity* has lately become a favorite term in corporate rhetoric and a buzzword in nebulous constructions of public policy. As such, it should be treated with extreme caution; yet in discussing the human generative processes behind a-life art's own generative artifice, the term is largely unavoidable. So, to put it bluntly, what if emergence is a property not only of the cultural systems in which a-life art operates but of the subjective, creative processes that bring it, and art in general, into being?

One of the merits of creativity is that it has become a focal point, and thus a point of access, for transdisciplinary research in fields including cognitive psychology, design science, and artificial intelligence. Contemporary AI recognizes creativity as an attribute that is highly desirable in artificial systems yet poorly defined and poorly understood. At a 1999 AI conference, the artist and researcher Harold Cohen presented a paper that clearly links emergence, creative practice, and computation.[36] Cohen is well qualified to speak on these issues; his pioneering work has entailed the development, over some three decades, of a computer program that makes paintings. AARON embodies Cohen's attempts to analyze, quantify, and externalize his own expertise as a painter, to off-load his knowledge of painting into a formal computational system.

In a case study of the drawings of his young daughter, Cohen proposes a handful of salient features of what might problematically be labeled creativity. The first feature is adoption, the imitation of preexisting forms and processes: "this is how we draw a face." Adopted strategies are modified and adapted through personal experience and observation; Cohen recounts his daughter's "discovery" of nostrils. Another form of adaptation is the combination of prelearned or observed processes across contexts. Adoption, adaptation, and observation occur in an ongoing cycle because the created artifact is also observed. The key point is that, as Cohen observes, this cycle contains the seeds of the unknown, of surprise. Some adaptations bring unintended side effects or by-products: "Every artist," Cohen asserts, "has known the experience of finding something happening in his work that he hadn't intended to happen, but which nevertheless causes a change in direction." This is the "something more" of emergence, which is for Cohen "a critical element" of creative behavior; "the individual has to find something in the work that he never consciously put there." The emergent properties of the work may arise from a conceptual juxtaposition or from the complexity of a technological process, and while they are in themselves unintended, they may trigger the intentional development of new conceptual or technological structures, or the modification of existing goals.

This requires more than a string of surprises or accidents. Cohen argues that "the individual must also notice that something has emerged, and be prepared to act upon what that something suggests." Important, then, is that creativity is "not manifested in a single unexpected outcome but rather in a capacity for continuous self-modification." Emergence and its incorporation join adaptation and adoption in an ongoing cycle. In this model it is possible to see that emergent features can over time become stable, known, reusable structures, and that these in turn can become involved in new layers of complex interactions and emergent results.

Cohen's discussion is not the only one to identify emergence as an aspect of creative activity. In the domain of the cognitive sciences, creative thought has recently become an object of some interest. In a new subfield named creative cognition, an attempt is made to plot the "basic cognitive processes and structures" that give rise to creativity in all its forms.[37] "Conceptual combination" is one widely identified process that acts as a wellspring of creativity; bringing two or more concepts together often results in a new conceptual whole with new, emergent properties. While it seems to bear little relation to art practice, the identification of emergence at this basic cognitive level resonates with Cohen's analysis.

How relevant are these theorizations of creativity to the artistic practices considered here? Clearly, there are problems inherent in any abstract general notion of creativity, and placing that conceptual cart before the horse of artistic practice would be a mistake. Yet, there are some striking connections, some threads waiting to be joined, however propositionally.

There is an alignment of emergences. The dominant micro-macro usage of emergence in a-life and a-life art has a given set of elements that come together to form something unpredictable and unexpected. This tallies with the usages of emergence in Cohen's analysis and the wider literature of creativity in the cognitive sciences. Even Cariani's analysis, which foregrounds the role of the observer of emergence, is compatible with Cohen's model of creativity. Each entails the iteration of a single moment of emergence into a process characterized by continuous self-modification. This moment corresponds closely with the key moment of emergence in an a-life system, the surprise or excess, the "something more" that arises from a designed, known substrate.

What if a-life involves a recapitulation of the cognitive structure of human creative processes, albeit in a tightly constrained, formal medium? Perhaps this would account, in part, for the enthusiasm with which a-life has been embraced by new media artists. Perhaps artists recognize something in the systems and techniques of artificial life that replays that moment of emergence, surprise, or excess characteristic of creative processes. The biological references of a-life systems are inescapable and clearly present in much a-life art, however it is equally clear that theoretical (or even hypothetical) biology is peripheral to the interests of many of these artists. In fact, if it is possible to identify a single central concern in this diverse field, it would be an interest in the dynamics of (meta)creation rather than in the dynamics of life.

