

2003

# The future of human nature: a symposium on the promises and challenges of the revolutions in genomics and computer science, April 10, 11, and 12, 2003

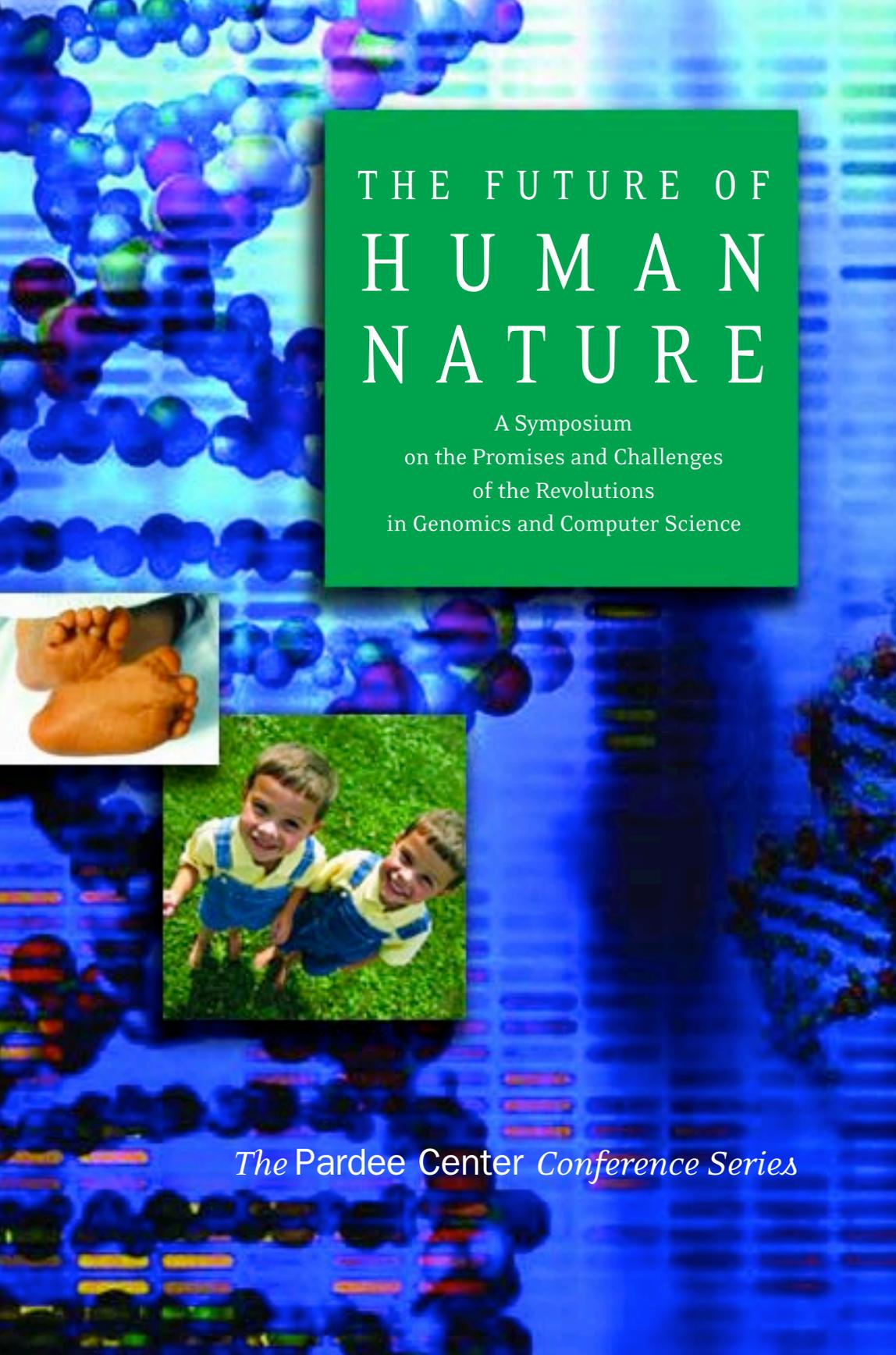
Annas, George

Boston University Frederick S. Pardee Center for the Study of the Longer-Range  
Future

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*Boston University*



# THE FUTURE OF HUMAN NATURE

A Symposium  
on the Promises and Challenges  
of the Revolutions  
in Genomics and Computer Science



*The Pardee Center Conference Series*



*Frederick S. Pardee*

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THE FUTURE OF  
HUMAN  
NATURE

A Symposium  
on the Promises and Challenges  
of the Revolutions  
in Genomics and Computer Science

April 10, 11, and 12, 2003

Co-organized by

Charles DeLisi

and

Kenneth Lewes

Sponsored by

Boston University

The Frederick S. Pardee Center

for the Study of the Longer-Range Future

David Fromkin, Director

Pardee Conference Series

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## FOREWORD

Technologies drive change. The printing press, the railroad, the automobile, and the many other technologies that make modern life possible have all, to varying degrees, altered demographic patterns, shifted the distribution of wealth and social caste, and affected the international power balance, influencing our lives as individuals and as a society. In the twentieth century, life itself has been markedly extended by applying the methods of civil engineering to large-scale waste removal and water purification, and biomedical technologies to the search for disease targets and associated therapeutics.

Until recently, the technologies of the modern age have been based largely on the mechanical and electrical properties of matter; they have acted upon the quality and style of life of individuals and societies but have had relatively little effect on human nature.

The twenty-first century will see the emergence and influence of at least two major technologies: computer science and genomics. The one deeply rooted in communication, the physical sciences, and the cognitive sciences; the other emerging from chemistry and biology. The intersection of the two, and each on its own, can have profound consequences not just on the quality of life as we know it, but on the nature of life itself—on its shape and form, on what it means to be human.

### **BACKGROUND**

The importance of considering the social, political, and economic ramifications of technology is widely recognized, and so-called technology assessment studies are common, if not enlightening. Indeed, the federal government has responded to the genomic revolution by substantially increasing its support for research into the social implications of the new biology.

Although this support has led to important developments in such areas as patents, insurance, privacy, and civil liberties, most prognostications have been rather short-ranged, limited to ten or twenty years. Some of the deepest implications of science, however, are relevant to technologies that are not likely to be viable for several generations. Serious discussion of this longer-range future is uncommon.



## GOALS

Our conference focuses on scientific and technological advances in genetics, computer science, and their convergence during the next 35 to 250 years. We are especially interested in directed evolution, the futures it allows, the shape of society in those futures, and the robustness of human nature against technological change at the level of individuals, groups, and societies.

We take as a premise that biotechnology and computer science will mature and will reinforce one another. During the period of interest, human cloning, germ-line genetic engineering, and an array of reproductive technologies will become feasible and safe. Early in this period, we can reasonably expect the processing power of a laptop computer to exceed the collective processing power of every human brain on the planet; later in the period human/machine interfaces will begin to emerge. Whether such technologies will take hold is not known. But if they do, human evolution is likely to proceed at a greatly accelerated rate; human nature as we know it may change markedly, if it does not disappear altogether, and new intelligent species may well be created. The goal of our symposium is to bring together leading scholars with diverse views from the humanities and the social and natural sciences to reflect on the following:

- The feasibility and safety of technologies related to directed evolution, including but not limited to germ-line gene engineering, human somatic cell cloning, and computer interfaces with the central nervous system;
- The social factors that are likely to affect the adoption of these technologies;
- The consequences of adoption for the individual, the family, the nation, and the world;
- The extent to which we can sensibly discuss the above, and the assumptions we are making in such a discussion.

—Charles DeLisi and Kenneth Lewes

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**SESSION ONE**

Kenneth Lewes

*Prolegomena*

Welcome. We hope in the next few days you will hear more ideas and possibilities than you can possibly handle. Although we constantly hear about the benefits that the future will bring us, a coherent and broad view of technological progress is not readily available. Since we fully expect that some of the projections to be presented here will verge into the realm of science fiction, you might find it helpful if we suggest some ways of ordering and evaluating the welter of facts and speculation you will soon hear presented.

This conference was stimulated by an exchange of letters in 1933 between Albert Einstein and Sigmund Freud on the prospects of eliminating war from human experience. Einstein expressed a hope that human beings might be able to resist another regression to a primitive way of settling conflicts between nations. Freud, however, remained pessimistic for two reasons. He thought that the obstacles in the way of international agreement were too substantial to be overcome. But, more important, he thought that the impulse to destruction was inherent in human nature itself.

A consideration of current news, as well as a survey of recent cultural developments, suggests to some people that Freud may have been right. If so, it raises some difficult questions that are directly relevant to some of the presentations we will hear during this conference. Specifically, we must consider the complex relation of our progressive and increasing scientific knowledge of the world and its resulting technologies to what has up until now been our essential human nature. In these terms, is the recent astonishing progress in science and technology to be welcomed as the promise of a new Eden or dreaded as the threat of a terrible nightmare? Should human beings be entrusted with the power that science offers them? Or, on the contrary, have the age-old limitations on human power been a protection from our own capacities for hatred and destruction?

One source for hope is the possibility that science, in the near future, may be able to change human nature itself. This may happen by eliminating certain destructive traits or by enhancing others. Or it may occur because the abundance



that technologies can offer us will make greed and competition no longer necessary for human survival. Yet even this hope brings along with it its own dread. The brave new world of the future may finally prove to be a horrifying dictatorship or a bland, intolerable state of boredom.

The very question of human nature, though abstract, impinges directly on our ability to imagine and plan for a future. Are there constraints placed on possible developments by essential components of human nature? Or perhaps the very nature of a human nature that transcends historical conditions is no longer a useful idea and has been rendered obsolete by the promises of science and technology. But if we discard the idea of an essential human nature, we are then left with no apparent way of measuring, judging, or controlling the future as it comes near. We are very far from being able to formulate these questions satisfactorily, let alone provide a useful answer to them.

Another difficulty that arises if we think that science can change human nature is trying to anticipate what will determine the shape and direction of scientific and technological progress. Science, of course, possesses its own internal determinants of what direction it will take. Nature and the world out there provide others. But equally powerful ones are generated by politics, social institutions, and economics. It is important to remember that scientific and technological progress, which seems to us so ineluctable, can be changed, redirected, or completely stopped by changes in the culture. The kinds of critical questions that once provided the themes for Victorian science fiction are turning into the reality of today. We must learn to look at them with a seriousness and steadiness that they never demanded of us before.

**SESSION ONE**

Charles Cantor

*Human Evolution at the Crossroads*

One hundred years ago, DNA was unknown. Today we know the entire DNA text of several human beings. Similar data exist on many model organisms. We have gained the ability to manipulate this text almost at will in organisms even as complex as mice. In the next few years our ability to do this will extend to humans. This means that we can now direct and accelerate human evolution along any paths we deem desirable. Hopefully, our wisdom in choosing these paths will match the power we have gained in using them. It seems an inevitable consequence of evolution that some species eventually reach that key threshold where they control their own evolution. This is now where we are.

The easy choices are to improve our quality of life by reducing the costs and discomforts of the major diseases that today affect mankind. Surely this is not controversial. However, there may well be differences of opinion whether the ultimate goal is a longer life span or a more disease-free existence at the current average life span. The hard choices are what human properties do we enhance and which do we leave as is. That we will shortly have such choices is astounding, but the implications are profound. Should we enhance our olfactory capabilities, offer the capability for regeneration; produce enhanced cognition; more efficient interfaces with computers, wireless communication? In my crystal ball, boredom could easily become the major scourge of an advanced human species; yet surely we will find ways to keep fascinated or engineer ourselves around this dilemma. Do we want to travel to far distances in the galaxy? Both boredom and radiation sensitivity will need to be overcome to make this feasible.

In my talk I will give an overview of the methods currently available to direct human evolution: their current limitations, and the likely time scales needed to overcome these limitations. But based on past experience, any projections I make of the timing and magnitude of directed human evolution will be far too conservative. I will illustrate this dilemma with the current explosion in the rate of discovery of the genes that underlie complex human disease.\*

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If I had given this talk ten years ago, my conclusions would have been the opposite of those I come to today. I would simply have said, “None of this will ever happen. We will never allow it.” Many individuals and institutions today share my previous pessimism. Both the CIA and various think tanks for defense intelligence are concerned about the risk that technology will destabilize society as we know it. At the other end of the spectrum, there are the venture capitalists who are concerned with how they are going to make money on the new technology. Everybody tends to see these developments from his own narrow perspective, but the time has come for us to try to think outside the box. In my own thinking on this matter, I have found modern fiction to be very provocative and eye-opening.

