Science as Culture, Volume 10, Number 4, 2001

ARTIFICIAL LIFE, INC.: Darwin and Commodity Fetishism from Santa Fe to Silicon Valley

STEFAN HELMREICH

'We Create Smart Bots for e-Business' reads the legend at the top of the website for Artificial Life, Inc., a company that makes 'intelligent' software robots (www.artificial-life.com). Artificial Life, Inc. is in the business of manufacturing virtual agents to perform such electronic financial service tasks as online customer profiling and web-based portfolio management. The company lifts its name from the field of 'Artificial Life', a kind of Information Age theoretical biology founded in the late 1980s devoted to modelling evolutionary dynamics on computers, much as Artificial Intelligence sought to model cognition. Densely interdisciplinary, Artificial Life has positioned itself at the intersection of biology and computer science, asking whether the logic of life might be captured *in silico* (Langton, 1989). How is it, then, that this rather rarefied academic pursuit has been ported into the world of business and dot-commerce? And what have been the social and practical consequences of applying biologically inspired programming and modelling techniques to the automation of business activities? What happens when Artificial Life is 'enterprised up', to use Marilyn Strathern's felicitous phrase (1992), when it travels from the world of dot-edu to dot-com?

The migration of Artificial Life techniques from academia into the corporate world follows shifts in the institutional location of Artificial Life scientists, which in turn have tracked the changing fortunes of the field. By the late 1990s, Artificial Life's early promises to rebuild biology and computer science from the bottom up began to seem over-ambitious. On a theoretical level, Artificial Life had failed to challenge prevailing orthodoxies in evolutionary biology. Very few biologists accepted digital organisms as models for real-

Address correspondence to: Stefan Helmreich, New York University, Draper Program in Humanities and Social Thought, Graduate School of Arts and Science, 14 University Place, New York, NY 10003, USA, E-mail: sgh2@nyu.edu

0950-5431 print/1470-1189 online/01/040483–22 © 2001 Process Press
DOI: 10.1080/09505430120093595

world creatures; when most life scientists were asked to view as genetic codes the computer codes underwriting the emergent behaviour of virtual entities, they were unmoved, even if they remained convinced of the integrity of the coding idiom for carbon-based creatures. On an experimental level, Artificial Life researchers persuaded only a handful of mainstream biologists of the utility of doing empirical or theoretical science in virtual worlds—within the topography I have elsewhere termed 'silicon second nature' (Helmreich, 2000b). After a decade of gestation at the Santa Fe Institute for the Sciences of Complexity, an interdisciplinary centre for simulation-based science in New Mexico, Artificial Life failed to develop into a recognized discipline with proper programs, professorships, or degree-granting departments at major universities—as had its predecessor, Artificial Intelligence. The field had also been eclipsed by the movement of computer science away from theoretical questions to practical concerns about how to manage interconnectedness and interactivity. And the siting of Artificial Life at the Santa Fe Institute (SFI), where it operated on soft money, also worked against disciplinary consolidation.

The latest wisdom about Artificial Life is that, in the end, it produced no really new theory of life or computing, but only a collection of new programming techniques—like genetic algorithms, for example, a computational operation that uses an abstraction of Darwinian dynamics to 'evolve' optimal solutions to complex problems. Genetic algorithms exemplify the informatic vision of biology animating Artificial Life; in this procedure, researchers generate 'populations' of possible mathematical solutions to optimization problems and then code these solutions in bit strings, metaphorically treating these strings as the 'genomes' of individuals that can be organized to 'mutate', 'compete', and 'mate' to eventually produce populations of 'fitter' solutions [see Holland (1992) for a popular summary, or Helmreich (1998) for a cultural analysis].

Artificial Life came into a crisis of credibility, along with a consequent reduction in funding. The response of many Artificial Life researchers to this has been a move away from academia to private corporations. This is not a surprising shift; it is rather the norm in worlds such as biotech (see Rabinow, 1996, 1999). A few people from SFI, finding themselves without steady support, left to start financial consulting firms, offering simulation skills honed in

Artificial Life work to the complexifying world of online business. Genetic algorithms have been one major tool offered to businesses to help with such procedures as optimizing electronic investment and trading strategies. Here we begin to understand the origin of such entities as Artificial Life, Inc.

In this brief essay, I propose that examining the world of Artificial Life-animated online commerce can help us draw the outlines of a new brand of commodity fetishism, one keyed to emergent languages in economics and computationally-inflected biology. In *Capital*, Karl Marx named as commodity fetishism the logic through which markets and commodities are seen to come to life. In 'The Fetishism of the Commodity and Its Secret', he wrote that, in exchange relations under capitalism,

> the definite social relation between men [sic] ... assumes ... for them, the fantastic form of a relation between things ... [T]he products of the human brain appear as autonomous figures endowed with a life of their own, which enter into relations both with each other and with the human race. So it is in the world of commodities with the products of men's hands. I call this the fetishism which attaches itself to the products of labour as soon as they are produced as commodities (Marx, 1867, p. 165).

For Marx, the 'life' in commodities derives from the organic and social life of human labour in the capitalist relation. When labour is treated as a commodity, this obscures a fundamental inequality between those who buy and those who sell it. Workers who sell their labour power for a wage enter into an asymmetrical relation with those who hire them; capitalist employers can apply and extend workers' labour power to the creation of property and profit in a way not available to workers whose only property is their labour.

