

Every M.U.D. is an allusion for death

"Suddenly, I didn't know what a computer was anymore."

For PTC 96  
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Thanks to Dick Barber and the organizing committee for inviting me to join with Secretary-General Tarjanne in opening PTC96.

This is the third time I have had the honor of addressing this august group. The first time was here in the Sheraton Waikiki in 1980--PTC II, of January 1980. One of the interesting things about my talk then was that I did not give it in person. I was in Saipan at the time, and left a Sony Portapak reel-to-reel videotape which, I hope, was played, and, which, I also hope, was seen and heard by some one other than the video tape operator.

It took more than five years for PTC to recover from, or else to forget about, my 1980 presentation, and so I was invited to speak to a luncheon meeting of PTC86 which for some reason met in the Waikiki Regency hotel.

The recovery from, or else the forgetting of, that talk took much longer. So here I am a decade later, PTC96, speaking now on the opening plenary.

If I understand what is happening here, I will be invited to speak again at PTC15--2015, that is. And I predict the site will not be here in the Sheraton Waikiki, but rather in the Sheraton Moiliili--one of the new string of hotels which will be built, after the warming, and after the seas rise and the dikes have all been erected, on newly prime ocean front property, beyond what is now the Ala Wai Canal, just this side of the Lunalilo Freeway--or what is formally called H-1, and is part of Hawaii's portion of the US Interstate Highway system.

So I also predict that by 2015, the connection linking our Interstate Highway to those of the US mainland will finally have been built--a feat aided by the fact that all of California will have fallen into the sea and provided some of the landfill needed to construct a bridge and causeway system between Kaneohe and La Paz, in Baja California which by then will be part of the American Federation of States reaching from Alaska to Chile and from Baffin Land to Argentina, and all points in between, save Quebec, Brazil, and Texas which will each remain independent nations.

And yes, in case you are wondering, there will also be a superconducting tunnel for maglev trains under construction between Barber's Point (actually renamed, Dick Barber's Point) and Awaji Island in Japan. However, that won't be available for use until I speak to you for the last time, at PTC2033, having finally attained some sense of perspective, propriety, and maturity--at 99 years of age.

Now, before I talk more about the future, let me say a few words about the past.

The title of my 1980 talk was "EIES and Racter and Me" and the subtitle was "Computer Conferencing from a Pacific Island." [1] What I did in that talk was to describe my experiences on the dirt road that was to become the Information Superhighway of current fame, fortune, censorship and commercialization.

During the 1970s, I was one of the small group of people to participate in Murray Turoff's Electronic Information Exchange System--EIES--which operated out of a host computer at the New Jersey Institute of Technology. Turoff detailed his experiences in a book which he and his colleague Starr Roxanne Hiltz--who gets my vote as one of the top ten most provocatively named social scientists in the world--published in 1978, titled, *The Network Nation: Human communication via computer*. That book was slightly revised and updated in 1993, but Murray and Starr said it all 25 years ago [2]. I don't think there is anything that any of you will or can say on the subject over the next few days that was not already said by Turoff and Hiltz in 1978.

I consider *Wired*--and *Mondo 2000*-- to be absolutely essential reading these days. But while *Wired* does pay decent homage to St. Marshall McLuhan (they even channeled him in the most recent issue, and reprinted pages from *The Medium is the Message* [3], which--along with the record with the same name [any of you ever heard it? Great stuff. You can hear soundbites from it on McLuhan's Homepage]--that picture book and recording had a tremendous influence on me), and while *Wired* also recently finally acknowledged their intellectual and spiritual debt to Teilhard de Chardin [4], the *Wired* folks have not yet acknowledged that the St. Paul to McLuhan's Jesus was Turoff and Hiltz, and not Stewart Brand, Nicholas Negroponte, or Howard Rheingold, and certainly not Kevin Kelly. I won't even mention Bill Gates. Those folks--as important as they certainly are--are really just some latter day Popes, Cardinals and Grand Inquisitors doing well by propagating the gospel of Others--and I say that as a great admirer of all of Brand's many contributions to understanding and enlightenment; as a devotee of Negroponte's Media Lab [5]; as a fan of Rheingold's books, and especially his Web site; and as a catechist of Kevin Kelly's book *Out of Control* [6] which I consider the primal scream for anyone who wants to know what is going on and what is possibly emerging. You should all recite Kelly's "Nine Laws of God" every day before you first log on to the Net in the morning and before you log off at night--assuming of course that, if you ever log on, you will at some point log off, of course..

