ESSAY

Icarus 2.0

A Historian's Perspective on Human Biological Enhancement

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Some of the most important watersheds in human history have been associated with new applications of technology in everyday life: the shift from stone to metal tools, the transition from hunting and gathering to settled agriculture, the substitution of steam power for human and animal energy. Today we are in the early stages of an epochal shift that will prove as momentous as those other great transformations. This time around, however, the new techniques and technologies are not being applied to reinventing our tools, our methods of food production, our means of manufacturing. Rather, it is we ourselves who are being refashioned. We are applying our ingenuity to the challenge of redesigning our own physical and mental capabilities. Technologies of human enhancement are developing, ever more rapidly, along three major fronts: pharmaceuticals, prosthetics/informatics, and genetics.[1] Though advances in each of these three domains are generally distinct from those in the other two, their collective impact on human bodies and minds has already begun to manifest itself, raising profound questions about what it means to be human. Over the coming decades,

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1. The scholarly and popular literature on human biological enhancement is voluminous and growing rapidly. For a bibliography (presently comprising some 260 titles and counting), see my project website at http://www.vanderbilt.edu/historydept/michaelbess/Currentbookprojects (accessed 14 November 2007).

these technologies will reach into our lives with increasing force. It is likely that they will shake the ethical and social foundations on which contemporary civilization rests.[2]

One fascinating feature of this phenomenon is how much it all sounds like science fiction. The bionic woman, the clone armies, the intelligent robot, the genetic mutant superhero: these images all form part of contemporary culture. And yet, this link with science fiction is potentially misleading. Precisely because we associate human enhancement with the often bizarre futuristic worlds of novels and movies, we tend to dismiss the evidence steadily accumulating around us. Technologies of human enhancement are incrementally becoming a reality in today's society, but we don't connect the dots. Each new breakthrough in genetics, robotics, prosthetics, neuroscience, nanotechnology, psychopharmacology, brain-machine interfaces, and similar fields is seen as an isolated, remarkable event occurring in an otherwise unaltered landscape. What we miss, with this fragmentary perspective, is the importance of all these developments, taken together.

The technological watersheds of the past came about gradually, building over centuries. People and social systems had time to adapt. Over time they developed new values, new norms and habits, to accommodate the transformed material conditions. This time around, however, the radical innovations are coming upon us suddenly, in a matter of decades. Contemporary society is unprepared for the dramatic and destabilizing changes it is about to experience, down this road on which it is already advancing at an accelerating pace.[3]

2. Some authors argue that the biotechnology revolution will be rivaled in its transformative social impact by concurrent revolutions in nanotechnology, informatics, and robotics. They maintain that, rather than think of the mid-twenty-first century as being defined primarily by biotechnology, we should conceive of it as a period of conjoined and intertwined innovations: the nano-bio-info-cogno (NBIC) era. This makes good sense at one level, because it is undoubtedly true that human enhancement technologies will be partly a result of, and deeply imbricated with, radical new capabilities in these other areas. But I believe the defining feature of the era will still be the technologies of human enhancement. It is one thing to alter the nature of the objects and devices with which we surround ourselves, and quite another to alter fundamentally our own bodies and minds. In one case we are reshaping our tools; in the other we are reshaping ourselves. Of the two, it is the latter change that cuts deeper qualitatively, and that will, I think, come to be seen as the more important transformation. See Mihail C. Roco and William Sims Bainbridge, eds., *Converging Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technology, and Cognitive Science* (Dordrecht, 2003), and Ray Kurzweil, *The Singularity Is Near: When Humans Transcend Biology* (New York, 2005).

3. The discussion that follows focuses on the United States, but the gist of my argument applies to most other industrialized nations as well—despite the significant differences in culture, institutions, and traditions of science and technology policy that apply in individual countries. The importance of cross-national variation should not be underestimated, of course. For example, the average Western European citizen today faces a quite different array of health policy options than the average American, and over

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Let me begin with two brief stories.[4] They are, in a sense, Promethean parables, tales of the human aspiration to rise above earthly limits. But they are also anti-Promethean, in that both begin with tragedy and end on a cautiously hopeful note.