For Marx, the result is that when labour is treated as equivalent to other commodities, the life-force that animates it rubs off on other commodities and gives the impression that these inanimate things generate themselves as well as their own value. This misplaced concreteness leads to a vision of commodities as possessed of self-moving powers. Marx described the animation of the market and of commodities using the metaphor of the fetish, which he drew, with an ironic wink, from 'the misty realm of religion' (p. 165). What I

argue is now happening, with Artificial Life-enabled techniques for managing finance, is that the reasoned realm of science is being employed by some capitalists and their apologists—explicitly, without irony, and certainly not in the spirit of critique—to give a biological, neo-Darwinian cast to the 'life' with which products of the human brain have become endowed. Further, commodity fetishism is being given a novel twist as markets are not only increasingly theorized in terms of the latest biological metaphors, but as those metaphors themselves come to structure the organization of such computer-mediated practices as online investment and trading. This new regime creates a circumstance in which 'products of the human brain appear as autonomous figures endowed with a life of their own', not just subsequently to the facts of finance and production, but prior to them. Here, the 'life' that is for Marx the output of the fetish is getting plugged in beforehand.

In *The Devil and Commodity Fetishism in South America*, Michael Taussig (1980) argued that Bolivian and Colombian peasants newly articulated to capitalism often 'saw through' the unfamiliar and extractive logic of capital accumulation by associating it with the illegitimate and proliferative work of the devil, whom, they believed, could enable inorganic and inanimate things—like money—to take on the reproductive properties of living things. For the peasants among whom Taussig worked, capitalists, with their mysterious ability to turn money into more money, seemed to participate in an unnatural project best understood through the figure of the devil; business people were understood to make money grow through contracts made with Satan. For companies such as Artificial Life, Inc., in contrast to Taussig's peasants, capital accumulation is understood as a reflection of a fundamentally *natural* order of things—so natural, in fact, that for its secular practitioners, capitalism is productively thought of through the figure of Darwinian evolution. If Taussig's labourers have been engaged in a kind of anthropological reflection that seeks to make the unfamiliar familiar (and delivers an analysis not far off from Marx's), Artificial Life-inspired business people have sought—to twist the converse anthropological cliché back on itself—to make the familiar familiar, to naturalize their common-sense value system. Certainly such a möbius folding of profit-making into evolution is not surprising, since economic and biological metaphors have, at least since Malthus,

been used to reinforce one another, but there is at least one new dynamic at work here. Previously, biological metaphors provided a *post hoc* justification for capitalist relations and social inequality. Today, such metaphorical apparatus is actually getting used to *program* the new informatic infrastructure, to anticipate and organize economic and financial futures.

My strategy in this paper will be to glance at the websites of some prominent companies offering Artificial Life rhetoric and tools to business customers, commenting on the extent to which these rhetorics and tools might actually reformat business practice. Along the way, I supply some history for these rhetorics, drawing upon fieldwork I conducted at the Santa Fe Institute in the middle of the 1990s (before many of the scientists I write of here left for industry). I argue that the economy to which these metaphors speak and the relations of capital production they presuppose are qualitatively different from those invoked by earlier biological metaphors in economics; the economy is now flexible and post-Fordist, and it is enabled by a computerized technological infrastructure that is increasingly automated, networked, global, and capable of being operated at such a speed as to outpace human decision-making. In a second, shorter portion of the paper, I try to overturn the transcendentalist rhetoric often found in Artificial Life-inspired business models by looking closely at the practices of making semiconductors, a crucial element in contemporary computers. Behind the 'life' of the cyberspatialized market lurks stories of illness and death for people putting together the materials on which the so-called new economy depends. Although I return in the end to a rather classic reading of Marx on commodity fetishism in order to access exploitative relationships between production and consumption that usually remain hidden from view, I extend Marx's commodity fetishism argument to address contemporary formations of cybernetic capitalism, particularly as these are organized around the things we call computers.

■ ARTIFICIAL LIFE ECONOMY

☐ *Enterprising up*

Chris Langton, the man who christened Artificial Life in 1987, in 1997 founded The Swarm Corporation, 'to provide expert consulting and modeling capability to businesses and government agencies

facing complex dynamics in various aspects of their organization, physical plant, or resource base' (www.swarm.com). Swarm, the computer model that is the company's major tool and product, is a simulation platform designed to model the complex concurrent dynamics of individuals in populations. According to the Swarm Corporation website, it is part of 'a suite of products that bring the power of evolutionary computing to bear on difficult problems. ... We target domains defined by distributed ecologies of interacting and evolving agents, which includes Consumer Behavior, Natural Resource Management, Internet-enabling technologies, and virtual environments' (www.swarm.com). Swarm has garnered praise from such publications as *Business Week*, which reported in its June 1997 issue on Information Technology that the Swarm technology was the 'best thing to emerge from the Santa Fe Institute' (www.swarm.com).

Theoretical biologist Stuart Kauffman, known for his models of self-organizing systems and once a major player at SFI [and more recently the author of various popular science books on complexity (see Kauffman, 1995)], recently founded the BiosGroup, a company that offers the computational tools of evolutionary modelling to help companies 'become adaptive in an ever-shifting marketplace' (www.biosgroup.com). One of the 'product suites' BiosGroup offers is a software package called 'MarketProwess' which, according to its webpage,

> is a next-generation set of tools designed to dramatically enhance the value end-users receive from trading hubs. MarketProwess delivers value by enabling trading hubs to host complex transactions and by providing a mechanism that allows buyers and sellers to achieve highest value trades. MarketProwess has a substantial competitive advantage over what exists in the market today. It features multi-dimensional matching, flexibility, and trade-off analyses based on advanced algorithms (www.prowesssoftware.com/home.htm).