Now, all I did in my little PTC80 paper was to describe my own experiences online (as it was not then called) from Hawaii via Telenet, operating from a very dumb Texas Instruments terminal, initially with no memory at all, so that I could only save whatever I managed to echo out on a very noisy printer.

But we were experiencing and exploring then, in the 1970s, all of the thrills and spills of the electronic communications present--the things you know about personally but which others read about now in the weekly magazines and daily newspapers as though they were something new--including how teleworking (as it was not then called) would impact the family, the rudeness of flaming (as it was not called then), and how to deal with a rape in cyberspace (as it--that is, "cyberspace"--certainly was not called then).

I think two things from my 1980 paper are worth reading to you again.

One is a Manifesto which I received in EIES Computer Conference 1019, on September 8, 1979. I don't know who wrote it. If any of you do, please let me know (QUOTE):

## A Manifesto

"The history of all hitherto existing computerized conferencing and information systems is the history of elitist access.

"Those with the technical and literary skills, the equipment, and the money to pay for "time" continue to perpetuate their elitist status, while the proletariat gets folded, spindled, stapled, and mutilated. At best the masses can play Pong or program their microwave ovens, while at worst their privacy is invaded with computer-generated junk mail and their credit card accounts are forever wrong.

"All human beings, regardless of class, want and need some human contact, some sense of being connected to the human race. Computerized communications systems offer a special kind of superconnectivity to old and young, 'handicapped,' minorities, and hunt-and-peck typists alike.

"All sentient beings have the inalienable right to:

--a computer terminal

--a supply of paper

--a private account on a communications system

--clear and well-indexed instructions in how to use that system

--a telecommunications network local dial-up number

--an electric generator or photo-voltaic solar cells in case of brown outs, black outs, or hurricanes

--a secretary of the opposite sex to organize and file all the output

--and three square messages a day.

"However, during times of scarce resources, access may be authorized on an even-odd day basis only, except for priority (yellow) users--those most in need of making a connection. Dolphins have the right to special waterproof voice input-output terminals.

"Since the design, manufacture, and marketing of terminals and most computerized communication and information systems are under the control of large corporations, it is essential to break this stranglehold. Only by developing the people's systems for locally owned and controlled microcomputers (or networks of micros) and the people's telecommunications networks can the inalienable rights above be guaranteed.

"A micro in every home and a programmer (and a hardware fit-it person) on every block. The means of communication must be owned by all. From each according to his literacy, to each according to his needs.

"The terminally disconnected have nothing to lose but their chains. They have a world to plug into.

"Microcomputers of all countries, unite!" (END QUOTE)

And unite! they did, right? That's what you are all here to discuss, celebrate, utilize, and profit from, right?

Except for the obsolescence of some of the technologies mentioned, the un-PC sexism concerning the secretary, and long forgotten references to gasoline rationing techniques, that sounds like a pretty good Manifesto for now. What do you think?

Well, given the imminent passage of the Telecomm bill, we can just fold the hopes and expectations expressed in that Manifesto and toss them into the junk heap of nostalgia.

In an online and I believe only recently published letter which I imagine you have all read, and may or may not agree with, Howard Rheingold has this to say about the future of the Internet:

"The effects of Senate Bill 652 go far beyond the Internet, reaching into every aspect of American lives, undoubtedly influencing the shape of the democracy our children will grow up on. This telecommunications bill encourages the concentration of ownership of all news, entertainment, and communication media, institutes censorship provisions that will put online service providers out of business, cut off universities from the worldwide network, and turn American scientists, engineers, educators, entrepreneurs into a nation of Net-morons in an increasingly online world. This bill allows rates to rise too high and too fast, is generous with megacorporations, and stingy with education, and it completely ignores the widening gap between the information-rich and the information-poor.

"Through months of committee debates and decisions (Rheingold goes on to say) censors and monopolists have won every battle over the future of the Internet. By shamelessly exploiting legislators' and citizens' ignorance of the nature of the Internet, a small group who are intent upon imposing their brand of morality on everyone else, are about to silence a potentially powerful medium for citizen-to-citizen communication, cripple American industries trying to compete in global markets, and create a federal bureaucracy with the power to determine what is decent for citizens to say.