A major cornerstone of modern biology is evolution. In its classical formulation, the fittest species survive. This notion of fitness is really quite a boring idea. All that matters is the number of fertile offspring. We must remember, however, that evolution takes place in a fluctuating environment and is not a continuous, gradual process. It proceeds in fits and starts. That other thing to remember is that the present is not the termination and end-all of the evolutionary process. Not only has evolution not stopped, but it probably is about to go much faster.

All of us—every species—is essentially a convolution of genes we are dealt at birth and the environment we experience starting at conception. Any attempt to predict on the basis of genes alone—or the environment alone—is doomed to failure. This has always been true, but the notion of evolution is changing. We are still interested in the best genes for a given environment, but we now control the environment. And, as a result of sequencing the human genome and the growth of genetic engineering, we now control the genes. Our species is no longer simply buffeted by the environment; it now controls it. That is the power we now have. In other words, natural selection no longer determines the evolutionary process; artificial selection does.

One hundred years ago, DNA was unknown. Fifty years ago, before Watson and Crick, we did not know that genes were DNA. Today, we have the entire DNA sequences for some species and understand many of their rules. What will our knowledge and technology be like in fifty years? Based on my own prediction

and experiences, I would say that any prediction, even the most outlandish, will prove too conservative. The Human Genome Project gave us a map with an interstate highway system on it that you could not really use to find anything specific. Now we can find anything we want, and we can do it rapidly.

In my own organization, Sequenom, we discover genes that underlie complex human traits and common, complex human diseases that affect everyone. In the last eighteen months, we have done more human genetics than has been done in the history of the planet. The automated system we have developed makes up to two hundred thousand human genetic measurements a day. Using it, we have discovered genes that underlie many of the diseases we care about: skin cancer, cardiovascular disease, breast cancer, adult diabetes, HDL, osteoarthritis, lung cancer, schizophrenia. We are finding genes that account for about twenty-five percent of each of these diseases. An indication that we are on the right track is the fact that, using blind studies, we have rediscovered genes that we already knew were implicated in several diseases.

A major implication of these developments is that medicine will have to change in dramatic and essential ways. This is because the inherited differences that predispose us to disease will have to be addressed. This will require individualized therapy. At least half the targets we find responsible for human disease are not addressable using traditional therapies. Instead the medicine of the future will seek to contain disease using gene therapy. Medicine will move from a reactive mode to a preventive one. The least controversial of the new gene therapies is somatic, where a virus or stem cells are used, but do not enter the germline and so are not inherited. Their effect is merely palliative. They disappear when the organism dies. More problematic, however, because it is permanent and inheritable, is the use of embryonic stem cells. These changes are passed on to the offspring.

I think it is only a matter of time before human cloning and human germline gene therapy become fairly standard. There are, however, cultural traditions standing in the way of this development. Generally speaking, European traditions are suspicious of, if not hostile to, genetically modified organisms. On the other hand, China and India are extremely enthusiastic about the possibilities.



In some provinces in northern India, the sex ratio at birth is four males to three females. The premier of China is on record as having said, “We will use genetic engineering to change our people to reduce our health care costs.” It will not be possible to stop such development. The driving force behind them is economics.

I do not know if it will be possible to develop a uniform set of rules regulating this kind of technological development. But the person who directs the selection is potentially the survivor. Nevertheless, it is not so difficult to make predictions about some of the things we should not do. First, we must be careful not to go down the road to homogenization. Evolution always favors diversity, because it allows for survival in case the environment turns sour. Homogenization is also very boring, and I think we have to be very afraid of being bored in the future.

If one of us could take a trip forward two hundred years in a time machine, I am not sure he would be able to recognize humans, they would have changed so utterly. We have the tools today not just to control evolution, but to speed it up in a massive way. The cat is out of the bag. Evolution is in our hands. I only hope we have the wisdom to use it wisely.

## **SESSION ONE**

Lee Silver

### *The Inevitability of Human Genetic Enhancement and Its Impact on Humanity*

Incredible advances in reproductive and genetic technologies will someday provide prospective parents with the ability to enhance their embryos so that their children can be born with genetic advantages that they themselves do not carry. This technological leap into “reprogenetics” will be the most important in the history of humankind because it could change the very nature of the human species. There is much debate about both the science and the ethics of human germ-line genetic engineering. Some scientists claim it will never be possible to develop the technology for use in a safe way. Many bioethicists believe that even if safety concerns are overcome, it is still unacceptable to “tamper” with a child’s genes, even to combat disease. I will argue that recent scientific advances leave no doubt about future technical feasibility. I argue, as well, that nearly all of

the objections raised by bioethicists are logically inconsistent or based on narrow religious beliefs. Instead, I believe the fundamental ethical dilemma is rooted in the conflict between individual autonomy and social equality. Principles of social equality might lead a society to reject the use of a technology that could greatly widen the gap between affluent and nonaffluent segments of humanity. In America, however, principles of individual autonomy and noninterference into private family matters are paramount. And the natural desire of parents to give all possible advantages to their children will be the driving force of reprogenetics. Each individual use of reprogenetic technology may have no effect on society at large. Indeed, in affluent societies, the technology could become quickly affordable to the middle class, and may even be promoted institutionally as a way of reducing long-term societal health care expenses. But as genetic enhancements accumulate from one generation to the next in affluent countries, the gap between affluent and nonaffluent countries could widen unimaginably until our species commonality is irrevocably severed. The only alternative seems remote today and it may never be viable: a pan-global health maintenance system which provides all human children with the same genetic protections and the same opportunities for health, happiness, and success.\*

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In a liberal, democratic society, like the one we live in, individual parents have the choice about what they do with their children. For example, they may spend \$150,000 to send their children to first-class universities, all for the chance of providing their children with an advantage to succeed in life. In the near future, we will see the technology which depends on our knowledge of DNA combine with reproductive technology to give us reprogenetics, reproductive and genetic technology, which will be able to ensure or prevent the inheritance of particular genes in children. While there is a danger that governments may tell people what to do with their children, it is more likely that individual parents will be deciding what is best for them.

In the past, many eminent biologists doubted that genetic manipulation of the kind we are discussing would ever be possible, primarily because of the infinitesimal sizes involved. We now know that it can be accomplished, and, in several



cases, already is. Other doubts have arisen based on the margin of error involved. Advances in technology, however, allow us to operate within acceptable risks. In fact, very soon reproductive technology will operate at levels of risk below that of natural sexual intercourse. Other doubts arise from religious and philosophical objections to reproductive technologies and involve vague ideas about the human soul or hesitations about taking on responsibilities that traditionally have been left to divine power or the operations of chance.

Even people who espouse these philosophical objections are less clear when they are faced with the specific choices that will become available to them. In the United States there does not seem to be a consistent preference for the gender of children; in other places in the world, there is. Most people, however, agree that the prevention of disease in children is an appropriate aim. It is also only natural for parents to wish to endow their children with advantages, especially those that will affect their children's economic success in later life.

There are several common examples of genetic manipulation that occurred long before the discovery of DNA, which people accept almost as a matter of course. The diversity of breeds of dogs with different physical and mental characteristics, all from a single species of gray wolf, is a case in point. Another is the development of modern corn from a weed that once grew in Mexico. In addition, wool does not exist naturally, but was bred over centuries from a goat that was hairy. Recently, more sophisticated engineering has made it possible to increase the size of the cerebral cortex in mice. It is rapidly becoming possible to control the distribution of certain traits that affect future economic success for individuals. Height is an example. Should parents be able to determine characteristics like these in their children? The natural distribution of traits is inherently unfair. So is it unfair to control the distribution by choice and planning? Similar arguments apply to susceptibility to disease, as well as to athletic, artistic, or intellectual ability. Americans will ask, "Why can't I give my children advantageous genes that other children get naturally?" The issue boils down to who will do the selection: God, nature, chance, the government, or parents. Parents should be able to choose what they want for their children as long as they do no harm to them.

It can still be asked if we are going to change human beings in an essential way. With respect to the changes we have been discussing, we are not really changing human nature, but only the frequencies of alleles in the population. Two things basically define us as humans. One is the way we look, the other the way we think. It is unlikely that the appearance of human beings will change in the future beyond small, superficial characteristics, since it is essential that human beings continue to find each other attractive. As for mental abilities, it is unlikely that natural selection itself will change that, since smarter people do not have more babies.

The issue of who will choose whether to enhance children genetically is very difficult. At one extreme, the government can provide such services to all its citizens. At the other, it could be left up to individual parents and their economic condition. It is most likely that in the future there will be a widening gap between people, especially those in rich and poor countries. Generation after generation of genetic enhancements could accumulate until humanity finally separates in distinct species. This, however, is not a scientific question, but a social and political one. Scientists do not really control technology. It is people and governments who use scientists and determine how all these technologies will be used.



## SESSION TWO

Marvin Minsky

### *What's Wrong with People?*

ABSTRACT NOT AVAILABLE

I will start by talking about what is wrong. If you make a list of serious problems, you see that most of them are due to there being too many people. That includes problems of garbage disposal, disease epidemics, the depletion of natural resources, the disappearance of biodiversity, and the distribution of wealth. One solution would be to reduce the size of people from six feet to six inches. That way you could get a trillion people on the planet with less pollution.

Or we could reduce the size of neurons. Neurons might be filled with stuff they do not need, and you could simplify them. Or if you could reproduce people's minds on computers, you could probably store the total amount of human memory on a CD. There's no evidence that people have more than 100 megabytes of knowledge. Nobody knows how to figure it out, but we have 50 trillion synapses. In any case, although neuroscience is doubling every few months, we still do not know simple things, like how memory works in any high-level sense.

There are also alternatives to traditional ways of having children and living in families. When we understand what the genome contains, we could make forty-six people. A fairly simple form of genetic surgery would be to decide which are most important to you. Instead of implanting a whole nucleus, you ought to be able to implant carefully selected chromosomes, so that forty-six people altogether could have fifteen or twenty children. Then everybody would have lots of relatives and live in a big family, and each person would reproduce for every two in previous generations.

My major point is that although there are many serious problems, we are not smart enough to solve them. Right now it takes about 100 years to learn biology. People do not live long enough to understand and solve biological problems. Maybe we need to figure out how our minds work and put them in computers. That has lots of advantages. You could live forever, since you can replace parts. And there would be all sorts of wonderful enhancements you can get through fairly simple biotechnology. People could communicate better, assuming you can

translate between one private mental language and another, and international travel could then be banned, because you could simply e-mail yourself to any place without the risk of spreading diseases.

One of the problems with smart machines is that the first thousand of them would be wildly insane. After all, a very large percentage of people are quite crazy, infested as they are with systems of memes called religion. Still, we may well ask why we do not have artificial intelligence. So far, there has been a lot of progress making machines that understand things in particular domains and specialized areas. But around 1980, people discovered that, with the exception of certain little pockets of mathematics, computers could not solve hard problems. No computer can understand a first-grade children's story. People then tried inventing machines that would get smart, but nothing came of it.

Computers do not really think. A lot of people are trying to figure what consciousness is, but, in fact, it may not be anything at all. Instead, there are twelve or sixteen things that the mind does, each of which is pretty complicated, like remembering what you just did. Other functions include envisioning different possibilities, explicitly formulating plans, or comparing results. Looking for a single answer or a single function is not going to be successful. Still, there are lots of fads. The worst is building those stupid little robots, which concentrate on doing something with minimal degrees of freedom.

Similarly, the interest in logic is misguided. It is too rigid and inexpressive. Nobody has gotten a logical system to make even childish analogies. And most of thinking involves using analogies. Machines, to be effective, should do their thinking in a natural language, like English, where each word may have a dozen meanings and contains metaphors that have been evolved by millions of people for thousands of years. Ambiguities allow you to change an approach a little bit and not get stuck in a problem. Logic is appropriate in the world of mathematics, but not when you are learning by example and analogy.

There has been some recent work on how to get common-sense knowledge into computers. At first they tried logic, but quickly ran into problems. If you try to make an orderly hierarchy without sufficient cross connections, you get two rather similar things very far apart on the tree, because of the differences



between function and structure, for example. I concluded that you should classify knowledge by the kind of problems it can solve. As yet, we do not have a classification of that sort.

Thinking must have evolved into many ill-defined states. Bacteria have many programmed reactions, but cannot solve a problem by imaging two different actions, envisioning the results, and then comparing them. That is what humans and some primates do on the deliberative level. We need all these different levels, not some magic bullet that tries to do everything.