From this perspective, a-life art seems a perversely complicated attempt to engineer a reward that is already ubiquitous. However, an a-life system also offers a particular purchase on that reward: it formalizes and externalizes a nonformal internal process. It renders that emergent moment — in creative thought a moment of non-control, a moment of being subject to the work — in a medium that is both highly dynamic and highly controllable. Computation seems to promise the literal animation of the work, an expansive transformative potential; it leaves stubborn materiality behind, vaporizes it into flickering digital units. Together with the generative architectures of a-life, it promises an acceleration and extension of that familiar creative moment, the moment of emergence. It seems to offer a way for that cycle of variation, recognition, and assimilation to uncouple from human subjectivity and loop in on itself; this can be seen as either a moment of creative transcendence — a triumph for the creative will — or the final move in a process of artistic self-elimination. Ironically, as argued earlier, the process of externalizing and formalizing this creative dynamic, of encapsulating it and turning it in on itself, is exactly the process that constrains it and circumscribes it. The most striking instances of emergence can still be found at the level where, for Cohen at least, they have always been found, in the cycles of manipulation and discovery that are the stuff of art making. In a-life art those cycles are clearly visible in the pathways of development and change described by the work of individual artists. Steven Rooke's ongoing reengineering of his image evolution system illustrates this well, and Rooke also reveals some of the expectations that future developments will meet or recast.

The notion of a structural parallel between a-life and art making has even more expansive implications if a-life's claims to model the distributed dynamic structures of organic systems are taken seriously. Human creativity appears to echo the inherent creativity of nature or matter. The iterative synthetic mechanisms of human thought and action parallel the bottom-up synthetics of complex material systems. The implication is of a continuity of generative processes: creative interiority dissolves into (or emerges from) the exterior dynamics of matter. This grandiose conjunction recalls that modernist-organicist nexus that has appeared at various points in the preceding chapters. Klee has a notion of creative process that closely parallels the mechanisms of organic and material morphogenesis; he models visual creativity on natural dynamics. The organicisms of Malevich and the Russian avant-garde carry similar implications, a sense of art (like science) pursuing the synthetic potential of natural laws. Jack Burnham's trajectory for modern art moves in the same direction, toward art's final cybernetic realization of organic laws and the ultimately autonomous artwork. In each of these discourses, a-life lurks, unnamed, as a final destiny or a limit point for modern art, for the point when creation finally crosses over into metacreation.

The process of following emergence through leads towards a kind of hyperbolic edge, a point at which conventional categories break down or are transcended. Again, it should be stated that the purpose here is not to predict or anticipate a trajectory for a-life art nor to argue the ideological or artistic merit of any of these pathways. Rather, the intention has been to simply extrapolate on the basis of contemporary practice and thought, and to use that extrapolation to further an analysis of the field. Of course, contemporary practice gives little indication of fulfilling these extrapolations, of evaporating into dynamic immanence, achieving Frankensteinian autonomy, or escaping the institutional and intentional boundaries of art. In fact, the work seems, for all its innovations, thoroughly circumscribed by the technological structures on which it depends. What the preceding discussion has sought to show is simply that these limits, these edges, are implicit in a-life art.

Emergent Futures

Whatever emergences a-life art imagines and strives to manifest, whatever connectionist futures it projects, it operates, of course, in a more quotidian present, where it remains a practice in a small and somewhat esoteric cultural niche. Yet there are indications that this practice is developing, as artists continue to engage and be engaged by the concepts and techniques of artificial life. When asked in 1997 about the reasons for the proliferation of a-life in new media art, Bill Vorn gave a striking answer:

> I heard something during the ISEA symposium (I think it was from Bill Seaman): emergent content. This is the answer to your question. Artists are now able to do things that have no sense, let them interact, and the overall meaning is going to emerge just by itself. Artificial Life is the Spirograph of the 90s.[38]

The Spirograph was a popular creative toy of the 1980s, a system of interlocking plastic cogs that guided the user's pen through intricate radial op-art patterns. Its attraction was that its aesthetic payoff required little skill or innovation on the part of the user. On the other hand, the user had a quite limited range of control over the results. Spirograph art is instantly recognizable, a visual artifact of a generative technique turned mass market toy. Vorn's implication is clear: that a-life technique covers for the conceptual laziness or vacuity of the artists who use it, and that a-life is a faddish generative technique producing pretty but insignificant results. Perhaps, if Vorn is right, a-life techniques will eventually expire through senseless overuse in the same way that certain Photoshop effects have now become clichés. The marketing of generative systems using artificial life signals that a-life techniques and artifacts are already part of the software repertoire of graphic pop-culture and may ultimately be relegated to Spirograph status.