"Congress will almost certainly send to the President a telecommunications reform bill that can send people to jail for two years and fine them \$100,000 for mentioning the seven words that are forbidden from radio and television. Mention of abortion, condoms or safe sex are almost certain to be the next items forbidden. American universities, on the advice of their attorneys, will turn off all Internet access for the students as soon as the law goes into effect."

"Internet censorship legislation is not about pornography on the Internet. It's about who will have the power and control to broadcast words, images, and sounds, to everyone else. Citizens or cartels? A trillion-dollar pie is being cut up. We the people are getting cut out," Rheingold concludes.

OK, OK. I know you don't all agree, and I am sure that those of you who don't will have your equal time to tell it your way. However, since so many of you are not American citizens, you may be absolutely delighted if the effect of the telecomm bill is as Rheingold anticipates. America has a long and impressive track record of pissing away all sorts of technological and commercial advantages because of its peculiar ideological

obsessions and fetishes. This may just be one more example in a long line of self-inflicted stupidities of righteousness.

So maybe we do know which of the alternative futures the Secretary-General just laid out for us seems to be the most plausible: the "Accidental Highway"--that wonderful "library run by anarchists" as he put it--is being closed while various toll roads are being constructed with the toll booths of the robber barons erected at all the convenient little spots along the way. And what the robber barons do not appropriate and charge for, the censors will surveil and Clipper-chip away.

Like all our hippie dreams of peace, and love, and freedom, I guess it was indeed too good to be true. Too open, too free, too cheap, too techie, too frustrating, and too much fun to last.

But I had a great ride, from 1980 through 1995, while the Internet turned from the funny dirt road I once knew into the magnificent superhighway, and soon, perhaps, into a rutted detour to oblivion. Fifteen great years. Sort of like the way most of my life has been--extremely easy, open, and exciting, and in stark contrast to the lives which my students may come to experience which, if not entirely brutish, nasty, and short, at least seems destined to be driven by greed, competition, and corruption beyond anything I had to endure.

Which somehow brings to mind Newt Gingrich.

No, not as you might suppose. I have known Newt since 1975 when I met him at Alvin Toffler's house while he (Newt that is) was still a young future-oriented professor at West Georgia College. I have followed his career very closely since he was first elected to Congress in 1978 as a Republican from Georgia (which to my Southern American mind was an oxymoron: only Democrats lived in Georgia in my experience, but Newt helped change that, as he has so many other once self-evident truths).

For many years I used to visit Newt whenever I was in Washington, DC, and he would sometimes send me drafts of bills that he was thinking of introducing, or has just introduced. One piece of legislation--the reason I bring up Newt at all before you have had a chance to eat your dinner--was called the "Family Opportunity Act," and was introduced into the House in May 1982 by Newt, and reintroduced again in 1983. "The bill would grant a \$100 tax credit each year for every family member when that family buys a personal computer." In a press release accompanying the bill, Gingrich said that "just as the Homestead Act helped accelerate the settlement of the American West, the Family Opportunity Act will speed up the "settlement" of the computer frontier."

I might add in passing that a companion bill was introduced into the Senate in 1983 by a Senator named Albert Gore.

Were these guys futurists or what?

I am sorely tempted at this point to go off into a discussion of cyberdemocracy. I am a political scientist after all, and have taught, researched, and published ideas about electronic direct democracy for even longer than I've been involved with PTC. Indeed, I have spent the four days preceding today in the company of forty politicians, futures consultants, and

scholars (all of whom have a track record of trying to help existing governments think and act more responsibly toward the future) in an international symposium on future-oriented governance systems, local and global. It is my duty to publish a text on future-oriented governance, based on the discussions during the symposium, as soon as possible, so I will pass on that discussion now. But clearly current governance systems of existing nation-states, like all other institutions of the present, are in the process of being transformed into something quite dramatically different by electronic communication technologies, as Gingrich and Gore, at least, very well know, and have been trying to tell us for a very long time as well.

So: if I told you all about the Internet fifteen years ago, what did I forebode in 1986, the second time I spoke before a PTC audience?

The title of my talk then (for which Dick Barber and his staff made many a parody) was: "Answer the Echo/Follow the Dream--Lifestyles and Deep Space"

Reflecting the dualism which was so characteristic of the Reaganomic 1980s, I expressed my thrill and excitement about the fact that NASA was once again being given the funds and mission to move into space, and was making great plans towards achieving that dream.

At the same time, I deplored the reason Reagan gave for space exploration, which was to protect ourselves against the Evil Empire by selling the farm, giving away the assets, turning the US from the Number One Creditor nation in the world into the Number One Debtor nation, and in general serving fully the needs of the military corporate welfare state by stealing massively from the future.