My own general scheme looks a little like Freud's, who was the first to make a sophisticated architecture of how the mind works. In all cases, there is an expectation of what should happen, but then there is a bug. I am not looking for a general, elegant solution that has just a few parts. Instead, I think in terms of a large computer system that works pretty well but has bugs. Then people fix the bugs. That is what evolution does.

## **SESSION TWO**

Christine Peterson

### *Preserving Human Nature: Peaceful Coexistence Among Diverse Entities in a World of Hyper-Advanced Technology*

It is possible to make potentially useful projections regarding technological developments in the 50-to-250-year time frame, but strong discipline is needed to avoid our natural tendency to focus on nearer-term issues. Organizers of the Conference on the Future of Human Nature are hereby encouraged to continually redirect the group into discussing the desired time frame. This will be difficult given the senior level of many participants—not to mention their independent natures—but it will be necessary in order to make any progress on the challenge before us.

Serious forecasts in the target time frame must include what we would regard today as extraordinarily advanced technology. If our scenarios do not “sound like science fiction,” we will have failed at our task.

For purposes of this essay, human nature can be thought of as the set of characteristics our species has shared for millennia in the past. Rather than specify these in more detail here, we'll borrow the famous judge's quote on another topic: “We can't define it, but we know it when we see

it.” The case presented here is that it should be possible for our species to continue into the long-range future, where, by definition members of “our species” are entities sharing what we think of today as “human nature.”

### **Assumptions**

The assumptions we need to make in order to have any coherent discussion of the 50-to-250-year time frame include the belief that some tools we use today will still be applicable, e.g., the laws of physics, the laws of economics, and the laws of human nature—this last defined above to be roughly stable for current purposes. Our understanding of these laws changes over time, but to have a discussion now we need to assume that some of today’s tools will still be useful in the future.

### **Technologies of Matter and Information**

Our understanding of human nature today includes the fundamental tendency of some members of our species to do creative engineering: to make new technologies, both physical and informational. This, combined with the laws of physics and economics, is expected to lead to a capacity for total control of the structure of matter, down to the individual atoms. Results should include systems of molecular machinery which are more complex than those evolved by nature. Time estimates on the nearest end of our 50-to-250-year time frame; many expect it even earlier. Terms for this include: molecular nanotechnology, molecular manufacturing, and “strong” nanotechnology. It can be regarded as a highly advanced form of artificial “dry” biotech: molecular machine systems under external design and control, with a level of complexity equivalent to, and even beyond, today’s most complex such systems (ourselves).

One result of this technology should be computers of mind-boggling raw computational ability: at a minimum, the power of a billion of today’s desktop machines in the volume of a sugar cube. Raw power does not automatically translate into machine intelligence, but combined with evolutionary strategies in software, we can expect computational entities with human-level intelligence to arrive on the near-term end of our 50-to-250-year period. Unlike humans, these entities should be able to “think” together in a tightly integrated way, so we should assume that shortly after arrival they will surpass us in raw intelligence.



In considering the future of directed evolution of our species in the time frame of interest, we need to keep in mind these other technological developments. Our species' technical ability to change the structures of ourselves and our offspring should be far in advance of germ-line genetic engineering and human somatic cell cloning. It should be possible to construct tissues and organs without using biological mechanisms at all, if desired. Changes more extreme than those encoded, or even encodable, in DNA should be technically possible.

A major benefit of these abilities is that it should become unnecessary to implement genetic changes on future generations, regardless of how disastrous a given gene is. Rather than tamper with DNA, the needed change could be implemented directly, enabling health without altering genes. The problem gene would remain in place, with its undesired operation compensated for in other ways. One early application we should expect is computer interfaces with the central nervous system; crude efforts at this are underway even today, in attempts to enable the blind to receive visual signals. Given the level of technology expected in the 50-to-250-year time frame, we should assume that these interfaces will become seamless, and that what will appear externally to be a standard human body may contain computational power many orders of magnitude beyond today's humans. A minor result is that sense data reaching such an entity should be assumed to be recorded internally, regardless of copyright rules.

### **Eastern vs. Western Attitudes**

In speculating on the social factors affecting the adoption of various directed evolution technologies, we can build on observations of early patterns seen today. Germ-line engineering, reproductive cloning, and even stem cell research are controversial in Western countries, roughly correlating with the prevalence of Christian-based values. In contrast, countries whose belief systems have other bases, especially much of Asia and the Middle East, are not finding these technologies so objectionable and are moving forward. (An exception is the Chinese Academy of Sciences ban on reproductive cloning, for reasons of "ethical morality." In contrast, stem cell research is actively encouraged in China, Saudi Arabia, and Israel.)

However, as sketched above, in the 50-to-250-year time frame we can expect to move beyond controversial biological techniques to those which fix problems without changing DNA or harming embryos. Western ethical objections may decrease.

Today we are seeing ambivalence in the West toward technologies that promise major changes in the human body, such as the distinct-but-related goals of extending human life span and improving human performance significantly. Today's U.S. administration includes both ethics advisor Leon Kass, who opposes life extension, and nanotechnology initiative leader Mihail Roco, who advocates human performance enhancement. From this we can speculate that deep controversies can be expected in the West on whether "improving" the human body should be publicly funded, or even permitted. But again, it is not clear these issues will be controversial in much of Asia, where a "full steam ahead" attitude may well prevail. If these technologies are seen as militarily or economically important—highly likely—the West may feel forced into moving forward in parallel, regardless of disagreements.

### **The Goal: Peaceful Coexistence**

Given the seeming inevitability of a wide variety of entities in the 50-to-250-year time frame—including traditional humans, augmented humans, and machine-based intelligences—an obvious goal is to work for peaceful coexistence. This would include ensuring that the use of augmentation technologies is voluntary, and that the physical security and assets of humans are protected against coercion. A subgoal would be that traditional human families and communities continue to be able to live as they choose, without either physical force or confiscatory taxation levels making it impossible for them to live by their traditions.

How can this be accomplished in a world with entities that are far more intellectually (and, presumably, economically) powerful than traditional humans? Our species already has some experience in handling such entities: our governments. The best answer found to date seems to be the use of checks and balances. Additional insight can be obtained from the field of strategy known as game theory. Preliminary theoretical work has been done on this issue by nanotechnology theorist K. Eric Drexler and is now being written up for publication.



## Summary

In the 50-to-250-year time frame, we can expect advanced molecular manufacturing and machine intelligence to far surpass near-term biological directed evolution techniques. Military and economic competition will drive these technologies to be used by nations which desire to remain in positions of technological dominance. The goal becomes to protect the safety and assets of traditional humans, i.e., those who exhibit what we today call human nature.\*

Special thanks to Foresight chairman K. Eric Drexler for advice on this essay.

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I will try to be as outlandish in my projections as I can here, but I nevertheless think that my ideas are probably too conservative. Things will change radically. The question we need to consider, therefore, is not “Can we change human nature?” but “How can we preserve it?” Whenever one thinks about progress in the next two hundred years, one begins to sound like a science fiction writer. This is not entirely unfortunate. Many of them spend a lot of time thinking about these subjects, and some of them are not stupid. Some of them have backgrounds in physics and biology.

I am not prepared to say exactly what human nature is. I will just say that it is a set of characteristics that we have had for quite a while. So assuming that people are not going to change very much in the next 250 years, let us start with some basic things we already know about people. First, people want more money. Second, there is also the tendency of a subset of our species to do creative engineering and push technology forward. If you add these things up, what you get is technological advance to the limits allowed by nature. Estimating time limits is more difficult. But applying Moore’s Law to technological progress, we estimate that we will achieve total control of the structure of matter down to individual atoms by 2017.

In the near future, we can look forward to molecular manufacturing. Today we have already achieved atomic precision at a very minute scale. We can also make large, complex structures that are not atomically precise. The goal now is

to do both—to build anything we want, no matter how big, and control it down to the atomic level. The most exciting application of this technology will be to the human body. We will be able to tackle all diseases and aging. To do this, we will be inspired by the way living systems work. After all, we are systems of molecular machines, with little machines inside us. We are beginning to understand and control these processes.

Beyond that, we will arrive at the point where we will not have to model ourselves on natural machines any longer. Instead we could design quite different machines. The difficulties, of course, are great, but the payoffs are immense, both economic and military. Presently we are able to design machines whose parts consist of individual atoms and molecules. Machines such as these give us enormous raw power. We will soon be able to put the equivalent of one billion desktop computing machines into the volume of a single sugar cube.

Combining this kind of raw power with evolutionary strategies, we will be able to understand how evolution created intelligence, and, being able to duplicate it on whatever level of detail is required, we could do it all over again. That would give us human-level machine intelligence that is far smarter than we are. We could also construct tissues and organs without using natural biological mechanisms to do so. An artificial liver, for example, would do everything that a natural liver does, but not look at all like a liver. We would not have to worry about how these artificial organs might change the way we look, since all of them would be internal.

These developments bring up certain ethical questions. One of them concerns passing permanent genetic changes on to our offspring. One solution would be confining ourselves to non-genetic changes to our children and deferring genetic changes until they are old enough to decide for themselves. Such changes might involve the integration of machines into humans or implanting chips into people. When nanotechnology is fully developed, we can expect seamless integration. So the human body, which will continue to look standard on the outside, would be quite different internally. Human enhancements could include immense computational abilities and increased recording capacities for sense data, including new ones.



Attitudes towards these controversial biological technologies vary greatly from country to country. Asia, in particular, does not share American reservations about technological advances. But other Western countries, like Sweden, are not as inhibited as we are. There are economic and military reasons why the West will eventually feel that it must move forward with technology, especially in the area of improving and enhancing human performance in general. We certainly want augmentation and enhancement to be voluntary options. Many people presently do not want to avail themselves of these possibilities, but this point of view is falling by the wayside. I personally think that parents should not make such decisions for their children.

As long as there is a choice, however, there will be imbalances in power, intelligence, and wealth. And with imbalances in power comes the possibility of physical coercion. We will want to protect weaker entities in our society from stronger ones, just as we do today. The police and the military exist to protect weaker members of society from those who would want to coerce them. People should be able to choose to continue to live in the way they wish. We should also try to preserve traditional families and communities. They need to be able to live without interference by physical force or very high levels of taxation. The Amish are an example. The best way of ensuring this goal is through a system of governmental checks and balances, where the government as a segmented entity plays the different parts off against each other.

In summary, in the time frame we are looking at—which is not very far off—we can expect advanced molecular manufacturing, machine intelligence, and genetic engineering techniques that will far surpass what we see today. The challenge is to protect and preserve human diversity.

**SESSION THREE**

Steven Pinker

*Can We Change Human Nature?*

After decades of exile, the concept of human nature is back. It has been rehabilitated both by scientific findings that the mind has a universal, genetically shaped organization, and by philosophical analyses that have dispelled the fear that the concept is morally and politically tainted. So if human nature exists, can it be changed? Attempts to redesign human nature by directed evolution (eugenics) or directed social engineering (revolutionary utopianism) are generally recognized as futile, dangerous, and unnecessary to achieve moral and political progress. What about voluntary changes, such as parents genetically engineering their children? Despite widespread concern that human genetic engineering will change human nature, I present a number of reasons for skepticism that it will ever be a significant phenomenon.

- (1) There is a built-in bias toward luridness and glibness among scientists and journalists who write about technological change over long time spans in the future. Their dramatic predictions rarely come true.
- (2) Though we have good reason to believe that tens of thousands of genes acting in complex combinations affect mental abilities in the course of development, we have no reason to believe that a single gene (or a small number of them) could be inserted in a fetus to enhance mental abilities.
- (3) Most genetic effects are probabilistic: identical twins, for example, are similar, but they are far from indistinguishable.
- (4) The human species comprises six billion individuals whose mental traits vary quantitatively in statistical distributions. It would take an unimaginably massive intervention to shift these distributions significantly.
- (5) Ethical constraints on experimentation with humans impose an impediment to research and development on human genetic enhancement, preventing the high-speed trajectories we have seen in other areas of technology.