In 1997, a fifty-three-year-old man named Johnny Ray had a massive stroke while talking on the telephone. When he woke up several weeks later, he found himself in a condition so awful that most of us would have a hard time imagining it. It is called "locked-in" syndrome: you are still you, but you have lost all motor control over your body. You can hear and understand what people say around you, but you cannot respond. You have thoughts and feelings but cannot express them. You cannot scream in frustration or despair; you can only lie there. The only way Johnny Ray could communicate was by blinking his eyelids.

In March 1998 two neurologists at Emory University and Georgia Tech inserted a wireless implant into the motor cortex of Ray's brain. The implant transmitted electrical impulses from Ray's neurons to a nearby computer, which interpreted the patterns of brain activity and translated them into cursor movements on a video display. After several weeks of training, Ray was able to think "up" and thereby will the cursor to move upward onscreen. After several more months, he was able to manipulate the cursor with sufficient dexterity to type messages. By that point, the brain-computer interface had become so natural to him that using it seemed almost effortless. When the doctors asked him what it felt like to move the cursor, he spelled out, N-O-T-H-I-N-G. Johnny Ray had escaped from his terrible isolation and returned to the rich world of language.

My second story is about a girl named Ashanti DeSilva, born in 1985 with the genetic disorder known as "bubble boy disease." Her body lacked the gene required for making the protein adenosine deaminase, or ADA. Without it, her immune system was drastically impaired: just about any virus or bacteria she encountered threatened her life. She lived in total isolation at home, kept alive by injections of synthetic ADA. Her parents knew

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the coming decades this disparity will probably translate into similarly divergent possibilities for human enhancement. Nevertheless, such dissimilarities should not obscure the underlying fundamentals that all the industrialized nations share in common. A banking crisis or an oil spill might well produce different responses in France than in the United States, but the basic features of such a crisis—its causes and extent, and the range of possible solutions—will be determined by the many underlying social, technological, and economic factors that clearly characterize both nations. In a similar way, the basic tectonics of the coming civilization of human enhancement will possess fundamental common features across national boundaries, despite important differences from country to country.

4. For the illustrative anecdotes in this essay, I draw extensively from the excellent book by Ramez Naam, *More Than Human: Embracing the Promise of Biological Enhancement* (New York, 2005).

that the effectiveness of the injections would diminish over time, and that their daughter would eventually die of her disease. The only other alternative, a bone-marrow transplant, was impossible, because no compatible donor could be found.

Out of desperation, Ashanti's parents turned to what was at that time cutting-edge experimental medicine. In 1990, a team of doctors at the National Institutes of Health Clinical Center in Maryland extracted blood cells from her veins, then used a hollowed-out virus vector to insert working copies of the ADA gene into those blood cells. They were, in effect, repairing the deficient gene that had caused her disease. When the modified blood cells were injected back into Ashanti's body, the results were dramatic. Within six months her immune system became sufficiently active to allow her to go safely out of the house. Within two years she was enrolled in school and began for the first time to experience a normal childhood. Ashanti DeSilva is alive and healthy today, though she still requires periodic renewal of the gene therapy to boost her immune response. Hers is the first case of successful gene therapy on humans.

The stories of Johnny Ray and Ashanti DeSilva have two striking features in common. First, it is remarkable how far the science and technology have come in the short time since these pioneering feats took place. Johnny Ray's brain implant possessed only a single electrode for linking up with his nervous system. A mere eight years later, an owl monkey at Duke University was equipped with a similar implant containing seven hundred electrodes and a high-bandwidth interface. This far more powerful device allowed the monkey—staring at a video screen, arms dangling motionless at its side—to control the movements of a robot arm in another room by thought alone. The monkey played games using its new arm, and appeared to have seamlessly incorporated this machine appendage into the functioning of its own body. Human trials on this technology are already in the works; more than a dozen universities and private companies are currently in a race to push this line of research still further. Meanwhile, the progress in genetic technologies has been even more dramatic. In 1997 Dolly the sheep became the first successful clone of a mammal; in 2003 the Human Genome Project produced the first complete map of human genetic material; in 2004 there were 987 gene-therapy trials under way around the world.