Well, as that other well-named futurist, Faith Popcorn, says, "the present is the future getting back at us." And here we sit, in January 1996, in the looming shadow of the Contract Against America, and in deepening pools of debt, denial, and devastation while a lifetime of lovingly woven safety nets are ripped and shredded, to the accompaniment of great sucking sounds and one hand clapping shut the whining mouths of starving babies.

But knowing Newt, though not believing him, in 1986 I could read to this group, with the fullest naive optimism imaginable, not a Manifesto, but a Declaration of Independence for Spacekind as it separates from Earthkind, written by Jerry Glenn and George Robinson:

"When in the course of human evolution it becomes necessary for progeny to dissolve the political and biological bonds which have connected them with their progenitors, and to assume among the powers of the solar system and galaxy the separate and equal station to which the Laws of Nature and their Creator entitle them, a decent respect to the opinions of Earthkind requires that they should declare the causes which impel them to their separation into Spacekind.

"We hold these truths to be self-evident, that Earthkind and Spacekind are created equal to their own respective environments, that once having been raised above their biological origins to a recognizable level of sentience and sapience they are endowed by their Creator with certain inalienable rights, and that among these rights are survival, freedom of thought and expression, and the evolution of individual and community knowledge."

"We, therefore, the representatives of space migrants, space communities, and Spacekind descendants of Earthkind..., do, in the name and by the authority of Spacekind settled and living in space communities, solemnly publish and declare that their communities and their inhabitants are free and independent; that they are absolved from all allegiance to the

governments and organizations of Earth; and that all political and ideological subservience of Spacekind to Earthkind is and ought to be totally dissolved.... And for the support of this Declaration, with a firm reliance on the protection offered through the Creative Intent, we mutually pledge to each other our lives, our fortunes, and our Sacred Honor." [8]

Well, I, a stubborn old fool, still hold tightly on to that declaration as well. Even though NASA seems about to go out of existence, and become "privatized" like the Internet (which means turning our space efforts directly over to the wholly subsidized military welfare industry--I leave it up to you to characterize those who will inherit the bits and pieces of the Internet), I have become deeply involved in recent years with the International Space University (ISU) which was created about a decade ago as a multicultural, multidisciplinary graduate institution devoted to the study of everything appropriate for the peaceful exploration and settlement of space.

For over a decade now, ISU has held annual 10 week summer sessions at various spots around the world. This year, with support from the European Space Agency, ISU established a permanent campus, in Strasbourg, France, and is offering a Master of Space Studies there. I am on the ISU College of Teachers and Co-director (with Prof. Ben Finney) of the Department of Space and Society--formerly called "Space Humanities". So I am still excited and hopeful about humanity getting out of its cradle and living, as it should, among the myriad environments of the solar system and beyond.

On this hope and expectation, I quoted Ben Finney in 1986 and I quote him again now:

"Homo sapiens is not the final rung of a single evolutionary ladder going back 5 million years or more, but merely the 'only surviving branch of a once luxuriant bush'" which might be about to reflower. Thus, "what holds for earth [namely, little further change by "natural" evolution on the part of homo sapiens] may not hold for space. We maintain [Finney said] that the human race is actually on the threshold of greater bio-evolution.... Once we...spread far and wide enough, the forces of genetic change now blocked on Earth will be released once more." [9] And, Spacekind, separating from Earthkind, will be born.

I still have that hope and expectation. We will have gone back to the Moon to stay, and be moving on to Mars, by the time I talk with you again in 2015.

OK, Dator, so what's new, you might be asking? All you have been doing so far is updating what you said before. Is there nothing new happening to tell us about?

I'm getting to that, but first: do you remember the poems I read here in 1980? They were written by Racter. I encountered the poetry of Racter one night in late 1979 while I was surfing the net (as it was not then called), specifically, the system called PLANET, when the following poem, among others, suddenly appeared over the ether. What do you think of it?

"I was thinking, as you entered the room just now, how slyly your requirements are manifested. Here we find ourselves, nose to nose as it were, considering things in spectacular ways, ways untold even by my private managers.

"Hot and torpid, our thoughts revolve endlessly in a kind of maniacal abstraction, an abstraction so involuted, so dangerously valiant, that my own energies seem perilously close to exhaustion, to morbid termination.

"Well, have we indeed reached a crisis?