Certainly, the simple generative utility of the Spirograph corresponds to one aspect of a-life art practice. In all the works considered here, a-life technique is employed for its generative capacity; it operates as a computational engine and a technical resource, and delivers a handful of characteristic rewards, each of which pivots on the notion of emergence and the extension and amplification of creative agency. However, while this generative utility is ubiquitous in a-life art, it never operates in isolation, and it is never as vacuous as Vorn's comment suggests. There is a more complex form of engagement here, where a-life techniques are open to creative decomposition, reengineering, and variation, and artists come to grips with both their formal generative mechanisms and their figurative structures. As cultural critics such as Helmreich and Hayles suggests, artificial life is a cultural object as much as a technical one; it is a personal and institutional practice, a discursive field, and in particular a set of metaphors, philosophies, and ideologies. Artists, in taking up a-life, are not simply adopting its technical processes but simultaneously engaging with its meanings, associations, and implications, with the *ideas* of artificial life. In all the works considered here, a-life operates both as technique and as conceptual content.

Often these works are endorsements or even celebrations of artificial life, where the characteristic metaphors and discourses of a-life science are taken on and reproduced. These endorsements take many forms. Simply reproducing a-life's language of gene, organism, sex and evolution marks a basic acceptance of the value of those terms and the mappings which they imply. More radically, some artists take up a-life's strongest aspirations for truly autonomous synthetic life. More widespread, however, is a form of endorsement built in to the aesthetic content of a work, where a-life is presented as recognizably natural and above all beautiful.

While many artists approach a-life as, in a sense, believers, others such as Jon McCormack and Natalie Jeremijenko articulate doubts even as they employ its techniques and follow cultural critics in recognizing the problematic narratives embedded in a-life. This equivocation can be aesthetic as much as discursive: Latham's grotesque digital-arthropod coils and Demers and Vorn's robotic dystopias counterbalance any sense of a-life as natural, beautiful, familiar, and unproblematic. Driessens and Verstappen's *Ima Traveller* strikes a balance, a pure manifestation of rich organic complexity which is at the same time overwhelming, vertiginous, and terrifyingly endless.

So, contrary to Vorn's comment, a-life art is no Spirograph. Rather than being an empty appropriation of a generative device, a-life art manifests a complex and varied engagement with the concepts and techniques of artificial life. It draws a-life into a wide range of philosophical, aesthetic, and conceptual projects; unravels it, rebuilds it, reinterprets it, undermines it, imagines its final autonomy. Not that this practice is unproblematic: it is often far too credulous of artificial life, reproducing (and aestheticizing) a-life's omissions and oversimplifications, and adding new layers of its own questionable rhetoric. The drives for interactivity and immersion that a-life art manifests, and which it shares with new media art practice more widely, are difficult in themselves, as are its more characteristic drives for emergence, autonomy, and generative excess.

However, even at its most awkward, in its most naive, utopian, unreflective moments, a-life art is marked by a particular currency; and five years after Vorn's comment, that currency has only increased. Inasmuch as it engages with a-life both technically and conceptually, it is involved in a wider process that is highly significant in contemporary culture: the difficult intertwining of technology and the living. A-life art's lasting significance will derive from its ability to take up the debates around this dynamic and pursue the aesthetic, subjective, social, and cultural implications of these technologies.

It is uniquely positioned to offer an experience of a nascent artificial life that is unconstrained by scientific or commercial agendas; a foretaste of what technoculture promises, leavened with a sense of how things might be otherwise, performances, like those which Helmreich imagines, of "life as it could be." While a-life science offers technical and conceptual starting points, these need not be uncritically absorbed or followed through. These techniques carry with them crucial questions regarding information and embodiment, determination and openness, complexity and self-organization, the nature of agency, indeed the nature of nature; a-life art is well placed both to ask these questions and to experiment with possible answers. While the expansive generative potential of these techniques is explored, their inherent constraints need not be concealed or ignored, for if we are to be offered an increasingly artificial life, it is crucial that we be aware of its limitations.