A second common feature in these two stories is less obvious, but equally important. The same pathbreaking techniques that render healing possible usually also render enhancement possible. If I can place a brain implant in Johnny Ray to let him out of his "locked-in" world, I can also use a similar device, down the road, to let healthy people manipulate robotic arms by thought alone. If I can insert new genetic instructions into Ashanti's blood cells, making them produce ADA, then I can also use a similar procedure, down the road, to make other human cells produce other proteins of my own choosing. The technologies for repairing a malfunctioning human body are inseparable from the technologies that allow us to push human capabilities to ever higher levels. Where we can heal, we can also tweak, boost, reconfigure, redesign.[5]

The implications have not been lost on scientists and technology developers. Large numbers of them are busily at work today, in universities, government labs, and private companies, extending the biotechnologies of healing ever further into the domain of enhancement. They are, in effect, working to build a better human.

Three Major Areas of Enhancement

People are using pharmaceuticals in increasingly sophisticated and powerful ways to reshape their bodies and minds. I need not belabor the highly publicized rise of chemicals such as steroids, which enhance physical traits like speed, strength, and endurance, and have caused major upheavals in the world of competitive athletics. But the realms of human cognition, learning, and emotion are being shaken up in equally profound ways. Behavioral traits such as restlessness and short attention span, formerly viewed as problems of character and will power, are being medicalized, redefined as illnesses treatable with potent drugs like Ritalin. Conditions such as depression, which used to be approached through endless hours on the psychiatrist's couch, are increasingly being handled through the administration of an ever growing array of neurotransmitters, hormones, and other mood-altering chemicals.

In the process, our society's sense of what constitutes normal ability and basic mental well-being is being destabilized. As Carl Elliott describes it in his 2003 book *Better than Well*, we are engaged today in a sort of chemical arms race, seeking to push our own physical and mental abilities to ever higher levels. When college students discovered, for example, that certain attention-deficit hyperactivity disorder (ADHD) drugs like Ritalin also enhance the cognitive performance of purportedly normal individuals, the outcome was thoroughly predictable. A black market rapidly developed among healthy students, many of whom reported that the drug helped them think more clearly, concentrate better, and remember new information more accurately than before. The motivation to enhance was strong, given the competitive nature of our educational system and broader soci-

5. This point is forcefully made in Joel Garreau, *Radical Evolution: The Promise and Peril of Enhancing Our Minds, Our Bodies—and What It Means to Be Human* (New York, 2004), and in James Hughes, *Citizen Cyborg: Why Democratic Societies Must Respond to the Redesigned Human of the Future* (Cambridge, Mass., 2004). Hughes is one of the leading figures in the World Transhumanist Association, an international body devoted to promoting human enhancement; see http://www.transhumanism.org/index.php/WTA/index/ (accessed October 2007).

ety. Moreover, the line between healing and enhancing proved extremely difficult, in practice, to draw.

A second important area of human enhancement lies in the field of neuroscience and its intersection with the technologies of prosthetics, robotics, informatics, and artificial intelligence. As the story of Johnny Ray makes clear, the boundaries between human body and information-processing machine are beginning to blur. Ray became a kind of human-machine hybrid, in the sense that key aspects of his individuality—his ability to communicate in language with other people—came to be linked to the functioning of machine components that he had incorporated into his being. For now, such deliberate blurring of boundaries occurs only in animal experiments or extreme cases like Ray's. But over the coming decades it is likely that such human-machine hybrids will proliferate. We will have the ability to link directly into the human nervous system or sensorium with an increasingly broad array of electromechanical and informatic devices. Within thirty or forty years, some of the blind will see again, some of the deaf will hear again, some of the paralyzed will walk again.

Prosthetic technologies that already exist today are bringing such "futuristic" capabilities closer and closer to reality. In 2002, for example, the brain researcher William Dobelle created a media sensation by partially restoring sight to a totally blind patient. Dobelle implanted electrodes in the man's visual cortex and linked them through a portable computer to a tiny video camera mounted on the man's glasses. The result was grainy, blurred vision—but vision nonetheless. Dr. Dobelle's blind patients could see well enough to drive a car around a parking lot (slowly!) and carry out simple everyday tasks. Equally remarkable advances are taking place with cochlear and brain implants to restore hearing, and with prosthetic devices and neurosurgery to restore motility to paralyzed patients.