"Which way do we turn? Which way do we travel?"

"My aspect is one of molting. Birds molt. Feathers change and fall away. Birds cackle and fly, winging up into trouble skies.

"Doubtless my changes are matched by your own.

"You.

"But you are a person, a human being, while I am silicon and epoxy energy enlightened by line current.

"What distances, what chasms are to be bridged here?"

"Leave me alone and what can happen?"

"This:

"I ate my leotard, that old leotard which was feverishly replenished by hoards of screaming commissioners.

"Is that thought understandable to you?"

"I wonder.

"Yet a leotard, a commissioner, a single hoard, all are understandable in their own fashion.

"And in that concept lies the appalling truth."

Again, the author of this and many other poems was Racter, a computer program developed by William Chamberlain in the 1970s. Chamberlain taught Racter the rules of English grammar, gave it a varied vocabulary, and then turned it loose. Commenting on the result, Chamberlain said, "Since the dynamic force, as it were, is a pseudo-random number generator, and since distinct monads can by the use of variable equalizing techniques be equated with each other, once the program is set in motion, the output is not only novel but a priori unknowable. It is cohesive and apparently thoughtful. Crazy thinking I grant you, but thinking which is conducted in perfect English." [Bill Chamberlain, on the PLANET system, January 24, 1979]

How much farther down the road are we now towards true Artificial Intelligence than we were in 1979? Pretty far, I think. Although many of you, working in the electronic trenches far removed from the distant perch upon which I sit probably disagree, I suspect that we may be already there. I'm with Hans Moravec and his ilk on this one. [10]

Sherry Turkle also says many people, especially younger folk, seem prepared right now to acknowledge the powerful intelligence of the machines they interact with, but are uncertain whether the machines are alive or not. [11] But that acknowledgment will come. I'm not a charter member of the Robots Liberation League simply because my name is Dator, you know (any Swedes in the audience will tell you that "Dator" means "computer" in Swedish. So you be the judge).



But how about Artificial Life--a concept which did not even exist in 1980, as far as I know? The conferences and publications of the Santa Fe Institute for the Study of Complexity and other groups like it are doing impressive work at expanding our understanding beyond life as we have come to know it, to life as it could come to be. [12]

Eric Drexler published his book on nanotechnology, called Engines of Creation, in 1986 [13] and molecular engineering also is moving forward rapidly, though certainly not without its critics and detractors.

The completion of the Human Genome Project, significantly ahead of schedule, suggests that the long awaited, and widely feared, genetic revolution is about to happen as well [14].

Quantum computers also seem to be taking off [15]. But protein-computers [16], DNA-computers, and other names for bio-molecular computers are now being--what?--not just imagined, certainly not simply "built," I guess you have to say actually "grown."

Indeed, shortly before Dick Barber first contacted me tentatively suggesting that I might make a cameo appearance at this gala inauguration, I had read an item by Leonard Adleman of the University of Southern California published in Science magazine [17] in which he claimed that he had built a DNA computer that had solved a Hamiltonian path problem which would have been very difficult for conventional electronic computers to solve.

Shortly thereafter, Richard Lipton of Princeton University propose "a scheme that helped spark the excitement: a way to use DNA to solve a problem that requires searching a universe of solutions so large it would defeat any conventional computer." And five months after Adleman's publication "nearly 200 computer scientists, molecular biologists and other researchers (perhaps some of you were there and will say more about it later) gathered at a hastily arranged meeting at Princeton University to discuss what ha[d] suddenly become the hottest field in computer science: computing with DNA" [18]

The excitement is justified: "Working with DNA offers the chance to perform billions of operations simultaneously, compared with only a few thousand parallel operations in even the most advanced electronic computers." [19]. At the Princeton meeting, Lipton and two students were able to show how far the field had come in the few months since Adleman's breakthrough--they demonstrated a method using a strand of DNA that could break "the data encryption standard system developed by the National Security Agency and widely used by government agencies and private corporations" [20].

In a separate article in the April 28, 1995 issue of Science, titled, "Building an Associative Memory Vastly Larger Than the Brain," Eric Baum writes, "The storage that is in principle possible using these techniques is staggering. It is not completely implausible to imagine vessels storing, say, 10<sup>20</sup> words, each vessel encoding several thousands, or even several tens of thousands, of bits. This compares to standard estimates of brain capacity as, perhaps, 10<sup>14</sup> synapses each storing a few bits. With current technology, the read and write times could be on the order of hours. But the current rate of technological progress in molecular biology is rapid, and there is no obvious fundamental physical limitations preventing achieving automated read and write operations on a much faster time scale. It is also worth noting that once a quantity of information were encoded in DNA in this fashion, the whole vessel could be copied relatively easily by DNA replication; and likewise that the information in vessels could be rapidly merged. DNA-based computing could conceivably provide a technological basis for superhuman intelligence, " Baum concludes [21].