The 'advanced algorithms' used by MarketProwess™ include 'flexible software solutions and decision support tools that combine many powerful complexity science-based techniques including agent-based modeling, learning heuristics, multi-objective optimization, data mining, and genetic algorithms' (www.biosgroup.com).

The BiosGroup page adopts a utilitarian reading of evolution in its description of genetic algorithms:

> In nature, the search for beneficial adaptations to a continually changing environment (i.e. evolution) is fostered by the cumulative evolutionary knowledge that each species possesses of its forebears. ... Genetic algorithms mimic and exploit the genetic dynamics underlying natural evolution to search for optimal solutions to general combinatorial optimization problems. They have been applied to the traveling salesman problem, VLSI circuit layout, gas pipeline control, the parametric design of aircraft, neural net architecture, models of international security, and strategy formulation (www.biosgroup.com).

Kauffman's company draws explicit parallels between economies and ecologies, rendering businesses as complex organisms in a competitive, Darwinian world; puns on 'organization' and 'corporation' are taken seriously as guides to implementation. MarketProwess™ is advertised as 'the brains and the muscle behind e-commerce', a motto that is clearly meant to be metaphorical, but is cut from the same cloth as BiosGroup's more scientific rhetoric about genetic algorithms. In both instances, computer programs, described through organic language, appear to be doing things by themselves. This hides not only the material constitution of computers, the menial labour that constructs them, but also the professional work that promotes biological analogies in the service of rendering legible and credible the union of life sciences expertise and business.

People with recent professional origins and links to SFI have been engaged in the trading of metaphors between economics and biology for some time now. In 1988, Artificial Life researcher and genetic algorithm inventor John Holland wrote, symptomatically, in an article penned for an SFI workshop on economics, 'The role of utility in economics is quite similar to the role of ... fitness in evolutionary genetics' (p. 120). And, freely mixing the language of economics and ecology, 'The arena in which the economy operates is typified by many niches that can be exploited by particular adaptations. ... Niches are continually created by new technologies and the very act of filling a niche provides new niches' (Holland, 1988, p. 118). A few years ago, Holland and others sought to

operationalize such views of the economy in a computer model of the stock market named 'Artificial Economic Life'. In this system, a specialist program posts price, dividend, and interest rates. 'Traders' are represented by strategies encoded in bit strings. Using the genetic algorithm, new kinds of traders are 'evolved' and ever 'fitter' traders emerge. In the wake of reduced funding for Artificial Life, models such as Holland's, favourably reviewed in an article in *Futures*, a magazine for derivatives traders and money managers, are now becoming commercially available to online traders. As journalist Gibbons Burke wrote in his *Futures* article: 'Researchers have found that nature's way of adapting living organisms to the environment—evolution—can answer difficult questions. Applied to the world of finance, it yields surprising market insights' (1993, p. 26).

More recently, NeuroDimension, Incorporated has elaborated a program similar to 'Artificial Economic Life' called TradingSolutions™, marketed to that new sort of capitalist, the e-trader working from his or her home personal computer. 'Have you been losing money in this volatile market?' asks the NeuroDimension web site. 'With TradingSolutions', it promises, 'you can use any combination of financial indicators in conjunction with advanced neural networks and genetic algorithms to take advantage of the volatility and turn it in your favor'. Here's a description of how the product can be used to play the stock market:

> The process of selecting a stock starts by loading in the data for a large group of stocks, such as the S&P 500 or the NASDAQ 100, into the TradingSolutions portfolio. A neural network prediction is defined for the entire group and the training stage is initiated. After a couple of hours of processing ... , TradingSolutions sorts the stocks in the portfolio by the profit of the underlying models. ... [T]he top performing models from the group are retrained individually many more times with different combinations of the initial inputs. A genetic algorithm is used to select the input permutations in order to find the combination that produces the lowest error in the cross validation set (http://www.tradingsolutions.net/products).

This process hard-wires financial market decision-making, embedding it into a set of automated procedures modelled after evolution.

Is there anything new about the way biology is used here, anything substantially different from earlier social Darwinist or sociobiological rationalizations of market processes? Yes. To reiterate: here, Darwinian notions are not just after-the-fact descriptions, but are instantiated in the process of commodity exchange itself. This is interesting not just because it represents a reversal, but because it speaks to the exigencies of a new, flexible, highly networked, computerized economy, as well as to new ways of thinking and acting promoted under this regime. How might we understand this? Learning a bit more about how these models came into being, by reaching back into the history of Artificial Life scientists' involvement with economists at SFI, can help locate these collaborations within broader economic and social changes.

☐ *Circuits of exchange between artificial life and economic science*

The Santa Fe Institute's earliest search for private benefactors brought scientists into contact with Citibank/Citicorp, a company known for its credit card and banking business. At the suggestion of Citicorp CEO John Reed, the Institute sponsored a workshop on 'International Finance as a Complex System' (1986) and, later, one on 'Evolutionary Paths of the Global Economy' (1987), the proceedings of which were both published in *The Global Economy as an Evolving Complex System* (Anderson *et al.*, 1988). Citibank/Citicorp has remained a major financial contributor to the Institute, and many other information and service industry-based companies concerned with financial management have joined as sponsors. Importantly, all became interested in the sciences of complexity because they were dissatisfied with standard neoclassical economics, finding it inadequate to speak to the unpredictabilities of the contemporary economy.