Here again, technologies of healing will be inseparable from technologies of enhancing. If I can put a functional artificial eye into a blind patient, then it is but a short step, technologically speaking, to add extra features to the implanted device, such as a telescopic lens or an infrared sensor. The result would be a formerly blind person who not only can see normally, but who can also zoom in clearly on very distant objects and see extremely well at night. She would see, in Carl Elliott's apt formulation, better than well. It would be remarkable, under such circumstances, if some people with normal vision did not hanker to have their own optical sensorium similarly tweaked, as long as the technology was safe and affordable.

These kinds of developments, not surprisingly, have elicited great interest—and significant funding—from the military. In the United States, the Defense Advanced Research Projects Agency (DARPA) envisions a battlefield of the not-so-distant future in which enhanced humans and potent machines are deeply interwoven at all levels. Imagine a soldier who can

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sprint at top speed for five miles with a heavy backpack, yet not get tired, because his blood has been modified to carry oxygen more efficiently. Imagine a soldier who can stay awake and alert for seventy-two hours because his nervous system has been augmented accordingly. Imagine a pilot who controls his aircraft directly through a brain-machine interface. Imagine a flexible, semi-intelligent armature, worn like an exoskeleton, that allows a soldier to lift 250 pounds effortlessly. Even if *you* are not imagining such things, DARPA is, and it is supplying considerable amounts of money to advance both the basic science and the practical technology for such capabilities.

Not all this research will bear fruit, of course. But that should not obscure the broader point. We are gaining an ever more sophisticated understanding of how the human brain works, how the nervous system and sensory organs function. We are building ever more powerful robotic and informatic devices. And, most significantly, we are getting better and better at linking these two realms, human and machine, and teaching them to work as one. Over the next few decades, these functional hybrids will become more and more a part of our lives.

Direct intervention at the level of the human genome is potentially the most powerful form of enhancement, because it can modify not just a single individual in the here and now, but entire lineages of humans down through the generations. No one knows for sure today how great a role genes play in making us who we are, how each of us is shaped by inherited genetic predispositions, and to what extent our personalities and capabilities are the result of nongenetic factors in our upbringing and life experience. But we do know a lot more than we did a mere ten or twenty years ago. Moreover, with the decoding of the entire human genome in 2003, we possess powerful tools for learning more quickly. Breakthroughs in genetics come almost every month.

Three basic principles undergird genetic intervention. First, some diseases are caused by malfunctions in a mere one or two genes. Fixing the gene removes the disease. Second, some intangible human traits, such as intelligence or shyness, are probably linked to complex systems of genes rather than to isolated genes. To adopt a musical metaphor, they depend not on single notes but on chords or even symphonies. Third, by altering individual components in certain systems of genes, we can directly affect complex and intangible traits in predictable ways.

In 1999, for example, a Princeton biologist, Joe Tsien, modified a single gene in laboratory mice that controls production of a chemical known as nerve growth factor (NGF). To his astonishment, the NGF-enhanced mice performed up to five times better than normal mice in tests of memory, learning, and intelligence. Other biologists, such as Eric Kandel and Tim Tully, have tinkered with a different gene, responsible for the production of a chemical that strengthens brain synapses. Through manipulation of a single gene, they have significantly boosted the learning abilities of mice, fruit flies, and sea slugs.

Let me be clear: this does not mean that genetic enhancement of human intelligence is just around the corner. But it does point to a conclusion that should get our full attention: genetic enhancement of basic human traits is no longer a topic of fantasy. The pieces of the scientific and technological puzzle are coming together, in real developments happening today. Neuroscience and psychology are telling us more and more about the electrochemical basis of how brains function and produce specific states of mind. Genetics is telling us more and more about how particular genes regulate the production of certain chemicals. Our technological ability to modify individual genes is growing rapidly.

Taken together, these elements form a recipe for powerful genetic interventions to redesign human bodies and minds. The time frame, depending on which expert you consult, is probably a matter of three to five decades. Within the lifetime of today's college seniors, our society is going to face some very tough choices about whether to use, and how to use, these extraordinary genetic powers.

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Let us suppose, for the sake of argument, that a majority of U.S. citizens were to decide today that human enhancement is a bad road, and that we should refuse to go down it.[6] Could we stop this process? What would that entail?