- (6) People make choices according to their costs and benefits, not according to their benefits alone. It is far from clear that the imaginable benefits of genetic engineering (such as a child with some probability of having a slightly higher IQ) will outweigh the costs, such as the trauma and expense of IVF, the risk of a deformed child, and violations of deep-seated intuitions about naturalness (which act as a brake on the acceptance of other technologies, such as genetically modified food). Similar skepticism should surround other claims about radical changes in human nature such as those surrounding enhancing drugs and human-machine interfaces. These uncertainties speak against restricting beneficial research on the basis of dystopian fantasies.\*

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Before I get to the subject of human nature itself, I'd like to say a few words about the concept of human nature. Presently, we are witnessing a rediscovery of the concept of human nature. Part of this comes from common sense. Anyone who has raised a child knows that children are not indistinguishable lumps of putty waiting to be shaped. They come into the world with a distinct personality. The environment alone does not determine behavior. Innate abilities play a role. The concept of human nature has been also rejuvenated by the recent study of human universals, despite traditional anthropological emphasis on differences in culture, which, of course, can be profound. Finally, the importance of our genetic endowment has been highlighted by discoveries in behavioral genetics and cognitive neuroscience.

MRI images of related living human brains show that large amounts of gray matter are influenced by the degree of genetic similarity. These similarities are not just meaningless differences in anatomy, but have well-known consequences for intelligence and personality. Studies of identical twins separated at birth show astonishing similarities in personality, intellect, and many idiosyncratic personal quirks. So, if there is such a thing as human nature, we may well ask if we are able to change it.

There have been notorious attempts to change human nature in the twentieth century, like the New Socialist Man of Stalinist Russia, the coercive eugenics

of Nazism, as well as milder forms which occurred in Western democracies. I will set these to the side and concentrate instead on a more benign form of changing human nature—namely voluntary genetic engineering. Many people believe that it is simply a matter of time before designer babies become a reality, and that we should anticipate and intervene now before it is too late.

I have a somewhat skeptical view of that inevitability. In fact, I have three reasons for thinking it highly unlikely that it will happen within our lifetime. The first is the historical fallibility of predictions about complex technology. The second are the theoretical impediments to changing human nature that arise from the study of behavioral genetics. And third is some difficulties of changing human nature that arise from human nature itself.

Predictions about the future based on the development of complex technologies are notoriously unreliable. There are several reasons for this. First, is the fallacy of constructing a linear or exponential extrapolation for progress. Moore's Law has been applied without justification to almost anything. Second, prognosticators often underestimate the number of things—technological, psychological, and sociological—that have to go exactly right for the projected scenario to take place. Third, many futurologists do not adequately consider the costs as well as the benefits of a new technology. Finally, there is the general built-in incentive for dramatic futurological predictions. People pay less attention to a prediction that things will be pretty much the same as they are now.

The prospect for designed babies is further qualified by what we already know about behavioral genetics and neural development. The most important of these findings is the rarity of single genes that have consistent beneficial psychological effects. Tens of thousands of genes working together have a large effect on the mind, but so far we have found no single genes that can explain schizophrenia, autism, or OCD, let alone talents like musical ability, likeability, intelligence, and so on. The human brain is not a bag of traits, with one gene for each trait. Neural development is staggeringly complex, with many genes interacting among each other in complex feedback loops. The effects of genes are often non-additive, and the pattern of the expression of genes is as important as which genes are present.



There are other impediments to genetic enhancement. Even identical twins raised in the identical environment don't end up identically. Sheer chance and stochastic processes play an enormous and underappreciated role in making us who we are. Genes also have multiple dominance effects. The effect a gene has depends on what other allele it is paired with. Most genes have multiple effects, and evolution selects for the best compromise. There are also ethical impediments to research on human enhancement. We do not know how to make these processes safe or to weed out deleterious side effects. Finally, most genes are desirable at intermediate, not extreme, values.

Last of all, there are some impediments in human nature itself to enhancing it. Although it may be true that most parents wish for the best for their children and want to provide them with a competitive edge, an equally strong parental motivation is the wish to spare their children any harm or the risk of harm. We must also recognize the widespread aversion to artificial life forms and technologies that are viewed as sinister. For genetic enhancement to change human nature, not just a few, but billions would have to agree to it.

For all of these reasons—the complexity of neural development, the rarity of single genes with consistent beneficial effects, the tradeoffs of risks and benefits of genetic enhancement—I do not think that changing human nature by voluntary genetic enhancement is inevitable. An effective bioethics policy should acknowledge the unreliability of long-term technological predictions and base itself on fact, not the fantasy of exponential extrapolation.

**SESSION THREE**

Richard Schacht

*The Future of Human Nature*

The idea of human nature once was quite respectable in philosophy; but it came under attack from many quarters in the course of the 20th century, and has fallen into such disfavor that it now is rarely even mentioned in polite philosophical society, and is generally shunned in the curricula of mainstream philosophy departments. I consider this to be unfortunate; and, after a glance at this sorry history of the idea's decline and fall, I argue that the time has come to resurrect it—or rather, to revisit and rethink it—in a manner that can and should give it a new lease on philosophical life. In doing so I make common cause with David Hume, and to an even greater extent with Friedrich Nietzsche, who is often (but quite wrongly) thought to be one of the arch-enemies of the very idea of human nature. Both were critics of metaphysical conceptions of some sort of human essence; but both were advocates of naturalistic reconceptions of our human nature, and of its philosophical investigation in a manner attuned if not restricted to what can be learned about it by way of the various human sciences. I suggest what some of the themes of such a “philosophical anthropology” might be, and conclude with a sketch of some of my own thinking along these lines, to give a more concrete indication of the sort of philosophical approach to the question of human nature that I believe has—or at any rate, deserves to have—a future.\*

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I am in essential agreement with Steven Pinker's position, although I will say a few other things later on which perhaps diverge from him. To start with, I would like to say something about what happened to the concept of human nature in twentieth-century philosophy, and then to go on to discuss David Hume and Friedrich Nietzsche, who powerfully and interestingly revived the concept. Finally I want to conclude, after speaking somewhat critically about the notion, to suggest some things that are still worth talking about.

The question of whether there is anything beyond the strictly biological that is true about human nature is still a subject of hot debate. Michel Foucault and his followers, for example, think that the idea is a nineteenth-century misunderstanding whose time has long passed. They admit that there are, of course, plenty of



human beings around, but all of them are historically contingent affairs. They deny that there is anything like a blueprint of humanity that we all exemplify or ought to exemplify. These attitudes, extreme though they sometimes seem, are quite representative of many twentieth-century philosophers of various schools.

This, however, was not always the case. John Locke and David Hume both emphasized the concept, and French Enlightenment philosophers took up the idea with enthusiasm, as did Hegel. With Marx, Kierkegaard, and Nietzsche, however, the situation becomes more complicated. All three had deep and significant sets of reservations about the concept. A movement called philosophical anthropology revived some of these ideas in the 1920s, but it was overshadowed by Heidegger, the Second World War, and then by existentialism, Marxism, post-structuralism, and deconstruction.

Most twentieth-century schools of philosophy reject the notion of human nature as philosophically useful. Phenomenologists object to the idea of assuming that our nature is fundamentally human, and existentialists insist that existence precedes essence. They also think that the notion of human nature serves to help us avoid facing our ultimate freedom and responsibility. Marxists condemn the idea as a reactionary ideological construct intended to subvert the recognition for the need for a profound transformation of social and economic conditions. Similarly structuralists reject the notion for the way it detracts attention away from historically contingent arrangements.

Although many of these schools claim Nietzsche as their spiritual grandparent, my own reading of that philosopher finds him to be an important proponent of the concept. He was the heir of Hume, who proposed establishing a science of human nature. Nietzsche explicitly proclaimed his project of naturalizing ourselves in a newly redeemed notion of human nature and of attaining a kind of anthropological optic in thinking about philosophical questions. Although the common view of Nietzsche sees him as taking a strongly reductionist and biologicistic point of view, I see him as thinking of animal life as having been transformed and shaped with the advent of society into human life, stressing both social and cultural phenomena. For him, our humanity has a history and a genealogy, and it remains capable of further transformation.

Human life for Nietzsche is both a biological and a socio-cultural affair. Social and cultural diversity stand in contrast to the relative constancy and uniformity of our biological constitution. Human life is open-ended with respect to the possibility of the emergence of new socio-cultural forms. That is why a good deal of what goes on in human life is not explicable in merely biological terms. This socio-cultural supervenience might be called our true supernaturalism. We are creatures of nature who have outgrown our animality. A thoroughgoing dialectic of nature and nurture makes it impossible to disentangle them.

Our human nature is therefore a question of biology, our historicity, and our psychosomaticity, which includes our senses, our emotions, and our sexualities. The dynamics of the interrelations between the psychosomatic and the socio-cultural are the heartbeat of humans. Another feature is objectification, the way subjectivity finds its objects in and undergoes transformation under the impact of humanly produced objectivities. Our nature also includes the phenomenon of human intersubjectivity, mediated by symbols, conventions, and institutions, but not fixed by any of their forms and structures. Another feature of our human existence is our relation to our own bodies, a thing we both have and are. In a similar way, we have both brains and minds. All this is bound up in the genealogy of our humanity.

This is only a small list of topics that might constitute the agenda suggested by Hume and Nietzsche. It posits a notion of human beings quite different from that of traditional Western philosophy, starting from Plato. It also differs from the one we find among those who take a cognitive science point of view, which sees the mental dimension of human life as just disguised neurophysiological events. Although everything that goes on in us has these dimensions, such an analysis does not take us very far in understanding human reality, which finds its objective expression and embodiment in social and cultural phenomena.

The information we take in is schematized and bound up with the interpretive and evaluative contexts within which its meaning is constituted. We take in these systems, and, as we learn them, we make modifications and refinements. We relate to each other by means of them. These representations owe at least as much to the symbolic systems we internalize as to the sensory and neural appa-



ratures with which we are endowed. It is the meaning content of the representations, not the locus where such representations become effective, that is of paramount importance in human life. And that content requires an analysis that reflects its symbolic elaboration and socio-cultural objectification.

Nietzsche thought that we could make naturalistic sense of this project. We can imagine a Hobbsian creature, a body with a brain, entering into group arrangements that emphasize the development of communication and the coordination of behavior. These lead to more complex social arrangements and to further elaborated systems of conventions and rules. In addition, relations among elements can begin to affect their very use and function, and various social dynamics, in turn, can come to be reflected in them. The resulting conceptual, interpretative, and evaluative schemes come to structure ways in which human beings encounter each other. Their existence has come to be mediated by socially generated domains of symbolic phenomena. Psychosomatic human nature has not disappeared, but has been transmuted and superceded. And it has also entered into socially and symbolically constructed forms of life.

As human beings, we often do things in response to some event, signal, or communication in the socio-cultural world. The brain is certainly involved in this, but it is not the only party running the show. The brain makes our remarkable manner of existence possible. It determines what forms these social and symbolic structures will take and what courses of events will unfold. Other animals have brains, but they are quite oblivious to the sorts of things we respond to. This is because they lack minds. What is needed to mediate between symbolic systems and neural processes underlying behavior? There must be a way of internalizing them and representing their contents. In other words, there must be an intermediary between an objectified symbolic order and the neural order.

Our minds work with a kind of social symbolic education. We have a neural apparatus, but in describing it, we must remember the difference between the truth and the whole truth. I think that the idea of human nature does have a future and that a consideration of it from both philosophical and scientific points of view is not only possible, but quite interesting. It will, of course, remain a rather untidy and tentative affair. But the same is true with respect to human life itself.

**SESSION FOUR**

Daniel Kevles

*Science and the Deconstruction of Human Nature*

The century-long trend to reductionism in the life sciences has increasingly impacted ideas of human nature. Various lines of scientific investigation have revealed that human beings are physico-chemical machines; that their mental processes can be seen in vivid colors on imaging machines; that their physical and behavioral traits can be tied to genes. The trend to reductionism has reached deeply into the medical arena, where the person is often dealt with as a collection of parts to be diagnosed, repaired, or even replaced. The trend has been exacerbated by biotechnology and law, which together have created a market and intellectual property rights in human genetic parts. But these developments need not reduce conceptions of human nature to commercializable entities of physics and chemistry nor void our notions of humanness. We think of ourselves as something more than the operations of genes and firing neurons, and we insist on treatment that respects personhood, autonomy, and dignity. Such considerations have found expression in the imposition of ethical constraints in human subject research, European patent law, and the response to the prospect of human cloning.\*

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I would like to talk about a profound revolution that has recently occurred in our perception of ourselves as human beings, and then discuss this development in some sort of historical perspective. This contemporary revolution, which is about genetics and neuroscience, is really the third in historical memory. The first, of course, involved the removal of the earth from the center of the universe. The second, Darwin's revolution, destroyed our sense of uniqueness in the realm of living beings. Both, however, left us with the sense that as human animals we are uniquely endowed with high intelligence, a basket of emotions and capacities for morality, aesthetics, language, culture, and science—in short with the capacities that lie at the core of what we call human nature. My concern today is not really with the scientific and scholarly aspects of this shift in attitude, but with a change in how people in the larger culture think about human nature.