Where neoclassical economists emphasize the perfect rationality of economic agents and assume that economies are self-regulating, Santa Fe economists have argued that economic agents always act with imperfect knowledge, that their actions affect economic outcomes, and that economies are rarely in equilibrium. They focus on how agents act 'adaptively' in a world structured by contingency. In

a summary of 'the SFI approach', resident program director Blake LeBaron wrote:

> Rather than reaching equilibrium, this economy is seen as being in a continuous dynamical struggle of adaptation and evolution. New goods are created which change the entire economic landscape for existing production processes. Financial markets struggle toward efficiency as price patterns, eliminated by adjusting strategies, are replaced by new patterns (1993, p. 1).

Certainly the language of 'struggle' among inanimate entities like 'financial markets' is not unique to the post-neoclassical economic register in which LeBaron writes. But what is different is the logic under which the struggle unfolds; it is not about maximization and perfect knowledge, but about unpredictability and instability.

Brian Arthur, a Stanford-based economist who works at SFI, described the distinction between neoclassical and complexity economics to me in a 1993 interview, in a way that I think illustrates the difference:

> Under the standard view of economics, the economy is a gigantic machine. We are standing in front of the control panel and, like a big electric power station, there's all kinds of dials and needles pointing places. The only thing is, nobody quite knows what's connected to what, and if you could just figure out where to set these dials, everything would be just nice. Now, I don't think that that's at all useful—I don't think it's correct in any sense of the word. The economy is not like that. The economy is like an ecology and with an ecology you think of yourself more as a forest ranger, a gardener, a landscape architect. It's evolving organically, you can to some degree influence where it goes—you can water here and weed there, you can put up fences. ... But basically, it's a huge ecology and one that has a multiplicity of consistent patterns.

The 'multiplicity of consistent patterns' referred to by Arthur is an indication that we are not interested here in perfect rationality, but in a more flexible, adaptive dynamic, in which the intentionality of economic agents is not at stake.

☐ *Post-neoclassical economics, post-Fordism, and the post-human*

The questioning of the neoclassical paradigm behind adaptive models results from a sense that economic reality has changed in recent decades. From the perspective of social history (see e.g. Mandel, 1975; Aglietta, 1979; Harvey, 1989; Jameson, 1991), there has indeed been a sea change in the way the global economy is organized, with manufacture and production shifting from Fordist to post-Fordist principles. Under Fordism, production was organized around large-scale industrial production for mass markets. Domestic workers were supported with a family wage and encouraged to participate as consumers in the economy for which they produced. Responding to inflexibilities in Fordist production (strong labour unions, costly commitments to limited product lines), post-Fordist production has been characterized by the flexible responses of capital to changes in international labour laws and markets, exchange rates, and patterns of consumption. Under regimes of 'flexible specialization' or 'flexible accumulation', production is done rapidly, in small batches, and by labourers who can be speedily fired and hired. Companies switch specialties quickly to maintain a standard of profit accumulation. The labour force employed by manufacturers is increasingly global, as multinational corporations circuit the globe to take advantage of international differences in labour costs, laws, and demographics. Workers and consumers are no longer the same people; they may be thousands of miles, or many social strata, apart.

These transformations have been accompanied by changes in the way money is manipulated in financial markets. Post-Fordism relies on technologies of rapid information transfer and communications both to implement production and design and to support transnational banking, investment, and trading. Rapid navigation through the new economic waters of speculating on futures, options, and currency markets and putting funds into offshore financial centres, is increasingly facilitated by internationally networked computers. With such computers, businesspeople can make quick decisions about what and when to buy and sell—even programming computers to make decisions on their behalf, as TradingSolutions™ demonstrates. David Harvey notes that 'Computerization and electronic communication have pressed home the significance of instantaneous international coordination of financial flows' (1989, p. 161). These are the changes around which, I would suggest, business folk are crafting

the new languages of cybernetic adaptation. As Emily Martin notes, 'In order to survive in this changed environment, a wide variety of human resource managers, consultants, and authors are advocating that American corporations must become like biological systems that successfully survive in nature' (1994, p. 208).[1]

As I have been arguing here, companies are being advised to take on board more than just a computer-age biological language; new tools are being made available that allow them to burn metaphors of evolutionary process into the infrastructure of finance. The techniques extend to manufacturing, too; genetic algorithms have been employed to organize post-Fordist production regimes of factory flow and staff scheduling (Cleveland and Smith, 1989; Easton and Mansour, 1993). Along another scale, Artificial Life, Inc. markets genetic algorithms as components in tools for the financial needs of the individual middle-class consumer. The presentations of such products purport to level and democratize economic agency by making 'everyone' a potential trader who can tap into the Artificial Life world of evolved solutions. In the bargain, the software that 'does the decision-making' and crunches the numbers is also apparently labourless; 'the computer' does the work.

In 'Complex Subjects: Offshore Finance, Complexity Theory, and the Dispersion of the Modern', Bill Maurer argues that biologically inspired complexity theory in economics posits a fundamentally different sort of subject than that of neoclassical economics: 'In "illuminating" the ontological identity of economies, immune systems, ecologies, and so forth, complexity theory renders the modernist distinction between subject and object obsolete: the human subject, like the ecology and the economy, becomes a complex adaptive system' (1995, p. 116). This new economic theory 'evacuates the position of the subject that was a central component of neoclassical economics', with the result that the subject disperses 'into new networks of power with no originary point, cybernetic structures of infinite feedback and non-originary unfoldings. The "subject" of complexity theory ... is posthuman' (p. 125). Maurer sees this exemplified in the following passage from a president's message in *The Bulletin of the Santa Fe Institute*:

> There is something in the SFI environment that reshapes our thinking and the things we say. I was reminded of the 'SFI effect' recently while reading an interview published in the magazine *Manhattan, Inc.*, in which John Reed, CEO of Citicorp and a sponsor of the SFI economics program, described himself as a complex adaptive system (Cowan, 1990, p. 2).