This is a sketch of what might be described as a mature form of a-life art, one that has moved beyond the excitement of an initial encounter with a-life technique. That maturation is well underway, as the strongest work here shows. This practice also shows, in a promising way, that this informed engagement with a-life does not equate to homogeneity in critical consciousness or creative approach. Experiments in utopian ecoengineering coexist with wailing, thrashing, a-life underworlds; distributed bio-social-informational systems coexist with solipsistic shape generators. Each approach offers its own sense of what a-life might be, how it might work, what it might mean, where it might lead. This diversity is particularly important; as the cultural critics of a-life science argue, we have reason to be wary of anything that claims to exclusively determine what life (in any form) can be. Similarly in a-life art, the best we can hope for is a proliferation of possible lives, aesthetics, agencies, systems, and critiques. The range of work considered here gives an indication that a-life art will continue to diversify, to internalize and reconfigure a-life techniques, and to remain open to the cultural, scientific, and technological developments that surround it. As it draws on these structures, a-life art offers a valuable exploration of the potential that subsists in them. In order to retain that value, a-life art need only do as it has always wanted, and keep mutating.

APPENDIX: ON-LINE RESOURCES

I have made extensive use of the Web in researching this book. It has provided documentation of primary material — artists and works — and a wide body of secondary and supporting material. Here the most important on-line resources are ordered as they appear in the text, so that they can be navigated in parallel with the book. In cases where a site (usually an artist's) contains several resources, only a single, top-level URL is included.

For more convenient browsing, this appendix is itself available on-line, at <http://mitpress.mit.edu/0262232340>.

1 Introduction

Art and Artificial Life International Competitions 2.0–5.0. <http://www.fundacion.telefonica.com/at/vida/english/index.html>.

2 Breeders

Karl Sims. <http://www.genarts.com/karl>.

William Latham. <http://www.artworks.co.uk/artworks.htm>.

Steven Rooke. <http://www.azstarnet.com/~srooke/>.

Nik Gaffney. *(Mutagen)*. <http://rorschach.test.at/mutagen/>.

Andrew Rowbottom. <http://snaffle.users.netlink.co.uk/form/evolutio.html>.

Ken Musgrave. <http://www.wizardnet.com/musgrave/mutatis.html>.

Peter Kleiweg. <http://odur.let.rug.nl/~kleiweg/genart/genart.html>.

Tatsuo Unemi (SBART). <http://www.intlab.soka.ac.jp/~unemi/sbart/>.

John Mount *(GeneticArt III)*. <http://home.pacbell.net/ja_mount/g3.html>.

Jeffrey Ventrella (Absolut). <http://www.ventrella.com/Art/Absolut/absolut.html>.

3 Cybernatures

Christa Sommerer and Laurent Mignonneau. <http://www.iamas.ac.jp/~christa/index.html>.

TechnoSphere. <http://www.technosphere.org.uk/>.

Robb Lovell and John Mitchell *(EIDEA)*. <http://www.intelligentstage.com/eidea.early/eidea.html>.

Troy Innocent *(Iconica)*. <http://www.iconica.org/main.htm>.

Jon McCormack. <http://www.csse.monash.edu.au/~jonmc/art.html>.

Natalie Jeremijenko *(OneTrees)*. <http://www.onetrees.org/>.

4 Hardware

Yves Amu Klein. <http://www.livingsculpture.com/>.

Kenneth Rinaldo. <http://www.ylem.org/artists/krinaldo/>.

Bill Vorn. <http://www.billvorn.com>.

Simon Penny. <http://www-art.cfa.cmu.edu/Penny/>.

Erwin Driessens and Maria Verstappen. <http://www.xs4all.nl/~notnot/>.

Rodney Brooks. <http://www.ai.mit.edu/people/brooks/index.shtml>.

5 Abstract Machines

Paul Brown. <http://www.paul-brown.com/>.

Scott Draves. <http://draves.org/>.

Erwin Driessens and Maria Verstappen. <http://www.xs4all.nl/~notnot/>.

Richard Brown. <http://www.mimetics.com/>.

Mauro Annunziato. <http://www.plancton.com/>.

Matthew Fuller *(Human Cellular Automaton)*. <http://www.axia.demon.co.uk/hca.html>.

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3. Langton, "Artificial Life," 2.