While it may be true that notions of human nature have been out of fashion in scholarship and philosophy for a century or so, most people until recently would have agreed that there is such a thing as human nature. The current revolution challenges that conception by deconstructing us into constituent body parts. This is not, of course, an entirely new development. For more than a century we have known that we are physical and chemical machines, in terms of our bodily structure and functions, not to mention breakdowns and dysfunction. Still, the deconstruction of our day strikes at the essence and autonomy of being human. Two developments lie at the core of this shift: the rapid advances in human genetics, coupled with the new reproductive technologies; and the stunning advances in the neurosciences. Such progress has both fascinated the public and also caused a degree of worry and anxiety.

Recombinant DNA has emancipated human genetics from a dependence on analyzing family pedigrees by allowing it to isolate individual genes and analyze their function in terms of DNA coding. Now the swift mapping and sequencing of the human genome is steadily revealing the code's actual contents and thus allowing us to obtain the specific blueprint for any one of us. Drawing a blueprint of what is essential to our human functions, especially emotion and cognition, deflates the sense of wonder we may once have felt about human life. Rapidly expanding neurosciences have been exposing how our senses and cognitive abilities are the products of neurotransmitters, hormone surges, neural networks, and a hundred billion intricately connected nerve cells. Neurobiologists can detect function in particular regions of the brain by keying in on neurotransmitters. Such techniques have been used not only to study disease, but also to analyze certain abnormal, especially socially destructive, behaviors.

Many expect that genetics and the neurosciences will ultimately meld, so that genes will be correlated with what brain scans reveal. The result will be a genetic functional account of our behavior and our human identities. Our materiality and the physiological process that governs it will account for our capacity for being human. According to some biologists, these capacities include art and aesthetics, which are seen as selected products of evolution.

Developments in genetics and neuroscience have led to a remarkable shift in the social uses of human biology. In the previous century, social Darwinism and its ally, eugenics, were often used by conservatives to block the attempt to improve the condition of individuals through ameliorating the social environment. Eugenicists saw the proliferation of suffering or deprived people as a threat to the quality of American society. But biological eugenics was also embraced by progressives, who were attempting to halt trends to degeneration. Using science, even for progressive social and political ends, often resulted in the curtailment or damage to individual liberties.

The contemporary biologization of behavior, however, is not yet being used as a warrant for social engineering. In fact, the trend now is to use it to emancipate people from moral responsibility. If it's in your nature to misbehave, then it's not your fault. One response to a no-fault biology, of course, would be to modify the environment as a compensation for defects in biology. The most recent trends, however, seem not to be addressed to changing the environment, but to resorting to pharmaceuticals to change the individual. Similarly, although gene therapies are used to protect against disease, they may also be used to enhance characteristics that society deems valuable, such as intelligence, athletic ability, and beauty. One sign of the recent decomposition of human nature is the widespread belief that you can change it.

One remarkable feature of recent trends in biologization is that it is occurring in an intensely commercial, free-market environment. There are many alarming consequences of this combination. The acquisition of genetic information can be used to deny insurance or employment. The incentives for traffic in human body parts, including those in which our essence is thought to be concentrated, are powerful. In this legally sanctioned realm of commodification, patent protection has been extended to genetically engineered plants, animals, and human genes, and could conceivably extend to genetically engineered human body parts or even human beings themselves.

Many people are concerned about the potential impact of biotechnology on ineffable human qualities such as individuality, ambition, or genius. The use of psychopharmacology is similarly alarming in the way it makes deviant or incon-



venient behavior into a pathology that merits chemical restoration to a conformist norm. Francis Fukuyama, in particular, worries that basic notions of justice, morality, or human rights are being undermined by biotechnological developments. He fears that the enterprise is too driven by commerce and ambition to exercise self-restraint, and he calls for the laying down of a political marker at an early point in development to demonstrate that the development of these technologies is not inevitably beyond control.

Such alarms may be a kind of overreaction. The trend to biologization has been pervaded by considerable scientific extravagance. No one knows much about how genes actually control behavior, how neural networks make for perception and knowledge, or how the complex system of the brain works to create consciousness. It is not likely that under the United States Constitution anyone will be able to hold property rights in another human being. Still, we need ethics in this realm. If ethics is relegated to peripheral and obsolete questions, while industry deconstructs, redesigns, and manufactures human components like any other commodity, laws that exempt these components from patenting, licensing, and other property rights will lose their moral basis. The United States has taken the lead in the recent biologization and commercialization of the components of human nature, and it is the Old World that has insisted on the introduction of ethics in this area. It may be that with the globalization of the high-tech economy, a similar impact will be felt in the way we treat the deconstruction of human nature.

We managed to absorb the conceptual consequences of our Copernican dethronement from the center of the universe, and people who accept the Darwinian theory of evolution do not nowadays resort to a primitive nihilism. Most Americans are appalled by the excesses of previous movements in eugenics and sterilization, even if they do not understand the shoddiness of the science that underlay them. Surely we can live with the knowledge that we are creatures of parts—of genes, neurons, and so forth. We can still think of ourselves as something more than the operations of genes and the firing of neurons. Whatever we do, we can and should insist on treatment of people that respects personhood, autonomy, and dignity, even if we know that we are all only the construction of various parts.

**SESSION FOUR**

George Annas

*Genism, Racism, and the Prospect of Genetic Genocide*

One great promise of genomics is that it will demonstrate that all humans are essentially the same and help eliminate racism by destroying its pseudoscientific rationale. But a reductionistic genetics could simply replace racism with genism, and fuel a new eugenics project—to construct “better humans” through genetic engineering. It has been suggested that this will be all to the good for humanity, even that it is wrong to think of genetically modified humans as post-humans. But that view is ahistorical. If genetic engineering produces a different type of human, the relationship between these new humans and “standard” humans is potentially, even likely, lethal. Human history suggests differences will be socially magnified and that the two now different types of humans could consider each other as legitimate targets for preemptive extermination. It is this prospect for what I have termed “genetic genocide” that leads me to conclude that we should apply the precautionary principle to human genetic engineering and prohibit it by treaty. Substantive and procedural conditions for creating and lifting a global prohibition on human inheritable genetic alterations will be suggested.\*

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My talk is going to follow on some of Professor Kevles’s ideas quite well. He brought us up to where we are now, and I’m going to try to look at the future. Prediction is always difficult. The question I’d like you to ask yourselves is whether it is possible to stop nanotechnology or germ-line engineering from creating a new, different kind of human being, if not a different species altogether. However you answer that question, there is still another. Is there a mechanism we can develop to direct the use of that technology and protect ourselves from annihilation, extinction, and exploitation by a new, powerful subspecies or species?



Geneticists, and scientists in general, tend to be optimistic about their field and often assume that all is going to work out well in the end. They frequently argue that many of the dangers that alarm people—like genetically modified foods or the possibilities of genetic genocide—are based on misunderstandings of scientific facts. Steven Pinker urges us to base our bioethics policy on facts, not fantasy. But I do not understand why ethics should be based only on facts, while science can be based on speculation as well. I think both of us can fantasize about good and bad scenarios in the future.

When the Human Genome Project was first announced, many scientists claimed that one of its benefits would be to discredit the concept of racism for all time. It was going to prove that we are all fundamentally the same. It was going to abolish racism and all the differences among human beings. That would have been nice. But we are already seeing a counterattack on this benign view. It is now claimed that since drugs act differently on blacks and whites, it really is not true that there are not some fundamental biological difference among the races. The point is not who is right, but that the promise that the Human Genome Project was going to end racism was hype that is not going to be fulfilled. And there are other forms of hype. One of them is that all we have to worry about is protecting the subjects of human genetic experiments who will be injured by them. What I want to talk about is the species-wide dangers and implications of such technological developments.

It is important that we consider this point of view. Vaclav Havel argued that only by developing a species consciousness can we hope to avoid totalitarian dictatorships and the use of weapons of mass destruction. Similarly, Francis Fukuyama derives the very notion of human rights from a previous conception of human nature. After World War II, the Universal Declaration of Human Rights established, first, that there was such a thing as human rights and, second, that they were universal. From this was also derived the idea that there were specific crimes against humanity.

The usual crimes against humanity include things like murder, genocide, slavery, torture, arbitrary detention, disappearance, and things of that nature. But I want to argue that there is another kind of crime against humanity which does not involve these types of destruction loosed against people with the permission of the state. It involves a direct attack on the human species itself in an effort to change the nature of what it means to be human, and to engage in species-altering activities. It includes making germ-line genetic changes in an individual that may make him so different from other members of his species that he might be considered not as a member of the species or as belonging to a different species entirely. Human cloning provides the perfect opportunity for the world community to ban a technology that has worldwide, species-altering implications. Germ-line engineering is another example of technological interventions that threaten to change the nature of what it means to be human. When you change that, you undermine and take away the basis for human rights.

A fundamental human right is the freedom from having your body invaded or forced against your will. This may involve a question of sterilization or adding an implant to your brain that will improve you. That right is fundamental to autonomy and personhood. I do not know how you could justify such a right in a creature that is fundamentally different from you. Many scientists argue for establishing such a right. They think it is a form of hubris to think we know how to change a 3.5 billion-year-old DNA sequence to make better children.

Establishing this right would be only the beginning. We would also have to set up an enforcement mechanism, something like the international criminal court. We would also need an international treaty, with all nations involved. Last of all, we would need a forum, some kind of international bioethics human rights council democratically elected and representative of the entire species. Its job would be to debate issues like cloning, germ-line genetics, nanotechnology, xenografts, and any other type of procedure that was species-altering or that put the human species at risk of extinction.



Such procedures would be outlawed by the treaty. To change it and permit a new technology, you would have to show that its benefits to humanity outweigh its risks. And if there is some fundamental principle involved that we do not want to violate, then a risk-benefit analysis would not be sufficient. Rulings of the council would not necessarily be permanent, but there would be a precautionary principle applied to species-altering procedures. The burden of proof would lie on scientists, proponents of technology, and corporations to demonstrate that a new development is a good thing.

These measures are justified because once you change the nature of human beings, there is the potential for genocide. Science fiction writers have been thinking and writing about this for a long time. Once different creatures are perceived as nonhuman, then a genocidal impulse develops. People who think a lot about nanotechnology and robotics have come to similar conclusions.

The hardest problem would be getting such a treaty passed. International organizations presently face enormous procedural difficulties. Nevertheless, we should outlaw reproductive cloning and germ-line engineering. But it is not at all clear how such adjudications should be made. A cost-benefit analysis is not adequate. What would the rules of decision be? When would the planet be safe for new species? Maybe the species would have to wait for 100 years without a genocide occurring before it is thought safe to introduce another species. Some will say we could never get through 100 years without a genocide. But if we cannot go 100 years without killing ourselves, maybe we should not be trusted to create new humans.

**SESSION FIVE**

George Church

*Ecology, Economics, and Exponentials: Modeling Technological Goals and Human Nature*

ABSTRACT NOT AVAILABLE

[Editor's Note: George Church's presentation made extensive use of charts and other visual representations. A verbal summary is not able to convey his general ideas or his specific points adequately. The following summary, therefore, will necessarily appear disjointed and even incoherent in places.]

My talk will involve the convergence of genomics and computer science, with an emphasis on what sorts of timelines are plausible. I will also discuss the economic consequences, not only in terms of dollars, but also environments, ecologies, and so forth. I would like to give you a feeling for the kinds of things we do in systems biology, and then go on to discuss speculatively some implications it has for human nature. My background is in modeling, not only of the evolution of biopolymers such as proteins and DNA, but also structures that constitute molecular machines, and eventually whole ecosystems.

I have lived through two small revolutions, not as momentous as the Galilean and Darwinian, but quite important nonetheless: recombinant DNA and genomics. Both are reductionistic, and both rejuvenated systems biology, an old discipline. We now think of molecular processes as machines, but we can integrate them into metazoans like ourselves, cancerous stem cells, and ecosystems.

One way of modeling is to plot some calculated property on one axis and another observed property on another. Then we look for outliers, which are not to be swept away. They are not indicators that our model has failed. They are our friends and are potential discoveries about how our methods are not working. Some of these correlations have very interesting deviations from optimality. We are interested in how to take this ten-thousand-year history of genetically manipulating single molecules and, when we have a satisfactory level of precision, get to diversity. Despite doubts about what is acceptable in human breeding terms, it is quite possible that there is a great tolerance for diversity.