Maurer points out that the adaptation at stake here is not about will, but about doing 'what comes naturally'. The subject of the new economics is not a Robinson Crusoe, carefully measuring costs and benefits, but is a creature of instinct.

In 'Simulating Narratives', N. Katherine Hayles argues that a similar subject is materializing 'in the distributive complex adaptive systems created by digital technologies in conjunction with global capitalism' (1999, p. 16)—what she terms the 'digital subject', following Mark Poster. Hayles contends that Artificial Life and complexity models of organisms are symptoms of a new way of thinking about and inhabiting agency; the digital subject does not so much make choices as instantiate and realize a series of already installed processes, that is, realize its nature as a complex adaptive system.

The new bio-babble, then, speaks in the idiom of powerful new practices and epistemologies organized around digital computing—not surprising, since computational metaphors of coding powerfully inform this kind of popular biology (see Blume, 2001; Borsook, 2000; Helmreich, 2000a). This rhetoric also calibrates the use of computers in high finance with rhetorics of nature and even with environmental language, exempting people from responsibility for their actions, not because evolution determines the choices they must make, but because choice has been factored out entirely. And, as Maurer demonstrates in his anatomy of the complicities between the formulations of complexity economics and the ever-shifting networks of off-shore finance, computers are a key metaphor and material for this alignment. As Maurer also points out, Citibank/Citicorp has not only been a major guiding influence for SFI economics, but also happens to be one of the largest producers of tools for offshore banking.

Companies such as the Swarm Corporation, BiosGroup, and Artificial Life, Inc. have both literally and figuratively incorporated Artificial Life, seeking to inject the language of natural science and the technology of computer science into contemporary business

practices, simultaneously legitimating such practices as 'natural' and working to hardwire them into the market infostructure. This use of Artificial Life language and technology solidifies and materializes the rhetorics of 'adaptability' and 'flexibility' that have saturated and oriented business practice in the post-Fordist age. 'Artificial Life, Inc.' is a metonym for the way this biological language is edging into the software that organizes the market. Computer and business networks fold together in the programming protocols of Artificial Life, and computers and the market come oddly 'to life'.

TOXICITIES OF COMPUTER MANUFACTURE IN SILICON VALLEY

Artificial Life, with its claim that computers can embody the logic of life, might be seen as the apotheosis of commodity fetishism, since the digital organisms that swarm and multiply *in silico* are not only treated symbolically as though they contain a kind of life force separate from their programmers, but are explicitly theorized as such. I want to use Marx's argument—in a somewhat literal way—to look more closely at the economies within which the 'raw materials' of the Artificial Life economy—computers—are embedded. I mean to destabilize the assignment of vitality to the Artificial Life-enabled market by bringing in stories of disease and death in the industrial production of computers in California's Silicon Valley.

I do not mean here to argue that the 'life' of computers and of the market is illegitimately conferred and ultimately stems from the sovereign vitality of people whose labour is sucked into the circuits of capitalism through the appropriation, in the wage relation, of their species-being; the world of simulation and cyborgs we inhabit has dissolved the possibility of grounding epistemological and moral claims in any self-evident category of 'life' except in the most essentialist way (like that associated with 'pro-life' rhetoric). Perhaps a better way to put my case here is that I wish to argue that what I call the 'silicon second natures' of Artificial Life are networked to what Donna Haraway (1991) has called the informatics of domination; that is to say, the activity of the market *is* linked to the activity of labourers, though not through the transference of a magical substance called 'life', but rather, quite simply, through the relations of production that characterize our high-tech post-Fordist

age. When I examine the assignment of vitality to the market, I aim not to return 'life' to its rightful organismic owners, but rather to examine what this curious fetish obscures and enables. Following the trail from Santa Fe to Silicon Valley requires us to keep metaphorics and materialities in constant juxtaposition, no matter whose practices we are writing about.

The most popular tales we hear about the Silicon Valley gold rush are those of hard-working visionaries who have parlayed their hacker histories into entrepreneurial success. But those are the folks at the top of the pyramid; there are many others involved in making these things we call computers. Following the trail back from entrepreneurs to programmers to those who assemble computers takes us into a different world. It is the world of the global assembly line, in which national and international differences in labour costs, safety laws, and demographics are exploited and reinforced by multinationals to reduce production costs (Harvey, 1989).