The answer is sobering. Bringing the enterprise of human enhancement to a halt would require a vast, draconian system of surveillance and regulation. Precisely because the technologies of healing and the technologies of enhancement are intrinsically connected, a ban on enhancement would prove ineffectual unless it severely curtailed research in such areas as computers and informatics, genetics, robotics, neuroscience, nanotechnology, cognitive psychology, pharmaceuticals, and many fields of contemporary medicine. Moreover, it would require that this highly restrictive system be imposed with equal rigor in all the world's nations at the same time, to prevent the research and innovation from simply migrating overseas to the least-regulated regions of the planet. The chances of such a coordinated global relinquishment are small indeed.

Nevertheless, to admit that we cannot ban enhancement technologies outright is not to say that we are powerless to exert any control at all over the situation. I believe the history of the environmental movement offers a

6. Three thoughtful advocates of this position (albeit from sharply differing ideological backgrounds) are: Bill McKibben, *Enough: Staying Human in an Engineered Age* (New York, 2003); Francis Fukuyama, *Our Posthuman Future: Consequences of the Biotechnology Revolution* (New York, 2002); and Leon Kass, *Life, Liberty, and the Defense of Dignity: The Challenge for Bioethics* (San Francisco, 2002).

useful model in this regard. Here, too, humankind faced a similarly daunting challenge: reorienting the totality of our economic system by profoundly changing not only products, laws, and industrial practices but also consumer habits and mentalities. A mere forty-five years ago, in the early 1960s, almost no one even knew there *was* such a thing as "the environment," much less a serious set of problems associated with it. In the decades since, humankind has become aware of the crisis and mobilized to shift economies and habits toward ecological sustainability. We remain far indeed from reaching that goal, but it would be foolish to deny the substantial progress that has been made in less than half a century.[7]

The green movement is particularly instructive because it has made a significant impact despite vehement disagreement about the nature of the ecological crisis and the best ways to deal with it. There was never any point at which a straightforward consensus developed in the population at large; rather, the terms of debate gradually became clearer and more concrete. Can a factory run cleanly and still turn a profit? Can we find economically viable alternatives to fossil-fuel energy? Animated by pragmatic questions like these, public opinion slowly shifted, incrementally incorporating ideas that had once seemed marginal or downright radical. Ultimately, the overall trajectory of social practices was successfully deflected down a new course. Humanity saw the problem and partially changed direction.

There is hope in this green story. It offers reasonable grounds for optimism that humankind may be able, in a similar fashion, to exert some measure of control over the immense social and economic forces involved in human enhancement. We are not helpless before these technological changes; we can have some say in how they transform our lives. In particular, I see four main issues that these accelerating developments will compel us to confront.

The Challenges We Face

Human enhancement is going to be very hard to resist, once you and I personally are offered it. It not only taps into our instinct for self-preservation, but also draws upon our concern for those we love. Most parents go to extreme lengths to give their children the greatest possible chance of leading healthy, educated, fulfilling lives. If biotechnology safely increases that chance, or appears to do so, how many will be able to resist? This pressure will ratchet up even further as parents see their children competing with others whose capabilities have been augmented in various ways. We have here, in short, a classic case of a slippery slope.

Biotechnological modifications are likely to come in discrete, incre-

7. See Michael Bess, *The Light-Green Society: Ecology and Technological Modernity in France, 1960–2000* (Chicago, 2003).

mental packages, each offering a slight improvement in some aspect of our bodies or minds, along a steadily increasing gradient of potency and sophistication, as the science and technology advance each year. Over decades these increments will add up to significant qualitative changes in our physical and mental makeup, but at any given moment they will seem like small, sensible extensions of capabilities we already possess. The net result will be a social context in which the very meaning of the word "normal" is constantly shifting. What was normal last year becomes slightly subpar this year; what was normal ten years ago is completely obsolete today. Once enhancement technologies become widespread, people will have to accept a continual, unending process of upgrades and boosts, simply to keep up with the ever-shifting baseline of normal human performance.