We think about diversity especially when we consider the limits to what we are able to do, and then try to extend them. Running speed, depths to which people can dive, breadth of the visible wavelength, temperature people can endure, the length of memory are all examples of limits that interest us. Once we exceed these limits, are we still within the range of human nature as we know it? We should remember that the Darwinian breakthrough, or clusters of Darwinian breakthroughs, allowed us to become hyper-adaptable and no longer dependent on DNA for inheritance and evolution. We are no longer limited by our germ-line. For some people laptops are as much a part of their being as their DNA. Maybe we should not change their germ-line but their laptops.

Does germ-line engineering hold the fastest promise for change? I would argue that somatic engineering is much closer at hand. Change through germ-line engineering takes about twenty years to manifest the result. On the other hand, somatic engineering—putting inorganic prosthesis or organic chemicals or somatic cell genetics into or outside our bodies—can take mere days. The other problem with germ-line engineering is the ethics of allowing adults to choose for their children or for other adults. Using the phenotype is more predictable. You can choose among a series of fertilized eggs, but that's not very predictable. By the time to get to adulthood, on the other hand, it's very clear what prostheses and drugs will and will not work. Similarly, if we want to work on our cells, histo-compatible adult stem cells may be more accessible and more appropriate, as will interfaces with organic engineering, nanotechnology, and more ordinary inorganic engineering.

When we plot growth in order to predict timelines, we see that the number of CPUs or CPU power will certainly overtake that of the population. CPU growth is definitely steeper than exponential growth and closer to a parabolic fit. When we compare the processing power of computers and the human brain, using Moore's Law, we see a cross-over point at about ten to the fourteenth instructions per second. This does not address when or whether the entire internet will be equivalent to human intelligence. In addition to physical limits, we also need to think about cost limits and to compare them with other programs and their

benefits, like launching satellites, or eradicating disease or sequencing the human genome. While undertaking any project always costs something, we should also remember that not undertaking them also entails a cost, which can often be considerable. Five percent of the global gross domestic product is dedicated to hackers and e-viruses.

The cost of progress, however, is not measured only in dollars. There is also the question of its effects on the environment. Since humans are hyper-adaptable, the amount of computing that we and our machines will be able to do is going to be limited primarily by the amount of energy at our disposal. There is, of course, sunlight and other sources of energy, like nuclear power. But we still have the problem of getting the heat off the earth. Right now we are consuming within three or four logs of the maximum. But not all energy is used for computation, and the efficiency of computation can change. In addition, there are alternative natural mechanisms that are doing similar jobs that are just now being discovered.

What will happen to diversity? There is the problem that a replicating system will turn the entire surface of the earth into itself. But there are other, more insidious ways of losing diversity. We may have to start thinking seriously about using geographical isolation to achieve this goal. It has played one of the major roles in evolution. We need to know not only common mutations, but every mutation that occurs, not just in our germ-line, but in our somatic cells as well. One problem here is devising the instrumentation that can monitor these changes and making it inexpensive enough to use.

We have seen maybe four logs of improvement in efficiency over the course of the genome project, but we're still ten logs away from the efficiency of some very commonly used equipment, like video recording. We would like to be able to get DNA analysis and nucleic acid analysis down to the level of video recording costs. We have discovered that existing organisms can do inorganic and organic nanofabrication beautifully. We need to harvest the biosphere for these remarkable molecular machines. In a certain sense, therefore, we already have achieved atomic precision.



I've been talking about systems biology because it is so embracing and more holistic than our usual speculations. The timelines I've been discussing are often higher than exponential. They may not continue at these rates, but their limits are determined by mass and cost. We should start thinking about our inheritance in larger terms than DNA. Germ-line changes are the least of our worries.

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## **SESSION FIVE**

Lynn Margulis

### *Biosphere Technologies and the Myth of Individuality*

The “Gaia Hypothesis” explains the tendency of the Earth’s surface to maintain its temperature, reactive gas concentration, and alkalinity within astronomically narrow limits for millions of years. The self-maintaining properties of cells, organisms, communities, and ecosystems can be extrapolated to the atmosphere and surface sediments of planet Earth. Not only are we people (*Homo sapiens* mammals), one of the more than 10 million existing species components of the Gaian regulatory system but so are our machines. I argue that although not by themselves alive, like viruses and beehives, machines are capable of growth, reproduction mutation, and therefore evolution. Machines change through time. Even though they are not self-sustaining and they have no metabolism, machines do evolve.

No single species is privileged. Many populations of organisms, like us, disrupt their own habitats by outgrowing their own ecological support systems. The Gaian Earth-regulating system which responds to perturbation by changes in metabolism, differential survival, growth, and species origin and extinctions maintains dynamic stability of the planet’s surface. The fossil record informs us that, for members of any given species, habitat loss is followed by population decline and, eventually, by extinction.

Technohumans grow now as “mammalian weeds.” Non-human ecosystems are converted to the agro-urban-technological, primarily by water and solar-radiation rerouting, soil depletion, and fossil-fuel combustion. The extremely successful recent human reproductive strategies alter or even extinguish lacustrine, riparian, dunal, marine coastal, forest, grassland, chaparral, and other non-human, primarily terrestrial, ecosystems. The

agro-urban network overgrowth adds cellulose, hemicellulose, lignin, polymeric plastics, metal oxides, aldehydes, aromatics, and hundreds of other compounds and sedimentary particles even to ocean water. The accelerated patterns of surface transformation to the agro-urban network coupled with *Homo sapiens*-induced species extinction are reminiscent of a phenomenon at a smaller size-scale: malignant melanoma and other solid tumor metastasis. Although ecological alteration of the Gaian body politic is about  $10^5$  times larger than melanoma or other cancers, the two phenomena share at least these characteristics: uncontrolled growth stimulated by the prototactic imperative to reproduce, and metabolic dependency on surrounding supportive communities by rerouting of energy, fluids, and organic compounds to the sites of most rapid proliferation. Lack of neural or other centralized control unleashes destructive, compulsive, proliferative behavior in cells, tissues, organisms, populations, communities, and beyond. Although we perceive ourselves, usually as individuals, scientific analyses shows each of us to be at least 10 percent dry weight “foreign” (i.e., bacterial). By means of a video (I hope) we will see how we, like all “individual animals” are complex composites, integrated communities that require chemical, microbiological, and ecological studies to be properly understood.\*

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[Editor’s Note: A large part of Professor Margulis’s presentation consisted of slides and a long film of various microorganisms. Some of her commentary which is comprehensible only in conjunction with its illustrations has therefore regrettably been omitted.]

I feel so humble in the face of the past that I cannot talk about the future. The past, the evolutionary past, is so complex that thinking about the future in technological terms just boggles my mind. Emily Dickinson wrote:

A little Madness in the Spring  
Is wholesome even for the King,  
But God be with the Clown—  
Who ponders this tremendous scene—  
This whole Experiment of Green—  
As if it were his own!



That's how I feel about this meeting. It's clowning to think that we can predict in detail the carbon dioxide of the atmosphere or the germ-line.

I want to impress you with the fact that technology belongs to the biosphere—what traditionally is called the noosphere. I want to show you some technologies that are extremely ancient. There is, for example, architectural habitat alteration that controls light, temperature, chemical composition, and water better than this room does. The one thing that distinguishes our species from the rest of nature is speech and symbolism. We can talk, and therefore we can lie. Deceit is all over biology.

When we look at these ancient natural technologies and then think about what I call the myth of individuality, we begin to appreciate the extent to which organisms are composite. We are also going to see how the World Wide Web, a communication among what looks like individual organisms, has been on the earth for maybe 35 hundred million years. It's not silicon technology, but it is true technology. The idea that humans can synthetically adopt and incorporate photosynthesis into themselves is a real possibility and already exists in nature. Some predatory animals have developed associations with very efficient photo-synthesizers.

Examples of biospheric technology are the large termite mounds in Africa. Temperature there is regulated to within half a degree centigrade, humidity is maintained at 95 percent in extremely dry surroundings, and there is as much of the termite mound below ground as there is above it. Air flows through it, and there are divisions maintained into morgues, school rooms, and hatcheries. The termites derive their source of carbon and energy from the fungi they have learned to grow as crops. There can be as many as 30 million termites in these mounds, along with all sorts of associated animals that live with them.

We share 99.9 percent of our DNA with chimps. From a biological point of view, we are just another chimp. If we want to think about technological potentials for ourselves, we might take a look at how problems have already been solved in nature. Here is a stromatolite from the sea floor. It is the product of bacteria and has lasted hundreds of thousands if not hundreds of millions of years. It is a very complex community of microorganisms that are constantly

maintaining and stabilizing sediment and recycling carbon and phosphorus in ways we have not even begun to approach. There are also examples of web organisms that communicate with each other, and photo-synthesizers that produce carbon and energy for the rest of the community and recycle the sulphur. These are stable, worldwide communities. We don't know how they're communicating, but they are communicating well enough for the same composition to be fundamentally the same worldwide.

As for the subject of individuality, here are mollusks that live entirely by photosynthesizing, having incorporated photosynthesis into their own bodies. Some animals incorporate the photosynthetic chloroplasts of algae. Others actually focus light on the photosynthetic entities that support it. These mechanisms suggest more feasible technologies than changing the germ-line of people.

[Professor Margulis showed a video and commented on it.]

Any organism has a multiple genomic background. The theory of the origin of species does not really lie in mutation. Mutations just modify. If you want to change organisms in serious ways, you can think about acquiring and integrating genomes that have already been optimized by natural selection. I want Emily Dickinson to have the last word:

But nature is a stranger yet;  
The ones that cite her most  
Have never passed her haunted house,  
Nor simplified her ghost.  
To pity those that know her not  
Is helped by the regret  
That those who know her, know her less  
The nearer her they get.



## SESSION SIX

Roger Shattuck

### *A Tale of Two Species*

ABSTRACT NOT AVAILABLE

Steven Pinker quoted Ortega y Gasset that “Man has no nature.” But the quote continues. “What he has is history.” I would like to discuss one of the most striking early thought experiments in human nature, which has not been mentioned at this conference. It makes use of the commanding position occupied in the eighteenth century by voyages of discovery to unknown lands to discover and describe unknown flora, fauna, and exotic human societies. A similar position is occupied today by research in molecular biology. *Gulliver’s Travels* appeared in 1726, and its veracity was vouched for by its publisher. It is a classic work of literature and a clever hoax. It is also an experiment on human life.

In the fourth book, Gulliver is cast ashore on an island where human nature has been passed through a prism. A society of horse-like creatures, the Houyhnhnms, has received reason and language and lives in peace, while bands of apelike Yahoos get the rest and live like quarrelsome brutes. Gulliver spurns the humanoid Yahoos, and in one uproarious episode a naked rutting female Yahoo goes after him as an attractive representative of her own species. Gulliver works himself up into a rant against both species and goes mad, rescued finally by a humane Portuguese sea captain.

In Swift’s day, the satire was taken to be a complex political and philosophical warning against going too far in favoring reason above all other faculties and feelings. For us today, Swift’s tale of an island where humans have evolved or regressed into two separate species is a double dystopia, a warning against tampering with our nature, lest we cause ourselves grief and diminishment. The monstrosity of both the bestial Yahoos and the haughty Houyhnhnms unhinges Gulliver to the point of insanity.

A second work, H. G. Wells’s *The Time Machine*, was written in 1895 and appropriates Swift’s device of a traveler marooned in a land inhabited by two species descended from humans. The vacuous doll-like Eloi, descended from wealthy landowners, live without toil. Driven underground long ago, the working

classes have turned into Morlocks, machine-making savages who feed on the Eloi like livestock. For Wells, the future reveals the social and biological decadence of mankind brought about by our incorrigible selfishness.

Now, a century later, in Lee Silver's *Remaking Eden*, we find yet another traveler to a society in which humankind has evolved into two distinct species: the gene-rich, favored by every medical, genetic, and scientific cure and enhancement, and the naturals, left behind in the dust of unimproved humanity. It is a giddily optimistic book, promoting reproductive genetics and germ-line enhancements of every kind. Silver names Wells twice, but neglects Swift, although he is our Gulliver more than he knows. He endorses and justifies the genetic measures available to improve ourselves and our offspring, unrestrained in the open marketplace by any special scruple or limit other than potential individual harm. Like Gulliver fawning over the reasonable Houyhnhnms, Silver revels in the "unimaginable extensions of human capacities available to favored children." Only in the epilogue does he express some misgivings. A fictional Dr. Varship of the future surveys the results of genetic enhancements and wonders if we have gone wrong. But he recognizes that it is too late to do anything at all. He expresses a regretful resignation over the division of human nature into two incompatible and stunted species. But there is no satire here, no spoof, only muffled sorrow. I have rarely read a book so deeply ambivalent trying to put on a brave face.