Much electronics assembly—the placing of electronics components onto printed circuit boards, for example—is done in offshore production zones, but a good deal is also done by immigrant and/or ethnically disenfranchised labour in the US, in such locations as Silicon Valley, where electronics workers have met with notorious corporate resistance to unionization. As Chuck Carlson puts it in 'Bled Dry by the Cutting Edge: A Short History of Labor in the Silicon Valley', 'In the intensely competitive atmosphere of today's market for electronics commodities, the exploitation of women and legal and illegal immigrant workers has become a key to remaining competitive' (1997, p. 18). This exploitation has been not only economic but densely physical. Carlson notes that 'By the late 1980s, worker compensation statistics revealed that half of all occupational illnesses of semiconductor workers resulted from "systemic poisonings" brought on by exposure to toxic chemicals' (p. 20). In his important *Behind the Silicon Curtain*, Dennis Hayes (1989) describes the conditions of so-called 'clean rooms' where workers fashion chips, disc surfaces, and disc-drive heads, and where phosphine and chlorine impart electric properties to microchips and chemical injury to workers in *bunny suits*—those astronautic outfits worn to protect chips, not people, from dangerous microparticles (in recent years, Intel ads have featured these as fantasy disco getups worn by happy workers). Assembly often requires cleaning electron-

ics parts with such substances as ethylene glycol, which has been linked to miscarriage (Bacon, 1997). Women who have worked under such injurious conditions and whose activism has led to health studies confirming the deleterious effects of glycol ethers are the sort of women Donna Haraway first theorized as real-life cyborgs (1991; and see Ong, 1987; Fernández-Kelly, 1983). The post-Fordist, flexible labour of these workers, then, is not simply the 'ground' which enables the practices of computation, but exists as a highly technologized form of life integrated with but invisible to Santa Fe style theorizations of an evolutionary economy.

Even farther out of public view than assembly workers are those charged with disposing of the toxic wastes generated by computer assembly. In Silicon Valley, many of these people are Latino and Asian immigrants working in nonunionized conditions for disposal companies subcontracted by such companies as National Semiconductor and Hewlett-Packard. The mid-1990s saw a number of accidents at disposal sites. In 1995, Rodrigo Cruz, an employee of Romic Environmental Technologies, a company that disposes of wastes for major Silicon Valley firms, suffered a near-blackout inside a railroad car filled with residue from solvents used in computer assembly. Soon after, he was diagnosed with delayed post-hypoxic encephalopathy, a kind of low-level brain damage. His case prompted investigation by the California Occupational Safety and Health Administration, which found conditions at Cruz's workplace unsafe. It also generated a networked activist response in which doctors, lawyers, and collectives like the Toxic Avengers Theatre group came together to draw attention to environmental injustice in Silicon Valley. Though legal action against Romic undertaken by the Santa Clara Center for Occupational Safety and Health has led to a settlement for Cruz, many similar cases have not had a proper hearing. Organizations such as HealthWATCH (Workers Against Toxic Chemical Hazards)—a network of Filipino electronics workers that also took up Cruz's case—have found it difficult to organize legal and economic programs of attention to workplace hazards because of a long history of union busting in Silicon Valley (Bacon, 1997).

Resisting unionization has been an explicit strategy promoted by the economically privileged entrepreneurs of the industry. In *Silicon Valley Fever*, Robert Noyce, a cofounder of Intel, is quoted on this

The Toxic Avengers Theatre group, clad in "bunny suits".
Credit: Himal South Asian, http://www.himalmag.com/99Dec/hitech.htm

matter: 'Remaining nonunion is an essential for survival for most of our companies. This is a very high priority for management here' (1984, quoted in Bacon, 1997, p. 17). When we think back to the flexibility, the ability to adapt, celebrated by entrepreneurial Artificial Life, we must remember that flexibility and adaptation do not mean the same thing for everybody. For a CEO, adaptation might mean using a genetic algorithm to rearrange the capital in his or her portfolio while, for a worker of colour, it might mean accepting reduced or eliminated benefits and nastier working conditions, or considering relocation to another country. Even so, these two flexibilities are obviously connected, and the second enables the first. As Gayatri Spivak writes, in an example that usefully highlights the ascription of agency to computers,

> ... whereas Lehman Brothers, thanks to computers, 'earned about $2 million for ... 15 minutes of work', the entire economic text would not be what it is if it could not write itself as

> a palimpsest upon another text where a woman in Sri Lanka has to work 2,287 minutes to buy a t-shirt (1985, p. 171).

In dynamics like these, a kind of vital agency is reassigned from underpaid labour to managerial labour, and increasingly, to the computers that management uses, which are, with the help of formations like Artificial Life, Inc. understood to enact 'natural' dynamics.

Now, of course, the financial markets and capital investments that companies like Artificial Life, Inc. hope to assist are anything but natural; they are maintained, legitimated and protected by government apparati that keep definitions of private property stable and, ultimately, enforce these though law and military force. In this regime, managerial flexibility means being able to forget the poisonous labour conditions that can enable increasing profits. The fetishization of Artificial Life, Inc. obscures even as it naturalizes these forms of life and death, as it vivifies computers, companies, and the market. It forgets that 'computers' are not things in themselves, but are important nodes in relationships among persons. Programs like 'evolving web-searching agents' of the sort manufactured by Artificial Life, Inc. only 'come to life' when the many kinds of people behind them are rendered (differently) invisible. Silicon second nature contains the hidden human toxicities of silicon tetrachloride.

BEYOND SILICON

My emphasis on the metaphorics and materialities of silicon in this analysis may, however, be as misleading as it is revealing. It is, of course, not silicon as such that is at issue here, but the animation of computing and of the market more generally.