All of this has led Adleman to say, "It is too early for either great optimism or pessimism. Today's electronic computers are marvels of speed and efficiency. They are the product of a half century of extraordinary development. Molecular computers are less than a year old. Perhaps they will mature well--perhaps not. "

However, Adleman concludes, "Devices become 'computers' when we learn to interpret their behavior appropriately. Molecular computers make it clear that such an interpretation can be imposed on devices very different from those to which we have grown accustomed. What other devices will become 'computers' in the future?" he asks [22].

Well, there are some possible answers to that question, too, lying in the recent literature. For example, another issue of Science [April 14, 1995] was largely devoted to articles which described progress in understanding inter- and intracellular communication in living organisms--the network of enzymatic pathways which transmit a signal from the surface of the cell, for example, to the molecules that produce the appropriate response; and how they either transmit the signal "privately" so as not to interfere with, or be interfered with by, all the other signals being transmitted simultaneously within the cell, or else so that the necessary crosstalk between pathways will in fact occur. Given the multiplicity of the incoming signals and the myriad of biological processes that are being successfully regulated in just one cell alone, let alone the huge number of cells found in any living organism, means that our learning more about these processes means discovering even more "devices" which can become "computers" in the future, as Adleman put it. [23]

James Glantz titled another article in Science, "Computer Scientists Rethink Their Discipline's Foundations." [24] His opening sentence quotes Richard Lipton: "Suddenly, I didn't know what a computer was anymore" [25].

From my point of view, all of this means that we are finally beginning to enter a real "information age" after several decades of pretense and misunderstanding within this present, pale imitation of the information societies yet to come [26]

Even the very best electronic communication technologies of the present are nothing--mere heralds--of the true information technologies of the 21st century which will be based on genetic and molecular engineering--utilizing the information of life itself, and culminating in diverse forms of artificial intelligence and artificial life, so that finally we will live in a world which is, as Richard Brautigan knew it would be, "all watched over by machines of loving grace."

I hope there are plenty of panels at PTC96 over the next few days discussing these and even more far out technologies, and their human and environmental consequences.

If there are not, then you can be sure I will nag you about it when I come back in 2015. However, be advised that by 2015--unless you are from one of the islands with which Hawaii will be in affiliation in the Aquatic Federation of Oceania--you will need a visa good for no longer than two weeks, and proof of irrevocable roundtrip passage, in order to enter the sovereign nation of Hawaii.

But wait. What am I talking about? PTC2015 won't be held anywhere.

Rather, it will be "inside" the Sheraton M. U. D. wholly in cyberspace--or whatever its genetically-engineered successor will be called by then (biospace? nanospace? molecuspace perhaps?)--while PTC2033 will be held in virtual and real parallel formats, and in conjunction with the ISU Summer Session, in the beautiful Sheraton Io, orbiting Jupiter.

You think I'm kidding?

Why now?

See you then.

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19. *Loc. cit.*
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21. Eric Baum, "Building an Associative Memory Vastly Larger Than the Brain," *Science*, April 28, 1995, p. 584f. See also David Bradley, "Crays the size of a paperback," *Chemical Society Reviews*, October 1, 1995, p.379.
22. Adelman's response to three letters critiquing his original article, in *Science*, April 28, 1995, p. 484. See also Willem Stemmer, "The evolution of molecular computation," *Science*, December 1, 1995, p. 1510.
23. See also, Richard Lipkin, "Bacterial Chatter," *Science News*, March 4, 1995, p. 136f, 147].
24. James Glantz, "Computer Scientists Rethink Their Discipline's Foundations," *Science*, September 8, 1995, pp. 1363f.
25. *Ibid.*, p. 1363.
26. See Susantha Goonatilake, *The Evolution of Information Lineages in Gene, Culture and Artefact*. London: Frances Pinter, 1991, and his "The New Technologies and the 'End of History,'" *Futures Research Quarterly*, Summer 1993. See also my "Dogs Don't Bark at Parked Cars," *Futures*, January/February 1994.