4. Langton, "Artificial Life," 2.

N O T E S

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6. See, for example, Rodney Brooks, "New Approaches to Robotics," *Science* 253 (1991): 1227–1232. <http://www.ai.mit.edu/people/brooks/papers/new-approaches.pdf>.

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11. See, for example, Plato, *Phaedrus,* 264c; Aristotle, *Poetics,* ch. 7.

12. Peter Salm, *The Poem as Plant: A Biological View of Goethe's Faust* (Cleveland, Ohio: Case Western Reserve University, 1971), 24.

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14. Quoted in Philip Ritterbush, *The Art of Organic Forms* (Washington: Smithsonian Institution Press, 1968), 18.

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17. Paul Klee, "Primary Forces of Form-Production, Form-Creating and Form-Articulating Nature," in *The Nature of Nature,* vol. 2 of *Paul Klee Notebooks,* ed. Jürg Spiller (New York: Overlook Press, 1992), 5.

18. Klee, "Primary Forces," 22.

19. Paul Klee, "Lecture of Tuesday, 9 January 1924," in *The Nature of Nature,* 269.

20. Paul Klee, "Lecture of Monday, 15 May, 1922," in *The Thinking Eye,* 454.

21. Kasimir Malevich, "On New Systems in Art," in *Essays on Art 1915–1928,* ed. Troels Andersen, trans. Xenia Glowacki-Prus and Arnold McMillin (Copenhagen: Borgen, 1968), 85.

22. Kasimir Malevich, "From Cubism and Futurism to Suprematism: The New Realism in Painting," in *Essays on Art 1915–1928,* 19–24.

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25. Norbert Wiener, *Cybernetics, or Control and Communication in the Animal and the Machine.* (Cambridge, Mass.: MIT Press, 1948; 2d ed. 1961).

26. Nicholas Schöffer, "Sonic and Visual Structures: Theory and Experiment." <http://www.olats.org/schoffer/savs2.htm.>

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29. Jonathan Benthall, *Science and Technology in Art Today* (New York: Praeger, 1972); Gene Youngblood, *Expanded Cinema* (London: Studio Vista International, 1970).

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3. Sims, "Genetic Images," 404.

4. Karl Sims, "Artificial Evolution for Computer Graphics," *Computer Graphics* 25, no. 4 (1991): 320. <http://www.genarts.com/karl/papers/siggraph91.html>.

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7. Karl Sims, "Genetic Images." Paper presented at the Third International Symposium on Electronic Art, Sydney, Australia, November 1992 (author's audio recording).

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12. For images of Latham's work, see Todd and Latham; and Computer Artworks, "Artworks." <http://www.artworks.co.uk/artworks.htm>.

13. William Latham, *The Evolution of Form* (1990) (computer animation). Excerpt <http://www.mediaport.net/CyberScience/BDD/Mov/90/evolution_1_90.mov>.

14. Todd and Latham, 2.

15. Todd and Latham, 41–51.

16. Todd and Latham, 68, 75, 105.

17. D'Arcy Thompson, *On Growth and Form* (Cambridge: Cambridge University Press, 1942).

18. Philip Ritterbush, *The Art of Organic Forms* (Washington: Smithsonian Institution Press, 1968), 86.

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20. For images, see Steven Rooke, "Online Portfolio." <http://www.azstarnet.com/~srooke/portfolio.html>.

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31. Andrew Rowbottom, "Organic, Genetic and Evolutionary Art." <http://snaffle.users.netlink.co.uk/form/evolutio.html>. Notting Hill Publishing. <http://www.nottinghill.com> (October 1999).

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40. Todd and Latham, 75; Sims, "Artificial Evolution for Computer Graphics," 319.

41. Quoted in Kevin Kelly, *Out of Control* (London: Fourth Estate, 1994), 345.

42. Dawkins, 43.

43. Dawkins, 58.

44. Dawkins, 52–53.

45. Dawkins, 57.

46. Stuart Kauffman, in *The Third Culture,* ed. John Brockman (New York: Simon and Schuster, 1996), 92.

47. Dawkins, 67.

48. Dawkins, 73.

49. Dawkins, 116.

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51. Todd and Latham, 207–208.

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53. Nik Gaffney, e-mail to the author, August 18, 1998.

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55. Kelly, "Genetic Images," 114.

56. Ruth Barter, "Review of William Latham Exhibition at Connaught Brown Gallery, October 8–November 2 1991," *Arts Magazine* 66 (1) (1991): 92.

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