Important signals of this larger logic began to appear on the pages of popular computing magazines in the year 2000. One high-profile article in *WIRED* announced that the development of current microelectronic technology will hit a wall within the next 20 years (see Overton, 2000); silicon-based chips can only be miniaturized so much without running into physical limits that have to do with the material properties of silicon itself. According to Intel cofounder Gordon Moore, the article reported, ever-smaller silicon chips will soon no longer be able to sustain the processing power demanded of

them. 'Moore's Law' predicts that this will happen in the year 2017. Computing, the argument then goes, will only survive by moving into different media. The *WIRED* article declared the imminent 'death of silicon' and the rise of what is called 'molecular electronics' or, simply 'molectronics', a nascent field of inquiry at the intersection of chemistry and computer science that, according to a description in *Scientific American* by some of its primary advocates, promises to craft a variety of individual molecules that can 'perform functions analogous to those of ... transistors, diodes, conductors, and other key components of today's microcircuits' (Reed and Tour, 2000, p. 69).

Using techniques similar to those employed to chemically engineer new pharmaceuticals, molectronics researchers hope to build molecules that can behave like switches or serve as memory devices (through storing electrons on demand or making use of such quantum mechanical phenomena as superposition). Such techniques will be necessary, they argue, because 'the exponential increase in [silicon] transistor densities and processing rates of integrated circuits is being sustained only by a similar exponential rise in the financial outlays necessary to build the facilities that produce these chips. Eventually the drive to downscale will run headlong into these extreme facility costs, and the market will reach equilibrium' (Reed and Tour, 2000, p. 70). In this view, the chemistry of computation and the economy of capitalist manufacture share a mutually reinforcing trajectory.

Portraying the move of computation from one chemical substrate to another as the logical entailment of a 'law' of exponential increase and of market demands of course erases the political and economic decisions that will lie behind this process when and if it happens. The neoliberal biological language in which the market is understood further serves to naturalize the value systems and institutions of advanced capitalism, posing their human authors as mere instruments of processes beyond their control. The result is that computing as a process and as an industry is granted a 'life of its own'—to paraphrase Marx. *WIRED*'s announcement of the 'death of silicon' displaces the logic of biography onto the symbol of contemporary computing. More, the article continues to erase the productive processes that will be required to bring new chemical compounds to

market and manufacture, even as it asks, evidently pleased with its own cleverness, 'Can you say Thiophene Ethynylene Valley?'

Even if Artificial Life as a discipline is on its way out, it is clear that the commodity fetishism which it has recently been used to naturalize and operationalize is far from defunct. And Artificial Life lives on in the new biological metaphors employed to forecast the future of computing and computer markets. Understanding the logic of commodity fetishism at the beginning of the twenty-first century turns out to require decoding the info-evolutionary language in which the market is being made to speak and act. The devil is in the digital Darwinian details.

■ ACKNOWLEDGEMENTS

I thank Les Levidow and *Science as Culture*'s anonymous reviewer for helpful suggestions on developing this article. I extend my gratitude, too, to Heather Paxson, without whose help this piece could not have been written.

□ *NOTES*

1. Michael Rothschild's 1990 *Bionomics: The Inevitability of Capitalism*, a book that floated around SFI while I was there and which was a favourite of a few Artificial Life researchers, pitched this argument in the informatic terms that became central to Artificial Life, Inc. and its ilk: 'In the biologic environment, genetic information, recorded in the DNA molecule, is the basis of all life. In the economic environment, technological information, captured in books, blueprints, scientific journals, databases, and the know-how of millions of individuals, is the ultimate source of all economic life' (1990, p. xi). 'A capitalist economy can best be comprehended as a living ecosystem. Key phenomena observed in nature—competition, specialization, cooperation, exploitation, learning, growth and several others—are also central to business life ...' (p. xi). Rothschild drew a moral lesson: 'Capitalism [is] the inevitable, natural state of human economic affairs. Being for or against a natural phenomenon is a waste of time and mental energy' (p. xv).

□ *REFERENCES*

Aglietta, M. (1979) *A Theory of Capitalist Regulation: The U.S. Experience*, translated from the French by D. Fernbach. London: NLB.

Anderson, P., Arrow, K. and Pines, D. (Eds) (1988) *The Economy as an Evolving Complex System*. Redwood City, CA: Addison-Wesley.

Bacon, D. (1997) 'Silicon sludge: immigrant workers fight toxic working conditions in anti-union Silicon Valley', *San Francisco Bay Guardian*, 24 December: 17–19.

Blume, H. (2001) 'Cyberbole', *The American Prospect*, 12(5). Online at http://www.prospect.org/print/V12/5/blume-h.html.

Borsook, P. (2000) *Cyberselfish: A Critical Romp Through the Terribly Libertarian Culture of High Tech*. New York: Public Affairs.

Burke, G. (1993) 'Good trading a matter of breeding?' *Futures*, 12(5): 26–29.

Carlson, C. (1997) 'Bled dry by the cutting edge: a short history of labor in the Silicon Valley', *Arcade*, 2(2): 16–20.

Cleveland, G. A. and Smith, S. F. (1989) 'Using genetic algorithms to schedule shop flow releases', in J. D. Schaffer (Ed.), *Proceedings of the Third International Conference on Genetic Algorithms*. San Mateo, CA: Morgan Kaufmann Publishers, Inc.

Cowan, G. (1990) 'President's message', *The Bulletin of the Santa Fe Institute*, 5(2): 1.

Easton, F. F. and Mansour, N. (1993) 'A distributed genetic algorithm for employee staffing and scheduling problems', in S. Forrest (Ed.), *Proceedings of the Fifth International Conference on Genetic Algorithms*. San Mateo, CA: Morgan Kaufmann Publishers, Inc.

Fernández-Kelly, M. P. (1983) *For We Are Sold, I and My People: Women and Industry in Mexico's Frontier*. Albany: State University of New York Press.