A second challenge of the enhanced future will stem from the sheer outlandishness of the traits and capabilities that many citizens of that era will be able to choose for themselves. Popular science fiction has not been much help in this regard. From *Star Trek* to *Star Wars*, we see a lot of strange critters running around: intelligent robots, not-so-intelligent robots, bizarre species from galaxies far, far away. But these aliens exist alongside perfectly ordinary-looking human beings. For the most part, the only humans who are profoundly modified are the evil ones, like Darth Vader in *Star Wars* or the Borg in *Star Trek*.

This is a telling point: it indicates that we are psychologically unprepared for what is actually far more likely to happen. Over the coming century, some of us—perhaps many of us—will be increasingly merging with our machines, while at the same time modifying our own biology in ever deeper ways. By the year 2050, our society is likely to include a wide variety of truly hybrid beings, part genetically modified human, part machine. To be sure, some individuals, and some entire family lines, will no doubt follow a conservative path, rejecting major modifications. But others will push their enhancement possibilities to the limit. No one can foresee what those more aggressively modified people will look or act like. But it is probable that, from today's standpoint, they will be deeply unsettling to behold, both when they are at rest and when they do the things they do. Many of their behaviors will lie well beyond the range of current human capabilities.

A skeptic might argue that humans have been enhancing both their abilities and their appearances for centuries, if not millennia, and that most societies have adapted rapidly and seamlessly to such innovation. How long did it take, for example, for people to accept the wearing of eyeglasses as perfectly normal, or to consider an airplane flight across the Atlantic routine? Might not the myriad enhancements of the mid-twenty-first century find a similarly swift and easy embrace? What many would consider a freak today might seem utterly mundane tomorrow.

This is a valid point, but it should be qualified in two important respects. The enhancements of the mid-twenty-first century will be far more

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potent than anything witnessed thus far in human history. They will affect the qualities we deem most centrally and deeply human. Personality, emotions, cognitive ability, talents, memory, perception, physical sensation, the boundaries between one person and another—all these will be subject to deliberate manipulation. It is hard to see how such an unrelenting succession of profound changes would not produce a disorientation—a continually destabilized identity—among the citizenry of the coming era.

It is also worth noting how much of today's economic activity and technology are oriented toward fashion performance, entertainment, embellishment, or sexual behavior. What will be the equivalent of cosmetics, body piercings, tattoos, Botox, and Viagra for the people of 2050? What will take the place of recreational drugs like marijuana or Ecstasy? What will the people of that era do to their bodies and minds for the simple purpose of signaling their individuality, or experiencing a new form of erotic pleasure? The mind boggles. We should not underestimate the sheer strangeness of the future that awaits us, just a few decades down the road.

A third key issue confronting us in that future will be the socially disruptive potential of enhancement technologies. They hold out the possibility of liberating humans from many of their constraints and afflictions, but also of dividing humankind more profoundly than at any time in recorded history. It is not at all clear whether a population of highly enhanced humans can coexist peacefully alongside a population of unmodified humans. There will be plenty of opportunities for prejudice, resentment, and dehumanizing stereotypes—going both ways. Within the population of the enhanced, moreover, we are also likely to see ever growing levels of heterogeneity. The people of that era will not only look far more different from each other than we do today, they will also possess a much wider variety of physical and mental capabilities, arrayed in all manner of combinations. Diversity, in such a context, will be based on varying biologies, dissimilar machine components, sharply contrasting abilities. Can our culture absorb such a riotous level of heterogeneity? The historical track record in this regard is not very promising.

Finally, what happens to the moral ideals of equality and human dignity in such a world? By the concept of "human dignity" we usually mean a quality of intrinsic and absolute value that all humans possess in the same measure—whether a tiny baby, a genius, or a mentally handicapped person. It is the quality that leads us, for example, to consider murder an equally serious crime regardless of the victim's personal characteristics.

The technologies of enhancement threaten human dignity precisely because they tempt us to think of a person as an entity that can be "improved." To take this step is to break down human personhood into a series of quantifiable traits—resistance to disease, intelligence, and so forth—that are subject to augmentation or alteration. The danger in doing this lies in reducing individuals to the status of products, artifacts to be modified and reshaped according to our own preferences, like any other commodity. In this act, inevitably, we risk losing touch with the quality of intrinsic value that all humans share equally, no matter what their traits may be. In this sense, the well-intentioned effort to enhance a person can result in treating them as a mere *thing*.