One last point, one of the most desired human enhancements is healthy longevity, culminating in immortality. Silver's long list of enhancements in the last chapter, including cognitive attributes, moral character improvements and radio telephathy, cries out for longevity and immortality as the culminating offerings. But Silver has avoided the big question: Is genetically programmed death one of the defining characteristics of human nature? He therefore missed the opportunity to carry Swift's and Wells's story to the further challenge of mortality and human nature. Is life without death worth living?

I'd like to add that I respect Silver's book very much and was deeply stirred by it. This is the result.



## SESSION SIX

### George Annas

I would like to ask two questions. The first is: What kind of humans do we want in the future and how would we like to change them? The second is: How do we create a world where differences are respected and not a grounds for extermination. To explore these questions I want to look at the most well-known cautionary tales of our time, *Brave New World* and *1984*.

*Brave New World* shows a society based on conditioning and drugs. There, you are born into pods of 96 identical embryos and assigned a specific class, which defined you for life—what job you'd do, what you'd wear, etc. Not only were you conditioned to be that way, but if you were found to be dysfunctional, or needed to maintain your functioning, you were administered slogans or heavy-duty drugs, which many people point out are already available. This view of society, in which we dehumanize ourselves and take away the freedom and creativity that we think defines us as humans, is, by the way, essentially the view adopted by the President's bioethics council. They think that the only way to stop dehumanization and the commodification of humans is to prohibit things like human cloning and germ-line genetic engineering and to worry a lot about embryo research, organ and egg sales, etc. I think their next step will be trying to regulate Lee Silver's reproductive technology. They would be horrified by the word rerogenetics, and they will try to stop it.

*1984* is Orwell's vision of a government that does not rely on conditioning and drugs to dehumanize its people, but on fear, surveillance, and a strategy of perpetual war to convince its citizens that they should surrender their humanity and submit to a regime that observes and controls them. Since September 11th, Big Brother has emerged as a much more likely scenario than a Brave New World. John Ashcroft says he's going to protect our civil rights by doing away with the need for warrants for searches and wiretaps, putting people in jail without habeas corpus, sticking people on Guantanamo, removed from constitutional rights, and countenancing torture. We will have to start taking very seriously a society based on perpetual war, especially in light of developments in nanotech-

nology and some of the genetic technologies we have heard about. Any powerful technology in the wrong hands reverses its potential for good into one for evil.

Eric Fromm asked if it was possible to change human nature so that we would forget our longing for freedom, dignity, integrity, and love. In other words, can man be made to forget that he is human? I do not know the answer to this question, but I would like to remind you that there are at least two other life forms on the planet that will have a lot to say about our future. One is the corporation. The other is the nongovernmental organization.

Corporate life forms are potentially immortal. They have no natural life span. Since they can also acquire wealth forever, they can grow to be very, very powerful over decades and centuries. They can control large segments of our society and our technology. They are also already running most of the governments of the world.

Nongovernmental organizations are a life form that people have very ambivalent feelings about. They have grown in numbers almost exponentially in the past decade, as a counterbalancing force both to governments and, most importantly, to corporations. Some people look to them as the best hope for preserving the planet and humanity. In the last thirty or forty years, most of the degradation of the planet has been caused by corporations doing whatever they want in order to extract resources from the earth. Environmentalists have tried to plead with governments, with very little success. Now nongovernmental organizations are trying to find new strategies, like renting rain forests or buying land and keeping it for purposes of biodiversity and conservation.

When we ask how we can create a world where differences are respected and not grounds for extermination, we may talk about governments and self-regulation, but we should also recognize the existence of two other life forms that have enormous power for good and for evil—the corporation and the nongovernmental agency.



## SESSION SIX

### Anthony Gottlieb

When I first starting thinking about the subject of this conference, I remembered a book by David Bolter, *Turing's Man*, which deals with the impact of the computer on the way we think about ourselves. It argues that the current conception most of us hold regarding human nature has been significantly affected by the development of the digital computer. One of the things I'd like to talk about today is the concept of a defining technology for an era. A defining technology is a way of doing things that is so successful and impressive that people say, "Everything works like that, even ourselves. It's the key to the universe."

The first defining technology we know about is from the Greeks. It is the idea of the craftsman—in particular the potter—who fashions form out of raw matter. Plato's divine master craftsman who fashioned the world out of raw matter, imposing form on it the way a potter does, is an example of this. His theory of Ideas is, in effect, a consequence of this image in the way it sees physical reality as the imposition of form on matter.

The next informing technology was the machine—in particular the clock. People thought the whole universe was a clock and the human body a machine. That was Descartes' thesis, although he thought the mind could not be handled satisfactorily that way. His implausible and unconvincing attempt to relate mind and body led people to conceptualize the mind itself as a machine. The conception of scientific knowledge was also informed by that defining technology. According to Locke, if we could ever understand all the bits of the world in the way that a clockmaker understands the clock he has manufactured, we would really understand nature. Most of us probably still think of nature that way.

The third great defining technology is, of course, the digital computer. It is related to the mechanical world picture and builds on and extends, rather than obliterating it. We think of our minds as if there were computers and regard our memories and even our characters as software running on the hardware of the brain. In science fiction we wonder whether we will be able to transport ourselves vast distances by downloading ourselves, either by transmitting matter or simply information. There are also people who speak of the whole universe as if it were a computer. That is our own defining technology.

An important question to ask is: Is this the end of the road? Is this the real defining technology? Is this what the universe is really like? It is impossible to answer that question because, by definition, the defining technology is the one we think of as really embodying the truth. But if we adopt the point of view of the intellectual historian, we see that in the past people thought that they really possessed the truth. Are we any different? Will there be other technologies that will lead us to think of the universe and ourselves in an entirely different way?

Part of the answer to that question depends on whether another technology will come along that works sufficiently impressively. I've thought of a few possibilities. One is nonclassical quantum computers. We may start to think of ourselves as being sometimes in superpositions or states. We may borrow the language of quantum mechanics to understand our own human nature. Another possibility is string theory, which might affect the ways we think about ourselves, although it is difficult to say just how. A third possibility is somatic engineering, including prosthetics, pharmacology, and nanotechnology. Will we start to think of human nature as a set of states that we can manipulate with drugs, for example?

I should also mention that the main technology we have been discussing at this conference has also been affected by the digital computer. We speak of the genetic code and try to explain it almost completely in terms of the digital computer. Will that change if another defining technology evolves?

The last issue I would like to raise comes from an essay on nature written in the 1850s by John Stuart Mill. In it, he refutes the idea that there is a coherent objection to what we might do technologically by claiming that it interferes with nature. Objections like this, in fact, are based on a systematic ambiguity in the way we use the term nature. If by nature we mean "everything that happens," then we do not have to worry. If nature is everything that happens, we can never change what happens. If, on the other hand, we mean by nature what happens without human intervention, then the only way we can avoid interfering with nature is by doing absolutely nothing. So I do not think that the notion of interfering with nature is even remotely useful or interesting. If we want to evaluate a project, we should instead look at the consequences and the harms that might ensue.



## SESSION SIX

Evelyn Fox Keller

I originally thought I would speak against the idea of human nature, but I decided not to, primarily because I believe in it, or in something like it. I believe that we are biologically determined. There are, however, several problems with this position. First, I don't think we are determined solely by individual biology. Second, talk about human nature usually involves us in all sorts of difficulties that keep us going in circles. It ends up only encouraging those opposed to the idea of human nature. Let me try to specify some of the difficulties we often get into.

Several people at this conference defined human nature as something that is universal to the human species. There are several problems with this notion. First of all, it is almost inevitably a normative notion. What counts as a human being if we demand that human nature be universal? Human beings are bipedal, erect animals. Does that mean that people without legs are not human? Is the desire to have children an essential and universal part of human nature? What does that stricture do to people who don't want children? So one of the first things to stress about human nature is that, if indeed there is such a thing, it is necessarily variable in the species.

Another difficulty with most talk about human nature is the problem of location. Where is human nature? For most of the speakers at this conference, it resides inside of our bodies. The brain makes up the mind. But I could argue that all our brains together collectively make up the individual mind. The individual human mind is a product of sociality. It is our sociality that is distinctively human about us. Many people argue that what distinguishes us from apes is our capacity for mimicry and imitation. They establish a social world that enables the process of cultural evolution, which in turn changes our brains. It changes it in two ways: the culture in which we live rewires our brains; but the blueprint of who we are includes more than our DNA. DNA itself changes in response to cultural evolution. The Baldwin effect states that when we change human nature, we necessarily change the conditions under which natural selection operates.

Take, for example, the arrival of literacy. Literacy did not arise in individual brains, but out of a social community. But the fact of literacy changes our

brains. It enhances our memory, our capacity and rewires us in important ways. Literacy is still not a universal trait, but the time will come when we can say that literacy is an essential part of human nature. But where will it reside? That will partly depend on the stage of our evolutionary process. We may have become biologically adapted to literacy in important ways, and in the process changed our human nature.

Yet another problem that has surfaced in these discussion is the assumption that if a trait is universal, it must be genetic. The example of literacy shows that this is not so. A trait can be universal without being genetic. It is important to see that traits that are universal cannot a priori be distinguished on the basis of whether they are genetically determined or the products of particular social and cultural forms.

How do we know what is universal? We labor under an almost irresistible tendency to extrapolate from our own cultural expectations to the species as a whole. For example, we have been told that it is wired into our human nature to maximize our self-interest. Recent studies, however, show that not all people pursue their lives according to the principle of rational economic man. Similarly, the desire to have our own genetic offspring is important in this culture, but not in others. So let us be very wary about talking about human nature as a universal characteristic.

Finally, there has been very little discussion at this conference about changing species-wide characteristics. Most of it had to do with changing the nature of some humans. Two questions immediately arise. Which humans are we going to change, and how are we going to change them? Right now we are particularly infatuated with the possibilities of change presented by genetics. But there are all sorts of nongenetic ways of approaching this project. One of the most important ways is changing the cultural, economic situation of people, a mode of changing human nature that has been little talked about in this community.

If we want to talk about changing the nature of some human beings, then we should be explicit about the various ways in which we can do it. We must then envisage the results, compare them and assess risks, cost, and their implications for future generations. What is so special about genetically manipulating the nature of some humans?

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Professor Annas is a fellow of the American Association for the Advancement of Science, a member of the Institute of Medicine, co-chair of the American Bar Association's Committee on Medical Practice and Medical Research (Science and Technology Section) and the Committee on Health Rights and Bioethics (Individual Rights and Responsibilities Section), and an honorary fellow of the American College of Legal Medicine. For five years, he was the director of the Boston University School of Law's Center for Law and Health Sciences. Professor Annas teaches bioethics.

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Professor Berwick conducts research in computational and systems biology at MIT.

His goal is to use applied mathematical and modeling principles to develop abstract models for complex biological systems. He is working towards understanding the relationship among genotype, environment, and phenotype, and developing a synthetic approach to modeling biological systems. He holds a PhD in computer science from MIT.



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Professor Campbell was appointed Provost *ad interim* of Boston University in July 2004 and he is also Dean of the College of Engineering.

Professor Campbell received his bachelor's degree in physics and chemistry from Harvard College in 1966, Part III Mathematics Tripos, with distinction, from Cambridge University (England) in 1967, and his PhD in theoretical physics and applied mathematics from Cambridge in 1970. He has pioneered the systematic study of inherently nonlinear phenomena throughout physics. The central theme of his work is the role of nonlinear excitations—solitons—in novel states of matter. Professor Campbell is a leader in the emerging field of nonlinear science. His influential overview articles and his direction of the flagship journal, *Chaos*, of which he was the founding editor, have established key interdisciplinary organizing principles—the paradigms of solitons, chaos, and patterns—and have played a seminal role in defining the research agenda in nonlinear science.

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Charles Cantor is one of the pioneers of the Human Genome Project. He is a bioterrorism expert, Chairman of Sequenom, Inc.'s Scientific Advisory Board, and was appointed Chief Scientific Officer in June 1998. Dr. Cantor was previously the chair and professor of the department of biomedical engineering and biophysics, and director of the Center for Advanced Biotechnology at Boston University, and his research laboratory here remains active. Prior to this Dr. Cantor was chairman at Columbia University College of Physicians & Surgeons, and Professor of Molecular Biology, University of California, Berkeley. He was also director of the Human Genome Center Project of the Department of Energy at Lawrence Berkeley Laboratory. Dr. Cantor is a consultant to more than 16 biotech firms, has published more than 325 peer reviewed articles, been granted 26 U.S. patents, and co-authored a three-volume textbook on biophysical chemistry. He recently completed the first genomics textbook, *Genomics: The Science and Technology of the Human Genome Project*.