Haraway, D. (1991) 'A cyborg manifesto: science, technology, and socialist-feminism in the late twentieth century', in *Simians, Cyborgs, and Women: The Reinvention of Nature*. New York: Routledge.

Harvey, D. (1989) *The Condition of Postmodernity: An Enquiry into the Origins of Cultural Change*. Cambridge, MA: Blackwell.

Hayes, D. (1989). *Behind the Silicon Curtain: The Seductions of Work in a Lonely Era*. Boston: South End Press.

Hayles, N. K. (1999) 'Simulating narratives: what virtual creatures can teach us', *Critical Inquiry*, 26: 1–26.

Helmreich, S. (1998) 'Recombination, rationality, reductionism, and romantic reactions: culture, computers, and the genetic algorithm', *Social Studies of Science*, 28(1): 39–71.

Helmreich, S. (2000a) 'Flexible infections: computer viruses, human bodies, nation-states, evolutionary capitalism', *Science, Technology, and Human Values*, 25(4): 471–490.

Helmreich, S. (2000b) *Silicon Second Nature: Culturing Artificial Life in a Digital World*, updated with a New Preface. Berkeley: University of California Press (hardcover edition 1998).

Holland, J. (1988) 'The global economy as an adaptive process', in P. Anderson, K. Arrow and D. Pines (Eds), *The Economy as an Evolving Complex System*. Redwood City, CA: Addison-Wesley.

Holland, J. (1992) 'Genetic algorithms', *Scientific American*, 267(1): 66–72.

Jameson, F. (1991) *Postmodernism or, The Cultural Logic of Late Capitalism*. Durham: Duke University Press.
Kauffman, S. (1995) *At Home in the Universe: The Search for the Laws of Self-organization and Complexity*. New York: Oxford University Press.
Langton, C. G. (1989) 'Artificial life', in C. G. Langton (Ed.), *Artificial Life*. Redwood City, CA: Addison-Wesley.
LeBaron, B. (1993) 'The SFI approach', in *Emergent Structures: A Newsletter of the Economics Research Program at the Santa Fe Institute*. Santa Fe, NM: Santa Fe Institute.
Mandel, E. (1975). *Late Capitalism*, translated from the German by Joris De Bres. London: NLB.
Martin, E. (1994) *Flexible Bodies: Tracking Immunity in American Culture from the Days of Polio to the Age of AIDS*. Boston: Beacon.
Marx, K. (1867) *Capital, Vol. 1*, translated from the German by B. Fowkes. London: Penguin, 1976.
Maurer, B. (1995) 'Complex subjects: offshore finance, complexity theory, and the dispersion of the modern', *Socialist Review*, 25(3/4): 113–145.
Ong, A. (1987) *Spirits of Resistance and Capitalist Discipline: Factory Workers in Malaysia*. Albany: State University of New York Press.
Overton, R. (2000) 'Molectronics will change everything', *WIRED* 8.07: 240–251.
Rabinow, P. (1996) *Making PCR: A Story of Biotechnonology*. Chicago: University of Chicago Press.
Rabinow, P. (1999) *French DNA: Trouble in Purgatory*. Chicago: University of Chicago Press.
Reed, M. and Tour, J. (2000) 'Computing with molecules', *Scientific American*, 282(6): 68–75.
Rothschild, M. (1990) *Bionomics: The Inevitability of Capitalism*. New York: Holt.
Spivak, G. C. (1985) 'Scattered speculations on the question of value', in *In Other Worlds: Essays in Cultural Politics*. London: Routledge, 1988.
Strathern, M. (1992) *Reproducing the Future: Anthropology, Kinship, and the New Reproductive Technologies*. New York: Routledge.
Taussig, M. (1980) *The Devil and Commodity Fetishism in South America*. Chapel Hill: University of North Carolina Press.

Science as Culture, Volume 10, Number 4, 2001

THE GENE AS A RHETORICAL FIGURE: 'Nothing But a Very Applicable Little Word'

ELIZABETH SHEA

In a 1999 fashion supplement to the *New York Times*, hip-hop singer Lauryn Hill answers a question about how she feels about clothes:

> Oh, gosh, that is not a good question for me. My mother passed on the clothing gene to me. I can't help myself; I love clothes. I think that the way I dress says a lot about who I am (Green, 1999).

Like her hip-hop music, Hill's statement plays on the hypertextuality of cultural meaning. By sampling from seemingly disparate sources she challenges any remaining notion that one realm of culture can be neatly cordoned off from another without any traffic back and forth. Here, we need not be familiar with the biochemical mechanisms of deoxyribonucleic acid to recognize the rhetorical mechanism of a clothing gene that makes Hill's love of clothes so innate that it cannot be helped. Nor do we need to take literally her claim of not being able to help herself in order to grasp the claim to fixedness or innateness of her identity.

The genetic link in Hill's statement is a figurative link. The reference to a 'clothing gene' is not an illegitimate sampling of scientific evidence nor a simplification of scientific reasoning but rather an ironic twist on a cultural icon that has come to connote fixed realities and the possibility of material origins of the self. Coupling the material of fashion with the material of genetics, Hill's clothing gene disrupts and, thus, calls my attention to the familiar line of thinking that leads from genes as material origins to explanations of identity and culture.

Address correspondence to: Elizabeth P. Shea, English Department, Northeastern University, M.S. 0406 HO, Boston, MA 02115-5000, USA, E-mail: e.shea@neu.edu

0950-5431 print/1470-1189 online/01/040505-25 © 2001 Process Press
DOI: 10.1080/09505430120093603