The eugenics movements of the late nineteenth and early twentieth centuries showed us where such dehumanizing lines of thought can lead. One place they did lead was to Auschwitz. A central moral challenge of the coming decades will be to prevent the technologies of enhancement from eroding the foundations of equality and human dignity on which our political and social systems rest.

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None of us has a crystal ball, of course. We cannot know with any precision what shape the civilization of enhancement will take. Nevertheless, the broad outlines of what is coming are already clear enough: enhancement of human bodies and minds will become a defining feature of our society, whether we as individuals approve of it or not. Even if this future takes twice as long as anticipated to arrive—say, eighty years instead of forty—we are still speaking here of one of the great disjunctions in human history.

To some, putting the matter this way may smack of technological determinism. Ultimately, they would say, it is humans who make technology, and therefore it is up to humans to choose whether or not to go down this road. This is undoubtedly true. I have argued, however, that the very nature of these technologies will make many people *want* to have them, and that the collective impact of those desires, expressed as social and economic forces, will exert tremendous pressure to bring these technologies into being. Short of a cataclysmic war or ecological collapse, and short of a radical transformation in the basic profile of human aspirations and needs, the overall "parallelogram of forces" (to use Engels's artful formulation) will propel industrial civilization down this path.

It will be up to us as citizens and as consumers, of course, to decide just how, and at what pace, and in what configurations and distributions, these enhancements enter our lives. That is most certainly not predetermined. Our responsibility as citizens, therefore, requires that we start preparing ourselves as best we can today to make those decisions.

This will demand a great deal from us as individuals. It will require that we educate ourselves about the underlying science and monitor closely the ongoing developments in the many areas of innovation I have described. Most importantly, it will require that we clarify in our own minds the basic social, political, and moral values we wish to defend during this period of swift technological change.

It will also demand a great deal from us as a society. Our government will need to address basic issues of safety, devising effective ways to regulate new enhancement technologies without stifling scientific innovation in the

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process. This will not be an easy balance to strike.[8] Equally important will be the question of fairness: ensuring that opportunities for enhancement do not become the exclusive prerogative of a select few. If we fail in this, and the rich gain preferential access to the most potent enhancements, we will witness a further widening of the already cruel gap that separates people into haves and have-nots. This time around, however, that gap will not merely be expressed outwardly in social status and power: it will be written in biology itself.

Finally, we will need to create a civic culture that can deal constructively with ever-deepening diversity among the citizenry. In the end, this will probably require nothing less than a new ethics of personhood—an expanded conception of human dignity, a more generous understanding of the word "us." I will need to be able to stand before you, acknowledge how radically different you are from me—in looks, perceptions, abilities—and still feel that, underneath it all, we are members of a common family of beings.

Safety, fairness, social solidarity: these are not new moral imperatives in the history of human society. But the advent of enhancement technologies casts ancient social and political challenges in a particularly urgent light. We face a situation akin to the one lamented by atomic scientists like Albert Einstein and Leo Szilard in the late 1940s, as they contemplated the predicament of a nuclear-armed humanity. The invention of these radical new weapons, as these scientists saw it, confronted humankind with a basic choice: either to find a way, once and for all, to resolve international conflicts through peaceful means, or to face eventual annihilation in a final world war.

Enhancement technologies may well force a similar moral reckoning over the coming decades. Either human beings will learn how to reconfigure their societies along more equitable and civically inclusive lines, or the dehumanizing tendencies, identity tensions, and centrifugal forces unleashed by these technologies will risk tearing their societies apart. As with nuclear weapons, these devices confront humankind with the fateful disparity that Einstein repeatedly underscored in the last years of his life: the gap between human power and human wisdom, between our extraordinary technological mastery and our still primitive capacity for just coexistence. The innovations have gone on accelerating in the years since Einstein's death, and today we encounter a paradox that might have astonished even him: it is not just our weaponry that threatens us, but our technologies of healing as well. Our inventions have reached a degree of such potency that, turned back upon humans themselves, even the most seemingly benign of them risk turning our world inside-out.

8. Both McKibben and Fukuyama propose concrete political and legislative measures that they believe could be taken today to bring the forces of enhancement under greater control. It remains unclear, however, whether the measures they advocate would suffice to rein in the broader social and economic processes propelling enhancement forward.