Dr. Cantor's research is focused on identifying biological problems that are resistant to conventional analytical approaches and then developing new methodologies or techniques for solving these problems. His current interests include the development of new methods for faster DNA sequencing, the development of new variations and analogs of the polymerase chain reaction, the development of bacterial strains suitable for environmental detoxification, and the discovery of human genes associated with sense and taste. He is also interested in exploring the possible use of biological molecules for applications in nano-engineering and microrobotics, and in making detectors capable of recognizing specific single molecules.

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Charles DeLisi has made seminal computational and mathematical contributions to immunology, genomics, and macromolecular structure. He was Dean of the College of Engineering at Boston University from 1999 to 2000 and is currently Senior Associate Provost for Biosciences and Director of the All-University Doctoral Program in Bioinformatics. Before moving to Boston, he was Professor and Chair of Biomathematical Sciences at the Mount Sinai School of Medicine, Director of the Department of Energy's Health and Environmental Research Programs, and Chief of Theoretical Immunology at NIH. He is the recipient of numerous awards including the Presidential Citizens Medal from President Clinton for initiating the Human Genome Project.

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Professor Fromkin served for three years as a First Lieutenant in the Judge Advocate General's Corps, U.S. Army, stationed in Verdun, France, where he was a trial observer in French courts pursuant to the NATO Status of Forces Agreement. As prosecutor and defense counsel, he fought more than one hundred contested courts martial. He began his civilian career as an associate of the Wall Street law firm of Simpson, Thacher & Bartlett. After a varied career in law, business, and politics, he turned to writing works of history and studies of world politics. His shorter pieces have appeared in *Foreign Affairs*, *The New York Times*, and other publications. He is the author of seven books, including the national best-seller *A Peace to End All Peace* (1989), chosen by the editors of the *New York Times Book Review* as one of the dozen best books of the year and shortlisted for the Pulitzer Prize. His most recent book, published in March 2004, is *Europe's Last Summer: Who Started the Great War in 1914?* He has been a member of the Council on Foreign Relations since 1976.

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Evelyn Fox Keller received her PhD in theoretical physics at Harvard University. She came to MIT from the University of California, Berkeley, where she was Professor in the Departments of Rhetoric, History, and Women's Studies (1988–1992). She is now Professor of History and Philosophy of Science in the Program in Science, Technology and Society at MIT and serves on the editorial boards of various journals including the *Journal of the History of Biology* and *Biology and Philosophy*. She is the recipient of a MacArthur Fellowship and numerous honorary degrees. She is best known as a feminist critic of science.

Professor Keller's research focuses on the history and philosophy of modern biology and on gender and science. She is the author of numerous articles, and her books include *A Feeling for the Organism: The Life and Work of Barbara McClintock* (1983), *Reflections on Gender and Science* (1985), *Secrets of Life/Secrets of Death: Essays on Language, Gender and Science* (1992), and *Refiguring Life: Metaphors of Twentieth-century Biology* (1995). Her book *The Century of the Gene* was published in October 2000, and her most recent manuscript, *Making Sense of Life: Explaining Biological Development with Models, Metaphors and Machines*, appeared in April 2002.



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Daniel Kevles works at the intersection of the history of science and American history since the mid-nineteenth century. His current research interests include the interplay of science and society past and present, the history of science in America, the history of modern physics, the history of modern biology, and scientific fraud and misconduct. His courses include science and technology in American society, nuclear America, biology and society, and the engineering and ownership of life. He is the author of *The Physicists* (1978); *In the Name of Eugenics* (1985); and *The Baltimore Case* (1998); a coeditor of *The Code of Codes* (1992); and a coauthor of *Inventing America: A History of the United States* (2002). He is Director of Graduate Studies for History of Science and is currently writing a history of intellectual property in living organisms. Professor Kevles holds a bachelor's degree in physics and a PhD in history from Princeton University. He also studied European history at Oxford.

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Dr. Lewes is an independent scholar who maintains a private psychoanalytic practice in New York City. He was educated at Cornell University and later received a PhD in Renaissance English literature from Harvard University and another PhD in clinical psychology from the University of Michigan. He taught for several years in the English Department of Rutgers University.

Dr. Lewes is the author of *The Psychoanalytic Theory of Male Homosexuality* (1988), which is still in print, having been republished as part of Jason Aronson's "Masterworks Series" under the title *Psychoanalysis and Male Homosexuality*. The book has won several awards. He sits on the board of editors of several psychoanalytic journals and is a frequent reviewer of books on psychoanalysis, literary history, homosexuality, and gender representation. He is the author of numerous articles and reviews. His particular interests include psychoanalysis and creativity, homosexuality, and literary history.

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Professor Margulis began her undergraduate studies at the University of Chicago and went on to earn her PhD at the University of California at Berkeley. By 1970 she was an associate professor at Boston University. It was then that she wrote the most comprehensive account of her ideas: *The Origin of Eukaryotic Cells*. In 1981, Margulis published *Symbiosis in Cell Evolution*, a new version of the thesis in her first book. It marked a definite turning point in the acceptance of the symbiotic theory. Over the years her activities have spanned from original contributions to cell biology and microbial evolution to developing science teaching materials and hands-on garbage and trash projects in elementary schools. From 1977 to 1980, she chaired the National Academy of Sciences' Space Science Board Committee on Planetary Biology and Chemical Evolution to aid in developing research strategies for NASA. Extremely interested in Archean and Proterozoic evolution, her research now focuses on the serial endosymbiotic theory of the origin of cells, study of life cycles and sediment impact of the inhabitants of microbial mats, and theoretical aspects of James E. Lovelock's Gaia hypothesis. Professor Margulis was elected to the National Academy of Sciences in 1983. The Library of Congress, Washington, D.C., announced in 1998 that it will permanently archive her papers. Her publications, which span a range of scientific topics, include original contributions to cell biology and microbial evolution. She is best known for her theory of symbiogenesis, which challenges a central tenet of neodarwinism. At present she works on the possible origin of cilia from spirochetes.



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He received the BA and PhD in mathematics at Harvard and Princeton. In 1951 he built the SNARC, the first neural network simulator. His other inventions include mechanical hands and other robotic devices, the confocal scanning microscope, the "Muse" synthesizer for musical variations (with E. Fredkin), and the first LOGO "turtle" (with S. Papert). A member of the NAS, NAE, and Argentine NAS, he has received the ACM Turing Award, the MIT Killian Award, the Japan Prize, the IJCAI Research Excellence Award, the Rank Prize and the Robert Wood Prize for Optoelectronics, and the Benjamin Franklin Medal.

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She directs the Foresight Conferences on Molecular Nanotechnology, organizes the Foresight Institute Feynman Prizes, and chairs the Foresight Gatherings.

She lectures on nanotechnology to a wide variety of audiences, focusing on making this complex field understandable, and on clarifying the difference between near-term commercial advances and the "Next Industrial Revolution" arriving in the next few decades.

Her work is motivated by a desire to help Earth's environment and traditional human communities avoid harm and instead benefit from expected dramatic advances in technology. This goal of spreading benefits led to an interest in new varieties of intellectual property, including open source software, a term she is credited with originating.

Wearing her for-profit hat, she works with Freedom Technology Ventures LLC to advise investors on evaluating startups in nanotech and other key technologies and to help entrepreneurs improve their plans and locate funding. She also serves on the Advisory Board of Alameda Capital.

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Steven Pinker is an experimental psychologist who is interested in all aspects of language and mind. For the past fifteen years his research has focused on the distinction between irregular verbs like bring-brought and regular verbs like walk-walked.

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Professor Rosen specializes in the history of philosophy, metaphysics, social and political philosophy, and contemporary thought. Prior to coming to Boston University in the fall of 1994, Stanley Rosen was Evan Pugh Professor at Pennsylvania State University. He has also taught as a visiting professor at the University of California in San Diego, the University of Nice, and the Scuola Superiore in Pisa.

Professor Rosen has published fourteen books, the first a volume of poems, the others on subjects ranging from Plato to Hegel, Nietzsche, Heidegger, and analytical philosophy, post-modern hermeneutics, and the problem of nihilism. In addition, Professor Rosen has published over thirty papers in books and over sixty articles in professional journals, many in French, German, Italian, Spanish, Portuguese, Serbian, and Hebrew translations. He has held a variety of fellowships and honorary positions, including the Companys Professorship at the University of Barcelona and the presidency of the Metaphysical Society of America. He was a Fulbright research professor at the University of Paris, a postdoctoral fellow of the Humanities Research Institute of the University of Wisconsin, and pursued his research at Tübingen and Heidelberg Universities and the London School of Economics. Dr. Rosen is also the recipient of an honorary doctorate from the University of Lisbon (1997). In 1999 he was chosen to be the recipient of the Neu Family Award for Excellence in Teaching from the College of Arts and Sciences.

In November 2001, there was a colloquium on his work at the University of Paris, and in April 2002, there was another at Boston University.

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Professor Schacht's interests include post-Kantian continental philosophy (especially Nietzsche and Hegel), philosophical anthropology, social theory, and value theory. He has been a professor of philosophy at UIUC since 1980 and a Jubilee Professor of Liberal Arts and Sciences since 1990. Professor Schacht also serves as Senate Council Chair for the UIUC Faculty-Student Senate, is the executive director of the North American Nietzsche Society, and is affiliated with the Unit for Criticism and Interpretive Theory. He holds a bachelor's degree from Harvard and earned his master's and PhD from Princeton. He also studied at Tübingen University in Germany.

Professor Schacht's publications include: *Alienation* (1970), *Hegel and After* (1975), *Nietzsche* (1983), *Classical Modern Philosophers* (1984), *Classical Modern Philosophers: Descartes to Kant* (1984), *The Future of Alienation* (1994), and *Making Sense of Nietzsche* (1995). In addition, he has published more than forty essays and over thirty articles and has edited several books.

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Professor Shattuck is a distinguished literary critic and one of the world's foremost authorities on the works of Marcel Proust. He earned his bachelor's degree at Yale and was appointed to the Society of Fellows at Harvard. He has been a recipient of both a Fulbright and a Guggenheim grant and was a professor of romance languages at the University of Texas. He has served on the Advisory Board of the National Translation Center and has held the title of *Provéditeur Général du Collège de Palaphysique*. He has also served as President of the Association of Literary Scholars and Critics. His publications include *Proust's Way: A Field Guide to In Search of Lost Time* (2000), *Forbidden Knowledge: A Brilliant Exploration of the Dark Side of Human Ingenuity and Imagination* (1996), *Marcel Proust* (1974); and *The Banquet Years: The Origins of the Avant-Garde in France, 1885 to World War One* (1961).



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Alfred Tauber is a hematologist and biochemist by training. From his interest in basic immunology, he began a critical examination of modern biology and medicine. These studies have focused on scientific epistemology: positivism, reductionism, and the relationship of facts and values. As the Zoltan Kohn Professor of Medicine at the Boston University School of Medicine, Dr. Tauber teaches ethics at the Boston Medical Center and was appointed director of the Center for Philosophy and History of Science at Boston University in 1993. Before joining Boston University School of Medicine in 1982, he spent four years on the faculty at Harvard Medical School, and also served an internship and residency at the University of Washington Affiliated Hospitals, followed by advanced training at Tufts-New England Medical Center, Harvard Medical School, and the Robert B. Brigham Hospital.

Dr. Tauber is the author of five books, the most recent being *Henry David Thoreau and the Moral Agency of Knowing* (2001) and *Confessions of a Medicine Man: An Essay in Popular Philosophy* (1999). He is also the editor of numerous works, and has published more than sixty papers on ethics and on the history and philosophy of science and medicine.

Dr. Tauber earned a BS from Tufts University and an MD from Tufts University School of Medicine. He was elected to the Tufts Board of Trustees in 2003 and currently serves on the Academic Affairs Committee.

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Tommaso Toffoli is professor of electrical and computer engineering at Boston University, where he also heads the Programmable Matter Group. His primary research interests are the fundamental connections between Physics and Computation. He is the author, with Norman Margolus, of *Cellular Automata Machines: A New Environment for Modeling* (1987) and has published numerous papers.

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